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GEOLOGIC ATLAS

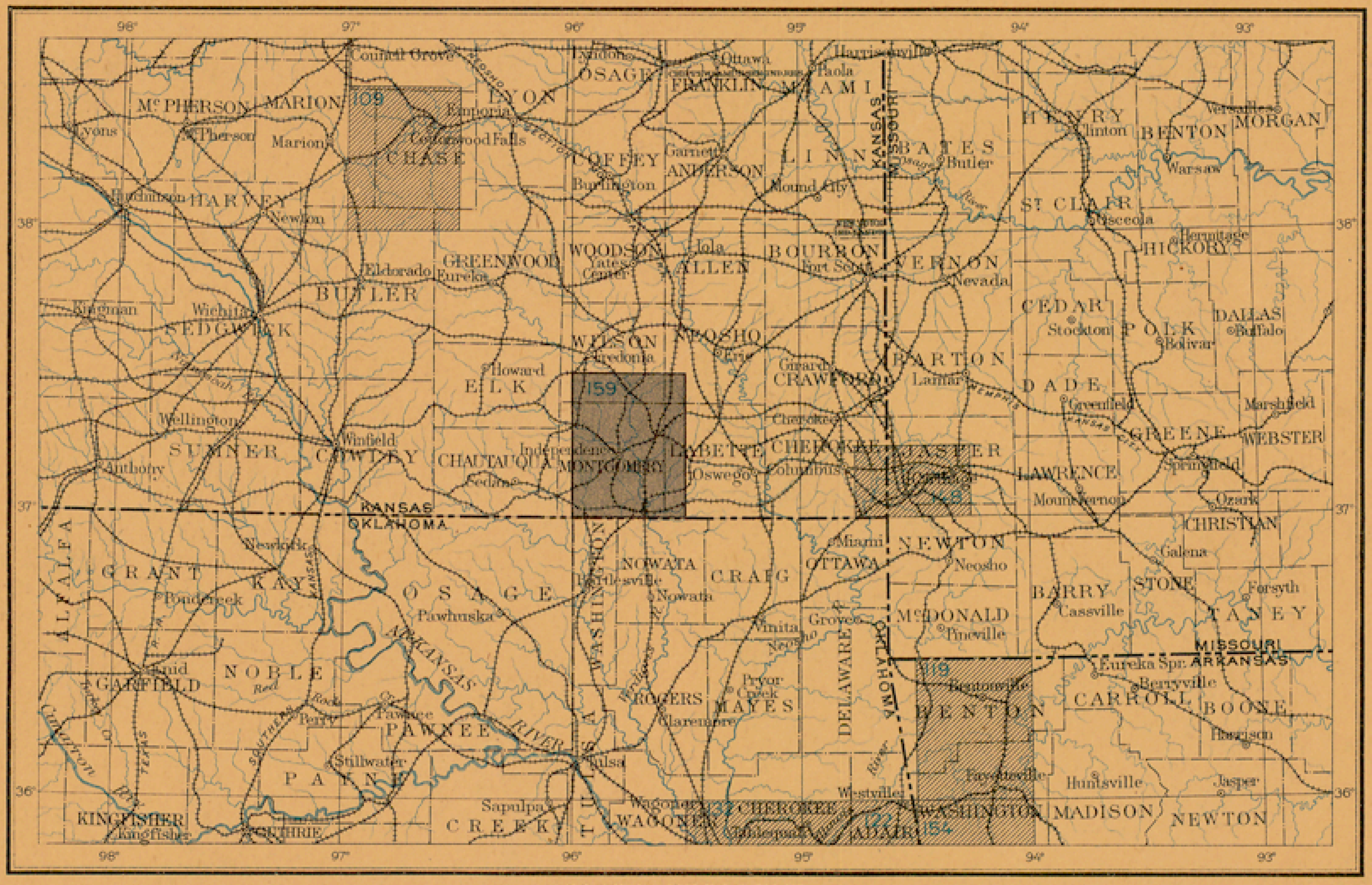
OF THE

UNITED STATES

INDEPENDENCE FOLIO

KANSAS

INDEX MAP



SCALE 40 MILES=1 INCH

INDEPENDENCE FOLIO

OTHER PUBLISHED FOLIOS

CONTENTS

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1908

GEOLOGIC AND TOPOGRAPHIC ATLAS OF UNITED STATES

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

THE TOPOGRAPHIC MAP.

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

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

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

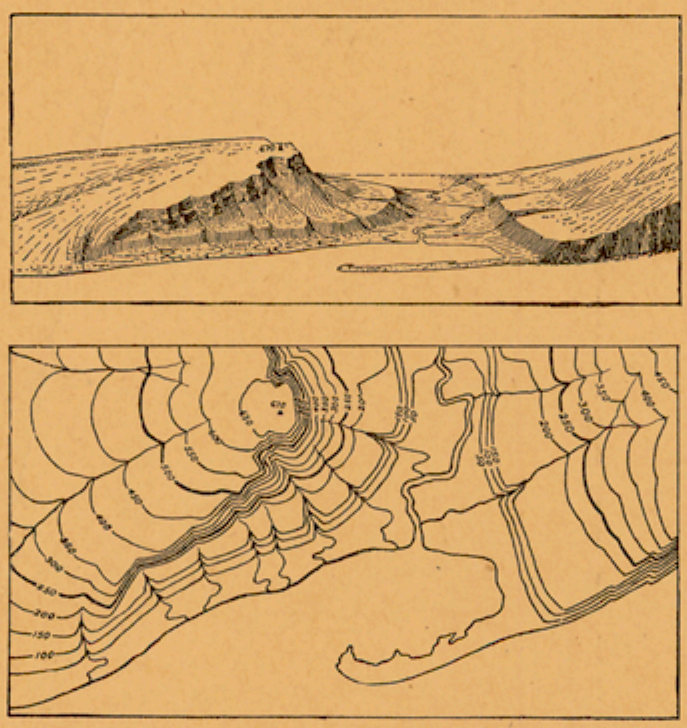

FIG. 1.—Ideal view and corresponding contour map.

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

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

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

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

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

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

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

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

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

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

The atlas sheets, being only parts of one map of the United States, disregard political boundary lines, such as those of States, counties, and townships. To each sheet, and to the quadrangle it represents, is given the name of some well-known town or natural feature within its limits, and at the sides and corners of each sheet the names of adjacent sheets, if published, are printed.

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

THE GEOLOGIC MAPS.

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

KINDS OF ROCKS.

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

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

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

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

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

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

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

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

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

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

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

FORMATIONS.

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

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

AGES OF ROCKS.

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

The sedimentary formations deposited during a period are grouped together into a *system*. The principal divisions of a system are called *series*. Any aggregate of formations less than a series is called a *group*.

(Continued on third page of cover.)

DESCRIPTION OF THE INDEPENDENCE QUADRANGLE.

By F. C. Schrader.

GEOGRAPHY.

GENERAL RELATIONS.

Location and area.—The Independence quadrangle is a rectangular area in southeastern Kansas lying between meridians 95° 30′ and 96° and parallels 37° and 37° 30′. Its southern border coincides with the Kansas-Oklahoma boundary and its eastern border is about 47 miles west of the Kansas-Missouri boundary. Its length is nearly 35 miles, its width about 28 miles, and its area about 950 square miles. It is located near the middle of the well-known Kansas-Oklahoma oil and gas field, of which it forms an important part. It includes the whole of Montgomery County and portions of Wilson, Neosho, Labette, Elk, and Chautauqua counties.

Outline of the geography.—Kansas is situated near the middle of the belt of the Great Plains and Prairie Plains, which in this latitude have a width of about 800 miles and incline gently eastward from the base of the Rocky Mountains toward Mississippi River. The elevation of this belt on the west is about 6000 feet and on the east, near the Mississippi, about 700 feet; the mean rate of inclination is about 10 feet per mile. The Kansas portion of the belt has an average elevation of about 4000 feet at its western border and about 900 feet at its eastern border, with a mean inclination of about 8 feet per mile.

In Kansas the Great Plains, occupying the western two-thirds of the State, are sharply marked off from the Prairie Plains by the Flint Hills escarpment, which extends in a north-south line across the State from Marshall County to Cowley County. The eastern third of the State including the Independence quadrangle, lies within the Prairie Plains. Each of these grand divisions comprises a number of smaller geographic divisions, separated in general by eastward- or southeastward-facing escarpments and rising gently in successive steps to the northwest. The Osage Prairie forms the western part of the Prairie Plains division and extends westward 25 miles beyond the Independence quadrangle to the Flint Hills escarpment, in the longitude of Grenola, and to the western part of Greenwood, Elk, and Chautauqua counties.

TOPOGRAPHY OF THE QUADRANGLE.

Relief.—The Independence quadrangle lies wholly within the Osage Prairie and its distinguishing surface features are eastward-sloping terraces and a few outlying or isolated hills and mounds. The region is essentially treeless except for fringes of forest along the larger streams and some areas occupied by black-jack oak in the sandstone hills. Its average elevation is about 900 feet. Viewed as a whole, it inclines, at the rate of about 10 feet per mile, gently east of south, which is likewise the general direction followed by the streams. The vertical range between the tops of the highest hills and the floors of the lowest valleys is about 440 feet. The lowest point in the quadrangle, 690 feet in altitude, is near its southeast corner, where Verdigris River crosses the State line. This is also the lowest point in the State. The highest part of the quadrangle is in its northwest corner, on the Dunham ranch, where the sandstone hills rise to the elevation of 1130 feet.

The topography is the result of dissection and erosion, and in a broad way the surface is gently undulatory or rolling. It varies with the degree of denudation suffered, however, ranging from a nearly flat plain in some localities to hilly or even rugged surfaces in others. The hilly or more rugged forms are found in the sandstone areas and along the western sides of the main valleys. Many of the hills along the valleys present steep-faced scarps 200 feet or more in height and are nearly flat topped. Locally they are known as mounds, especially where they rise as outliers separated from the main wall of the valley. Good examples of these outliers are Table Mound and Walker Mound, near the center of the quadrangle, and the mounds about Cherryvale.

More closely considered, the topography is of the terrace type, a series of nearly eastward-facing terraces of varying height and width rising successively northwestward. These terraces have been developed by erosion in the Pennsylvanian series, which here consists principally of heavy beds of soft shale and sandstone, alternating with thinner beds of hard limestone.

The interval between any two terraces ranges from a few feet to 200 feet or more. Both the height and the width of the terraces depend mainly on the thickness and softness of the intervening shales and sandstones, as compared with the scarp-forming limestone. The slopes follow the soft layers; the hard layers form the cliffs, scarps, and crests of the terraces.

Owing to the lateral migration of the drainage down the dip slope of the rocks, particularly the limestones, the larger valleys are bordered on the west and northwest by steep-faced bluffs or scarps, many of them 200 feet high. These bluffs overlook flat lowlands on the opposite sides of the rivers, where the confining banks are insignificantly low or absent, as along the Verdigris, 2 miles north of Coffeyville. Here the controlling agents in the development of this feature were the dip slopes of the Drum and other limestones which now outcrop a mile or more east of the river. Where the limestone is heavy and much more resistant than the overlying shale, its dip slope after the erosion of the shale may form a structural dip plain of considerable extent. Thus the Piqua limestone, about 40 feet thick, forms such a plain between Neodesha and Sycamore on the east, and Elk, Duck Creek, and Plum Creek on the west. This plain is 9 or 10 miles wide and slopes gently westward to the base of the scarp formed by the overlying Buxton formation. From Elk River it extends 16 miles northward to the limits of the quadrangle, beyond which it is still more perfectly and extensively developed in the country east and northeast of Fredonia.

The scarp formed by the strike edge of the Piqua limestone, from the point where it enters the quadrangle near Verdigris River on the north to the region beyond Elk River on the south, where the limestone thins, is so prominent as to be readily legible on the map. It extends northwestward up Fall River, with a gradual decrease in height beyond the edge of the quadrangle, and similarly westward up Elk River, as the dip plain gradually decends to the city of Elk. An outlier of this plain is Table Mound, the small limestone-capped butte south of Elk River, near the middle of the quadrangle.

The most rugged surface and the most important departure from the terrace type of topography is the hilly upland near the northwest corner of the quadrangle, known farther southwest as the Chautauqua Hills. The features of this upland have been carved out of the heavy-bedded sandstones of the Buxton formation and present considerable diversity. In the main they consist of irregular, generally steep or scarp-faced hills and trenched drainage ways. The hills of the upland rise from a few feet to nearly 200 feet above the main valleys, and the unreduced tops have a height of about 1060 feet. They are portions of a dissected plain or plateau with a gentle southwestward slope. The southeastward-facing escarpment of this plain is excellently shown northwest of Lafontaine and at other localities, as represented on the topographic map. Similar but smaller and less rugged areas occur in the Wilson formation between Jefferson and Verdigris River and along the southern border of the quadrangle, between Caney and Coffeyville.

Drainage.—Kansas is drained essentially by Kansas and Arkansas rivers and their tributaries, the divide between the two drainage systems trending about east and west through the middle of the State. The Independence quadrangle lies south of this divide and its master stream, Verdigris River, flows slightly east of south across the quadrangle.

Like most other rivers of eastern Kansas, the Verdigris is essentially a graded stream almost to its source. Throughout its course its channel is well defined and its valley partly infilled, with banks from 20 to 50 feet high. This statement is also true of the lower portions of its larger tributaries. It has a fall of about 2 feet per mile in its course across this quadrangle. It is essentially a stream fed by surface run-off; the flood flow is large and the summer flow small, and the fluctuations in height are extreme and rapid.

DESCRIPTIVE GEOLOGY.

GENERAL RELATIONS.

The consolidated rocks of the Independence quadrangle are a part of the Carboniferous beds, ranging from Mississippian to Permian in age, that cross eastern Kansas in a broad, nearly north-south belt and dip gently westward under younger formations. The rocks exposed in the quadrangle lie near the middle of this belt and are a part of the Pennsylvanian series. They are about 1000 feet in thickness and consist mostly of thick beds of soft shales and sandstones and thin beds of hard limestones, conformably alternating many times with one another. They include also a few beds of coal and locally some conglomerates, and are in the main of marine origin. Their distribution is shown on the areal geology map and a generalized section of them is shown on the columnar section sheet.

The rocks lying stratigraphically between those of the Independence quadrangle and those of the Cottonwood Falls quadrangle farther northwest, described in the Cottonwood Falls folio, are similar to those of the Independence quadrangle, and like them consist of alternating shales, sandstones, and limestones. These rocks also are of Pennsylvanian age and have an aggregate thickness of about 630 feet. The formations are likewise of similar character for a distance of 25 miles east of the quadrangle, but beyond this strip they alternate at wider intervals, and the eastern portion of the Carboniferous belt is occupied by long, broad subbelts, one being that of the Cherokee shale and the other that of the Mississippian or "Lower Carboniferous" limestones, including the Boone formation.

The rock formations exposed in the quadrangle are conformable and have an aggregate thickness of about 1000 feet, or approximately one-third of that of the "Coal Measures" in this region. As shown in the generalized columnar section, considerably more than three-fourths of this thickness is made up of shale and sandstone, and less than one-fourth of limestone.

The limestones strongly resemble one another throughout the section and can be differentiated only by a detailed study of their characteristics. They usually occur in beds of 1 to 5 feet in thickness, but the largest are 40 or 50 feet thick. Most of them are fine grained, crystalline, or semicrystalline. Those in the upper part of the section are more crystalline than those in the lower part. They are best developed in the northern part of the quadrangle and they thin or die out toward the south, as shown in fig. 1. They contain many cherty segregations in thin layers or nodules of various sizes and shapes. On account of their greater resistance to erosion the limestones usually cap the mounds and form the crests of the terraces and the scarps. Most of the terraces are composed of a hard limestone underlain and in part overlain by soft shale.

The shales are in the main thin bedded and vary in degree of purity, ranging from clay shale to impure limestone or sandstone. They are usually so firm as to require blasting where quarried for commercial purposes.

The sandstones are fine grained, some of them slightly micaceous, and occur in beds from 1 to 40 inches thick.

The coal seams are as a rule associated with the arenaceous shale or sandstone, and like the latter, denote littoral conditions when the raw material of the coal was deposited.

Marine fossils are locally abundant in some of the limestones, but occur rather sparingly in the shales and are rare in the sandstones. Here and there, however, the sandstones afford remains of plants that grew on the shore along which the sediments were laid down. The more important diagnostic and characteristic fossils collected in the quadrangle are given in the discussion of the several formations.

As shown by the drill records and represented on the columnar section sheet, the portion of the Pennsylvanian series that underlies the Independence quadrangle, and extends downward with a thickness of 770 feet to the Mississippian limestones, is similar in character to that exposed at the surface. By reason of the northwesterly dip of the series as a whole, each lower formation outcrops farther east than the one next above it. The Boone formation, which lies at the depth of 1560 feet below the surface at Caney in the southwestern part of the quadrangle, forms the surface of the country at Carthage, Mo., and at Bentonville and Rogers, Ark., as shown in the Joplin and Fayetteville folios.

ROCKS EXPOSED AT THE SURFACE.

CARBONIFEROUS SYSTEM.

PENNSYLVANIAN SERIES.

The rocks exposed at the surface in the quadrangle are here considered in ascending order, from the oldest to the youngest. Some of the formations or certain of their members have received formation names in the Iola quadrangle, to the northeast,[a] and these names are here employed so far as practicable. The general thinning and final disappearance of the limestone members from northeast to southwest, across the Iola, Fredonia, Parsons, and Independence quadrangles, are shown in fig. 1.

