DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS

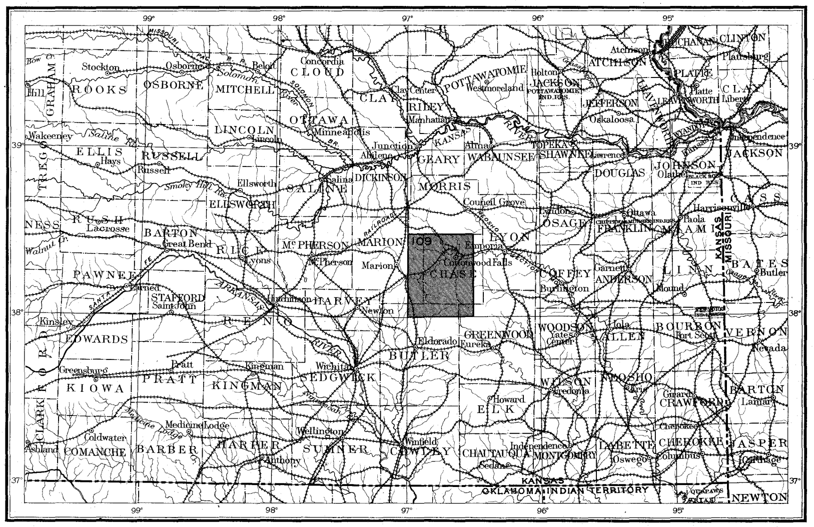
OF THE

UNITED STATES

COTTONWOOD FALLS FOLIO

KANSAS

INDEX MAP



SCALE 40 MILES=1 INCH

COTTONWOOD FALLS FOLIO

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COTTONWOOD FALLS FOLIO
NO. 109

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GEOLOGIC AND TOPOGRAPHIC ATLAS OF UNITED STATES.

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

THE TOPOGRAPHIC MAP.

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

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

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

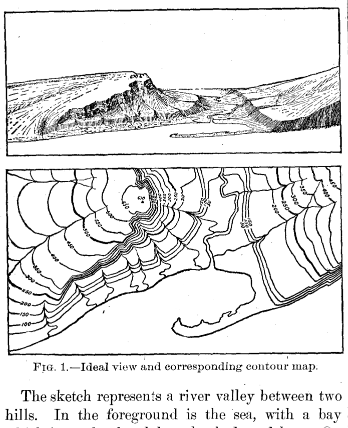


FIG. 1.—Ideal view and corresponding contour map.

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

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

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

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

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

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

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

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

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

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

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

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

THE GEOLOGIC MAPS.

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

KINDS OF ROCKS.

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

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

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

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

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

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

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

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

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

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

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

FORMATIONS.

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

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

AGES OF ROCKS.

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

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

(Continued on third page of cover.)

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.......	....	Ꞧ	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......	....	Æ	Gray-brown.

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

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

SURFACE FORMS.

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

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

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

THE VARIOUS GEOLOGIC SHEETS.

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

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

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

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:

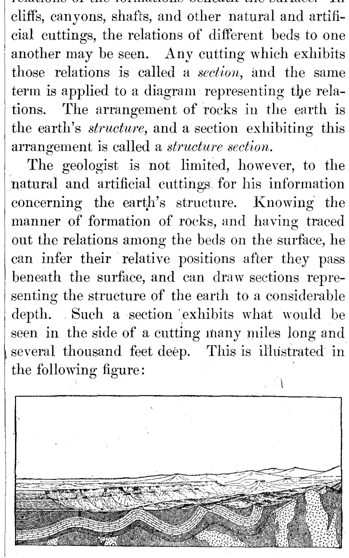


Fig. 2.—Sketch showing a vertical section at the front and a landscape beyond.

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:

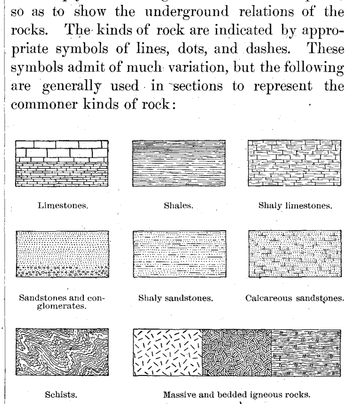


Fig. 3.—Symbols used in sections to represent different kinds of rocks.

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

On the right of the sketch, fig. 2, the se composed of schists which are traversed by of igneous rock. The schists are much co and their arrangement underground can

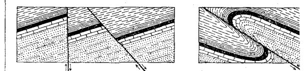


Fig. 4.—Ideal sections of strata, showing (a) *norm* and (b) a *thrust* fault.

inferred. Hence that portion of the sectior cates what is probably true but is not kno observation or well-founded inference.

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

The second set of formations consists of which form arches and troughs. These strat once continuous, but the crests of the arche been removed by degradation. The bed those of the first set, are conformable.

The horizontal strata of the plateau rest the upturned, eroded edges of the beds second set at the left of the section. The ove deposits are, from their positions, evidently y than the underlying formations, and the b and degradation of the older strata must occurred between the deposition of the olde and the accumulation of the younger. younger rocks thus rest upon an eroded s of older rocks the relation between the an *unconformable* one, and their surface of c is an *unconformity*.

The third set of formations consists of crys schists and igneous rocks. At some period o history the schists were plicated by pressu traversed by eruptions of molten rock. B pressure and intrusion of igneous rocks ha affected the overlying strata of the secon Thus it is evident that a considerable in elapsed between the formation of the schis the beginning of deposition of the strata second set. During this interval the schis fered metamorphism; they were the scene of tive activity; and they were deeply eroded. contact between the second and third sets is a unconformity; it marks a time interval be two periods of rock formation.

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

Columnar section sheet.—This sheet cont concise description of the sedimentary form which occur in the quadrangle. It pres summary of the facts relating to the cha of the rocks, the thickness of the formation the order of accumulation of successive depo

The rocks are briefly described, and their acters are indicated in the columnar dia The thicknesses of formations are given in f which state the least and greatest measure and the average thickness of each is shown column, which is drawn to a scale—usually feet to 1 inch. The order of accumulation sediments is shown in the columnar arrangem the oldest formation at the bottom, the young the top.

The intervals of time which correspond to of uplift and degradation and constitute int tions of deposition are indicated graphically a the word "unconformity."

CHARLES D. WALCOTT

Direc

DESCRIPTION OF THE COTTONWOOD FALLS QUADRANGLE.

By Charles S. Prosser and J. W. Beede.

GEOGRAPHY.

General relations.—The Cottonwood Falls quadrangle lies between parallels 38° and 38° 30′ and meridians 96° 30′ and 97°, and therefore constitutes a quarter of a square degree of the earth's surface. It is 34.35 miles long and 26.75 miles wide, and contains about 938 square miles. It is located east and a little south of the central part of Kansas, on Cottonwood River, and includes large portions of Chase and Marion counties and small portions of Greenwood and Butler counties.

The quadrangle is within the limits of the Great Plains, and in its western portion the plains are well developed. The eastern portion is occupied by the rough hills of an eastward-facing escarpment, which may be conveniently regarded as the dividing line between the Great Plains proper and the prairie plains of the Mississippi basin. The topographic forms found within the quadrangle are the result of erosive agencies acting on slightly tilted sedimentary rocks.

Origin of topographic forms.—Moisture begins to dissolve and frost to disintegrate rocks as soon as a land surface is elevated above the sea, and running water carries away much of the resulting fine material. Streams also wear away the rocks over which they flow. The harder rocks, being less easily decomposed and worn away, form the tops of hills and escarpments, while the softer rocks are etched out and form the sides and bottoms of the valleys. So long as the slope of the stream beds is steep the streams cut rather rapidly. After this erosion has progressed for a time, deep valleys with steep sides and deep, sharp-walled ravines are cut into the original plain by the streams, and the areas between the streams constitute an upland. When the rivers have cut their beds until the grades are no longer steep they cease cutting them deeper, and begin winding from side to side of their valleys. In this stage they widen their valleys, and at the same time gradually cover the bottom lands thus produced with fine alluvium, sand, and gravel. Finally the hills become worn away, and again the country has the features of a level plain, over which sluggish streams flow in shallow channels. This kind of a plain is called a lowland. It is very similar to the original plain —the plain formed when the land was first raised from the sea—but is lower.

When strata are upturned the rocks are more readily attacked by erosive agencies and wear away rapidly. When beds of unequal hardness are slightly tilted in a uniform direction erosion develops a terrace form of topography, which is excellently diplayed in eastern Kansas. The series of terraces developed here by the harder limestone layers interbedded with soft shales reaches its culmination in the Flint Hills escarpment, which extends across the State in a north-south line from Marshall to Cowley County. This escarpment occupies the eastern portion of the Cottonwood Falls quadrangle.

Physiography of eastern Kansas.—There are several important physiographic provinces in eastern and central Kansas. In the northeastern portion of the State, extending in part as far south as Kansas River, is an area in which the underlying terrace topography is masked by glacial drift. This area is called the Iowa prairie. South of it, beyond the border of the drift, an extensive lowland plain has been developed by the disintegration of the thick, soft Cherokee shales. This area is called the Cherokee lowland. West of the Iowa prairie and the Cherokee lowland, extending to the Flint Hills escarpment, is the typical terraced plains area, which is called the Osage or terraced plains. Within this area is a series of general north-south eastward-fronting escarpments separating lowland plains of varying width that rise successively and slightly to the west. These escarpments are developed by the various limestones of the Coal Measures. They vary from a few feet to 200 feet in height, and are fairly constant, though not everywhere equally developed. Their spacing is controlled mainly by the varying thickness of the intervening shales.

The terraced plains culminate in the Flint Hills escarpment, above which is developed, within the quadrangle, the Flint Hills upland. To the north this merges into the Smoky Hills upland. The Flint Hills upland is a highly dissected structural plain. Above the chert beds which form the escarpment are beds of softer rock, which weathers easily, and on this structural plain a great topographic plain has developed. The region is one of sluggish streams flowing in wide valleys, with very completely developed flood plains. It is the Great Bend prairie. To the west it merges into a more rolling country, occasionally called the Oklahoma prairie, limited by the Gypsum Hills escarpment, which separates it from the Red Hills upland.

Physiography of the quadrangle.—Within this quadrangle the Great Plains are represented by the Flint Hills upland and the Prairie Plains by the Osage or terraced plains. The two are divided by the Flint Hills escarpment, which runs through the eastern townships of the quadrangle. This is composed of several minor benches. These benches, which sometimes have the regular form of individual escarpments, are produced by thick limestones and cherts interbedded with softer shales. The hard beds are the Wreford and Florence flint and the limestones and chert of the Winfield formation. The Wreford limestone overlies the Garrison formation, which is made up largely of shales and is over 130 feet thick. Between the Wreford and the Florence is the Matfield shale, and between the Florence and the Winfield the Doyle shale intervenes. The limestones form the more abrupt parts of the scarps, and the shales the gentle slopes (see fig. 1). The shales of the Garrison formation contain thin limestones, which in the face of the escarpment have a wavy outline. Where sufficiently remote from streams the benches formed by the Florence flint and the Winfield formation often blend in the nearly even plain, so that it is very difficult to distinguish the formations. The bench made by the Winfield formation is the top of the Flint Hills escarpment. This escarpment enters the quadrangle on the north side of Cottonwood River, and bends back up the river in a tortuous course as far as Cedar Point. From Cottonwood Falls it retreats up South Fork nearly to its source, and leaves the quadrangle near Bazaar. In other words, the valleys of the larger streams are cut out of a high plain, and their bluffs form the Flint Hills escarpment as it is represented in this quadrangle. After leaving the quadrangle the escarpment becomes straighter as it passes southward.

The high plain which has for its eastern border the Flint Hills escarpment is known as the Flint Hills upland. In its eastern extension it is much dissected. To the west, however, the stream valleys are not so deep, the country becomes even more level and there are numerous little table-lands, caused by the unequal weathering of the soft limestones at the base of the Marion formation. West of the quadrangle, as noted, this upland grades into a lowland known as the Great Bend prairie, which is a monotonously level country where the streams flow in wide, shallow valleys that have gradually sloping bluffs. The streams are sluggish, and long ago ceased to wear away the land to any considerable extent.

A large part of the quadrangle lies about 1400 feet above tide water. In the eastern part hills or table-lands often rise to a height of 1500 feet, the highest being located in the southeastern part, which reaches a maxium of 1560 feet. By far the larger part of this quadrangle constitutes a plain having an elevation of 1400 feet or more. Except near Burns the altitude of 1500 feet is not reached in the western half of the quadrangle. In its eastern part the plain is greatly dissected by streams, while in its western half it is less dissected. The difference in elevation between the highest and lowest levels of the quadrangle is 310 feet.

Drainage. — Practically speaking, Kansas is drained by Kansas and Arkansas rivers and their tributaries. Osage and Marmaton rivers drain a little of the eastern portion. The northern half is drained by Kansas River, while the southern half is drained by the Arkansas. In the small triangular area with a point to the west, situated in the central part of the east end of the State, are Osage and Marmaton rivers, which empty into Missouri River in central Missouri. Smoky Hill River rises in eastern Colorado and western Kansas and flows eastward along the central line of the State nearly to the middle, where it turns and flows northward for some distance, and then again resumes its eastward course. At Junction it unites with Republican River, and the two form Kansas River. Kansas River flows nearly east and empties into Missouri River at Kansas City. Republican River rises in eastern Colorado and Nebraska and enters Kansas from the north. The larger tributaries of Kansas and Smoky Hill rivers flow from the north, and are, in order from west to east, the Saline, Solomon, Republican, Big Blue, and Delaware.

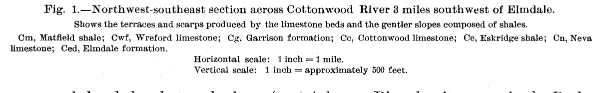


Fig. 1.—Northwest-southeast section across Cottonwood River 3 miles southwest of Elmdale.

Shows the terraces and scarps produced by the limestone beds and the gentler slopes composed of shales.

Cm, Matfield shale; Cwf, Wreford limestone; Cg, Garrison formation; Cc, Cottonwood limestone; Ce, Eskridge shale; Cn, Neva limestone; Ced, Elmdale formation.

Horizontal scale: 1 inch = 1 mile.
Vertical scale: 1 inch = approximately 500 feet.

Arkansas River has its source in the Rocky Mountains and crosses the western boundary of the State. It continues in a direction a little north of east to Great Bend, which is south of the middle of the State, and there turns to the southeast and flows into Oklahoma. It receives many small tributaries from the north before leaving the State. The largest of these is Walnut River, which enters it near the southern boundary line of Kansas. Little Arkansas River joins the Arkansas near Wichita. Cimarron River drains the southwestern part of Kansas, and, flowing into Oklahoma, empties into the Arkansas. East of the Cimarron is Salt Fork of the Arkansas, which follows a similar course. Most of southern Kansas east of the point of exit of Arkansas River is drained by Verdigris and Neosho rivers, both of which empty into the Arkansas in Indian Territory.

The surface of the Cottonwood Falls quadrangle is moderately rugged. The streams all show rock bottom in places. The river bluffs are usually rather steep.

The quadrangle is drained largely by Cottonwood River and its tributaries. This river, a western tributary of the Neosho, flows diagonally across the quadrangle in a northeast direction. Its principal northern tributaries here are, in ascending order, Fox Creek, Diamond Creek, Middle Creek, and Clear Creek. Fox Creek drains the northeast corner. A large area just west of this is drained by Diamond Creek. Middle Creek occupies the region west and southwest of the one last mentioned, and is the largest northern tributary of Cottonwood River within the quadrangle. Its mouth is near Elmdale. The northwest corner of the quadrangle is drained by Clear Creek, which enters Cottonwood River near Marion, outside this quadrangle. The largest tributary of Cottonwood River from the south is South Fork, which drains much of the eastern portion of the quadrangle. The south-central part is drained by Cedar and Coon creeks. Cedar Creek, the more westerly one, joins the river at Cedar Point, and has the larger drainage basin. The head of Fall River, a branch of the Verdigris, is in the extreme southeast corner of the quadrangle. The remainder of the southern part is drained by the headwaters of Walnut River and its tributaries, Whitewater, Wentworth, and Cole creeks. Whitewater Creek, the largest of these and the one that lies farthest west, drains the southwest corner. Doyle Creek, a large tributary of Cottonwood River from the west, joins the main stream at Florence, near the western edge of the quadrangle.

GEOLOGY.

The consolidated rocks of this quadrangle are of Carboniferous age, the lower ones belonging to the Pennsylvanian series (Coal Measures), and the upper being provisionally classed as Permian. The rocks are mostly shales, limestones, and cherty limestones. The shales were deposited in seas far from any shore, so that sand and coarser material had settled before reaching this portion of the sea, or else in water so deep that it was unaffected by currents. With changing conditions the waters became shallow, though clear, containing myriads of sea animals, whose skeletons accumulated in beds that are now represented by the limestone strata. After the formation of each limestone bed the old conditions returned, the water becoming muddy and the life less abundant; thus another layer of shale was deposited. Many of these cycles of change occurred, as may be seen by referring to the columnar section.

It is difficult to determine whence the mud came that built up the shales of this region, since much of the land that existed at the time they were deposited is now covered by rocks of later age. As these rocks are traced southward into Oklahoma the shales become more sandy and are often replaced by sandstone. These facts indicate that there were shores in that direction, though possibly far away.

The series of limestones and shales represented in this quadrangle has an aggregate thickness of 700 feet. The shales are laminated, or divided into thin layers, and vary from an almost pure clay to an impure limestone. They are usually soft, but the more limy ones are often very hard when first exposed. Both shales and limestones are often very fossiliferous. The limestones are mostly fine grained and occur in comparatively thin layers, the thickest single layer being not much over 5 feet. The chert segregations are either in thin layers or in large or small nodules in the limestone. No cherts are known to occur in the shales. The limestones of the upper formations are softer and much more porous than those nearer the base of the section.

At the time these upper limestones were formed beds of gypsum were deposited in adjacent areas. The difference in the character of the rocks here and in the region farther north probably was due to the greater concentration of calcium sulphate in the waters in the latter district. There the sea seems to have been cut off into local marginal basins.

DESCRIPTION OF THE ROCKS.

As stated above, the consolidated rocks of this quadrangle are of Pennsylvanian and probably of Permian age. The rocks below the Wreford limestone are considered to belong in the Pennsylvanian, while the Wreford and the formations above it are referred to the Permian. The alluvium of the valleys belongs to the Quaternary period. The rocks are described in the order of their age, beginning with the oldest or lowermost and continuing to the uppermost, which are found in the western and south-central parts of the quadrangle. They are graphically represented and briefly described in connection with the columnar section, and their geographic distribution is given on the areal geology map, the legend in the margin indicating their order of succession and relative age.