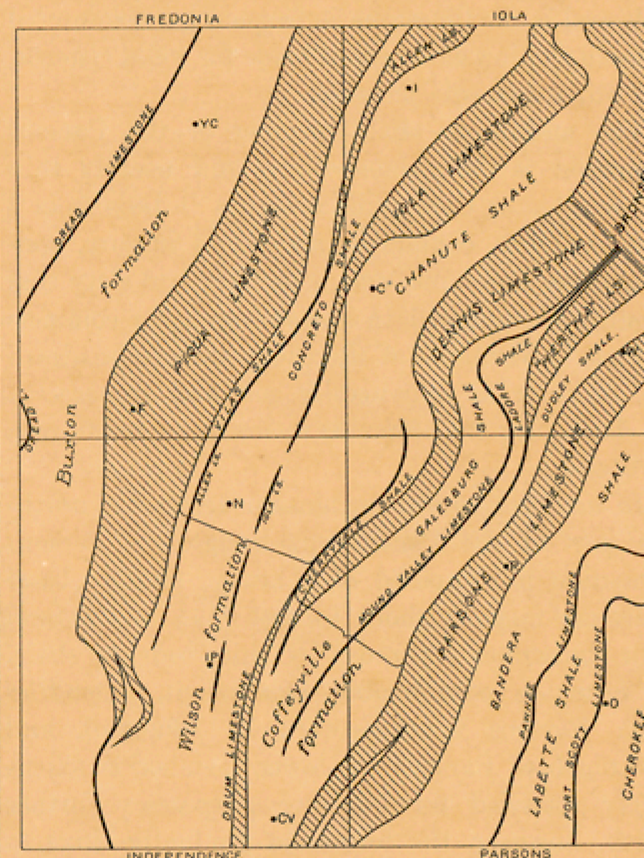

FIG. 1.—Sketch map of Fredonia, Iola, Independence, and Parsons quadrangles, showing the distribution of the formations and members and the thinning out of the limestone toward the southwest.

C, Chanute; CV, Coffeyville; F, Fredonia; I, Iola; IP, Independence; N, Neodesha; O, Oswego; P, Parsons; W, Walnut; YC, Yates Center.

PARSONS FORMATION.

The Parsons is the lowest formation exposed in the Independence quadrangle. Counted from the base upward, it is the third limestone-bearing formation in the Pennsylvanian series. It has a

[a] Bull. U. S. Geol. Survey No. 238, 1904, Pl. I.

thickness of about 80 feet and extends from the Bandera shale, which appears just southeast of the quadrangle, upward to the Coffeyville formation. The Parsons outcrops in a belt about 8 miles in width, trending northeast and southwest across the southeast corner of the quadrangle, and extends laterally from Coffeyville southeastward to Snow Creek, in Oklahoma. It is exposed in the banks of the Verdigris and its tributaries and in the surrounding hills.

The formation consists of three members, a lower limestone 15 feet thick, a shale member about 45 feet thick, and an upper limestone about 20 feet thick. In the shale member are excavated the brick pits in Coffeyville, on the banks of the Verdigris. At this locality the following partial section is exposed:

Partial section of the Parsons formation exposed in the Coffeyville brick pits and immediate vicinity.

	Feet.
Limestone (upper)	10
Shale, olive-green	2
Limestone	1½
Shale, jointed, hard, dark slate-colored, in beds 2 to 3 feet thick, containing some impure noncrystalline limestone nodules	15

The lower limestone is exposed at intervals in the bed of Pumpkin Creek northeast of Coffeyville for several miles and in the beds of Snow Creek and other small creeks tributary to the Verdigris in the southeast corner of the quadrangle and contiguous territory. It consists of two submembers with a parting of 2 or 3 feet of dark slaty shale. The lower submember is the harder and more crystalline of the two, and is the more easily identified by reason of the massive and persistent beds of large corals (*Chætetes*) which it contains in abundance. Good exposures of these corals occur at the highway crossing of Pumpkin Creek 4 miles east and one-fourth mile north of Coffeyville and on the small creek that enters the Verdigris at the State boundary. The upper submember is compact, bluish gray, and semicrystalline and contains numerous fossiliferous chert nodules, mostly in a light-colored layer near its top.

The upper limestone member of the Parsons formation is more crystalline and less compactly bedded than the lower limestone. It is pink or reddish, medium grained, and tough. Its basal portion is shaly, nodular, and impure; the upper part is heavy bedded and forms prominent scarps where incised by streams. It weathers into thin slabs or small angular and rounded fragments and furnishes a dark soil. It is exposed on several streams tributary to the Verdigris north of Coffeyville, in the banks of the river south and east of that town, and over a considerable area of country extending thence southeastward beyond the quadrangle into Oklahoma. It underlies Coffeyville and is the limestone so frequently encountered there in shallow excavations made for wells, cisterns, and other domestic purposes.

The middle or shale member of the Parsons formation is dark slate-colored and usually thin layered, but at Coffeyville it occurs in beds from 2 to 3 feet thick, containing nodules of impure, noncrystalline limestone, and is so hard and slaty that blasting is employed in excavating it for commercial use. Northeast of the Independence quadrangle, however, it is generally soft and arenaceous. Its dark color at Coffeyville seems to be due to iron carbonate.

In its northeastward extension across the northern part of the Parsons quadrangle the Parsons formation is composed of a heavy, massive basal limestone member about 14 feet thick and several thin limestones separated by thin beds of shale. It forms a considerable escarpment, extending from Parsons southeastward to Altamont, and just north of Parsons the lower member is extensively quarried for building purposes. Farther north, however, the formation gradually thins to a total thickness of but 10 or 15 feet and finally loses its complexity, so that in the Iola quadrangle it is reduced to a single member and becomes regular in character.

A list of the more important and characteristic fossils of the Parsons limestone follows. In connection with this list and others which appear under their respective formations, notes on the range and peculiarities of certain forms are quoted from the report made on the fossils by George H. Girty, who has collected the most of them and made the determinations.

The easily recognized coral *Chætetes milleporaceus* is diagnostic of the lower horizons of the section, occurring at many places in large masses and in great abundance. This is particularly true of the formations lower than those of the Independence quadrangle section, such as the Fort Scott and Pawpee limestones, but the same form is also abundant in the lower Parsons. Only a single and a doubtful instance of its occurrence at a higher horizon is furnished. This is in the Piqua limestone. *Chonetes mesolobus*, a strongly characterized species of the genus, and a type which is almost purely American, ranges no higher than the Parsons.

Lophophyllum profundum.	Productus cora.
Chætetes milleporaceus.	Marginifera wabashensis.
Derbya crassa.	Spirifer cameratus.
Meekella striaticostata.	Squamularia perplexa.
Chonetes flemingi.	Composita subtilita.
Productus punctatus.	Hustedia mormoni.
Productus nebraskensis.	Trepospira sphærulata
Productus semireticulatus.	

COFFEYVILLE FORMATION.

The Coffeyville formation, named after the town which stands upon it near the middle of its outcrop belt, comprises all of the geologic section between the top of the Parsons formation, just described, and the base of the Drum limestone. Its outcrop belt trends in a northeast-southwest direction and has a width of about 6 miles. The formation has a thickness of 250 feet, and comprises five members, four of which in the Iola quadrangle, to the northeast, have received distinct formation names. These members, named in the order of their position in the section, beginning at the top, are the Cherryvale shale, Dennis limestone, Galesburg shale, Mound Valley limestone, and Ladore-Dudley shale.

On the south, where the limestones are absent, the Coffeyville formation consists of alternating beds of argillaceous to arenaceous shale and sandstone, in many places without distinguishing characteristics between adjacent members; toward the northeast the Dennis and Mound Valley limestone lentils are present, representing the thinning or dying out of these formations to the southwest from their wide belts in the Iola and Parsons quadrangles.

Ladore-Dudley shale member.—The Ladore-Dudley shale extends from the top of the Parsons formation upward to the Mound Valley limestone lentil, and has a thickness of about 90 feet. The term Ladore-Dudley is here used to designate the beds that are the equivalent of the Ladore shale, the "Hertha limestone," and the Dudley shale southwest of the point where the "Hertha limestone" dies out, in the northern part of the Parsons quadrangle, as shown in fig. 1. This member consists essentially of soft, compact, argillaceous or arenaceous, thin-layered brown shale, with a little interstratified sandstone. It presents essentially the same lithologic characteristics and maintains about the same thickness wherever it is exposed. It is easily eroded so that its upper limit is usually defined by a scarp capped by the overlying limestone lentil, as on Big Hill Creek. It outcrops in a belt that has a maximum width of about 6 miles southeast of Liberty, but narrows to the southwest, toward Oklahoma. The town of Coffeyville, situated near the middle of the belt, stands on its basal layers, and the brick and tile pits a mile northwest of Coffeyville are excavated in it.

Mound Valley limestone lentil.—The Mound Valley limestone overlies the Ladore-Dudley shale member, but is known to be present in the Independence quadrangle only in the area lying northeast of Liberty. Near Big Hill Creek, to whose valley it is mainly confined, its outcrops form a belt several miles in width. It extends thence 13 or 14 miles northeastward to the head of the creek. It dies out about a mile north of Liberty and also near the eastern edge of Liberty Township, about a mile west of Potato Creek. It is from 8 to 15 feet thick, compact or fine grained, semicrystalline, and fossiliferous, and ranges from thin bedded to massive. Owing to its hardness and the softness of the underlying Ladore-Dudley shale, it is a prominent scarp former, especially where cut into by streams.

The following is a list of the more important and characteristic fossils of the Mound Valley limestone:

Productus cora.	Marginifera wabashensis.
Productus semireticulatus.	Squamularia perplexa.
Productus nebraskensis.	Composita subtilita.
Productus punctatus.	Acanthopecten carboniferus.
Productus sp.	

Galesburg shale member.—The Galesburg shale lies between the Mound Valley and Dennis limestone lentils. It has a thickness of about 40 feet and its maximum width of outcrop belt, west of Cherryvale, is less than a mile. It consists in the main of red arenaceous shale, but contains also some heavy beds of micaceous sandstone and thin seams of coal. Much of it weathers to a pronounced rusty brown, denoting the presence of considerable iron. The softer shales occur in the basal part of the section.

In the south bank of Drum Creek, 1½ miles west of Cherryvale, its upper part is exposed as follows:

Section of upper part of Galesburg shale on Drum Creek near Cherryvale.

	Ft.	in.
Limestone (Dennis).		
Shale, altered, earthy, rusty brown at base	1	
Coal, bituminous, comminuted		4
Shale, dark, earthy, altered, laminated		6
Shale, light drab and yellowish brown	1	
Sandstone, soft, calcareous		4
Shale, coarse, pale bluish and lead colored	1	3
Sandstone, light brown, fine grained		8
Sandstone, slaty, shelly		8
Sandstone		6
Sandstone, thin layered	3	6

Near the middle of the north edge of the Parsons quadrangle, about 4½ miles east-northeast of Galesburg, on a small creek that drains northeastward to Neosho River, between the top of the neighboring ridge and the bed of the creek, the Galesburg shale exposes the following vertical section:

Section of Galesburg shale 4½ miles east-northeast of Galesburg.

	Feet.
Limestone (Dennis).	
Shale, light yellow, very sandy	23
Sandstone, soft, incoherent	2
Shale, light yellow	20
Limestone (Mound Valley).	
	45

From this point northeastward the Galesburg member decreases in thickness and at Porterville, in the Iola quadrangle, becomes merely a member of the Bronson limestone.

Dennis limestone lentil.—Next above the Galesburg shale member lies the Dennis limestone lentil. It has a thickness of 10 to 50 feet and a breadth of outcrop of about 4 miles, extending southeastward from Drum Creek between Cherryvale and Morehead. It is named from the town of Dennis in the Parsons quadrangle, which stands upon it. Its southernmost recognized outcrop is on Drum Creek, at a point about 4 miles north of Liberty and 5 miles east of Independence. It forms the stream bed and low bluffs along Drum Creek, where in its northwesterly dip it disappears beneath the Cherryvale shale member. It is medium grained, hard, bluish gray, semicrystalline, fossiliferous, and usually massive, but because of the hardness of the underlying shale it does not form prominent scarps. It contains considerable chert and weathers to a black, fertile soil. Its thickness on Drum Creek 1½ miles west of Cherryvale is approximately 10 feet; at Morehead, Galesburg, and the head of Big Hill Creek 25 feet; and at Shaw 50 feet, showing a marked increase toward the northeast.

The following is a list of the more important and characteristic fossils from the Dennis limestone:

Productus cora.	Dielasma bovidens.
Productus semireticulatus.	Spirifer cameratus.
Productus punctatus.	Squamularia perplexa.
Productus nebraskensis.	Spiriferina kentuckyensis.
Marginifera wabashensis.	Composita subtilita.

Cherryvale shale member.—The Cherryvale shale, which is equivalent to the lower part of the Chanute shale of the Iola quadrangle, has a thickness of about 100 feet. Areally it extends from Morehead southwestward along Drum Creek in a comparatively narrow belt, which widens toward the east, however, below the mouth of Cherry Creek. The town of Cherryvale stands upon the shale and the pits of the Cherryvale pressed-brick plant are excavated in it about a mile south of the town.

It is exposed in the prominent chain of hills and mounds extending from Morehead to Liberty, where it is capped by the Drum limestone. Normally it is light drab in color, but in places it is red or yellowish. It is very fragile and easily disintegrated—a fact which accounts for the steep slopes of the scarps and mounds contained within its area. In the main it is an excellent brick shale, but locally it contains a variable amount of fragile sandstone and some thin beds of coal.

DRUM LIMESTONE.

The Drum limestone lies next above the Coffeyville formation and for the most part caps the mounds and their associated scarps that extend from Morehead southwestward into Oklahoma a few miles southwest of Coffeyville. It is named from Drum Creek. The maximum breadth of outcrop of the formation is about 7 miles and is found east of Independence, whence it narrows northeastward and southwestward. In the northern part of its area, from Morehead nearly to Liberty, the formation consists of a single limestone member, which ranges in thickness from 4 to 12 feet at Cherryvale and Morehead to nearly 100 feet near Independence, at the mouth of Rock Creek, where it is manufactured into Portland cement. The limestone is here strongly marked by cross-bedding. At the highway bridge crossing the river just east of Independence a thickness of 40 feet is exposed. It is medium to fine grained, ranges from dense to semicrystalline, and contains abundant invertebrate fossils. West of Drum Creek, on the divide between Cherryvale and Independence, it occupies extensive areas and is weathered into large bowlders.

Toward the south the formation loses its simplicity and becomes subdivided so that between Liberty and the Oklahoma line, on the west side of the Verdigris, it consists of three or more members. These are a lower heavy-bedded or massive limestone 12 feet thick, an intervening shale member 10 to 25 feet thick, and an upper thin-bedded flaggy limestone 2 to 10 feet thick. The upper limestone is usually hard, blue, and in many places flinty, and is important economically in being the source of the excellent flag, curb, and building stone supplied from the various quarries in the region between Coffeyville and Dearing. Three miles southeast of Liberty, just west of the house on the Copeland farm, the section exposed is as follows:

Section of Drum limestone 3 miles southeast of Liberty.

	Feet.
Sandstone (Chanute member of Wilson formation).	
Limestone, rough and stony	5
Limestone, flaggy, in layers 2 to 4 inches thick	10
Shale containing flaggy limestone toward top	25
Limestone, persistent, heavy bedded or massive, semicrystalline, and fossiliferous	12
Débris slope descending 4 feet to edge of the flats.	

About 5 miles north-northwest of Coffeyville, in a ravine cut in the surface of the upland, the formation shows the following beds:

Section of Drum limestone north-northwest of Coffeyville.

	Feet.
Sandstone (Chanute member of Wilson formation).	
Limestone, rough cap	7
Limestone, flaggy, and shale	20
Shale, containing some flaggy limestone	15
Limestone, heavy bedded or massive	18
Shale, black, slaty, slightly micaceous	1½
Limestone	4
Shale (Cherryvale).	

On the west side of Verdigris River, 5 miles north-northeast of Independence, the following section is exposed:

Section of Drum limestone north-northeast of Independence.

	Feet.
Sandstone, heavy bedded.	
Sandy shale.	
Limestone, very compact and crystalline	6
Shale, sandy, and yellowish clay	15
Limestone, cement type, massive to heavy bedded, coarse grained, soft, very fossiliferous, with some fossil forms well preserved, lamellibranchs and trilobites being present	10
Shale, 10+ feet, to river level.	

In its extension northeastward in the Parsons quadrangle the Drum consists of a single massive limestone which becomes very arenaceous and hard. It thins to 18 inches east of Thayer, near the northern border of that quadrangle, near which point it dies out in the Chanute shale.

The following is a list of the more important and characteristic fossils of the Drum limestone. "The interesting genus *Pseudomonotis*, which has sometimes been cited as a peculiarly Permian type, first appears in this formation and is rather abundant."

Fenestella sev. sp.	Acanthopecten carboniferus.
Polypora sev. sp.	Aviculipecten sculptilis.
Septopora biserialis var. nervata.	Pseudomonotis hawni var. equistriata.
Stenopora sp.	Myalina swallowi.
Dielasma bovidens.	Myalina kansasensis.
Spirifer cameratus.	Myalina subquadrata.
Squamularia perplexa.	Edmondia aspinwallensis.
Spiriferina kentuckyensis.	Cypricardinia carbonaria?
Composita subtilita.	Pleurophorus oblongus.
Hustedia mormoni.	Pleurophorella? costata.

WILSON FORMATION.

The Wilson formation, named after Wilson County, in whose southeast corner the rocks are extensively exposed, occupies the portion of the section included between the top of the Drum limestone and the base of the Buxton formation. It comprises six members, which, like those of the Coffeyville, have received formation names in the Iola quadrangle, to the northeast. These members, named in ascending order, are the Chanute shale, Iola limestone, Concreto shale, Allen limestone, Vilas shale, and Piqua limestone. They have been grouped into the Wilson formation on account of the discontinuity of some of the members and the irregularity of others, particularly the limestones. (See fig. 1.) This characteristic renders the Wilson, especially toward the south, essentially a shale and sandstone formation, like the Coffeyville. The formation contains also local limestone lentils, which are represented by a separate symbol on the geologic map.

The formation has a thickness of 280 feet, as shown in the sections. It outcrops in a belt about 16 miles in width, trending diagonally across the quadrangle in a northeast-southwest direction, and extending laterally from the vicinity of Morehead, Liberty, Dearing, and Coffeyville on the east to Fredonia and beyond Lafontaine, Elk, Havana, and Caney on the west. Its occurrence in the Caney-Wayside region, however, is principally in the valleys, the uplands being formed of the overlying Buxton formation. Probably its best exposed section occurs in the southwestern part of Table Mound. (See fig. 2.) It is as follows:

Partial section of Wilson formation in Table Mound.

	Feet.
Limestone, massive, coarse, crystalline, weathering to rough blocks (Piqua)	40
Shale, light yellow, argillaceous, water bearing (Vilas)	80
Limestone, semicrystalline (Allen)	3
Blue clay or shale (Concreto)	42

Chanute shale member.—The Chanute shale member of the Wilson formation is equivalent to the upper part of the Chanute shale as mapped in the Iola quadrangle. It overlies the Drum limestone and extends upward to the horizon of the Iola limestone, its thickness being 75 feet. It occupies a broad belt with an average width of about 5 miles, extending from the northeast corner of the quadrangle southwestward into Oklahoma, but near Independence the belt narrows greatly and the member thins to about one-half its normal thickness, the underlying Drum limestone becoming thicker, seemingly at its expense.

It consists of shale and sandstone in about equal amounts, and contains the shale used by the Independence cement plant. On the north it forms the expansive upland that slopes gently westward from Thayer, in the Parsons quadrangle, to Neodesha and Verdigris River, and contains in its upper part the Chetopa Creek, Thayer, and other workable coals. Toward the south it contains much sandstone, which forms, among other areas, the hilly sandstone country extending from Jefferson and Dearing northeastward to the Verdigris. This rock is locally used for building purposes in the Jefferson-Dearing and Thayer regions. The shale also contains limestone lentils, of which those at the schoolhouse 2 miles north and half a mile west of Liberty differ from the other limestones found in the quadrangle, the rock composing them being profusely and irregularly veined with calcite. This limestone is dull pinkish gray, massive, compact, dense to semicrystalline, and very fossiliferous, and is separated from the Drum by an interval of 30 to 40 feet of sandstone, upon which it rests.

Iola limestone member.—From the northeast corner of the quadrangle southward to the head of Rock Creek, southwest of Independence, extends a series of thin limestone beds and lentils, rarely exceeding 2 or 3 feet in thickness. The principal exposures are at Independence and on Choteau and Chetopa creeks and other small streams tributary to the Verdigris on the east, between Sycamore and the northern boundary of the quadrangle. From their lithologic resemblance to the Iola limestone at various points and their occurrence at or near its horizon, these limestones are believed to be the southward extension of the Iola, which southwest of Chanute and Earleton occurs only in disconnected lentils. Hence these beds are mapped as Iola, and the underlying and overlying shales are regarded, respectively, as the Chanute (upper part) and Concreto. The limestone ranges from crystalline to argillaceous. It is medium grained and fossiliferous, with crinoids locally plentiful.

The following is a list of the most important and characteristic fossils of the Iola limestone:

Chonetes flemingi.	Marginifera wabashensis.
Meekella striaticostata.	Dielasma bovidens.
Productus cora.	Spirifer cameratus.
Productus semireticulatus.	Squamularia perplexa.
Productus punctatus.	Spiriferina kentuckyensis.
Productus nebraskensis.	Composita subtilita.
Productus sp.	Acanthopecten carboniferus.

Concreto shale member.—The Concreto shale extends from the horizon of the Iola limestone upward to the Allen limestone member, with which its contact is well shown in the scarps west of Fall and Verdigris rivers, extending southward to Table Mound, near the center of the quadrangle. It has a thickness of about 60 feet. Though it is essentially a clay shale and contains shale of good quality, particularly in its upper part, in which the pits of the brick and cement plants at Neodesha, Sycamore, and Table Mound are excavated, it also contains much heavy-bedded brown and greenish sandstone. Useful stone from these beds is obtained at various localities, the most extensively operated quarries being near Independence and Neodesha.

The portion directly underlying the Allen limestone consists of 5 feet of calcareous shale, containing abundant crinoidal remains, and is definitely marked off from the underlying shale by an 8- to 10-inch layer of shaly limestone. It is well exposed in the eastern base of the scarp at the schoolhouse one-half mile south of the north edge of the quadrangle, 5½ miles north-northwest of Neodesha; in the south base of Little Bear Mound, near Neodesha; and in the north-south road just north of Dun.

Allen limestone member.—The Allen limestone occurs next above the Concreto shale and extends upward to the Vilas shale. It is exposed in the middle part of the section which forms the Fall and Verdigris river bluffs, extending from the northern border of the quadrangle southward to Elk River. Its southernmost recognized outcrops are at Crane and Table Mound, where it dies out in the shale. It occurs also as a small outlier capping Buff Mound, 4 miles north of Neodesha. As a rule only its edges are shown, but on Fall River, where the northwesterly dip carries it down nearly to the river flats and the bluffs above it are cut back, it is exposed in an irregular belt on either side of the river, in some localities nearly half a mile in width. It is well shown in the highway ascending the hill 2 miles west of Verdigris and half a mile south of the northern border of the quadrangle. It ranges from 4 to 70 feet or more in thickness, the average being about 30 feet, and thins both southward and northward from the locality of its maximum development. It is about 4 feet thick at Table Mound, and 55 to 70 feet at Neodesha, where it is used in making Portland cement. It is massive, semicrystalline, compact to coarse grained, fossiliferous, and in many places dark blue in color. Its extreme basal portion contains a persistent calcareous bed in which fossil sponges are abundant. At Neodesha it is much broken up, and has no definite bedding or layers, so that its topography resembles that of shale.

Dr. Girty in his report on the fossils gives the following notes:

The Allen limestone is generally characterized by the presence and abundance of fossil sponges belonging to the genera *Mæandrostia*, *Heterocœlia*, *Cœlocladia*, and *Heliospongia*. These have been noted in almost every collection from the Allen and are known at no other horizon within the area, save a few occurrences in the Piqua limestone. The brachiopod *Enteletes*, another striking genus, occurs first in the Allen limestone and is reasonably abundant at that horizon and in the Piqua and Oread beds. In the Allen again the *Producti*, so characteristic of the other faunas, are very scarce except for *Marginifera wabashensis* and *Productus symmetricus*.

The following are the most important and characteristic fossils:

Heterocœlia beedei.	Dielasma bovidens.
Mæandrostia kansasensis.	Spirifer cameratus.
Heliospongia ramosa.	Squamularia perplexa.
Cœlocladia spinosa.	Spiriferina kentuckyensis.
Lophophyllum westi.	Composita subtilita.
Fistulipora sp.	Hustedia mormoni.
Derbya bennetti.	Acanthopecten carboniferus.
Productus symmetricus.	Edmondia aff. nebraskensis.
Marginifera wabashensis.	Platyceras parvum.
Pugnax osagensis.	

Vilas shale member.—The Vilas shale overlies the Allen limestone and extends upward to the Piqua limestone. Like the Allen, it is exposed mainly in the scarps and bluffs occurring west of Fall and Verdigris rivers. It varies more in thickness than any other member in the quadrangle. At Table Mound it is 80 feet thick and at Dun 15 feet, while 2½ miles west of Neodesha it is absent, the underlying Allen and the overlying Piqua limestones being in contact. At Little Bear Mound it is 10 feet thick, at the north edge of the quadrangle about 20 feet, and in the Fredonia quadrangle, at Vilas, the type locality, west of Chanute, 75 feet. Its average thickness in the Independence quadrangle is estimated at about 70 feet.

The Vilas member is a clay shale, drab in the northern part of the quadrangle and light drab to pale yellowish at Table Mound and farther south.

Piqua limestone member.—The Piqua limestone, the top member of the Wilson formation, is one of the most important and prominent limestones of the quadrangle. It outcrops in a belt 1 to 8 miles wide, extending from north to south through the quadrangle somewhat west of its median line. It ranges in thickness from 50 feet at the north to only a few feet at the south, where it extends into Oklahoma, its occurrence here being in the form of lentils. Its average thickness is about 40 feet. It caps the scarps and mounds along the west side of Fall and Verdigris rivers from Table Mound to the northern border of the quadrangle. Its eroded dip plain having a width of 9 miles, slopes gently westward from the scarp at Neodesha, Sycamore, and Table Mound to the foot of the scarp formed by the overlying Buxton formation beyond Lafontaine and Elk. This dip plain is well shown along Elk River, where it contrasts strongly with the nearly level flood plain. In this plain the Piqua consists essentially of a massive bed 45 to 50 feet thick, and is whitish or light gray in color, medium to coarse grained, relatively pure, and the most completely crystalline of all the limestones encountered in the quadrangle, probably more than half of its mass consisting of crystalline calcite. It weathers to coarse, rough blocks. Farther south it loses its purity, becoming locally shaly, arenaceous, or conglomeratic, with pebbles of limestone and sandstone, and splits up into two or more thin limestones with intercalated shale or sandstone. The conglomeratic and arenaceous character marks the upper of two such separated limestones 6 miles west of Independence and 3 miles west of Walker Mound, while the fact that the lower remains relatively pure suggests that the upper bed probably represents an erosional unconformity.

A mile and a half northeast of Wayside, just northwest of the Atchison, Topeka and Santa Fe Railway, the Piqua presents the following section:

Section of Piqua limestone 1½ miles northeast of Wayside.

	Feet.
Limestone, impure	7
Sandstone	10
Limestone	10
Shale	8
Limestone, impure	12
Shale.	

At Tyro, however, as shown in the scarp 1 to 2 miles northeast of the village, it consists of a single limestone member 9 feet in thickness and is overlain and underlain by sandstone.

Outside of the quadrangle its dip plain extends northward and continues well developed beyond Fredonia, which is situated at the western edge of the outcrop belt, at the foot of the dip slope.

The following is a list of the more important and characteristic of the fossils of the Piqua limestone. According to Dr. Girty, *Enteletes*, a striking genus of the Brachiopoda, is reasonably abundant in this formation.

Enteletes hemiplicatus.	Marginifera wabashensis.
Productus cora.	Spirifer cameratus.
Productus semireticulatus.	Squamularia perplexa.
Productus punctatus.	Composita subtilita.
Productus nebraskensis.	Hustedia mormoni.
Productus sp.	Myalina subquadrata.

BUXTON FORMATION.

The Buxton formation overlies the Wilson formation and extends upward to the Oread limestone, its thickness being 320 feet. It is believed to be the equivalent of the formations named Lawrence shale and Leroy shale by the University Geological Survey of Kansas[a] and described as extending across the State from Leavenworth to Sedan, in a broad belt in which the valleys of Kansas and Wakarusa rivers are excavated.

The formation occupies the western part of the quadrangle, within whose limits its breadth of outcrop narrows from 8 miles at the north to about 2 miles at the south. In the northern part, except for a few small outliers occurring near the upper edge of the Piqua dip plain, it is limited on the east by a well-defined eastward-facing scarp about 100 feet in height, whose base the Roper and Peru branch of the Missouri Pacific Railway roughly follows from Fredonia southwestward to Elk.

The Buxton formation consists essentially of shale and shaly sandstone in about equal amounts, and contains some seams of coal and thin beds or lentils of limestone. It is notable for the commercial coal it contains farther northeast in Franklin, Douglas, and Atchison counties. It is the heaviest shale-bearing formation, except the Cherokee, in the Kansas "Coal Measures." Some of its shales are hard and perfectly laminated. The sandstone is usually soft and friable and contains considerable iron. The proportion of sandstone increases materially toward the south to the State boundary. To the sandstone beds of this formation is due the rugged hilly upland in the western part of the quadrangle. The southeastward extension of this upland forms the Chautauqua Hills, a feature in the topography of southeastern Kansas almost as prominent as the Flint Hills.

The valleys of the Buxton upland in this quadrangle are deep and bordered by many high, sandstone-capped bluffs. Four miles northwest of Elk the bluff on the south side of Elk River is about 200 feet high and exposes 180 feet, principally of shale, capped by 10 to 20 feet of massive sandstone. A similar section at Twin Mounds, near Fredonia, 2 miles north of the quadrangle, consists of 135 feet of shale, covered by a cap of heavy-bedded sandstone 15 feet thick.

The most important of the thin limestones are those outcropping on Duck Creek and near Elk. They are exposed in the Elk River bluff about 5 miles northwest of Elk, the upper bed at the elevation of 915 feet, near the top of the bluff, and the lower at 880 feet. The lower limestone has a thickness of 3 feet, is impure, soft, and fissile, and seems to represent the limestone which occurs in the river bed at Oak Valley, just west of the quadrangle. The upper limestone is 2 feet thick, bluish, hard, and crystalline, contains abundant fossils, and is believed to represent the limestone lentils occurring on Willow Creek and about Buxton. A limestone in the northwest corner of the quadrangle occurring at a higher horizon in the Buxton than those just described has been mapped as lentils, inasmuch as its connection has not been traced to localities where its relations are known. It is exposed near the divide between the head of Rainbow Creek and the east fork of Painterhood Creek, at about 50 feet below the top of the Buxton formation, the interval being occupied by a drab to olive-colored argillaceous to arenaceous shale. It is about 2 feet thick, light leaden gray in color, semicrystalline, medium grained, and fossiliferous.

OREAD LIMESTONE.

The Oread limestone occurs only in the northwest corner of the quadrangle, at the head of the east fork of Painterhood Creek, where it overlies the Buxton formation just described and occupies an area of less than a square mile. Stratigraphically it is one of the well-marked formations of the Kansas "Coal Measures" and gives rise to a scarp of considerable prominence along its line of outcrop, which is persistent across the State. It has a thickness of 12 feet, is reddish gray, thinly flaggy, semicrystalline, fine grained, and very fossiliferous, small brachiopods and various other forms being plentifully present. It weathers to a light chocolate-brown. This occurrence probably represents only the upper part of the formation as shown at Mount Oread, Douglas County.

A list of the more important and characteristic fossils of the Oread limestone is given on the next page. Dr. Girty states that, as in the Allen and Piqua limestones, *Enteletes*, a striking brachiopod, is reasonably abundant in the Oread.

[a] Haworth, E., Kansas Univ. Quart., vol. 2, 1894, pp. 110, 122.

Triticites secalicus.	*Productus nebraskensis.*
Fistulipora sp.	*Productus cora.*
Derbya crassa.	*Marginifera wabashensis.*
Meekella striaticostata.	*Spirifer cameratus.*
Enteletes hemiplicatus.	*Squamularia perplexa.*
Chonetes flemingi.	*Spiriferina kentuckyensis.*
Productus punctatus.	*Composita subtilita.*
Productus semireticulatus.	*Hustedia mormoni.*

ELGIN SANDSTONE.

Overlying the Oread limestone, in the extreme northwest corner of the quadrangle, is a body of hard, brown, medium-grained sandstone, which is believed to represent the Elgin sandstone, a member of the Kanwaka shale.[a] Only its edges, however, reduced by erosion to a thickness of but 10 or 15 feet, occur in this quadrangle, but farther northwest its thickness increases. It forms the highest ground of the quadrangle, reaching an elevation of 1130 feet above tide. It contains considerable iron and weathers rough.

QUATERNARY SYSTEM.

CHERT GRAVEL.

At various localities throughout the quadrangle and at all elevations there are surficial deposits of brown gravel. They may lie upon the surface of any formation, and range from a few scattered pebbles in some localities on the uplands to deposits 7 or 8 feet thick in the lowlands. The heavier deposits occur along the lower reaches of the larger valleys, whither they have been transported and accumulated by streams, and in some places deposited in beds. Most of the deposits are too inconsiderable, however, to be of economic value for macadam, ballast, or other purposes, except in a very small way.

The materials composing the gravel consist almost wholly of chert and flint, but include also a small percentage of sandstone and limestone and are derived from disintegrated limestones. For the most part the pebbles, though stream worn, are angular or subangular, and the larger deposits usually contain some associated sand and clay.

Among the localities at Independence the gravels are exposed just southeast of the county high school building in a road cut 2 or 3 feet deep, on Locust street between north Ninth and Tenth streets. At Coffeyville, near the Washington School, a few blocks west of the Mecca Hotel, they form a deposit at least 3 feet in thickness. In the southern part of this city also, near the Vitrified Brick Company's plant, on the banks of the Verdigris, is exposed a deposit of 2 to 4 feet of ferruginous red clay, loose sand, and stream-worn gravel. The material as a whole is crudely and discordantly stratified or cross-bedded, indicating its deposition in turbulent water.

Five-eighths of a mile south of this brick plant, on the Browne estate, the upper portion and slopes of the elongated mound which trends northwest and southeast, parallel with the course of the river near by, are composed of a 7-foot deposit of the gravel, covered in spots by a veneer of soil only a foot in maximum thickness. The gravel here contains just enough clayey material or matrix to enable it to stand vertically when faced, and being structureless it has in a fresh-cut bank somewhat the appearance of till. At the depth of 6 feet, however, the matrix becomes sandy, the sand being of the same light-brownish color as most of the sandstones within the drainage area of the Verdigris. The gravel is fine grained, most of the pebbles being less than an inch in diameter, though a few of the largest attain 3 or 4 inches. Some are corroded, pitted, scalloped, and cupped to varying forms and degrees, a few very deeply so.

Outside of the quadrangle the gravels were noted near Altoona and Fredonia, on the north, and Bartlesville, Okla., on the south. They extend eastward into Missouri and westward perhaps to the Tertiary rocks.

Although the gravels are here referred to the Quaternary, for the reason that they are derived from rocks in place by disintegration, which has been acting on these rocks ever since they have formed the surface of the country, it is quite probable that some of the gravels may belong to earlier periods, as is known to be true of similar gravels found in southwestern Missouri and adjacent portions of Arkansas.

[a] Haworth, E., Kansas Univ. Geol. Survey, vol. 3, 1898, p. 64.

ALLUVIUM.

The alluvium of the Independence quadrangle forms the flood plain or recent stream-laid deposits of detrital silt, soil, clay, sand, and gravel, that underlie the lowlands or flats along Verdigris River and its larger tributaries. It has been derived from the various rock formations by the processes of weathering and erosion, and it is the most recent and most composite of all the formations of the quadrangle. It is constantly receiving additions from high-water floods and wash from the neighboring hills, and may locally contain waste from all the formations occurring within the drainage basin of the stream above the point at which it is found. Hence much of it has come from outside of the quadrangle—some from the Flint Hills of Butler County, on the west, and some from Chase, Lyon, and other counties, on the north. It is commonly known as "soil" or "made ground." In some localities it has an average thickness of 35 or 40 feet.

Along the Verdigris and the lower reaches of its larger tributaries the alluvium forms a variable belt about 2 miles wide, the surficial portion consisting usually of a layer several feet thick of black, heavy, rich soil, mostly derived from limestone and shale. It follows the valleys and on the smaller tributaries usually becomes much narrower within a short distance upstream. On Fall and Elk rivers and Little Caney and Big Hill creeks it extends, with decrease in width, upstream beyond the limits of the quadrangle; on Drum Creek to a point about 30 miles above Cherryvale; and on Onion Creek nearly to Dearing.

SUBSURFACE FORMATIONS.

CARBONIFEROUS SYSTEM.