CARBONIFEROUS ROCKS.

Elmdale formation.—The lowest rocks exposed within the quadrangle consist of variegated shales interbedded with thin limestones. They have a thickness of approximately 130 feet and extend upward from the Americus limestone, which outcrops in the area immediately east of this quadrangle, to the Neva limestone. The shales are yellowish to bluish, while the limestones are grayish. In the Manhattan region, farther north, the shales have a great variety of color, showing bluish, yellowish, gray, blackish, and chocolate tints, and alternate with bluish to drab argillaceous limestones. The shales rest on the Americus limestone (so named by M. Z. Kirk, University Geol. Survey Kansas, vol. 1, 1896, p. 80). Near their top and from 10 to 15 feet below the base of the Neva limestone is a somewhat similar stratum, 3 to 5 feet thick, which was called by Kirk the lower Dunlap limestone, to which group he also referred the Neva and the intervening beds.

The principal area of these shales in the Cottonwood Falls quadrangle is in the bluffs on either side of Cottonwood River, for about 5 miles above and 3 miles below Elmdale. The shales also extend up Middle Creek Valley to a point about 5 miles northwest of Elmdale. The exposure of nearly the entire thickness of the member at this locality is due to the elevation of the rocks in the Elmdale anticline. There are better exposures, especially of the shaly portions, to be found northeast and north of this quadrangle, in Lyon, Wabaunsee, and Riley counties, particularly along Mill Creek near Alma and on Mount Prospect and Blue Mount at Manhattan, in the Kansas Valley. Within the quadrangle the best exposure of the beds below the Neva is in the bluff east of Elmdale. They occupy approximately the lower 130 feet of this bluff. The strata as shown along the highway mounting the hill are about as follows:

Section of bluff east of Elmdale.

	Feet.	Inches.
13. Shales	5	
12. Shales with hard filling in cracks		10
11. Shales	5	
10. Limestone, massive below and shaly above (lower stratum of Dunlap limestone)	3	4
9. Shale, calcareous, indurated	12	
8. Limestone, thin streak, containing *Pseudomonotis* and a few other fossils		few
7. Shale, yellowish green below, bluish above; but mostly covered	20+	
6. Limestone, massive, yellowish, weathering rough in center and containing a few fragments of fossils. The top of this stratum is approximately 60 feet below the base of the Neva limestone and its base is about 66 feet above Cottonwood River	4	
5. Shale, greenish, containing a few fossils and a thin layer of limestone at the base	2±	
4. Shale, olive, indurated in places	12	
3. Limestone and shale, with a 3-inch limestone near the base	2	
2. Limestone, hard		10
1. Covered slope to river level, with loose blocks of "Fusulina" limestone on the lower 30 feet.		

The massive yellowish limestone, No. 6 of the above section, is conspicuous in the hillsides near the road. It weathers to a rough surface and contains a few fragments of fossils. The accompanying shales and thinner limestones are shown to better advantage along the highway. About 30 feet above the base of the formation is a friable limestone, 4 feet thick in some localities, which is composed to a large extent of the tests of *Fusulina secalica* (Say) Beede?. (Dr. G. H. Girty has proposed the generic name *Triticites* for "the form from the Coal Measures strata of the Mississippi Valley, commonly identified as *Fusulina cylindrica*" or *F. secalica:* Am. Jour. Sci., 4th ser., vol. 17, p. 234.) The limestone weathers very readily and leaves perhaps a greater number of *Fusulina* in the soil than any other stratum containing that fossil in the Carboniferous rocks of Kansas. They are of the larger form, and in some places may actually be scooped up by the shovelful. Blocks of this limestone are found on the bluff nearly 30 feet above the river, and from that horizon down to water level they are numerous. At the mill east of Elmdale it is probable that the Americus limestone is but a few feet below water, perhaps only 5 feet. The limestone made up of *Fusulina* does not, as a rule, form a marked escarpment, owing to the readiness with which it disintegrates. Another locality at which specimens of *Fusulina* are very abundant is on the highway at the county farm for the poor, south of Cottonwood River and Elmdale.

The strata below the *Fusulina* ledge are not well exposed within the quadrangle. Mr. Alva J. Smith, of Emporia, Kans., has stated that they are well exposed a short distance outside of the quadrangle in a ravine north of Allen, Lyon County. A section given by Mr. Smith is shown below:

Section near Allen, Lyon County.

	Feet.	Inches.
11. Limestone, friable, including 4 inches of shale near the middle. Its top is comparatively hard and contains *Fusulina secalica* (Say) Beede?, *Chonetes granulifer* Owen, *Spirifer cameratus* Morton, and Bryozoa. The lower part crumbles very easily and is a mass of *Fusulina secalica* (Say) Beede?	6	3
10. Shale, yellow	4	6
9. Limestone containing brachiopods and crinoid stems	1	
8. Shale with black layer 6 inches thick, containing small brachiopods	3	
7. Limestone having a worm-eaten appearance, containing *Myalina*, very small gasteropods, and, in the débris below the stone, spines and plates of *Archæocidaris*		6
6. Shale, calcareous, containing *Fusulina*	3	6
5. Limestone, blue, with *Fusulina secalica* (Say) Beede? and *Productus semireticulatus* (Martin) de Koninck	2	
4. Shale, upper 2 feet yellow, lower 4½ feet blue to black, containing *Hustedia mormoni* (Marcou) Hall and Clarke, *Rhynchonella*, and crinoid plates	6	6
3. Limestone, the upper 6 inches of which is quarried for flagging	1	
2. Shale, blue	5	6
1. Limestone (Americus formation)	2	4

In the above section the strata included between the Fusulina bed and Americus limestone have a thickness of 28½ feet. Mr. Smith states that these strata are generally slightly thicker in Lyon County.

Neva limestone.—The Neva limestone is well shown at a number of localities in the northeastern part of the quadrangle, especially in the bluffs of Cottonwood River, Middle Creek, and South Fork Cottonwood River. It is finely exposed in the anticlinal fold on the Gamer farm, northeast of Neva, where it may be seen from the trains of the Atchison, Topeka and Santa Fe Railway. Other good localities are on the Blackshere ranch, 4 miles northeast of Clements, on Nortons Creek east of Bazaar, and near the base of the low bluff between Elinor and Strong on the northern side of Cottonwood River, where again the ledge is plainly visible from the railroad trains. This limestone is frequently a massive, bluish-gray stratum, 7 feet or more in thickness, often breaking down along the outcrop into large blocks having sharp angles and rough, jagged surfaces and weathering to a color not dissimilar to that of bleached bones. The telegraph road has cut through the formation on the Gamer farm, furnishing an excellent opportunity to study it. It forms a prominent ledge near the foot of the hill, especially in the rear of the Gamer farm buildings, northeast of Neva. Another locality where it forms a conspicuous ledge is nearly on the eastern line of the quadrangle between Strong and Elinor, where the top of the limestone is 18 feet above the railroad level. At this place the member consists of two limestone strata, separated by shale, and the limestone is capped by greenish shale, while 41 feet higher is the massive Cottonwood limestone. The section of the Neva limestone at this point is as follows:

Section of Neva limestone between Strong and Elinor.

	Feet.	Inches.
3. Limestone, upper, massive	4	2
2. Shale	2	
1. Limestone, lower, massive	4	8

The Neva limestone is so named from Neva, a station on the Atchinson, Topeka and Santa Fe Railway between Strong and Elmdale, for it is near this station, at the junction of the Diamond Creek and Cottonwood River valleys, that it occurs conspicuously in a prominent ledge.

Swallow described at this horizon at Manhattan, north of this quadrangle, and on Mill Creek the following section:

Section at Manhattan and on Mill Creek.

	Feet.
82. "Cotton rock," light cream-colored argillo-magnesian limestone; sometimes in thin beds, with shale partings	5
83. Marls, bluish brown	1
84. "Dry bone" limestone, brown, concretionary, and cancellated	5

It was stated that the above three numbers are sometimes represented on the Cottonwood by a bluish-gray and buff, porous magnesian limestone (Preliminary Rept. Geol. Survey Kansas, 1866, p. 16). The Neva represents the upper stratum of Haworth and Kirk's "limestone system number 12" (Kansas Univ. Quarterly, vol. 2, 1894, p. 112), to which system Kirk later apparently applied the name Dunlap limestone (University Geol. Survey Kansas, vol. 1, 1896, p. 81), stating that it consisted of two limestone strata separated by about 20 feet of shales. The Neva limestone represents only the upper stratum of the Dunlap as thus defined.

Eskridge shale.—Between the Neva and the Cottonwood limestone is a mass of shale, with perhaps some thin limestone layers, varying from 30 to 40 feet in thickness. The shale generally forms a covered slope between these two conspicuous limestones and is exposed at but few localities within the quadrangle. The well in Mr. Lantry's Fox Creek quarry west of Strong showed 15 feet of blue, greenish, and chocolate shales below the Cottonwood limestone. About 3½ miles farther up Fox Creek, at the Robertson bridge, there is shown the following section:

Section on Fox Creek at the Robertson bridge.