The underlying or subsurface portion of the Carboniferous section comprises the Bandera shale, Pawnee limestone, Labette shale, Fort Scott limestone, Cherokee shale, and Boone formation, named in descending order as encountered in drilling. A brief description of these formations follows.

PENNSYLVANIAN SERIES.

Bandera shale.—The uppermost formation of the subsurface portion of the section, the Bandera shale, underlies the Parsons formation and outcrops just beyond to the southeast corner of the quadrangle. It has a thickness of 140 feet and contains considerable thin-bedded sandstone.

Pawnee limestone.—The Pawnee is a massive limestone formation underlying the Bandera shale. It has a thickness of 30 feet.

Labette shale.—The Labette shale underlies the Pawnee limestone and is about 110 feet thick. It contains but little sandstone and has no characters that distinguish it from other shales of the series.

Fort Scott limestone.—The Fort Scott is the lowest "Coal Measures" limestone encountered in this area. It has a thickness of about 40 feet and comprises three members—an upper limestone 10 feet thick, an intervening shale and sandstone 15 feet thick, and a lower limestone 15 feet thick.

Cherokee shale.—The well-known Cherokee shale underlies the Fort Scott limestone and is of prime economic importance, as it is the great oil- and gas-bearing formation of the Kansas-Oklahoma field. It outcrops 30 miles east of the Independence quadrangle, in a broad belt crossing the southeastern part of the State and extending northeastward into Missouri and southwestward into Oklahoma. It is about 450 feet in thickness and consists mainly of soft shale, but contains beds of lenticular bodies of sandstone that vary in character, extent, and thickness.

MISSISSIPPIAN SERIES.

Boone formation.—The Boone formation underlies the Cherokee shale. It is the basal formation of the Carboniferous system, and is from 200 to 300 feet thick. Farther east it contains the well-known Galena and Joplin zinc and lead deposits in southeastern Kansas and southwestern Missouri. Its upper surface is eroded and forms a somewhat uneven floor, upon which the Cherokee rests unconformably. The general dip of the upper surface of the Boone formation from the eastern part of the State to the Independence quadrangle is about 21 feet per mile, and the dip of the overlying Pennsylvanian rocks is about 9 feet per mile, the difference in dip, or general angle of unconformity between the Pennsylvanian and the Mississippian series, being about 12 feet per mile. So slight is this unconformity that it can not be shown in the horizontal section on the structure and economic geology map.

PRE-CARBONIFEROUS ROCKS.

The rocks which underlie the Boone formation consist of 1500 feet of Devonian, Silurian, and Cambrian sediments extending downward to basal pre-Cambrian granite, gneiss, or schist. The deep well at Caney now being drilled in these sedimentary rocks has reached a depth of 2800 feet and, to judge from the depth and drill-core samples, has penetrated nearly to the Cambrian strata. The subjoined log shows the rocks thus far penetrated.

Log of deep well at Caney, Kans.

	Thickness.	Depth.
	Feet.	*Feet.*
Surface soil	30	30
CARBONIFEROUS:		
Coffeyville:		
Shale	165	195
Sand	30	225
Shale	85	310
Sand	10	320
Black shale	15	335
Shale	90	425
Limestone (Mound Valley member)	5	430
Black shale and gas	10	440
Sandstone	15	455
Shale	25	480
Parsons:		
Limestone	20	500
Shale	60	560
Limestone	20	580
Bandera:		
Black shale	2	582
Limestone	28	610
Shale	100	710
Pawnee:		
Limestone	30	740
Labette:		
Black shale	5	745
Shale	88	833
Fort Scott:		
Limestone	24	857
Black shale	8	865
Limestone	29	894
Black shale	6	900
Limestone	15	915
Black shale	10	925
Shale	25	950
Limestone	10	960
Cherokee:		
Shale	95	1055
Sandstone	20	1075
Shale	78	1153
Oil sand	15	1168
Shale	164	1332
Gas sand	18	1350
Shale	210	1560
Boone:		
Limestone	262	1822
DEVONIAN:		
Black bituminous shale, with traces of gas and odor of petroleum	35	1857
Limestone, variable, mostly fine grained	207	2064
Sandstone. fine grained	11	2075
SILURIAN:		
St. Clair:[a]		
Limestone, crystalline, gray	10	2085
Limestone, crystalline, hard, bluish gray (gas)	15	2100
Limestone, crystalline, hard, bluish gray, some brownish	10	2110
Limestone, crystalline, grayish, fine grained	13	2123
Limestone, crystalline, bluish gray	17	2140
Limestone, crystalline, brown, gritty (gas)	141	2281
Limestone, crystalline, brown, gritty	62	2343
Limestone, crystalline, variable	107	2450
ORDOVICIAN:		
Maquoketa:		
Sandstone, fine grained, white	22	2472
Limestone, soft, brownish gray (trace of asphalt ?)	28	2500
Limestone, cherty, porous } Polk Bayou and Kimmswick: Limestone, granular, light buff }	37	2537
Limestone, coarse in part } Limestone, bluish gray, crystalline (oil) }	63	2600
Plattin and Joachim:		
Limestone ? and shale ?	50	2650
Limestone, soft, clayey, bluish	100	2750
Limestone, magnesian, gray, sandy	4	2754
St. Peter:		
Sandstone, fine grained, gray to brownish, locally hard	46	2800

[a] Identification of formations below the Boone is only approximate.

The Cambrian rocks will probably be passed through in about 500 feet more of drilling and the underlying pre-Cambrian granites and other crystalline rocks be encountered at the depth of about 3300 feet.

The deep well located at Iola, 35 miles northeast of the Independence quadrangle, is 3085 feet in depth. All of the well except about the first 1000 feet is in Mississippian rocks, from which most of the limestone cuttings are reported to be of coarse granular texture, resembling sandstone or soft grit, but when treated with acid nearly all the cuttings dissolve, showing their calcareous character.

STRUCTURE.

GENERAL OUTLINE.

The Independence quadrangle forms a part of the great Prairie Plains monocline, which embraces all of eastern Kansas and portions of the neighboring States on the east. It is characterized by a very gentle dip of the rocks slightly north of west, shown in structure section A–A and fig. 2. Aside from this dip the rocks are on the whole only slightly deformed. In this quadrangle the dip

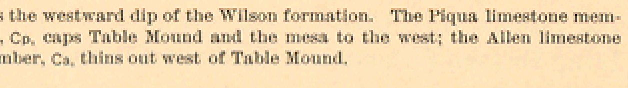

FIG. 2.—Section through Table Mound along line B–B on areal geology map. Horizontal scale: 1 inch=approximately 2 miles; vertical scale exaggerated 5 times.

Shows the westward dip of the Wilson formation. The Piqua limestone member, Cp, caps Table Mound and the mesa to the west; the Allen limestone member, Ca, thins out west of Table Mound.

averages about 15 feet per mile, but ranges from a maximum of 70 feet in the eastern part to 10 or 12 feet in the western. It begins to diminish along the line of Verdigris River, whence it gradually decreases to the western border of the quadrangle, so that the Verdigris in a general way lies on a very shallow north-south sag or bench on the Prairie Plains monocline.

STRUCTURAL DISTRICTS OF THE SURFACE ROCKS.

PRINCIPAL FEATURES.

A study of the exposed edges or croppings of the formations with reference to trend and elevation, as represented on the areal geology map, shows that the quadrangle contains two general structural districts of about equal size, a northern and a southern, the southern being slightly the larger. In the northern half of the quadrangle the general strike of the rocks is about N. 30° E. At about the latitude of Cherryvale and Elk the strike gradually swings until in the southern half of the quadrangle it is about north and south, or slightly west of north. This is shown by the trend of the outcrops of the Drum and Piqua limestones.

The east-west belt about 4 miles in width, within which the districts meet and the strike changes from east of north to west of north, consists in the main of a broad, low anticline or elongated transverse swell whose axis pitches very gently westward. Its southern limb forms part of the southern district, and its northern limb part of the northern district. It may be called the Cherryvale anticline, from the position of Cherryvale on its crest, near the point where the change in strike is pronounced.

In a narrow belt just south of this main axis and running from Elk to Liberty the strike swings to the northwest before assuming its general north-south direction. The southwest dips associated with this strike are plainly visible in the scarp of Piqua limestone at Elk River and in the Drum limestone west of Liberty. A similar diversion of the strike is to be seen along the State boundary at the south border of the quadrangle. The northeasterly strikes and northwesterly dips there shown, taken in connection with the southwesterly dips between Elk and Liberty, outline a broad, shallow basin covering most of the southern half of the quadrangle.

NORTHERN DISTRICT.

The dominant structure of the northern district is essentially the same as that of the Prairie Plains monocline in general. The average dip is northwesterly at the rate of about 15 feet per mile.

From Morehead to the Verdigris at Neodesha the rocks descend westward at the rate of about 23 feet per mile, but locally just west of Neodesha they lie nearly flat. Beyond this, however, a westerly dip of about 40 feet per mile is shown by the dip plain of the Piqua limestone extending to the Buxton scarp beyond Lafontaine and Elk. Other outcrops and stream sections show similar departures from the general strike and dip, as, for instance, west of the Verdigris between Neodesha and the north border of the quadrangle, where the dip is in places to the south at a very slight angle.

SOUTHERN DISTRICT.

In the southern district, though the rocks in many localities retain a westerly dip, on the whole they incline more to the southwest, and in some places nearly to the south. The dips for the most part are gentle, as in the northern district.

Just south of Cherryvale a southerly inclination is manifest. South of the cement plant on Rock Creek, a few miles southeast of Independence, at an elevation of about 800 feet, the Drum limestone shows a distinct minor fold with a nearly east-west axis and a southwestward pitch of about 60 feet per mile. On its line of strike about 5 miles farther southeast, at a point about 2 miles northwest of Liberty, at substantially the same elevation as near Independence, the dip is even greater in a southwesterly direction. South of this place, however, as shown in the scarps along the west side of the Verdigris, the strike veers to about N. 10° E. and the dip to westerly, so that the Drum limestone leaves the quadrangle in the same longitude and at about the same elevation which it has near Independence.

Another local irregularity occurs in the southeastern corner of the quadrangle, where, as shown by the Parsons limestone, a rather sharp anticline pitches southwestward toward the Verdigris. The limestone on the northwest side of the fold slopes down northwestward from the hilltops to the bed of the Verdigris, a descent of about 80 feet in a distance of 3 miles. In and west of Coffeyville the beds lie nearly flat. Parts of the north side of the same anticline are to be seen along the State boundary as far west as the latitude of Tyro. Between this fold and the main Cherryvale anticline lies a broad, shallow syncline pitching very gently toward the west.

The Piqua limestone, which forms the scarp northeast of Tyro above the 900-foot level, disappears at the surface, but well excavations show that it dips beneath the village situated at the same level, and it is exposed at a greater elevation farther southeast.

In the Went sandstone quarry 2 miles north of Independence, the beds dip very gently northward and show slight warping at two points 125 feet apart. Quaquaversal dips also occur denoting that the rocks have been warped into broad, low domes, most of which, however, are so gentle that without continuous exposures the structure can not be worked out. The anticlines or warpings in the Drum limestone south of the Independence cement plant and in the Parsons limestone 5 miles about east of Coffeyville partake of this domal structure.

Besides the folding and warping mentioned in the foregoing paragraph, the rocks also exhibit local zones or bands of jointing and cleavage. The Parsons shale in the brick pit at Coffeyville is cut by several systems of close jointing, the most pronounced of which trends in a northwest-southeast direction and has a nearly vertical dip. Similar but much more complicated systems occur in the Cherryvale shale, as exposed in the shale pit at the mound about a mile south of Cherryvale, and in the Concreto shale in the pits at Sycamore and a few miles farther north, near Neodesha. These joint systems locally resemble shear zones and in places zones of cleavage. They may be due to lateral compression, to settling, or to slight, nearly vertical faultlike movements. Thus far, however, no evidence has been found to establish their origin conclusively.

STRUCTURE OF THE QUADRANGLE SHOWN BY STRUCTURE CONTOURS.

On the structure and economic geology map the present shape of the upper surface of the Boone formation (beneath the Cherokee shale) is represented by contour lines. The figures on which these contours are based are derived from the identification of the Boone formation in the logs of various wells which have reached it. Owing to the small number of these deep wells the contours are necessarily generalized. They are drawn at intervals of 50 feet and indicate the depth below sea level of the surface of the Boone formation. In order to ascertain the depth from the surface of the ground to the top of the Boone at any point it is necessary to add to the depth of the Boone the elevation of the present surface above sea level, as shown by the topographic contours. In the area north of Elk River and west of the Piqua limestone escarpment the information as to the depth of the Boone formation is very meager and the location of the structure contours is only approximate.

It will be seen from the structure contours that the base of the main oil-bearing formation, the Cherokee shale, or the top of the Boone, has a general westward dip and that the average direction of the contours is north and south. The general surface is, however, uneven. Two ridges and two depressions are shown, all trending nearly east and west. The northern ridge passes about 3 miles north of Neodesha and the southern ridge 7 miles south of Independence, each of them trending somewhat north of west. The northern ridge apparently fades out toward the west and the southern ridge diminishes toward the east. The depressions between these ridges are shallow, amounting to little more than 100 feet. The change from depression to ridge is made within rather narrow limits.

About 1 mile east of Morehead and one-half mile east of the quadrangle the base of the Cherokee shale is at sea level. West of that point it descends to 950 feet below sea level in about 28 miles. This gives an average westward slope of 34 feet per mile in the northern depression. The slope along the southern ridge on a line running 2 miles south of Liberty amounts to 700 feeet in 28 miles, an average of about 25 feet per mile. A comparison of these figures with the slope of the strata at the surface shows that the Boone surface dips toward the west at an angle about twice as great as that shown by the rocks at the surface. This difference in dip, or unconformity, agrees with and is the westward continuation of that existing between the same rocks farther east and extending from the eastern line of the State to the Independence quadrangle, as described under "Mississippian series."

When the synclines and anticlines of the surface rocks are compared with the ridges and depressions at the top of the Boone formation a total lack of correspondence is seen. The Cherryvale anticline, the principal one of the region, coincides with the principal depression of the Boone surface. Similarly the main syncline south of Independence coincides nearly with the southern ridge of the Boone surface. The most striking divergence is along the line from Liberty to Elk, where the surface rocks dip southwest and strike northwest, at right angles to the dip and strike of the surface of the Boone along the same line. Southeast of Coffeyville, also, a considerable doming of the surface rocks overlies a rather level place in the Boone surface.

From a consideration of this area alone the discrepancies between the Boone surface and the present surface could hardly be explained. The features which characterize the Boone surface farther east, however, afford a simple explanation. After the deposition of the Boone formation there was a considerable period of erosion and solution, during which the surface of the Boone was rendered very irregular. A similar erosion period followed the deposition of the Chester, which was entirely removed from many parts of the region. Thus the Cherokee shale was deposited over an uneven surface of the beveled edges of the Boone formation. The irregularities of this surface bore little or no relation to the warping of the limestones themselves. The facts of this history are set forth in the Joplin district folio.[a] Evidence of this erosion epoch following the Boone can be seen wherever that formation is exposed, and its extension into the Independence region is considered to be probable.

When the conditions in the Independence quadrangle are considered in the light of this general relation of unconformity between the Boone and the Cherokee, it will be seen that the irregularities in the Boone surface shown by the oil and gas wells do not represent folding of the Boone rocks; they merely indicate that the surface is lower at certain points than at others. The presumption is that the irregularities were caused here by erosion, as they are in other places where all the facts can be traced. Thus the discordance between the Boone surface and the structure of the surface rocks is not so abnormal as appears at first sight. Inasmuch as the depressions on the Boone surface occupy areas of uplift, as determined by the flexure of the rocks at the surface, it is apparent that the present Boone depressions are shallower than the original ones by just the amount that the surface rocks have been deformed. The reverse is true of the Boone ridges underlying depressions in the surface rocks. The curious result appears, therefore, that original depressions have been made shallow and original ridges have been partly or wholly smoothed out.

The greater dip of the Boone surface as compared with that of the surface rocks is similar to the conditions observed farther east. It indicates a thinning of the Cherokee toward the east and a possible overlap of some of the oil-bearing strata. It also indicates the thickening of the Cherokee toward the west and the possible incoming over the Boone surface of the Chester, which should lie between the Boone and the Cherokee.

[a] Geologic Atlas U. S., folio 148, U. S. Geol. Survey, 1907.

GEOLOGIC AND PHYSIOGRAPHIC HISTORY.

The Carboniferous rocks of the Independence quadrangle were deposited for the most part conformably under water on a nearly level sea floor. At the close of Carboniferous time they were raised and tilted by the movement that formed the Ozark Mountains on the southeast and the great inland swell of the Mississippi Valley, and they were otherwise locally but as a rule slightly deformed. These sediments were derived from land by erosion, but from what particular area can not be stated, owing to subsequent physiographic and geologic changes. They are mostly deep-water deposits, consisting of fine silt, but also contain structural and textural evidence of littoral conditions. The limestones, which are usually underlain and overlain by shale and some of which are cherty, were deposited presumably at shallower depths than the shale, in clear water adapted to animal life, and contain accumulated calcareous skeletal remains of the marine animals that lived in them. The sandstones are composed of coarser sediments than either the shale or the limestone, and clearly denote shallow-water or shore deposition.

The gradual change from deep-sea to shoal or shore conditions is shown in many places where the shale and limestone strata gradually become arenaceous, or locally conglomeratic, until they pass either horizontally or vertically into sandstone. The alternation of these different rocks with one another at short intervals in the section shows that the cycle of change from deep to shoal water was many times repeated. Traced southward through the quadrangle into Oklahoma the transition of limestone and shale into sandstone becomes very marked—a fact which, together with other features of shallow-water deposits, notably the well-preserved fossil wave marks in the sandstone and ripple marks and mud cracks in the shale, indicates nearness to the shore line in that direction.

Since the uplift of the region, erosion and atmospheric agencies, acting through long periods of time on alternately hard and soft formations, have given rise to the several geographic provinces that have been described, and more recently the same agencies, dominated by erosion in the Verdigris Valley, have modified the topography of the quadrangle into its present forms.

With reference to its physiographic history the country is now in old age. Its surface has been much reduced. The truncated character of its tilted formations clearly shows that its original surface, which was probably nearly smooth, stood at a much higher level than the present surface. The drainage began on the original surface by the development of a few consequent streams, which with others that originated soon thereafter rapidly trenched the country by a system of canyons and V-shaped valleys nearly to the level at which the valleys stand to-day, so that the topography at that time may be characterized as a network of gorges and corresponding sharp-crested ridges. From that time on the ridges and interstream areas were reduced more rapidly than the valleys were deepened, and finally assumed the broad and rounded forms they present to-day. Their reduction is still going on and will continue until they are worn down nearly to base-level, the process becoming increasingly slow with the decrease in relief. The factors that have influenced the degradation of the region are elevation, relief, precipitation, temperature, softness of the rocks, and the nakedness or unforested condition of the surface.

ECONOMIC GEOLOGY.[a]

The important mineral resources of the quadrangle are petroleum, gas, coal, stone, glass sand, Portland cement materials, clays, soils, and water.

PETROLEUM.

Occurrence and development.—Petroleum is found in the lower "Coal Measures," which underlie the entire quadrangle. Though small quantities of it occur comparatively near the surface, most of it lies at greater depths. It is contained in coarse sandstone beds in or near but not below the Cherokee shale, and has been prevented from escaping by an overlying cap of impervious shales and limestones of great thickness.

At Coffeyville, where the strata overlying the Cherokee shale are thinner than at any other point, three oil sands are encountered at depths of 350, 600, and 900 feet. The best wells, yielding oil with a gravity of 32° B. and above, derive their oil from the middle or 600-foot sand. Near Independence the productive zone ranges in depth from 450 to 600 feet; at Cherryvale from 700 to 800 feet; at Neodesha from 800 to 900 feet; at Bolton and Caney from 1100 to 1200 feet, and at Wayside, midway between Bolton and Caney, two oil sands occur at the depths of 700 to 800 and 1350 to 1450 feet. The lower of these sands at Wayside are in the lower part of the Cherokee shale, about 150 feet above its base. They probably correspond to those of the Tyro pool, where most of the oil is struck at about 1300 feet. This is also approximately the depth at which oil occurs in the Bartlesville field, Oklahoma.

The oil does not occur in a single persistent stratum of sand nor at a definite horizon underneath the field, but in disconnected lenses or beds of sandstone at various horizons in the shale formation. These sandstone bodies are merely reservoirs and do not necessarily represent the beds whence the oil has been derived. Their storage capacity depends on the porosity of the rock, which in an ordinary fine-grained sandstone is from 8 to 10 per cent of the volume. Such fine-grained sandstones are frequently called "sugar sands" and are most productive where completely sealed by impervious shales.

The pressure under which the oil is confined and the size of some of the reservoirs are indicated by the facts that in the western part of the field, where the Cherokee shale is somewhat deeply buried, many of the wells have been free flowing, have had a large initial production, and have continued to be good producers for several years. A number of wells produced from 200 to 500 barrels per day during the first few weeks of their existence, and some of the larger wells had an initial daily production of 600 to 700 barrels. A great many which produced from 100 to 200 barrels per day several years ago are still good producers.

Though most of the old wells are steadily producing, there is much less development than there was several years ago. But few more than half as many new wells were drilled in 1905 as in 1904, and the number drilled in 1906 was slightly less than half the number drilled in 1905.

Character of oil.—Like most Kansas oils, the oil of this quadrangle has an asphaltum base, and contains also a very appreciable amount of paraffin. It is dark brown or black in color and rather heavy, but varies greatly in specific gravity from place to place, locally within narrow geographic limits. That derived from shale is usually lighter than that derived from sandstone. The specific gravity ranges from 28° B. (0.8750) to 37.3° B.

[a] For a more complete treatment of this subject see Schrader, F. C., and Haworth, E., Economic geology of the Independence quadrangle, Kansas: Bull. U. S. Geol. Survey No. 296, 1906, 74 pp.

(0.8433), and the Standard Oil Company, which purchases most of the product, sets the highest price on oil with a specific gravity of 32° B. (0.8641) or more. The following analyses represent typical samples of the oil:

Results of analyses of samples of oil collected by the United States Geological Survey from wells in the Independence quadrangle.

[David T. Day, analyst.]

No. of sample.	Location of well.	No. of well.	Depth of well.	Physical properties: Gravity: Specific.	Physical properties: Gravity: Baumé.	Physical properties: Color.	Distillation by Engler's method: Begins to distill at—	By volume: To 150° C.: Cubic centimeters.	By volume: To 150° C.: Specific gravity.	By volume: 150° to 300° C.: Cubic centimeters.	By volume: 150° to 300° C.: Specific gravity.
			Feet.		°		° *C.*				
	Coffeyville area, Montgomery County:										
106	Gilroy lease, Montgomery Township; Brown Brokerage Co., Coffeyville.	1–15	600	0.8861	28.0	Dark green.	96	4.0	--------	30.0	0.8155
107	M. Davis lease, 4½ miles northeast of Coffeyville; Dunkley & Odell, Coffeyville.	1–40	625	.8717	30.6	Dark green.	100	6.0	0.7289	33.0	.803
	Wayside pool, Montgomery County:										
113	J. Halls lease; Lynch & McSweeney, Wayside.	1–2	800	.8696	31.0	Black.	75	9.5	.710	28.0	.808
114	Tank sample, same lease	4 wells.	------	.8777	29.5	Black.	105	8.0	.7338	30.5	.8105
	Bolton pool, Montgomery County:										
115	G. L. Banks farm; Miller, Rider & Co., Independence.	4	1180	.8424	36.2	Dark green.	72	14.5	.7273	29.5	.8095
	Neodesha pool, Wilson County:										
119	D. Johnson farm, 2 miles from Neodesha; Dolly Johnson Oil and Gas Co., Neodesha.	13	800	.8373	37.2	Dark green.	80	17.0	.7172	30.0	.8005
120	Theo. Johnson lease; Prairie Oil and Gas Co.	3	820	.8368	37.3	Black.	88	16.0	.7158	36.0	.7925

Future development.—Inasmuch as this quadrangle lies wholly within the oil and gas belt, any part of the considerable area within it that has not been prospected may become productive when drilled. From what has been accomplished, however, it does not seem likely that the production will ever exceed its present rate. To judge from the history of the wells, not to say of the belts or districts, it will do well if it maintains this rate for any considerable number of years, for oil stored within the earth, however abundant, is strictly limited in quantity, and a reservoir once exhausted can be but partially replenished only after considerable lapse of time, and many reservoirs can not be replenished at all. During 1904 and 1905 development extended in a southwesterly course by which the Bolton, Wayside, Tyro, Caney, and Chautauqua areas were discovered or developed.

GAS.

Occurrence.—Gas occurs in intimate association with the oil of this quadrangle, but is generally more abundant and has been found in a larger number of places. Individual wells also usually pass through more gas sands than oil sands. Most of the gas wells are intimately associated with oil wells, and some wells produce both oil and gas. No definite rule can be laid down in regard to the relative positions in which oil and gas may occur in a given well. The gas may be found either above or below the oil. For the most part, however, the horizons of the two are separated by an impervious shale stratum 30 feet or more in thickness. The gas, like the oil, occurs under enormous pressure and in large volumes, some of the wells having a production of more than 33,000,000 cubic feet per day.

Character.—The gas is composed principally of marsh gas, which forms about 94 per cent of the volume; nitrogen, 4 per cent; carbon monoxide, 0.7 per cent; carbon dioxide, 0.4 per cent; olefiant gas, 0.3 per cent; and oxygen, 0.3 per cent.

COAL.

Distribution.—Within a belt 5 to 10 miles in width, extending diagonally across the quadrangle from its northeast corner to its southern edge, are several thin but workable beds of bituminous coal. The localities in which these beds are best exposed and developed, named from northeast to southwest, are Chetopa Creek, Brooks, Sycamore, Independence and Jefferson.

Occurrence.—The coal beds occur in the upper part of the Chanute shale member of the Wilson formation, below the Iola limestone. They lie nearly flat. No bed exceeds 2½ feet in thickness and a fair average for each locality is probably less than a foot.

The most important coal beds of the quadrangle are those outcropping on Chetopa Creek, in the northeast corner, approximately between Neodesha and Thayer, Neosho County, whence they are commonly known as the Chetopa Creek–Thayer and Neodesha–Thayer coals. The best of these beds are found in what is known more particularly as the Thayer field, an east-west rectangular area of about 15 square miles at the head of Chetopa Creek, in the extreme northeast corner of the quadrangle, its eastern edge being about 3 miles west of Thayer. The most important bed is that of Coal Hollow, a south-side head branch of Chetopa Creek in the northwest corner of Shiloh Township, 3 to 4 miles southwest of Thayer. The coal produced here is the typical Thayer coal and is of better grade than any other outcropping in the quadrangle.

About 6 miles west of Thayer the coal bed is 1½ feet in thickness and is overlain by calcareous sandstone and shale and underlain by 8 feet of arenaceous shale resting upon a thin limestone conglomerate. Five-eighths of a mile south of this locality, at the Scott bank, the coal occurs in two benches, as shown in the following section:

Section of coal at Scott bank, Wilson County.

	Inches.
Limestone lentils	12
Coal, good quality	10–12
Shale	6–10
Coal, good quality	8
Shale, arenaceous.	

About a mile northeast of Independence, on Verdigris River, occurs a coal bed from 1 to 2 feet thick. It is capped by an arenaceous limestone overlain by sandstone. A coal bed 1¼ miles southeast of Independence, in the north face of the sandstone hill situated south of Rock Creek, is 18 inches thick and the coal is of good quality. It lies between two shale beds each 30 to 40 feet thick.

About 3 miles south of Jefferson, on Fawn Creek, where a slope has been driven in for 175 feet, occurs a coal bed which measures 16 inches in thickness including two very thin shale partings. The roof is a thin layer of shale overlain by sandstone; the floor is shale underlain by bluish sandstone.

Deep-seated coal beds.—Deep-seated coals have been encountered in drilling in this area, the most important being found in the Cherokee shale, which contains the thickest beds of workable coal known in Kansas, such as the Weir-Pittsburg and others. Drill records 4 miles south of Independence show a 4-foot bed of coal at a depth of 600 feet, and a well on the Linscott farm, a mile farther south, is reported to have passed through a 14-foot bed of coal at a depth of 1100 feet. The same bed or one of like thickness is reported in the vicinity of Sycamore, in the northern part of the quadrangle. This bed may be regarded as the one represented in the upper part of the Cherokee shale in the general columnar section. The Cherryvale well log also reports a 29-inch coal bed in the Cherokee shale.

STONE.

Building stone.—Foundation and building stone is widely distributed over the quadrangle and occurs mostly in the Chanute and Concreto members of the Wilson formation and in the Buxton and Drum formations. Probably four-fifths of that used is sandstone. As shown on the structure and economic geology map, stone quarries have been opened near practically all the cities and towns and at many intermediate points. The principal source of supply near Independence is the Went quarry, situated on the level prairie 2 miles north of the city. The sandstone is in the Concreto shale and the exposure shows 10 to 12 feet, mostly of good stone, beneath a covering of 3 to 4 feet of surface soil and shaly sandstone. The stone now being worked consists of layers ranging in thickness from 3 or 4 inches at the top of the section to 2½ feet at the bottom. The section exposed here, borings made in the bottom of the quarry, and the log of a near-by well indicate a probable thickness of 50 feet of good stone. The stone is easily quarried, dressed, and fashioned and is taken out in all sizes, the thicker slabs being used for foundation and building purposes and the thinner ones for sills, caps, steps, curbing, and paving. Some handsome residences and churches are built of it. The sandstone near Liberty, east of Big Hill Creek, has supplied practically all the building and paving stone used in Liberty and has recently furnished the abutments for a new steel bridge across Pumpkin Creek. Sandstone houses at Caney, Jefferson, Larimer, and many other places in the quadrangle give evidence of the widespread utility of this stone for building purposes.

The most important source of limestone is from 2 to 4 miles northwest and west of Coffeyville. The quarries are in the upper member of the Drum formation, which extends in a narrow belt from Reservoir Hill westward to Dearing, thence southeastward along Onion Creek to the State boundary. The stone is mostly hard blue limestone, in some places flinty, and is more thinly bedded than the sandstone previously described. As in the case of the sandstone at Independence and elsewhere, the heavier beds are used principally for footing, foundation, and building purposes, and the thinner beds, having a thickness of 3 to 5 inches, make excellent flagging, paving, and curbstone. The following section, measured at the W. H. Gorton quarry, on the south side of Onion Creek, 3½ miles west of Coffeyville, is a fair average:

Partial section of Drum formation exposed in W. H. Gorton's limestone quarry, 3½ miles west of Coffeyville.

	Ft.	in.
Surface soil	0	9
Shale, in part weathered	3	0
Limestone, hard, blue, flags	0	4
Seamy parting	0	1
Limestone, hard, blue	0	9
Limestone, seamy	0	1
Limestone, hard, blue	0	6–7
Seamy parting	0	1
Limestone, hard, blue	0	11
Limestone, seamy	0	2
Limestone, hard, blue	0	4–5
Shale	3+	0

There is good reasan to believe that with careful prospecting deposits that will furnish as much and as good stone as that now quarried near Independence and Coffeyville may be found in other parts of the quadrangle.

Road material.—At Independence the Drum limestone is crushed for macadam, and from some places, notably Cherryvale and Morehead, it is shipped for railroad ballast. Limestone suitable for road metal also occurs near other towns, as Neodesha, Elk, and Coffeyville. The chert gravels are also excellent road material, but such deposits are usually too small to be of much value.

LIME.

The remnants of numerous lime kilns and the reports of settlers indicate that practically all the important limestones of the quadrangle have been utilized in the past for burning into lime. The Piqua limestone has been worked at Table Mound and to the northwest, the Drum limestone has been quarried east of Independence, and the Dennis limestone northeast of Cherryvale. The Allen limestone in the northern part of the quadrangle, on Fall River, contains layers suitable for burning to quicklime. The general distribution of these limestones is shown on the geologic map.

GLASS SAND.

At a number of localities in the western part of the quadrangle sandstone in the Buxton formation is of such purity, fineness, and evenness of grain as to give promise of usefulness in the manufacture of glass. It occurs in bodies of one-eighth to one-half square mile in areal extent. The best rock is found in heavy beds which have been least stained by the descending surface waters. Exposures of sandstone apparently suitable for glass making occur 4 miles northwest and 2 miles north of Caney. The long hill at the locality near Caney is capped by such a sandstone, here at least 10 feet thick. Other exposures occur farther north. That which seems to be the most worthy of attention is in the SE. ¼ sec. 22, Fall River Township, about 4 miles southwest of Fredonia, just north of the quadrangle boundary. Here the rock is exposed over an area of 10 to 15 acres and is about 12 feet in thickness, as nearly as can be judged from the topography and local prospects. It is reported that the glass factory at Fredonia procures its sand from the sandstone of this region.

PORTLAND CEMENT MATERIALS.

Materials suitable for making Portland cement are abundant in the Independence quadrangle, especially in its northern part. They consist mainly of the Drum, Allen, and Piqua limestones and associated shales, whose distribution is shown on the geologic map. The abundance of the raw material and the uniformity in its chemical composition, together with the large amount of natural gas available for fuel, render the field a very attractive one for cement manufacturers. Three large plants are now in operation, at Independence, Neodesha, and Table Mound, and a fourth is being constructed at the north border of the quadrangle on Fall River.

The plant at Independence utilizes the Drum limestone, which has a thickness of nearly 100 feet near the city and outcrops over several square miles. It is a very pure stone, massively bedded, semicrystalline, medium to coarse grained, highly fossiliferous, and entirely satisfactory in every way. The shale used is taken from the Chanute member of the Wilson formation, which immediately overlies the limestone and is likewise of good quality.

The material used at Neodesha is the Allen limestone, which caps Little Bear Mound northwest of the town, with a thickness of 55 to 70 feet, and the Concreto shale, directly underlying the limestone. Analyses of these rocks are as follows:[a]

Analysis of Allen limestone at Neodesha.

Silica (SiO_2) and insoluble matter	3.11
Alumina and iron oxide ($Al_2O_3+Fe_2O_3$)	1.06
Lime (CaO)	52.40
[Equivalent to 93.58 $CaCO_3$.]	
Magnesia (MgO)	Trace.
Sulphuric anhydride (SO_3)	None.
Loss on ignition	42.45

Analysis of Concreto shale at Neodesha.

Silica (SiO_2)	50.80
Alumina (Al_2O_3)	16.75
Iron oxide (Fe_2O_3)	4.84
Lime (CaO)	8.83
[Equivalent to 15.7 $CaCO_3$.]	
Magnesia (MgO)	2.19
Sulphuric anhydride (SO_3)	None.
Loss on ignition	12.24

At Table Mound, where the third cement plant has recently been erected, the limestone used is the Piqua, which is the most abundant, most persistent, and probably the purest limestone in the quadrangle. The section of useful materials exposed is as follows:

Section at Table Mound.

	Feet.
Limestone (Piqua)	45
Shale (Vilas)	80
Limestone (Allen)	5
Shale (Concreto)	40

At Table Mound and Neodesha the limestones overlie the shales and cap the hills. Quarrying the limestone uncovers the shale and both are carried by gravity into the mills. At Independence the limestone is obtained from an open cut, hoisted, and carried into the mills by rail. Conditions as favorable for cement making as those at Table Mound and Neodesha may be found along the Piqua limestone escarpment extending for many miles on the north side of Elk River.

[a] Ann. Bull. Mineral Resources, Kansas Univ. Geol. Survey, 1902.

CLAY.

Brick clay.—The clay resources of this quadrangle are abundant and consist of the numerous beds of shale which extend across the quadrangle and are exposed over wide areas aggregating many square miles. Some of the beds attain a thickness of 80 feet or more. The shale is usually buff, drab, or olive green and generally overlies or underlies some limestone formation. At present the most important and extensively developed beds are those in the Buxton formation at Buxton and Caney; in the Concreto shale at Buff Mound, Neodesha, Sycamore, Table Mound, and Tyro; in the Chanute shale at Independence; in the Cherryvale shale at Cherryvale; and in the Galesburg shale and Parsons formation at Coffeyville. The abundance of shales and natural gas in nearly all parts of the field renders it peculiarly favorable for the development of clay industries, which already include the manufacture of brick, roofing tile, and pottery. Of these industries brick-making is the most important. The chief product is common building brick; next in abundance is vitrified or paving brick, followed by sidewalk brick and the different styles of dry-pressed or re-pressed ornamental brick. Owing to the iron oxides in the shale used, the building brick burn to a beautiful, very uniform red color.