	Feet.	Inches.
4. Limestone, Cottonwood formation	5	3
3. Shale	12	
2. Limestone, thin, blue		10
1. Shale to low-water mark	2	

One of the best outcrops of the shale in the Cottonwood quadrangle is below the Rettiger quarry, near the eastern line of the quadrangle, on the southern side of Cottonwood River, and 2½ miles east of Cottonwood Falls. At this point 29 feet of greenish, chocolate, and yellowish shales is more or less clearly shown below the Cottonwood limestone. At the base the Neva is represented by 8½ feet of somewhat shaly limestone, termed a "bastard limestone" by the quarrymen. The upper 10 feet of these shales is shown on the township line highway one-half mile west of the railroad, about 2½ miles northeast of Bazaar. The formation is named from Eskridge, a town in Waubaunsee County, where the upper part of the shale is well exposed.

Cottonwood limestone.—This is a massive, light-gray to buff-colored foraminiferal limestone, frequently composed of two layers having a total thickness of 6 feet. The limestone on a fresh fracture is yellowish gray to buff in color, weathering to light gray. Generally it appears along the side of the moderately steep bluffs as a series of large, smooth, rectangular blocks which have broken off from the main ledge. It is not, as was at one time thought, magnesian in character.

The amount of chert in the rock varies greatly. In some localities it is scarcely perceptible, while in others the quantity is sufficient to make the rock comparatively valueless for economic purposes. It contains very few fossils with the exception of *Fusulina secalica* (Say) Beede?, which is extremely abundant in its upper part. The quarrymen call them fossil grains of wild rice, and on account of their abundance Swallow called the stratum the "Fusulina limestone" (Preliminary Rept. Geol. Survey Kansas, p. 16). The Cottonwood limestone may be easily identified by its abundant *Fusulina*, smooth surface, and light-gray color.

The constant lithologic character of this limestone and its line of outcrop, frequently marked by a row of massive, light-gray, rectangular blocks filled with *Fusulina secalica* (Say) Beede?, make it one of the most important stratigraphic horizons in the upper Paleozoic rocks for at least two-thirds of the distance across Kansas and into southeastern Nebraska. It appears within the quadrangle as a prominent ledge on the north side of Cottonwood River west of Elinor, and on the south side from a point east of South Fork Cottonwood River about 100 feet above water level it forms a conspicuous ledge as far as Cottonwood Falls. The limestone may be followed in the bluffs bordering the river valley from Cottonwood Falls and Strong to Clements, except where the synclinal fold a short distance west of the first-named towns carries it below the valley alluvium. It extends up the principal branches of the Cottonwood River as follows: Up South Fork to a point 3 miles south of Bazaar; Fox Creek for about 5 miles, to a point above Robertson bridge; Diamond Creek to Hymer; and up Middle Creek for 8 miles.

The limestone has been carefully traced from the northern part of Greenwood County across the Cottonwood Falls quadrangle as indicated above, then from Elinor across the divide into the Neosho Valley near Dunlap, where it follows the bluffs of the river for about one-half the distance to Council Grove. Here it turns northeastward, extending across the highland of Wabaunsee County and passing near Bushong and the heads of the various streams in the eastern part of the county to Eskridge, at the head of Dragoon Creek. From Eskridge it continues northward on the high land near the head of Mission Creek, reaching Mill Creek near Alma. It then crosses the divide toward Wabaunsee, when it follows the high bluffs on the south side of Kansas River to Manhattan and continues up the river valley to Sevenmile Creek just east of Ogden and about 5 miles below Fort Riley. From Manhattan it follows the western bluff of Big Blue River to Garrison, thence down the eastern bluff well toward the Kansas Valley, where it starts across Pottawatomie County, outcropping near Westmoreland and Wheaton, and continues to the hill near Barrett in Marshall County, on the southern side of Black Vermilion River. It then follows the line of the bluffs to Big Blue River, down which it continues to a short distance below Cleburn, while in the opposite direction it extends up the Big Blue Valley to Blue Rapids. The limestone then follows the eastern bank of the Big Blue down almost to its junction with the Black Vermilion, where it turns northward and crosses Marshall County, outcropping near Beattie and reaching the Nebraska line near Summerfield. It has been recognized in Nebraska, in Nemaha County, the second county north of the State line, at a point a few miles west of Auburn, beyond which it has not been traced.

For years this stone has been known commercially as the Cottonwood stone, or Cottonwood Falls limestone, when obtained from the quarries in the vicinity of that town or along the river, in the same way that it was termed locally, when taken from the quarries near the towns of Alma and Manhattan, the Alma and the Manhattan limestone. Haworth and Kirk, in their "Neosho River section," assigned numbers to the principal limestone strata, which they termed systems, and the one "exposed from the hilltop south of Dunlap to Council Grove" was termed "Limestone system number 13, which is considered the equivalent of the famous Cottonwood Falls limestone" (Kansas Univ. Quarterly, vol. 2, 1894, p. 112). In their Cottonwood River section, however, where this limestone is described in the vicinity of Cottonwood Falls, the same authors used for it simply the number 13, and did not apply to it the term Cottonwood Falls limestone (op. cit., p. 113). The same year Prosser proposed the name Cottonwood formation for the limestone and overlying fossiliferous shale on account of the excellent outcrops of both in the bluffs bordering Cottonwood River below and above Cottonwood Falls and Strong. The limestone constituting the lower part of the formation was named the Cottonwood limestone and the overlying shales the Cottonwood shales (Bull. Geol. Soc. Am., vol. 6, 1894, p. 40). The following year the formation and its two divisions were more fully described by Prosser (Jour. Geol., vol. 3, 1895, pp. 609–705). The name Cottonwood limestone is now adopted for this formation.

Garrison formation.—This formation is composed of two members, the yellowish, fossiliferous Florena shale at the base and the alternating gray limestone and various-colored shales above, called the Neosho member.

The Florena shales have a thickness of 13 feet near Strong, but decrease in thickness toward to the north, being at Alma only 10 feet, at Florena about 4 feet, and perhaps but 2 or 3 feet thick in the northern part of the State. The lower half of this shale in the Cottonwood region constitutes one of the most fossiliferous horizons of the upper Paleozoic, although it contains but few species that are extremely abundant. Wherever the shale has been exposed for some time to the action of the atmosphere large numbers of loose fossils, perfectly preserved, may be found. This is especially true of *Chonetes granulifer* Owen, which in places may be collected by the hundreds from the top of the subjacent limestone or in the soil formed by the decomposed shale. The other more abundant species are: *Derbya crassa* (M. & H.) Hall and Clarke, *Derbya sp.* (with marked projection at ventral margin of shell), *Seminula argentea* (Shepard) Schuchert, *Productus semireticulatus* (Martin) de Koninck, and *Meekella striaticostata* (Cox) White and St. John.

From the Cottonwood Falls quadrangle to at least the northern part of the State there is a very sharp line of division between the fossiliferous yellowish shale and the conspicuous massive Cottonwood limestone below, so that the beds are readily followed across the country.

The Neosho member of the formation is composed of green, chocolate, and yellowish shales, alternating with grayish limestones, while in the Big Blue Valley a bed of gypsum occurs near the base. As the yellowish shale approaches the Florena in lithologic character it frequently contains some of the species of that shale. Certain layers of the coarser shales and limestones contain a fauna composed largely of lamellibranchs, in which *Pseudomonotis hawni* (Meek and Hayden), *Pleurophorus subcostatus* Meek and Worth., and *Myalina kansasensis* Shum., are abundant or common. It is thought that the yellowish shales contain a fauna composed entirely of species found in the Pennsylvanian series of the West, while the limestones and coarser shales contain a mixture of these species and others which are found more frequently in beds that are considered Permian.

The lithologic composition of the Garrison formation as it exists in the Cottonwood Falls quadrangle is well shown by the section of Crusher Quarry Hill, supplemented by the exposures in Fox Creek quarry and the second railroad cut to the west, northwest of Strong, the whole making a section extending from the Cottonwood below to the Wreford above.

General section of the Garrison formation.

Member			Feet.
Neosho member.	16.	Shales, yellowish, fine at top, containing Florena shale fauna; the lower shales are coarser	23
	15.	Limestone, massive, in some localities 4 feet thick and occasionally quarried	3±
	14.	Shales, mainly yellowish, some greenish with thin shaly limestone	36
	13.	Limestone at top, containing *Pseudomonotis* 2 feet 10 inches thick; one layer of the limestone contains numerous small iron concretions and below are shales	10⅔
	12.	Limestone, light gray containing *Pseudomonotis*	1⅓
	11.	Shales, green and chocolate colored	20
	10.	Limestones, light gray, shaly, containing *Pseudomonotis* and other fossils	4
	9.	Shales about 4 feet or more in thickness	4
	8.	Limestone, dark gray, siliceous, on weathered surface very irregular with rough jagged prominences	2±
	7.	Shales, yellowish argillaceous, containing some of the Florena shale fauna	6
	6.	Shales, yellowish, blocky, containinga Lamellibranch fauna of *Pseudomonotis* and *Aviculopecten*, which in some localities appear to form a massive rough limestone similar to No. 8	5
	5.	Shale, greenish	7
	4.	Shales, chocolate and drab	4
	3.	Limestone, shaly	4
Florena member.	2.	Shales, buff, containing but few fossils and small geodes partly filled with gypsum (?)	5⅚
	1.	Shales, yellowish containing an abundance of fossils	7⅙

Numerous outcrops of the Garrison formation occur in Chase County along Cottonwood River and its tributaries. The formation extends up the Cottonwood Valley to the vicinity of Cedar Grove, for 10 miles up Middle Creek, up the Diamond and Fox Creek depressions beyond the limits of the quadrangle, and up South Fork Cottonwood River and Thurman Creek well toward the southeast corner of the quadrangle, where, after crossing the divide, it reappears on the headwaters of the streams flowing to the southeast.