Roofing-tile and pottery clay.—At Coffeyville the shale of the Parsons formation is manufactured into roofing tile and different kinds of fancy-shaped tile of different colors; also into a variety of ornamental patterns for cornices, gables, finials, and all kinds of stoneware, such as crocks, jars, etc. It burns to a rich, deep, uniform red.

SOILS.

Residual soils.—The soils of the Independence quadrangle consist in the main of two classes—residual and transported. The residual soils are those derived from the underlying or adjacent country rock, principally, through the agencies of weathering, disintegration, and corrasion. A residual soil varies with the nature of the rock whence it has been derived. Its composition, moreover, is modified by the character and amount of foreign material introduced. The soil-producing rocks of the quadrangle, named in order of their importance, are limestone, shale, and sandstone.

The limestone soil, though not the most abundant, occupying only about 200 square miles, or less than 20 per cent of the entire area of the quadrangle, is preeminently the most important. It covers a considerable portion of the limestone areas shown on the map. It is generally dark or black and heavy, greatly exceeds the other residual soils in fertility, and is less susceptible to drought.

Next in importance for agricultural purposes is the shale soil, which is clayey or argillaceous and usually light or buff colored. It is lighter in weight and less productive than the limestone soil, but is nevertheless somewhat extensively cultivated. It varies in character from place to place, decreasing in fertility with the increase in arenaceous material or sand, derived from sediments that were deposited with the shale. Shale soils cover about 400 square miles, or nearly 40 per cent of the area.

The sandstone soil is derived from sandstone and ranges from almost pure sand in some localities to sandy clay in others, depending on the amount of shale originally present in the sandy beds from which it has been derived. It is the least fertile of the residual soils and least adapted to agriculture. It supports the prairie grass and a native growth of black-jack oak (*Quercus nigra*), which constitute the most important vegetation of the uplands. These oaks, though not tall or stately forest trees, form numerous timbered areas several square miles in extent on an otherwise treeless prairie.

Transported soil.—As the name suggests, transported soil or alluvium has reached its present position through the agency of water. It constitutes the surface deposits of the lowlands or flood plains of Verdigris River and the lower reaches of its tributaries, where it constantly receives accretions at periods of high water. By reason of its character and position it is variously known as "soil," "made ground," "bottom land," and "bottom." It is the most composite of the soils of the area, being made up of particles derived from practically all the formations within the drainage basin above its present position. Most of it is the result of the disintegration of limestone and shale, but it contains also considerable humus and organic material gathered by the transporting water. Much of it has come from distant points beyond the quadrangle, as well as from the adjacent hills. It is usually black and heavy, retains moisture well, and constitutes some of the richest agricultural land in the Mississippi Valley, being unsurpassed in its heavy yield of wheat and corn. In some places it is so heavy, impervious, and tenacious as to be tillable only with great difficulty, and is locally known as "gumbo," but it is not related to gumbo as used in the geologic sense.

The alluvium supports most of the timber of the quadrangle—a mixed growth of hard wood bordering the streams and valleys. Its relatively low position and flatness of surface render it less susceptible to drought than the uplands. During the last three years, however, its immense crops have been almost wholly destroyed by the devastating spring and summer floods which in duration, magnitude, and destructiveness have surpassed any others within the memory of the oldest living settlers. So great has been the loss due to these floods in the Verdigris, Neosho, and neighboring valleys in recent years that their prevention has become an important problem for solution, and it is now being studied by the State and the United States Geological Survey. The results of such investigations indicate that as the topography is not adapted to water storage, the levee system is the best preventive now in sight.

WATER RESOURCES.

SURFACE WATERS.

Streams.—The surface water of the quadrangle, as described under "Drainage," passes into Verdigris River, which in its general course flows slightly east of south near the center of the quadrangle. Together with its tributaries it carries potable water—a fact which, taken in connection with its size, renders it a stream of great economic importance. Its flood flow is large and its summer flow small. Its average annual flowage or run-off is 0.45 second-feet per square mile, and its average velocity about 1.2 miles per hour. This large volume of water flowing through the quadrangle, together with the central position of the Verdigris, the widespread distribution of its tributaries, and the annual precipitation of about 44 inches, makes the region relatively well watered.

At times of high water, particularly during the spring and summer floods, the Verdigris overflows its banks and inundates its flood plain and adjacent country for a width of 1 to 3 miles, with the consequent destruction of crops and property. In its course of about 50 miles across the quadrangle it has a fall of 130 feet, which at favorable points makes it available for water power. McTaggart's mill, about 6 miles southeast of Independence, and the mill at Neodesha illustrate its possibilities. Owing to the cheapness of natural gas, however, no use is now made of this water power. Fall River is used for generating power for a flour mill at Neodesha, and Elk River supplies power at Elk. Fall River is reported to be less muddy and more steady in flow than the Verdigris, but Elk River fluctuates more than the master stream.

UNDERGROUND WATERS.

Springs.—The principal supplies of underground water in this area are in the alluvial deposits of the valleys; also in the sandstones and shales and surficial deposits of soil, gravel, and talus at the foot of hills or in the sides and heads of valleys on higher ground. Such sources are locally known as springs, and the water is used for stock and other domestic purposes. No deep-seated springs issuing from bed rock were noted in the area.

Wells.—Most of the wells in the area are shallow, supplying as a rule surface water only. Owing to the soluble salts contained in the rocks, and particularly in the shale, this water is usually hard, alkaline, or brackish. Exceptions occur where the wells are in sandstone, which usually yields good, soft, potable water, and in much of the lowland region, where the water has become purified in filtering through the alluvial deposits of silt, sand, and gravel. As shallow wells may fail in dry seasons, deep wells have been drilled to insure a permanent supply of water, especially in the uplands, but their water, though deep-seated in bed rock, is usually hard, and beyond a certain depth the deeper the well the more likely is the water to be brackish or saline.

MINERAL WATERS.

The term "mineral waters" here used refers to the health waters of a few wells at Independence, Coffeyville, and Cherryvale.[a]

The well at Independence is 1100 feet deep and is artesian in character. Its water is bromomagnesian and is derived from the Mississippian or lower Silurian. It compares favorably with other waters of its class and is used at a sanitarium and bath hotel in the northern part of the city.

The Coffeyville well is $1\frac{1}{2}$ miles east of Coffeyville. It is shallow and lies wholly within upper Carboniferous strata. Its water belongs to the chlorine-carbonate group and is used at a water-cure establishment built at the well for the accommodation of boarders. It is also sold to the people in the community.

The Cherryvale well is 3 miles northwest of Cherryvale and like the Coffeyville well lies wholly in the upper Carboniferous. Its water is said to come from a depth of 120 feet.

April, 1908.

[a] A fuller account of these wells is given in Bull. U. S. Geol. Survey No. 296, 1906, pp. 67 et seq.; and Univ. Geol. Survey Kansas, vol. 7, 1902.

Table of Formation Names.

System.	Series.		1866. Eastern Kansas (Swallow).[a]		1894. Southeastern Kansas and Adjacent Areas (Haworth and Kirk).[a]		1896. Southeastern Kansas (Haworth).[a]		1898. Southeastern Kansas (Haworth).[a]				1903. Southeastern Kansas and Adjacent Areas (Adams, Girty, and White).[a]		1904. Iola Quadrangle (Adams, Haworth, and Crane).[a]		1907-8. Independence Quadrangle (Schrader and Haworth).[a]		
Quaternary		1			Alluvium.								Alluvium.		Alluvium.		Alluvium.		1
Carboniferous	Pennsylvanian	2	Wellrock series		Shale.		Shale.		Upper Coal Measures.	Lecompton shales and Elgin sandstone.			Kanwaka shales.				Elgin sandstone, base of Kanwaka shales.		2
		3			Burlington or Garnett limestone.	Limestone. Shale. Limestone.	Oread limestone	Limestone. Shale. Limestone.		Douglas formation.	Oread limestone.	Limestone. Shale. Limestone.	Oread limestone.				Oread limestone (Painterhood).		3
		4			Leroy shales		Lawrence shales				Lawrence shales.		Leroy shales				Buxton formation	Sandstone and shale.	4
		5																Shale.	5
		6																Limestone lentils.	6
		7																Shale.	7
		8																Sandstone.	8
		9																Shale.	9
		10																Limestone lentil.	10
		11																Shale.	11
		12	Stanton limestone series: Stanton limestone, No. 151; shales; sandstones; and coal.		Carlyle limestone.		Garnett limestone (?), Iola limestone.			Pottawatomie formation.	Garnett limestone	Iola limestone.	Stanton limestone, Iola limestone.		Piqua limestone.		Wilson formation	Piqua limestone.	12
		13			Leroy shales.		Thayer shales, Lane shales.					Vilas shales.			Vilas shale.			Vilas shale (with sandstone lentil).	13
		14			Carlyle limestone.		Garnett limestone, Iola limestone, Carlyle limestone.					Earlton limestone.	Stanton limestone.		Allen limestone.			Allen limestone.	14
		15			Shale.		Thayer shales.				Lane shales.		Lane shales.		Concreto shale.			Concreto shale (with coal lentil).	15
		16			Iola limestone.		Iola limestone.				Earlton limestone, Iola limestone.		Earlton limestone,[b] Iola limestone.		Iola limestone.			Iola limestone.	16
		17			Chanute shale.		Thayer shales.				Thayer shales, Vilas shales.		Chanute shales, Vilas shales.		Chanute shale			Chanute shale (upper part).	17
		18			Erie limestone.		Erie limestone	Limestone (upper member).			Erie limestone.	Independence limestone.	Drum limestone.				Drum formation (limestone with shale lentils).		18
		19	Marais de Cygnes coal series.					Shale.				Cherryvale shales.	Cherryvale shales.				Coffeyville formation	Cherryvale shale.	19
		20			Erie limestone.			Limestone[b] (upper member).				Independence limestone.[b]	Dennis limestone.		Bronson limestone	Dennis limestone.		Dennis limestone.	20
		21						Shale.				Cherryvale shales.	Galesburg shales (?).			Galesburg shale.		Galesburg shale.	21
		22			Erie limestone.			Limestone (middle member).				Mound Valley limestone.	Dennis limestone.			Mound Valley limestone.		Mound Valley limestone.	22
		23						Shale.				Mound Valley shale.	Galesburg shales.			Ladore shale.		Ladore-Dudley shale.	23
		24			Erie limestone.			Altamont (?) limestone;[c] Bethany Falls limestone, No. 78.				Limestone.[c]	Hertha limestone.			Hertha limestone.			24
		25			Laneville shales	Shale.	Pleasanton shales		Lower Coal Measures.	Marmaton formation.	Pleasanton shales.	Upper Pleasanton shales.	Dudley shales.		Dudley shale.				25
		26	Bethany Falls limestone, No. 166.			Limestone.						Altamont limestone.	Parsons limestone	Upper Parsons limestone.	Parsons limestone		Parsons formation	Upper limestone.	26
		27				Shale.												Shale.	27
		28				Sandstone.								Limestone.[c]				Lower limestone.	28
		29				Shale.						Lower Pleasanton shales.	Bandera shales.		Bandera shale.		Bandera shale.		29
		30	Pawnee limestone series.	Pawnee limestone, No. 203.			Pawnee limestone.				Pawnee limestone.		Pawnee limestone.		Pawnee limestone.		Pawnee limestone.		30
		31					Shale.				Labette shales.		Labette shales.		Labette shale.		Labette shale.		31
		32	Fort Scott coal series	Fort Scott limestone, No. 212; shales; sandstone; and limestone.	Oswego limestone	Limestone. Shale. Limestone.	Oswego limestone	Limestone. Shale. Limestone.			Oswego limestone.		Fort Scott limestone.		Fort Scott limestone.		Fort Scott limestone.		32
		33	Fort Scott marble series. Lower coal series.		Cherokee shale	Shale; Swallow limestone; shale; Columbus sandstone; shale.	Cherokee shales.			Cherokee shales.			Cherokee shales.		Cherokee shale.		Cherokee shale.		33
	Mississippian	34	Lower Carboniferous.		Mississippian	Galena limestone.	Mississippian.		Mississippian or sub-Carboniferous.				Mississippian series.		Boone formation.		Boone limestone.		34

1866: [a] Swallow, G. C., Section of the rocks in eastern Kansas: Prel. Rept. Geol. Survey Kansas, 1866, pp. 9–18; also Proc. Am. Assoc. Sci., vol. 15, 1866, pp. 57–82.

1894: [a] Haworth, Erasmus, and Kirk, M. Z., A geologic section along the Neosho River from the Mississippian formation of Indian Territory to White City, Kans., and along the Cottonwood River from Wyckoff to Peabody: Kansas Univ. Quart., vol. 2, 1894, pp. 104–115.

1896: [a] Haworth, Erasmus, Résumé of the stratigraphy and correlations of the Carboniferous formations: Univ. Geol. Survey Kansas, vol. 1, 1896, pp. 145–217.
[b] In the Iola quadrangle the Dennis limestone was mistaken for the Drum.
[c] Trans. St. Louis Acad. Sci., vol. 2, 1861–1866, p. 320; Rept. Missouri Geol. Survey, 1872, pt. 2, p. 77.

1898: [a] Haworth, Erasmus, Stratigraphy of the Kansas coal measures: Univ. Geol. Survey Kansas, vol. 3, 1898, pp. 9–105.
[b] In the Iola quadrangle the Dennis limestone was mistaken for the Drum.
[c] The Bethany Falls limestone of Gallaher, J. A., Bienn. Rept. Missouri Geol. Survey, 1898; and No. 78 of Broadhead, G. C., Rept. Missouri Geol. Survey, 1892, pt. 2, p. 97.

1903: [a] Adams, George I., Girty, George H., and White, David, Upper Carboniferous rocks of Kansas: Bull. U. S. Geol. Survey No. 211, 1903.
[b] Not recognized at Earleton as the Iola limestone.
[c] Regarded by Adams as the Oologah limestone of Drake in Oklahoma (Proc. Am. Phil. Soc., vol. 36, 1897, p. 337).

1904: [a] Adams, George I. Haworth, Erasmus, and Crane, W. R., Economic geology of the Iola quadrangle, Kansas: Bull. U. S. Geol. Survey No. 238, 1904, Pl. III. Certain miscorrelations in the survey of the Iola quadrangle were not discovered until after the text of Bulletin No. 238 was printed. The necessary corrections were made on Pls. I and II and indicated on an "errata" slip at the beginning of that report; they have also been incorporated in the above list.

1907-8: [a] Schrader, Frank C., and Haworth, Erasmus, Economic geology of the Independence quadrangle, Kansas: Bull. U. S. Geol. Survey No. 296, 1907. Schrader, Frank C., Independence folio, Geologic Atlas U. S., 1908.

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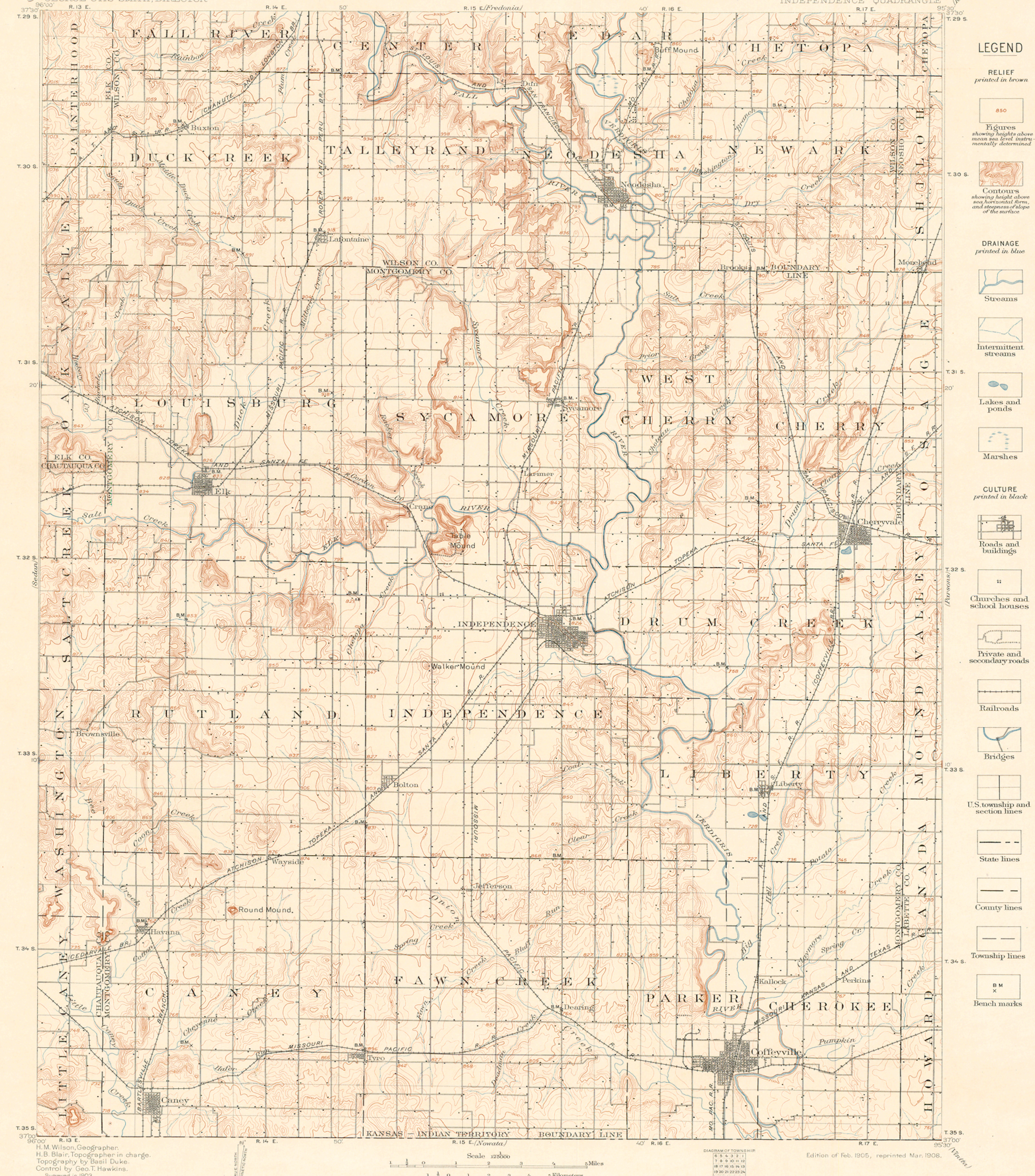
TOPOGRAPHY

KANSAS
INDEPENDENCE QUADRANGLE



H.M. Wilson, Geographer.
H.B. Blair, Topographer in charge.
Topography by Basil Duke.
Control by Geo. T. Hawkins.
Surveyed in 1903.

APPROXIMATE MEAN DECLINATION 1903.

Scale 1/125000
Contour interval 20 feet.
Datum is mean sea level.

DIAGRAM OF TOWNSHIP

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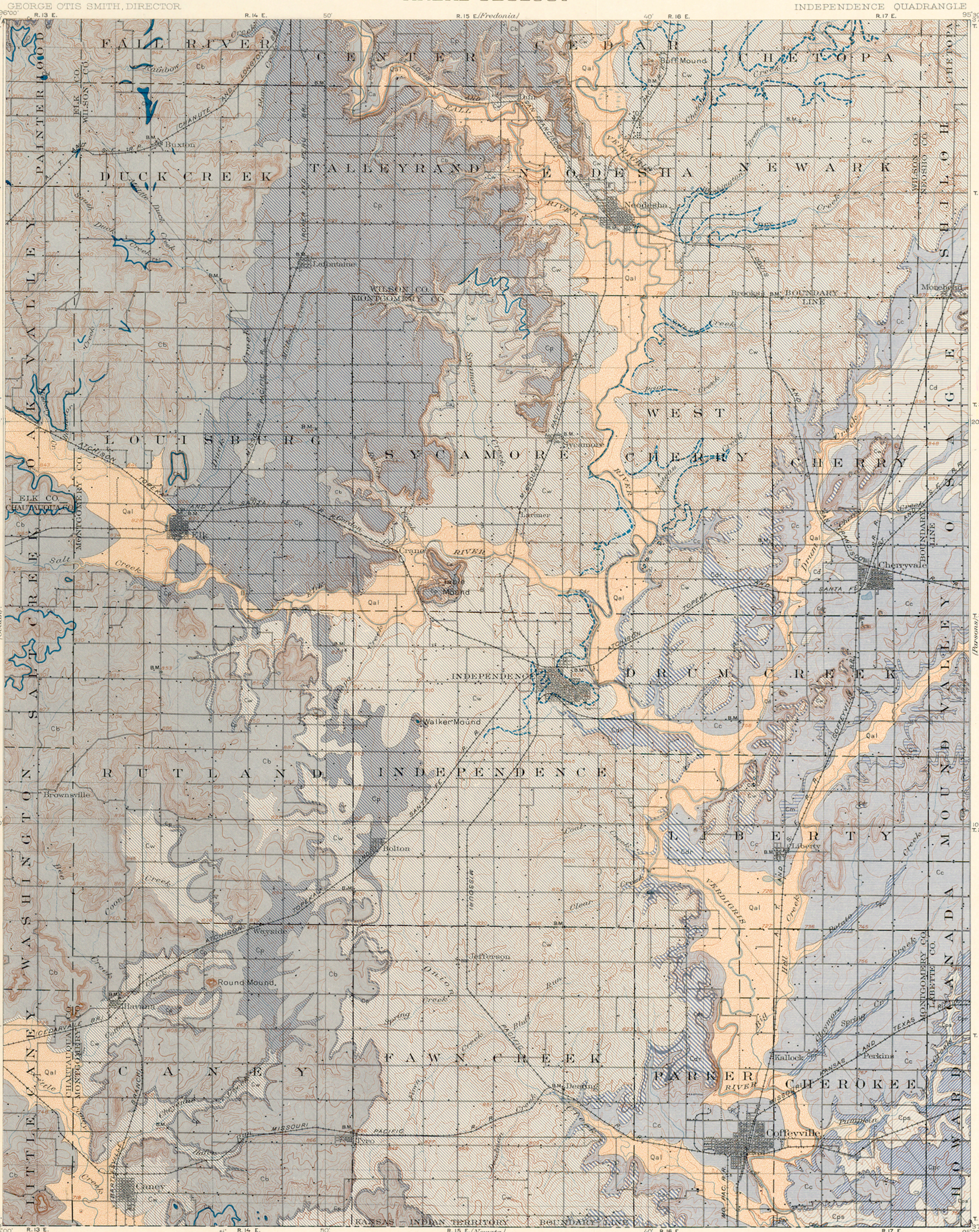
GEORGE OTIS SMITH, DIRECTOR

AREAL GEOLOGY

KANSAS
INDEPENDENCE QUADRANGLE



LEGEND

SEDIMENTARY ROCKS

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

QUATERNARY

Qal — **Alluvium** *(bottom land of larger streams)*

CARBONIFEROUS — *Pennsylvanian*

Ce — **Elgin sandstone** *(hard, brown, ferruginous sandstone)*

Co — **Oread limestone** *(reddish-gray, thin-bedded, semicrystalline, fossiliferous limestone)*

Cb, Cbl — **Buxton formation** *(shale and shaly sandstone, with few beds of coal and lentils of limestone, Cbl)*

Cp, Cw, Ca, Cwl — **Wilson formation** *(principally compact drab shale and gray sandstone, with coal seams and Piqua, Cp, Allen, Ca, Iola, Ci, and minor, Cwl, limestone lentils)*

Cdr, Cds — **Drum limestone** *(principally gray to blue, crystalline and flinty, massive and flaggy limestone with thin lentil of shale, Cds, in southern portion)*

Cd, Cc, Cm — **Coffeyville formation** *(drab shale and interbedded brownish sandstone, with Dennis, Cd, and Mound Valley, Cm, limestone lentils)*

Cpr, Cps — **Parsons formation** *(crystalline fossiliferous limestone, in part cherty, with dark, hard, shale member, Cps, near middle)*

H.M. Wilson, Geographer.
H.B. Blair, Topographer in charge.
Topography by Basil Duke.
Control by Geo. T. Hawkins.
Surveyed in 1903.

TRUE NORTH / MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1903.

Scale $\frac{1}{125000}$
1 ½ 0 1 2 3 4 5 Miles
1 ½ 0 1 2 3 4 5 Kilometers
Contour interval 20 feet.
Datum is mean sea level.
Edition of Mar. 1908.

DIAGRAM OF TOWNSHIP

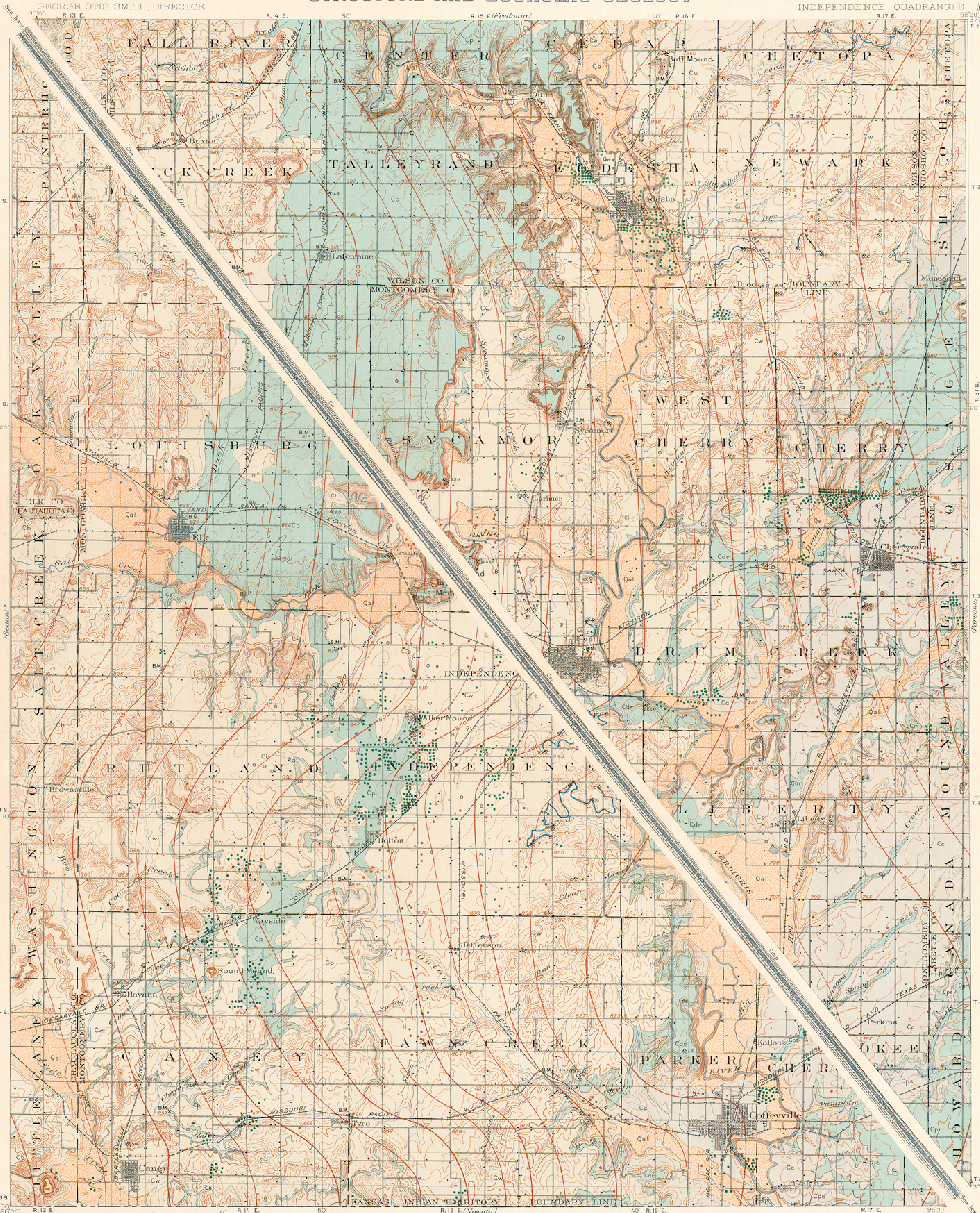
6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Geology by F.C. Schrader, assisted by Otto Veatch and G.L. Metcalf.
Surveyed in 1904.

U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

STRUCTURE AND ECONOMIC GEOLOGY

KANSAS
INDEPENDENCE QUADRANGLE



LEGEND

SEDIMENTARY ROCKS

SHEET SYMBOL | SECTION SYMBOL

QUATERNARY

Qal — Alluvium (bottom land of larger streams)

CARBONIFEROUS — Pennsylvanian

Ce — Elgin sandstone (hard, brown, ferruginous sandstone)

Co — Oread limestone (reddish-gray, thin-bedded, semicrystalline, fossiliferous limestone). Combined with Buxton formation on section

Cb, Cbl / Cbo — Buxton formation (shale and shaly sandstone, with few beds of coal and lentils of limestone, Cbl)

Cp, Cw, Ca, Cwl, Ci / Cw — Wilson formation (principally compact drab shale and gray sandstone, with coal seams and Piqua, Cp, Allen, Ca, Iola, Ci, and minor, Cwl, limestone lentils)

Cdr, Cds — Drum limestone (principally gray to blue, crystalline and flinty, massive and flaggy limestone, with thin lentil of shale, Cds, in southern portion). Combined with Coffeyville formation on section

Cd, Cc, Cm / Cdcp — Coffeyville formation (drab shale and interbedded brownish sandstone, with Dennis, Cd, and Mound Valley, Cm, limestone lentils)

Cpr, Cps — Parsons formation (crystalline fossiliferous limestone, in part cherty, with dark, hard, shale member, Cps, near middle). Combined with Coffeyville formation on section

Cck — Cherokee formation (oil and gas horizon). Does not outcrop in quadrangle

CARBONIFEROUS — Mississippian

Cbn — Boone limestone. Does not outcrop in quadrangle

Structure and economic data

Structure contours (showing depth below sea level of the top of the Boone limestone, interval, 50 feet)

Coal seams (workable beds in Wilson formation)

- Oil wells
- Gas wells
- Dry holes
- Cement plants
- Quarries, mines, and pits
- C Coal
- SS Sandstone
- LS Limestone
- LSSH Limestone and shale for cement
- SH Shale for brick

Note: Map has been cut in two and section inserted

H. M. Wilson, Geographer.
H. B. Blair, Topographer in charge.
Topography by Basil Duke.
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Surveyed in 1903.

APPROXIMATE MEAN DECLINATION 1903.

Scale $\frac{1}{125000}$

Contour interval 20 feet.
Datum is mean sea level.
Edition of Mar. 1908

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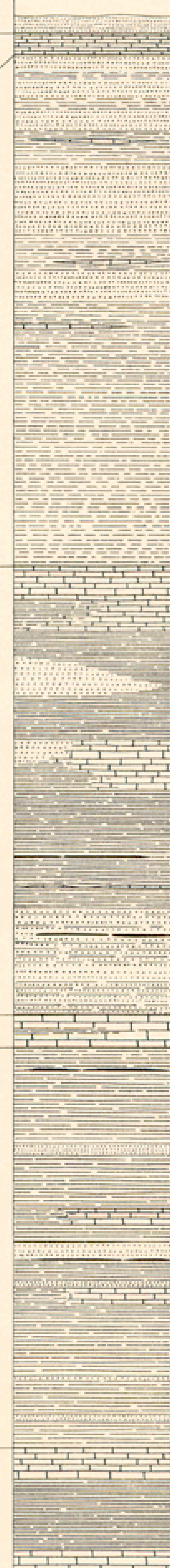
COLUMNAR SECTIONS

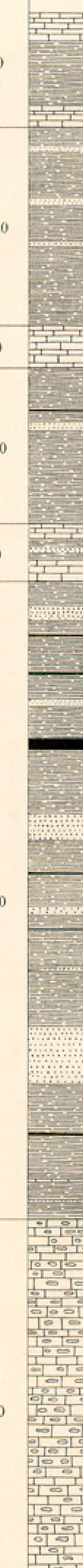
GENERALIZED SECTION OF ROCKS EXPOSED IN THE INDEPENDENCE QUADRANGLE.

SCALE: 1 INCH = 100 FEET.

System.	Name and Description of Formations.	Symbol.	Columnar Section.	Thickness in Feet.	Members.	Detailed Description of Rocks.
CARBONIFEROUS (Pennsylvanian series)	Elgin sandstone.	Ce		10		Hard ferruginous sandstone; weathers rough.
	Oread limestone.	Co		12		Reddish-gray, thin-bedded, fine-grained, semicrystalline, profusely fossiliferous limestone.
	Buxton formation. Shale and friable shaly sandstone in about equal amounts, with a few heavy beds of harder sandstone, seams of coal, and thin limestone lentils,	Cb		320		
				(48)	Sandstone and shale.	
				(20)	Shale with limestone lentils.	
				(45)	Sandstone.	
				(22)	Shale with limestone lentils.	
				(20)	Sandstone.	
					Limestone lentil.	
				(165)	Shale.	
	Wilson formation. Principally heavy-bedded drab shale and gray to brownish sandstone, with limestone lentils and seams of coal.	Cw		280		
		(Cp)		(0–50)	Piqua limestone.	Heavy-bedded light-gray crystalline limestone that weathers to rough blocks; pure in northern part of quadrangle; thins toward the south and is locally conglomeratic, shaly, arenaceous, or absent.
				(0–80)	Vilas shale.	Compact drab to pale-yellowish shale and sandstone, the latter thickening toward the south; variable in thickness and locally absent.
		(Ca)		(0–70)	Allen limestone.	Massive, semicrystalline, compact to coarse-grained dark-blue fossiliferous limestone; thins toward the south and is absent in the southern half of the quadrangle.
				(60)	Concreto shale.	Compact argillaceous to arenaceous shale and brownish thin- to heavy-bedded sandstone, with thin coal seams.
		(Ci)		(0–3)	Iola limestone.	Crystalline to argillaceous, medium-grained, fossiliferous limestone in thin lentils; absent in southern part of quadrangle.
				(75)	Upper part of Chanute shale.	Compact, heavy-bedded drab shale and thin- to heavy-bedded sandstone in about equal amounts, with seams of coal and a few thin limestone lentils.
	Drum limestone.	Cdr		2–100	Limestone. Shale. Limestone.	Gray to blue, fine-grained, crystalline, heavy-bedded to flaggy limestone. Toward the south contains drab to black shale, in part arenaceous.
	Coffeyville formation. Drab shale and brownish sandstone in alternating heavy beds, with limestone lentils.	Cc		250		
				(100)	Cherryvale shale (lower part of Chanute shale).	Light-drab to reddish or yellowish, compact, fragile shale, with some friable sandstone and seams of coal.
		(Cd)		(0–50)	Dennis limestone.	Medium-grained, hard, bluish-gray, semicrystalline, fossiliferous limestone, usually massive and chert bearing; absent in southern part of quadrangle.
				(40)	Galesburg shale.	Red to drab arenaceous shale, heavy beds of micaceous sandstone, and thin seams of coal.
		Cm)		(0–15)	Mound Valley limestone.	Hard, compact, semicrystalline, fossiliferous, thin-bedded to massive limestone; absent in southern part of quadrangle.
				(90)	Ladore–Dudley shale.	Soft, brown, compact, argillaceous to arenaceous, thin-bedded shale, with very little sandstone.
	Parsons formation. Crystalline fossiliferous limestone and compact shale.	Cpr		80		
				(20)	Limestone.	Reddish, medium-grained, tough, heavy- to thin-bedded limestone; nodular and impure at the base.
				(45)	Shale.	Dark, slate-colored, hard, compact shale, with nodules of impure limestone.
				(15)	Limestone.	Compact, bluish-gray, semicrystalline, chert-bearing, fossiliferous limestone, with massive beds of *Chætetes* and a thin bed of dark slaty shale.

GENERALIZED SECTION OF ROCKS ENCOUNTERED IN DRILLING IN THE INDEPENDENCE QUADRANGLE.

SCALE: 1 INCH = 100 FEET.