Within the Cottonwood Falls quadrangle this formation is well shown at the following localities: On Crusher Quarry Hill, about 1¼ miles northwest of Strong; on the western side of Cottonwood River opposite and above Clements; on Buckeye Creek, south of Cottonwood Falls; on Rock Creek west of Bazaar; and on South Fork Cottonwood River near Matfield Green. The section of the exposures on the slope and along the road up Crusher Quarry Hill, in connection with those of the Fox Creek quarry to the east and the second railroad cut to the west, probably gives as good an idea of the lithologic composition of this formation as can be obtained at any locality in the quadrangle. This section has already been given.

Farther south, outside this quadrangle, the upper part of the formation is admirably shown on the Missouri Pacific Railway line from Eureka to El Dorado, in a cut east of Summit station and west of the trestle. Another excellent section is that along the line of the Atchison, Topeka and Santa Fe Railway from Grenola to Grand Summit station, at which point the yellowish shale at the top of the formation occurs just east of the railroad cut, and the remaining portion of the formation itself is exposed along the railroad descending the slope to the east. North of the Cottonwood Valley the formation is splendidly shown in the Neosho Valley and its tributaries in Morris County, extending from 6 miles southeast to 3 miles northwest of Council Grove. In the Big Blue Valley it is well shown north of Manhattan at Garrison, and farther northeast, near Bigelow, it appears in the lower part of the Black Vermilion Valley.

In a preliminary description of these beds the Florena shales were called the Cottonwood shales and were classed with the Cottonwood limestone to form the Cottonwood formation. Lithologically, however, they belong with the alternating shale and limestone of the overlying Neosho member, with which they are now united to form the Garrison formation. Since the geographic name Cottonwood was already in use as the name of the subjacent limestone, in order to avoid confusion the term Cottonwood shales is abandoned and they are renamed the Florena shales, from the fact that they are well exposed above the Cottonwood limestone in the quarries at Florena, in Big Blue Valley. The Neosho member was named from the excellent outcrops in the Neosho Valley near Council Grove. Both members are well shown in the Big Blue Valley from Garrison down the river, and on this account it is now proposed to call them the Garrison formation.

Wreford limestone.—This formation is composed of limestone and chert, or flint, as it is popularly termed throughout the Flint Hills region, and varies in thickness from 35 to 50 feet. In general it is composed of three members, cherty limestones below and above, separated by a heavy limestone nearly free from chert. The chert occurs as concretions and in layers from 4 to 8 inches thick, which often have considerable extent.

The lower chert stratum and the succeeding massive cherty limestone are well exposed in the quarry at the brow of Crusher Quarry Hill, northwest of Strong, where the following section was obtained:

Section of Wreford limestone northwest of Strong.

		Feet.
3.	Limestone, massive light gray to buff, containing plenty of chert. The stratum quarried for the railroad crusher, 16 feet of which is exposed in the vertical face of the north side of the quarry	19
2.	Limestone, yellowish, shaly	2½
1.	Limestone, light gray, containing an abundance of chert. Base of the lower heavy chert stratum	1½

Better sections, showing the entire thickness of the formation, are found both south and north of the quadrangle. For comparison, one from each region is given in the next column.

The upper part of the formation is shown in Geary County at Wreford, south of Junction. At this point about 15 feet of rock is exposed in the quarry where it was formerly worked and burned for lime. The lower beds in the quarry are composed of a massive limestone containing one layer of chert; higher the rock is more cherty, and at the top is a shaly limestone. The base of the formation is apparently near creek level, 25 feet below the base of the quarry, so that the formation at this locality has a thickness of 35 to 40 feet.

Section of Wreford limestone near Summit station, west of Reece, Greenwood County.

		Feet.
3.	Limestone, massive, light gray, containing an abundance of chert. This forms a conspicuous stratum near the eastern crest of the Flint Hills and is well exposed in the railroad cut at this locality	10
2.	Limestone, bluish and yellowish, shaly, containing abundant fossils. Lower part of zone composed of maroon, bluish, and yellowish calcareous shale	29
1.	Limestone, massive stratum of light-gray color, containing a large amount of chert arranged in layers	11

Section near Council Grove, Morris County.

		Feet.
5.	Limestone, massive, gray	5 (?)
4.	Limestone, massive, containing an abundance of very coarse chert and some large brown concretions	10 (?)
3.	Shale, yellowish and fairly coarse	3¼±
2	Limestone, massive light gray to whitish, containing some chert. This stratum was quarried and burned for lime	18
1.	Limestone, light gray, containing considerable chert, arranged in regular layers	7½

The Wreford limestone forms the first conspicuous flint terrace above the Cottonwood limestone, and its line of contact with the subjacent shales is generally marked by seeping water on the hillsides and in favorable localities by a series of good springs. In many of the ravines a clump of bushes due to these springs marks the lower outcrop of this formation. The flint or chert from this horizon is often found spread over the hills far to the east of the present outcrop, forming a natural macadam for the roads following the hills. On account of the resistant quality of the chert and hard limestone they form on the steep escarpments rocky tops which are visible for long distances.

This formation is found on the high ground over a considerable part of the eastern third of the quadrangle and extends up Diamond Creek beyond Diamond Springs, Morris County; up Middle Creek nearly to Elk; along the Cottonwood Valley to a point a little above Cedar Grove; and nearly to the headwaters of Thurman Creek, near the southeast corner of the quadrangle. The base of the chert is about 100 feet above the level of the South Fork at Matfield Green, where this cherty limestone forms the upper part of the steep hills east and west of this town. The Wreford limestone is conspicuous south of this quadrangle near the crest line of the Flint Hills, and it is admirably shown east of Summit station on the line of the Missouri Pacific Railway crossing the Flint Hills, from Reece to El Dorado, where it has a thickness of 50 feet, the maximum shown by the section already given; on the Atchison, Topeka and Santa Fe Railway from Grenola to Grand Summit, where, east of the latter station, the lower 25 feet of the formation is clearly shown; and in the southern Flint Hills on the line of the Missouri Pacific Railway near Hooser, where 40 feet of the formation is shown. North of the Cottonwood Falls quadrangle it forms the conspicuous ledges on the bluffs of Neosho River at Council Grove, and its base reaches river level below the highway bridge which is about midway between Council Grove and Kelso. On West Mill Creek, in the western part of Wabaunsee County, its top is found in sec. 8 and its base in the northeast quarter of sec. 9, a short distance above schoolhouse No. 26, 8 miles below Alta Vista and 7 miles above Alma. On the north side of Kansas River it forms the top of the steep bluff one-half mile west of Ogden, at the eastern line of the Fort Riley Military Reservation, and may readily be followed from there to the Quartermaster's bridge, Fort Riley, where its base is shown. Below it at this point fine yellowish shale occurs, as on Crusher Quarry Hill near Strong. The thickness in the Fort Riley area is about 40 feet. South of Junction, on the south side of Smoky Hill River, at Wreford, the formation is from 35 to 40 feet in thickness. It is rather conspicuous at Keats, on Wildcat Creek, northwest of Manhattan; near Garrison and Blue Rapids on Big Blue River; east of Irving, where it forms the top of the steep bluffs east of the Big Blue; near Waterville on Little Blue River; and it probably extends up the Big Blue Valley to Holmesville, Nebr.

In an earlier description of these rocks this division was regarded as the lower member of the Chase formation and was termed the Strong flint, from the exposures on Crusher Quarry Hill near Strong. On account of its thickness, lithologic character, and marked topographic importance it is probably better to regard it as a distinct formation.

The exposures near Wreford, Geary County, south of Junction, were named the Wreford limestone by Professor Hay (Eighth Bien. Rept. Kansas State Board Agric., 1893, pt. 2, p. 104), who gave its thickness as 25 feet. The preceding report of the State Board contained the table showing Professor Hay's "Fort Riley section," but this division was called the Walford limestone, which was undoubtedly a typographic error for Wreford (Seventh Bien. Rept. Kansas State Board Agric., 1891, pt. 2, p. 94). The name Strong flint was published in 1895 (Jour. Geol., vol. 3, p. 773), and as the formation is now known to be equivalent to the Wreford the name Strong is withdrawn in favor of the earlier name, Wreford, which is here adopted for this formation.

The dividing line between the transitional Carboniferous and Permian (Dyas) rocks of Kansas was orginally drawn by Dr. Fritz Frech, the well-known German authority regarding these rocks, at the base of the Wreford limestone (Lethaea palaeozoica, vol. 2, pt. 2, 1899, p. 378); but later he included the Neosho (which at first he termed transitional Carboniferous) in the Palæo-Dyas (older Permian) (ibid., pt. 3, 1901, p. 514). The above opinion also agrees closely with that of Dr. Th. Tschernyschew, the most eminent Russian authority on the Carboniferous and Permian, who has personally studied these formations as exposed in the bluffs of Kansas River from Manhattan to Fort Riley, and who made the following correlation: "The layers of the Neosho, and perhaps the lowest part of the Chase [the Chase consists of the Wreford, Matfield, Florence, Fort Riley, Doyle, and Winfield formations] appear to be analogous to the Schwagerinen [the upper stage of the unquestioned Carboniferous] in Russia, while the remaining part of the Chase and the layers of the Marion one must recognize as strata homotaxial with the Russian Permo-Carboniferous and lower Permian" (Translation from Mémoires du Comité Géologique, vol. 16, No. 2, St. Petersburg, 1902, pp. 392, 393, or p. 703; and see table of formations, p. 295 or p. 706). The Permo-Carboniferous or Artinsk stage in Russia of Dr. Tschernyschew is considered by Dr. Frech and many other European geologists as lower Permian.

Matfield shale.—This formation is composed mainly of variously colored shales, with some shaly, buff limestones which in places are cherty, and a light-gray limestone about 2 feet thick which occurs approximately 30 feet below the top of the formation. The thickness ranges from 60 to 70 feet, the greatest thickness being in the northeastern part of the quadrangle. The light-gray limestone about 30 feet below the top of the shale is persistent, particularly in the southeastern part of the quadrangle, on South Fork, but it is generally seen only in isolated patches of about an acre in the northeastern part. In such places it is very conspicuous and the horizon is often marked by springs. On South Fork the rock is used by the farmers to a limited extent in the construction of fences.

This limestone contains an abundance of a few species of small lamellibranchs, of which *Pleurophorus subcuneatus* M. & H. and *Bakewellia* (?) *parva* M. & H. are the most common. It is more conspicuous farther north near Fourmile and Sixmile creeks, in the southern part of Morris County, and in the northeast quarter of sec. 15, Fourmile Township, west of Wolf Creek. This last locality is a favorable one for collecting the fossils that are characteristic of the bed.

The formation generally forms covered slopes between two heavy flint ledges, the Wreford below and the Florence above, and as a rule its shales are not favorably exposed. On this account it is more difficult to give an accurate section, but from fairly good outcrops in the vicinity of Elk, Cedar Point, and Matfield Green the section given below has been compiled. The lower part of the formation is perhaps best shown on Buckeye Creek, south of Cottonwood Falls; west of the Dunlap schoolhouse, 2 miles northwest of Matfield Green; and near Cedar Point. The upper shales are well shown on the bank of Middle Creek above Elk, and below Florence on the south side of Cottonwood River in secs. 15 and 16, Doyle Township, especially on a small run just east of the stone schoolhouse.

General section of the Matfield shale.

	Feet
5. Shales in three horizons: (1) yellowish shale and marl containing some fossils, 18 feet or more; (2) greenish shale, 4 feet; (3) mottled red and green shale, 5 feet or more, making 27 feet altogether. At Dunlap schoolhouse, near Matfield Green, these shales are apparently reduced to 15 feet and the whole formation is only 60 feet in thickness, but on Middle Creek above Elk they are about 31 feet thick	31
4. Limestone, light gray, in places arenaceous, containing an abundance of small lamellibranchs	2±
3. Shale, not well exposed	12±
2. Limestone, shaly, buff, containing large brachiopods. On the south side of Cottonwood River below Florence, near line between secs. 14 and 15, Doyle Township, this zone has a 2-foot stratum of massive whitish limestone at the top, below which is 8 feet of shaly limestone containing layers of chert	10±
1. Shale, yellowish, argillaceous, with greenish shales at the base. At the locality below Florence mentioned above, 19 feet of these beds are shown resting on a limestone a foot or more in thickness at the level of the run, which is probably at the top of the Wreford limestone. At Dunlap schoolhouse, near Matfield Green, this bed is 15 feet thick	15±

The Matfield formation is named after Matfield Township, where it forms the side of a steep escarpment above the Wreford limestone. On account, however, of the soft nature of the shales the slope underlain by this formation is usually covered and its rocks are not generally well exposed in the township or in the quadrangle. It covers the high ground in the northeastern part of the quadrangle, is found well up the slope of the divide between Diamond and Middle Creeks, dips below Middle Creek about 2 miles above Elk, crosses the divide from this creek to Cottonwood River, and disappears about 1 mile below Florence. It is found well up on the high ground southeast of Cottonwood River, as well as west and east of South Fork Cottonwood River, and extends nearly to the headwaters of Mercer and Thurman creeks, in the southeastern part of the quadrangle.

Florence flint.—This formation, which is about 20 feet in thickness, consists mainly of a very cherty limestone interbedded with definite layers of chert and having a band of shaly or white cellular limestone near the middle. The formation rests on the Matfield shale and extends up to the Fort Riley limestone. The following general section is made by combining the beds exposed in the Jones quarries northeast of Florence, on the McPherson branch of the Atchison, Topeka and Santa Fe Railway, with those exposed along Cedar Creek about 2 to 2½ miles southeast of Cedar Point:

General section of the Florence flint.

	Feet.
3. Limestone, massive cherty, separated by layers of chert, 10½ feet at Florence	10
2. Limestone, whitish, cellular, or shaly, from 1 to 2 feet thick	2
1. Limestone, massive, cherty, separated by layers of chert	10

This massive, cherty limestone, with the overlying massive limestones, forms a very marked topographic feature for a considerable part of its line of outcrop, especially where it occurs in the sides of bluffs bordering the streams. The lower limit of the flint outcrop is frequently marked by springs, especially during the rainy part of the year.

This formation is found on the highest land in the northeastern part of the quadrangle and east of South Fork Cottonwood River. Appearing on the high land west of Diamond Creek, it then crosses the quadrangle in a very tortuous line, dipping below the Cottonwood Valley near Florence and leaving the area in its southeastern part. South of the quadrangle the upper 15 feet is well shown on the south bank of Walnut River at the highway bridge south of Augusta, in the western part of Butler County. North of the quadrangle there are various outcrops of this flint in Morris County; its upper part is finely exposed at the base of the Rock Island Railroad quarry at Alta Vista, near the head of West Branch of Mill Creek, in the western part of Wabaunsee County. It is prominent in the bluffs of Clarks Creek above and below Skiddy, Geary County, and is especially well exposed in the railroad cut one-half mile north of Skiddy. On the highway over the bluff south of Smoky Hill River east of Junction, in the SE. ¼ sec. 7, Jefferson Township, the entire flint stratum is well exposed with a thickness of 21 feet, while on the north side of Kansas River it occurs in the upper part of Sheridan Bluffs overlooking the site of the old city of Pawnee, and then extends westward across the Military Reservation. It is prominent in the bluffs of Big Blue River from Stockdale, Kans., to Blue Springs, Nebr., except in the Blue Rapids region, where it is interrupted by an anticlinal fold. The best section in the Big Blue Valley is near the station at Oketo, 2 miles south of the State line, where almost all the flint and superjacent limestone are shown in a single vertical section. The Florence flint is here 17 feet thick.

The formation was named the Florence flint on account of its excellent exposures in the vicinity of that city.

Fort Riley limestone.—Overlying the Florence flint is a series of shaly and thin-bedded to massive, buff limestones, having a thickness of 40 feet or more. To these beds the name Fort Riley limestone is given. Near the center of the series there are usually one or two massive layers, which, upon weathering, form a conspicuous ledge that may readily be followed by the eye for miles in the bluffs of Cottonwood and Kansas rivers.

The outcrop of this limestone is frequently less conspicuous than that of the Florence flint below, though under favorable conditions the thick layers when weathered form a conspicuous ledge, often marked below by large blocks of nearly white stone. The formation is finely exposed in the Jones quarries, northeast of Florence, where 38 feet of rock is shown from the top of the Florence flint to the top of the quarry stone.

The following section was compiled from the exposures on the bluff from 1 to 2 miles northeast of Florence and from Grant Cliff south of Fort Riley:

Section of Fort Riley limestone near Florence.

	Feet.
3. Limestone, buff, thin bedded to shaly. In some localities certain layers of this zone contain a lamellibranch fauna composed of a large number of specimens of a few Permian species, as *Bakewellia? parva* M. & H., *Pleurophorus subcuneatus* M. & H., *Pleurophorus* sp., and others. These fossiliferous layers are apparently more abundant in the northern part of the State, and the quarries 1 mile west of Junction and north of Fort Riley are favorable localities for collecting. It was in these quarries that Professor Hay obtained the specimens of *Nautiloidea*, three species of *Metacoceras*, and one *Phacoceras*, which were described by Professor Hyatt	22
2. Limestone, massive, buff, which varies in thickness from 5 to 8 and perhaps 10 feet, and sometimes weathers into two or more layers	5
1. Limestone, buff, shaly to thick bedded, in some localities partly shales. In the Jones quarry, three-quarters of a mile up the McPherson division of the Atchison, Topeka and Sante Fe Railway, from the main line, the limestone of this zone varies from buff to a cream color, although in places the buff layers become bluish. The layers are much thicker than in the lower quarry near the railroad junction, varying from 1 foot to 2 feet 8 inches and even reaching 3 feet. In places the vertical wall of the quarry is 18 feet high. This is a very fossiliferous zone and contains a numerous brachiopod fauna in which there is an abundance of a few large species. In the old quarry 1 mile northeast of Florence and at other localities near that city over thirty species of shells were obtained, of which the more abundant are the following: *Derbya multistriata* (M. & H.) Pros., *Seminula argentea* (Shep.) Schuch., *Productus semireticulatus* (Martin) de Kon. var. *calhounianus* Swallow, *Meekella striaticostata* (Cox) White & St. John., *Derbya crassa* (M. & H) H. & C., *Meekella* (?) *shumardiana* (Swallow) Williams, *Ambocœlia plano convexa* (Shum.) H. & C., *Euomphalus subquadratus* Meek & Worthen. A number of species of lamellibranchs were obtained, but the specimens of each species are rare	15