System.	Series.	Formation Name.	Thickness in Feet.	Columnar Section.	Thickness and Character of Rocks.
CARBONIFEROUS	PENNSYLVANIAN	Parsons formation.	80		20′ limestone. 45′ shale. 15′ limestone.
		Bandera shale.	140		14′ shale. 4′ sandstone. 32′ shale. 6′ sandstone. 24′ shale. 4′ sandstone. 56′ shale.
		Pawnee limestone.	30		Massive limestone.
		Labette shale.	110		30′ shale. 0–6″ coal. 7′ shale. 6′ sandstone. 66′ shale.
		Fort Scott limestone.	40		10′ limestone. 15′ shale and oil-bearing sandstone 15′ limestone.
		Cherokee shale.	450		17′ shale. 10′ oil and gas sand. 11′ shale. 0–6″ coal. 25′ shale. 1′ coal. 19′ shale. 6′ sandstone. 22′ shale. 8′ coal. 45′ shale. 18′ oil sand. 23′ shale. 1′ coal. 22′ shale. 7′ oil sand. 11′ shale. 0–3″ coal. 23′ shale. 4′ oil sand. 40′ shale. 40′ oil and gas sand. 31′ shale. 2 coal. 31′ shale. 2′ limestone. 13′ shale. 2′ oil sand. 11′ shale.
	MISSISSIPPIAN	Boone limestone.	250		Chert-bearing limestone.

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

Stratified rocks often contain the remains or imprints of plants and animals which, at the time the strata were deposited, lived in the sea or were washed from the land into lakes or seas, or were buried in surficial deposits on the land. Such rocks are called fossiliferous. By studying fossils it has been found that the life of each period of the earth's history was to a great extent different from that of other periods. Only the simpler kinds of marine life existed when the oldest fossiliferous rocks were deposited. From time to time more complex kinds developed, and as the simpler ones lived on in modified forms life became more varied. But during each period there lived peculiar forms, which did not exist in earlier times and have not existed since; these are *characteristic types*, and they define the age of any bed of rock in which they are found. Other types passed on from period to period, and thus linked the systems together, forming a chain of life from the time of the oldest fossiliferous rocks to the present. When two sedimentary formations are remote from each other and it is impossible to observe their relative positions, the characteristic fossil types found in them may determine which was deposited first. Fossil remains found in the strata of different areas, provinces, and continents afford the most important means for combining local histories into a general earth history.

It is often difficult or impossible to determine the age of an igneous formation, but the relative age of such a formation can sometimes be ascertained by observing whether an associated sedimentary formation of known age is cut by the igneous mass or is deposited upon it.

Similarly, the time at which metamorphic rocks were formed from the original masses is sometimes shown by their relations to adjacent formations of known age; but the age recorded on the map is that of the original masses and not of their metamorphism.

Colors and patterns.—Each formation is shown on the map by a distinctive combination of color and pattern, and is labeled by a special letter symbol.

Symbols and colors assigned to the rock systems.

	System.	Series.	Symbol.	Color for sedimentary rocks.
Cenozoic	Quaternary...	Recent....... Pleistocene....	Q	Brownish-yellow.
	Tertiary......	Pliocene....... Miocene........ Oligocene...... Eocene.........	T	Yellow ocher.
Mesozoic	Cretaceous....	....	K	Olive-green.
	Jurassic......	....	J	Blue-green.
	Triassic......	....	Ћ	Peacock-blue.
Paleozoic.	Carboniferous.	Permian....... Pennsylvanian Mississippian..	C	Blue.
	Devonian.....	....	D	Blue-gray.
	Silurian......	....	S	Blue-purple.
	Ordovician....	....	O	Red-purple.
	Cambrian.....	Saratogan..... Acadian....... Georgian......	Є	Brick-red.
	Algonkian....	....	A	Brownish-red.
	Archean......	....	AR	Gray-brown.

Patterns composed of parallel straight lines are used to represent sedimentary formations deposited in the sea or in lakes. Patterns of dots and circles represent alluvial, glacial, and eolian formations. Patterns of triangles and rhombs are used for igneous formations. Metamorphic rocks of unknown origin are represented by short dashes irregularly placed; if the rock is schist the dashes may be arranged in wavy lines parallel to the structure planes. Suitable combination patterns are used for metamorphic formations known to be of sedimentary or of igneous origin.

The patterns of each class are printed in various colors. With the patterns of parallel lines, colors are used to indicate age, a particular color being assigned to each system. The symbols by which formations are labeled consist each of two or more letters. If the age of a formation is known the symbol includes the system symbol, which is a capital letter or monogram; otherwise the symbols are composed of small letters. The names of the systems and recognized series, in proper order (from new to old), with the color and symbol assigned to each system, are given in the preceding table.

SURFACE FORMS.

Hills and valleys and all other surface forms have been produced by geologic processes. For example, most valleys are the result of erosion by the streams that flow thru them (see fig. 1), and the alluvial plains bordering many streams were built up by the streams; sea cliffs are made by the eroding action of waves, and sand spits are built up by waves. Topographic forms thus constitute part of the record of the history of the earth.

Some forms are produced in the making of deposits and are inseparably connected with them. The hooked spit, shown in fig. 1, is an illustration. To this class belong beaches, alluvial plains, lava streams, drumlins (smooth oval hills composed of till), and moraines (ridges of drift made at the edges of glaciers). Other forms are produced by erosion, and these are, in origin, independent of the associated material. The sea cliff is an illustration; it may be carved from any rock. To this class belong abandoned river channels, glacial furrows, and peneplains. In the making of a stream terrace an alluvial plain is first built and afterwards partly eroded away. The shaping of a marine or lacustrine plain is usually a double process, hills being worn away (*degraded*) and valleys being filled up (*aggraded*).

All parts of the land surface are subject to the action of air, water, and ice, which slowly wear them down, and streams carry the waste material to the sea. As the process depends on the flow of water to the sea, it can not be carried below sea level, and the sea is therefore called the *base-level* of erosion. When a large tract is for a long time undisturbed by uplift or subsidence it is degraded nearly to base-level, and the even surface thus produced is called a *peneplain*. If the tract is afterwards uplifted the peneplain at the top is a record of the former relation of the tract to sea level.

THE VARIOUS GEOLOGIC SHEETS.

Areal geology map.—This map shows the areas occupied by the various formations. On the margin is a *legend*, which is the key to the map. To ascertain the meaning of any colored pattern and its letter symbol the reader should look for that color, pattern, and symbol in the legend, where he will find the name and description of the formation. If it is desired to find any given formation, its name should be sought in the legend and its color and pattern noted, when the areas on the map corresponding in color and pattern may be traced out.

The legend is also a partial statement of the geologic history. In it the formations are arranged in columnar form, grouped primarily according to origin—sedimentary, igneous, and crystalline of unknown origin—and within each group they are placed in the order of age, so far as known, the youngest at the top.

Economic geology map.—This map represents the distribution of useful minerals and rocks, showing their relations to the topographic features and to the geologic formations. The formations which appear on the areal geology map are usually shown on this map by fainter color patterns. The areal geology, thus printed, affords a subdued background upon which the areas of productive formations may be emphasized by strong colors. A mine symbol is printed at each mine or quarry, accompanied by the name of the principal mineral mined or stone quarried. For regions where there are important mining industries or where artesian basins exist special maps are prepared, to show these additional economic features.

Structure-section sheet.—This sheet exhibits the relations of the formations beneath the surface. In cliffs, canyons, shafts, and other natural and artificial cuttings, the relations of different beds to one another may be seen. Any cutting which exhibits those relations is called a *section*, and the same term is applied to a diagram representing the relations. The arrangement of rocks in the earth is the earth's *structure*, and a section exhibiting this arrangement is called a *structure section*.

The geologist is not limited, however, to the natural and artificial cuttings for his information concerning the earth's structure. Knowing the manner of formation of rocks, and having traced out the relations among the beds on the surface, he can infer their relative positions after they pass beneath the surface, and can draw sections representing the structure of the earth to a considerable depth. Such a section exhibits what would be seen in the side of a cutting many miles long and several thousand feet deep. This is illustrated in the following figure:

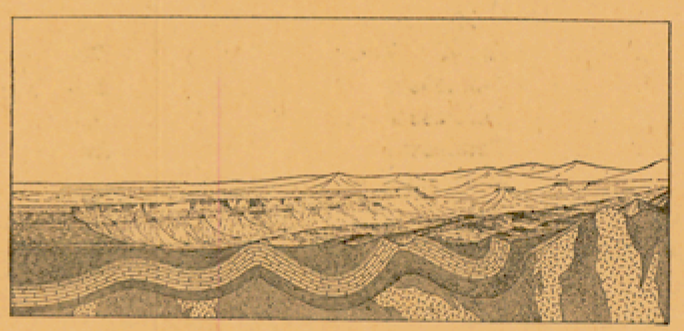


Fig. 2.—Sketch showing a vertical section at the front and a landscape beyond.

The figure represents a landscape which is cut off sharply in the foreground on a vertical plane, so as to show the underground relations of the rocks. The kinds of rock are indicated by appropriate symbols of lines, dots, and dashes. These symbols admit of much variation, but the following are generally used in sections to represent the commoner kinds of rock:

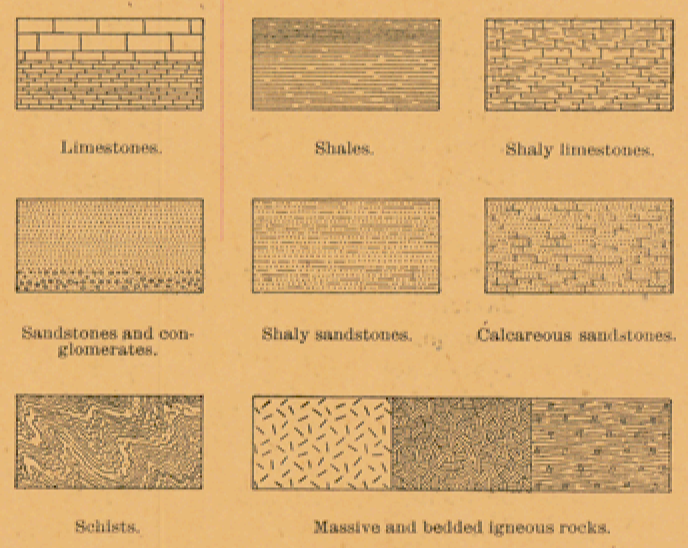


Fig. 3.—Symbols used in sections to represent different kinds of rocks.

The plateau in fig. 2 presents toward the lower land an escarpment, or front, which is made up of sandstones, forming the cliffs, and shales, constituting the slopes, as shown at the extreme left of the section. The broad belt of lower land is traversed by several ridges, which are seen in the section to correspond to the outcrops of a bed of sandstone that rises to the surface. The upturned edges of this bed form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shale.

Where the edges of the strata appear at the surface their thickness can be measured and the angles at which they dip below the surface can be observed. Thus their positions underground can be inferred. The direction that the intersection of a bed with a horizontal plane will take is called the *strike*. The inclination of the bed to the horizontal plane, measured at right angles to the strike, is called the *dip*.

Strata are frequently curved in troughs and arches, such as are seen in fig. 2. The arches are called *anticlines* and the troughs *synclines*. But the sandstones, shales, and limestones were deposited beneath the sea in nearly flat sheets; that they are now bent and folded is proof that forces have from time to time caused the earth's surface to wrinkle along certain zones. In places the strata are broken across and the parts have slipped past each other. Such breaks are termed *faults*. Two kinds of faults are shown in fig. 4.

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

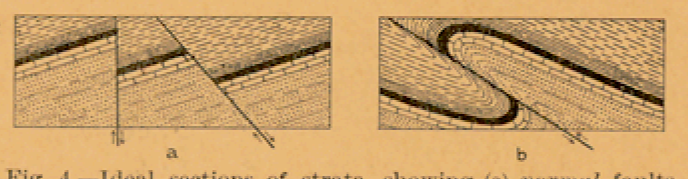


Fig. 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* fault.

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

The section in fig. 2 shows three sets of formations, distinguished by their underground relations. The uppermost of these, seen at the left of the section, is a set of sandstones and shales, which lie in a horizontal position. These sedimentary strata are now high above the sea, forming a plateau, and their change of elevation shows that a portion of the earth's mass has been raised from a lower to a higher level. The strata of this set are parallel, a relation which is called *conformable*.

The second set of formations consists of strata which form arches and troughs. These strata were once continuous, but the crests of the arches have been removed by degradation. The beds, like those of the first set, are conformable.

The horizontal strata of the plateau rest upon the upturned, eroded edges of the beds of the second set at the left of the section. The overlying deposits are, from their positions, evidently younger than the underlying formations, and the bending and degradation of the older strata must have occurred between the deposition of the older beds and the accumulation of the younger. When younger rocks thus rest upon an eroded surface of older rocks the relation between the two is an *unconformable* one, and their surface of contact is an *unconformity*.

The third set of formations consists of crystalline schists and igneous rocks. At some period of their history the schists were plicated by pressure and traversed by eruptions of molten rock. But the pressure and intrusion of igneous rocks have not affected the overlying strata of the second set. Thus it is evident that a considerable interval elapsed between the formation of the schists and the beginning of deposition of the strata of the second set. During this interval the schists suffered metamorphism; they were the scene of eruptive activity; and they were deeply eroded. The contact between the second and third sets is another unconformity; it marks a time interval between two periods of rock formation.

The section and landscape in fig. 2 are ideal, but they illustrate relations which actually occur. The sections on the structure-section sheet are related to the maps as the section in the figure is related to the landscape. The profile of the surface in the section corresponds to the actual slopes of the ground along the section line, and the depth from the surface of any mineral-producing or water-bearing stratum which appears in the section may be measured by using the scale of the map.

Columnar section sheet.—This sheet contains a concise description of the sedimentary formations which occur in the quadrangle. It presents a summary of the facts relating to the character of the rocks, the thickness of the formations, and the order of accumulation of successive deposits.

The rocks are briefly described, and their characters are indicated in the columnar diagram. The thicknesses of formations are given in figures which state the least and greatest measurements, and the average thickness of each is shown in the column, which is drawn to a scale—usually 1000 feet to 1 inch. The order of accumulation of the sediments is shown in the columnar arrangement—the oldest formation at the bottom, the youngest at the top.

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

GEORGE OTIS SMITH,

Director.

May, 1908.

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47	London	Kentucky	25
48	Tenmile District Special	Colorado	25
49	Roseburg	Oregon	25
50	Holyoke	Massachusetts-Connecticut	25
51	Big Trees	California	25
52	Absaroka	Wyoming	25
53	Standingstone	Tennessee	25
54	Tacoma	Washington	25
55	Fort Benton	Montana	25
56	Little Belt Mountains	Montana	25
57	Telluride	Colorado	25
58	Elmoro	Colorado	25
59	Bristol	Virginia-Tennessee	25
60	La Plata	Colorado	25
61	Monterey	Virginia-West Virginia	25
62	Menominee Special	Michigan	25
63	Mother Lode District	California	50
64	Uvalde	Texas	25
65	Tintic Special	Utah	25
66	Colfax	California	25
67	Danville	Illinois-Indiana	25
68	Walsenburg	Colorado	25
69	Huntington	West Virginia-Ohio	25
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79	Atoka	Indian Territory	25
80	Norfolk	Virginia-North Carolina	25
81	Chicago	Illinois-Indiana	50
82	Masontown-Uniontown	Pennsylvania	25
83	New York City	New York-New Jersey	50
84	Ditney	Indiana	25
85	Oelrichs	South Dakota-Nebraska	25
86	Ellensburg	Washington	25
87	Camp Clarke	Nebraska	25
88	Scotts Bluff	Nebraska	25
89	Port Orford	Oregon	25
90	Cranberry	North Carolina-Tennessee	25
91	Hartville	Wyoming	25
92	Gaines	Pennsylvania-New York	25
93	Elkland-Tioga	Pennsylvania	25
94	Brownsville-Connellsville	Pennsylvania	25
95	Columbia	Tennessee	25
96	Olivet	South Dakota	25
97	Parker	South Dakota	25
98	Tishomingo	Indian Territory	25
99	Mitchell	South Dakota	25
100	Alexandria	South Dakota	25
101	San Luis	California	25
102	Indiana	Pennsylvania	25
103	Nampa	Idaho-Oregon	25
104	Silver City	Idaho	25
105	Patoka	Indiana-Illinois	25
106	Mount Stuart	Washington	25
107	Newcastle	Wyoming-South Dakota	25
108	Edgemont	South Dakota-Nebraska	25
109	Cottonwood Falls	Kansas	25
110	Latrobe	Pennsylvania	25
111	Globe	Arizona	25
112	Bisbee	Arizona	25
113	Huron	South Dakota	25
114	De Smet	South Dakota	25
115	Kittanning	Pennsylvania	25
116	Asheville	North Carolina-Tennessee	25
117	Casselton-Fargo	North Dakota-Minnesota	25
118	Greeneville	Tennessee-North Carolina	25
119	Fayetteville	Arkansas-Missouri	25
120	Silverton	Colorado	25
121	Waynesburg	Pennsylvania	25
122	Tahlequah	Indian Territory-Arkansas	25
123	Elders Ridge	Pennsylvania	25
124	Mount Mitchell	North Carolina-Tennessee	25
125	Rural Valley	Pennsylvania	25
126	Bradshaw Mountains	Arizona	25
127	Sundance	Wyoming-South Dakota	25
128	Aladdin	Wyo.-S. Dak.-Mont.	25
129	Clifton	Arizona	25
130	Rico	Colorado	25
131	Needle Mountains	Colorado	25
132	Muscogee	Indian Territory	25
133	Ebensburg	Pennsylvania	25
134	Beaver	Pennsylvania	25
135	Nepesta	Colorado	25
136	St. Marys	Maryland-Virginia	25
137	Dover	Del.-Md.-N. J.	25
138	Redding	California	25
139	Snoqualmie	Washington	25
140	Milwaukee Special	Wisconsin	25
141	Bald Mountain-Dayton	Wyoming	25
142	Cloud Peak-Fort McKinney	Wyoming	25
143	Nantahala	North Carolina-Tennessee	25
144	Amity	Pennsylvania	25
145	Lancaster-Mineral Point	Wisconsin-Iowa-Illinois	25
146	Rogersville	Pennsylvania	25
147	Pisgah	N. Carolina-S. Carolina	25
148	Joplin District	Missouri-Kansas	50
149	Penobscot Bay	Maine	25
150	Devils Tower	Wyoming	25
151	Roan Mountain	Tennessee-North Carolina	25
152	Patuxent	Md.-D. C.	25
153	Ouray	Colorado	25
154	Winslow	Arkansas-Indian Territory	25
155	Ann Arbor	Michigan	25
156	Elk Point	S. Dak.-Nebr.-Iowa	25
157	Passaic	New Jersey-New York	25
158	Rockland	Maine	25
159	Independence	Kansas	25

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

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