The distribution of this formation is about the same as that already indicated for the Florence flint, except that it occurs above the flint, has a greater breadth of outcrop, and in general extends farther to the west. South of the Cottonwood Falls quadrangle it is well shown on the bank of Walnut River south of Augusta, at the locality already mentioned for the Florence flint, and there are frequent outcrops of the limestone from Augusta down the Walnut River Valley to Winfield. On the north it is finely shown in the Rock Island Railroad quarry at Alta Vista and as a prominent terrace along Clarks Creek below and above Skiddy, the top passing below the valley of Ralls Creek 1½ miles above Skiddy. On Kansas River it is conspicuous in the upper part of Sheridan Bluffs on the Fort Riley Military Reservation and at places farther west along Sherman Heights on Republican River, in the quarries west of Junction in the bluffs between Republican and Smoky Hill rivers, and in Grant Cliff south of Kansas and Smoky Hill rivers. The massive ledge near the top of the bluff north of Fort Riley is 6 feet thick and is the most conspicuous feature of the topography of that region. The marked topographic character of this layer was noted by Meek and Hayden in their first description of the Kansas Valley, forty-five years ago. They stated that bed No. 12 of their section "forms distinct horizon near summit of hills in vicinity of Fort Riley" (Proc. Acad. Nat. Sci., Philadelphia, vol. 11, 1859, p. 17). It was likewise noted by Swallow in his report of 1866 (Preliminary Rept. Geol. Survey Kansas, p. 14), and also by Hay, who termed it the Fort Riley main ledge (Seventh Bien. Rept. Kansas State Board Agric., pt. 2, 1891, p. 94), and later described it more fully (Bull. U. S. Geol. Survey No. 137, 1896, p. 18). It does not appear, however, as is sometimes supposed, that the massive ledge of limestone extending nearly across the State and found in the various ravines and bluffs always represents the same layer of this formation. In fact, it is found that what corresponds to the higher, thin-bedded or shaly limestones at Fort Riley appears in certain localities as the prominent massive ledge. In stratigraphic work it is important to bear in mind this particular, for a greater uniformity of appearance in outcrop has been assigned to this limestone than the facts justify. At Oketo, in the Big Blue Valley, near the State line, the limestone has a thickness of a little over 30 feet, while at Blue Springs, Nebr., only 16 feet is exposed.

Swallow in 1866, applied the term Fort Riley limestone to the massive ledge of this limestone in the vicinity of Fort Riley, which he described as "a buff, porous magnesian rock, in thick beds," with a thickness of from 8 to 10 feet (Preliminary Rept. Geol. Survey Kansas, p. 14). This name is now adopted for this formation, but its limits are extended to include the thinner bedded limestones both below and above the massive Fort Riley main ledge. The Florence limestone of Prosser, No. 15 of the Chase section (Jour. Geol., vol. 3, 1895, p. 773), is apparently equivalent to the Fort Riley main ledge, and the name is now abandoned.

Doyle shale.—This formation, 60 feet in thickness, is composed of variously colored shales with an occasional thin stratum of soft limestone.

In sharp contrast with the rough topography produced by the flint and massive limestone of the Florence and Fort Riley formations, are the gently undulating prairies formed by the easily weathering shales and rocks of the overlying formations.

The shales of the Doyle formation are well exposed on and near Cedar Creek west of Wonsevu and on Doyle Creek southwest of Florence. About 20 feet above the base of the shales is a thin, grayish limestone, which often appears at the surface. In the Wonsevu region there are about 62 feet of yellowish, chocolate, and greenish shales, with perhaps an occasional layer of thin limestone. Yellowish shale containing a few fossils is apparently always found at the top of this formation within the quadrangle, while green shale is frequently seen near the base. As the beds disintegrate readily into soil there are comparatively few outcrops of any great thickness, and it is difficult to describe precisely their lithologic characters. In sec. 9, Cedar Township, not far west of Wonsevu, the chocolate and greenish shales are shown, considerably crushed from folding. Still more typical are the outcrops on a brook just west of Cedar Creek, one-fourth mile southwest of G. W. Topping's house, where the concretionary limestone of the succeeding formation occurs 60 feet above the brook, and below the limestone are yellowish, chocolate, and greenish shales. In this region, in secs. 6 and 7, the Cedar Creek synclinal fold is well shown, and the rocks may be seen dipping 2° to the southeast, The upper 40 feet of these shales is shown in Walnut Valley, where the formation is apparently about 79 feet thick, in a railroad cut 2½ miles south of Douglas, Butler County, and underlie 11 feet of the massive Winfield limestone. The section of the shales is as follows:

Section of Doyle shale south of Douglas.

	Feet.
2. Shale, yellowish, argillaceous	20
1. Shale, argillaceous, variously colored—greenish, maroon, yellowish, etc.—extending to railroad level. Some of the maroon layers 2 feet thick. No fossils found in the shale.	20

These shales are exposed at various places in Doyle Creek Valley southwest of Florence, and this fact has led to the adoption of the name Doyle shales. They cover a considerable area in the western and southern halves of the quadrangle, which they enter from the north, near the headwaters of the northern branches of Middle Creek. They cross the divide near the headwaters of the various tributaries of Middle Creek and Cottonwood River to the bluffs near Florence, and follow these up Cottonwood River and Doyle Creek to the western line of the quadrangle. South of Doyle Creek and Cottonwood River they follow a very tortuous line across the southern half of the quadrangle, covering on the southern boundary a broad belt to the west of East Branch Walnut River. To the south and east of Wonsevu is an isolated area of this formation surrounded by rocks belonging to the two succeeding formations.

Winfield formation.—This formation has a thickness of about 25 feet and is composed of cherty limestone at the base, with a massive concretionary member at the top, the two limestones being separated by a yellowish shale. These layers vary in thickness in different localities, but the following section is compiled from several exposures near Marion and Burns.

General section of the Winfield formation.

	Feet.
3. Limestone, massive, containing large concretions, many of which are cherty. It is composed of two layers separated by a thin shale. This is the most conspicuous part of the formation, on account of the concretions, some of which are 2 feet across and of varied and grotesque shapes. They contain *Productus* and numerous fragments of other fossils, and weather to a dark reddish-brown color. At the head of Spring Creek, 6 miles south of Florence, this stratum is 10 feet thick. The upper 1½ feet of this limestone is shown at the excavation near the Baptist church in Marion, where numerous specimens of the dark concretions are firmly embedded in it. The top of the stratum is irregular, as if current worn for some time before the deposition of the succeeding buff limestone. In the shaly parting *Productus* and *Seminula* are common, extending for 6 inches into the superjacent buff limestone, and this 6-inch zone also contains small concretions. Five feet above the concretionary limestone is a 1- or 2-inch layer containing *Derbya* and echinoid spines, but these were the only fossiliferous zones noted in this 14-foot exposure of overlying drab limestone	10
2. Shale, soft, yellowish, alternating with thin limestone containing a few brachiopods. On highway above the bridge over Spring Creek, 1 mile below Marion, sec. 8, Center Township, 13 feet of these shales occurs between the two limestone strata; but in sec. 27, Fairplay Township, 4½ miles below Marion, and on the road east of Cedar Creek, about 2½ miles southeast of Cedar Point, they have possibly a thickness of from 14 to 15 feet. At some localities, however, they are apparently much thinner	13+
1. Limestone, light gray, generally containing chert. Well shown in the railroad cut just south of Spring Creek bridge, 1 mile below Marion, where it is a massive 4-foot stratum. A shaly layer on top of the cherty limestone is fossiliferous, but fossils are rare in the 12 feet of overlying gypsiferous, thin limestones and yellowish, argillaceous shales shown in the cut. Two feet or more of the conglomerate stratum overlying the shales is shown, and all three zones may be seen on the road above the Spring Creek bridge. Again the cherty limestone shows as a conspicuous stratum near the foot of the hill south of the stone house and factory, while 13 or 14 feet higher the concretionary limestone forms a marked ledge near the top of the terrace	4

This formation is the highest prominent chert ledge in the Kansas Permian. It makes a marked stratigraphic horizon that is of great assistance in determining the areal geology of east-central Kansas. The irregular worn upper surface of the concretionary limestone and the appearance of many of the concretions, as though they had been rolled in the mud on the sea bottom, indicate a shallowing of the sea at this time, followed by subsidence of the sea bottom before the deposition of the succeeding even- and thin-bedded limestones. This change of physical condition is indicated in the fauna by the nearly complete disappearance of the brachiopods and the survival of a fauna composed mainly of Permian lamellibranchs. The chert is not so uniform in occurrence as in the Wreford limestone and Florence flint, so that at some localities this horizon is represented simply by a prominent light-gray limestone nearly free from chert. The concretions in the upper limestone are persistent through long stretches of outcrop, although occasionally areas are found where they are small and inconspicuous or absent. As a rule, however, they are large, and the stratum may readily be traced across the country either by its exposure in bluffs on streams or by the line of loose, reddish-brown concretions stretching across the prairie. These are often very profusely scattered over the ground, and when in place clearly mark the top of this formation. Care must, however, be exercised in relying on them as marking the contact of these two formations, since they sometimes strew the ground over considerable areas from 50 to 100 feet below their stratigraphic horizon. Another horizon at some localities in the overlying Marion formation—for instance, east of Burns and north of Wonsevu—contains chert concretions which in areal work must not be confounded with those of the Winfield.

The formation covers a rather narrow belt of country across the western part of the quadrangle north of Doyle Creek above and to the west of the Doyle shale. It enteres the quadrangle about 5 miles east of Lincolnville and follows a tortuous line near the headwaters of the streams to the bluffs of Cottonwood River, where it crosses the western line of the quadrangle and continues up the river to Marion. It is found on the high land between Cottonwood River and Doyle Creek, west of Florence. South of Doyle Creek and Cottonwood River it follows a very irregular line that extends over the western two-thirds of the southern half of the quadrangle, covering a considerably larger area in the southwestern than in any other portion.

In the preliminary description of these rocks this formation was called the Marion flint and concretionary limestone (Jour. Geol. vol. 3, 1895, p. 772), from the outcrops below Marion, and was regarded as a subformation at the top of the Chase. The overlying buff limestones and shales, however, were named the Marion formation, and hence to avoid confusion the name Marion was dropped for the lower division, which was renamed the Winfield concretionary limestone, from the outcrops in the vicinity of Winfield, Cowley County, in southern Kansas (University Geol. Survey Kansas, vol. 2, 1897, p. 64). Fourteen months later Dr. Keyes published the name Winfield limestone, which he applied to a Cambrian formation found in the Mississippi Valley near Winfield, Lincoln County, Mo. (Proc. Iowa Acad., Sci., vol. 5, 1898, p. 60). Clearly the Kansas usage of the name has priority, and Winfield is therefore adopted as the name of this formation.

Marion formation.—Shales and buff, thin-bedded limestones mainly constitute this formation. In the upper portion some gypsum is present, and near the base a considerable number of siliceous geodes and some chert occur. It rests on the Winfield formation and extends upward probably to the Wellington. Only the lower portion occurs within in the quadrangle, the aggregate thickness of the beds outcropping being approximately 150 feet. The thickness of the entire formation is estimated as from 300 to 400 feet.

The opportunities are not so favorable for constructing an accurate section showing the lithologic character of the rocks composing the Marion formation as in the case of the preceding ones. The lower part of the formation is composed of rather soft, porous, buff to buff-gray, thin-bedded limestone and shaly layers, with shales, containing near the base, as noted, a considerable number of siliceous geodes and occasionally some chert. The soft limestones and shales erode easily and only the harder layers resist weathering sufficiently to form outcrops. About 50 to 60 feet above the base of the formation is a buff limestone containing large numbers of small lamellibranchs, as *Pleurophorus subcuneatus* M. & H., *Bakewellia (?) parva* M. & H., *Yoldia subscitula* M. & H., *Nautilus eccentricus* M. & H., *Schizodus curtus* M. & W., and *Schizodus ovatus* M. & H.

About 20 feet higher is another similar limestone containing large lamellibranchs, among which are *Aviculpecten occidentalis* (Shum.) Meek., *Myalina permiana* (Swallow) M. & H., *Pseudomonotis Hawni* M. & H., and *Pseudomonotis Hawni* var. *ovata* M. & H.

In some localities near this horizon is a limestone containing *Pleurophorus* and large chert concretions. These are shown in secs. 34 and 27, north of Wonsevu and east of Burns. Apparently the lower 100 feet or more of the formation, the portion occurring within the quadrangle, is composed mainly of thin-bedded, buff limestones and shales, the best single exposure of which is perhaps at the Crusher quarry, in Clear Creek Valley. The beds at the extreme base are not well exposed within the quadrangle, but they may be seen back of the Baptist Church in Marion. At this point about 14 feet of buff, rather thin-bedded limestone containing a little chert is exposed.

The upper portion of the formation, occurring north and west of the quadrangle, includes gypsum beds and some salt. Among the gypsum beds are the Solomon bed, as defined by Grimsley (University Geol. Survey Kansas, vol. 5, 1899, p. 61), and the Greeley gypsum of Cragin (Colorado College Studies, vol. 6, 1896, p. 10). In south-central Kansas there is probably a third gypsum bed that may also be referred to this horizon.

The formation is widely distributed. Within the quadrangle it covers the high ground of the northwestern part, the highest part of the divide between Cottonwood River and Doyle Creek, and a large area in the south-central and southwestern part. From Marion County, on the west, the formation extends southward, covering the western part of Butler County, and west of Walnut River to Arkansas River at Arkansas City, and thence into Oklahoma. To the north it covers the western part of Morris County and a considerable part of Dickinson County, extending to Smoky Hill River, from which it apparently continues northward into Nebraska.

QUATERNARY DEPOSITS.

Alluvium.—The latest formation in this quadrangle is the flood-plain deposit of the present streams. Several of the larger streams have developed moderately wide valleys in which mud and other deposits are made during overflow periods and which also receive the wash from the neighboring hills. The most important alluvial plain is that of Cottonwood River, which below Florence varies in breadth from one-half mile to more than 2 miles. The alluvium follows the above valley and the valleys of Doyle and Diamond creeks beyond the limits of the quadrangle; the valley of Middle Creek for more than a mile above Elk; that of Fox and Cedar creeks for more than 4 miles above their mouths, and finally the valley of South Fork Cottonwood River and its continuation in Thurman Creek to a distance of 3 miles above Matfield Green.

All these alluvial deposits are derived from rocks in the area drained by the streams in or near the quadrangle. This silty material is very black, often forming a deep, rich soil, and it is in these "bottoms" that the most valuable farming land is found. This alluvium has been deposited mostly within comparatively recent times and is largely the result of the decay of the limestones and shales of the adjacent country.

STRUCTURE.

The rocks found within this quadrangle were originally deposited under water and on nearly level surfaces. Since their deposition they have been tilted and slightly folded. This deformation probably occurred at the close of the Carboniferous. The main structure of the area is monoclinal, being a simple, slight dip to the west. In addition there are certain slight anticlines or domes, with intervening synclines or troughs.

STRUCTURAL PROVINCES.

There are three structural provinces concerned in this quadrangle. The largest is the general province known as the Prairie Plains monocline, which embraces all of Kansas east of its center and parts of neighboring States. It is characterized by a very gentle dip of the rocks in a direction north of west. The other two provinces are limited areas, perhaps confined to this quadrangle. The more important of these may be designated the Cottonwood province, which comprises a group of folds extending diagonally southwestward across the quadrangle; the other may be called the Diamond Creek province.

Prairie Plains monocline.—This term is applied to all of the area of eastern Kansas and parts of adjoining States, because the rocks dip generally to the north of west. The general dip of the strata in this quadrangle is from 10 to 30 feet per mile to the north of west, except in areas affected by local folding. This condition is shown on the areal geology map. Rocks in the eastern part of the area which are at the surface at an elevation of 1500 or more feet above sea level are seen to be covered to a considerable depth by younger rocks on the western side of the quadrangle, though the elevation of the surface there may be nearly 100 feet less.

Cottonwood province.—This is a local series of small folds extending from near Strong to the southwest corner of the quadrangle. There are three of these folds, the Elmdale dome, the Cedar Creek syncline, and the Burns anticline.

The Elmdale dome is a broad, low upward fold of the rocks, the center of which is about 3 miles southwest of Elmdale. The total elevation of the upper part of this fold is over 200 feet. The top has been worn away and Cottonwood River now runs through the central part of it, making the center lower than the sides. The sides form a rim around the central portion, with the rocks turned upward, sometimes as much as 3° or 4°. The east-west diameter of this fold is about 9 miles, while the north-south diameter is about 12 miles.

Roughly joining the Elmdale dome on the south is the Cedar Creek syncline, the lowest point of which is near the bed of Cedar Creek, just west of Wonsevu. This syncline approaches a basin in form, but its longer axis is directed a little east of north from the locality just mentioned, and it is nearly as low on Coon Creek north of Wonsevu. The depth of this depression is about 200 feet. The folding here is such that the rocks often lie parallel with the surface, so that a stratum of limestone may be seen cropping out all the way from the head of the ravine to its mouth. Such is the case generally in the tributaries of Cedar Creek from the southwest near Wonsevu.

South of the Cedar Creek syncline is the Burns anticline, the crest of which is about 200 feet or more above the trough of the syncline. The axis of this fold seems to extend more nearly east and west than does that of the syncline. The highest point of this anticline is about 3 miles southeast of Burns. It extends over a considerable area east and south of Burns, but is hardly as large as the Elmdale dome. The dip of the rocks away from this fold is apparent in many places on Wentworth Creek and on the branches of Cedar Creek.

Diamond Creek province.—In the northern part of the quadrangle there are several small folds, but

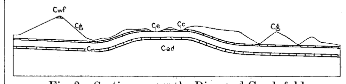


Fig. 2.—Section across the Diamond Creek fold.
Shows the sharp anticline exposed in the bluff north of Neva.
Cwf, Wreford limestone; Cg, Garrison formation; Cc, Cottonwood limestone; Ce, Eskridge shale; Cn, Neva limestone; Ced, Elmdale formation.
Horizontal scale: 1 inch = 1 mile.
Vertical scale: 1 inch = approximately 500 feet.

only two are of sufficient interest to be discussed here. On Fox Creek, near the northern border of the quadrangle, is one of the most abrupt folds in the area. On the western side of the creek the rocks are found to be about 80 feet higher than on the eastern side. The summit of the fold, however, is located farther west, on the township line at the divide between Fox and Diamond creeks.

Near the mouth of Diamond Creek is a fold which appears east of the creek as a sharp anticline in the bluff north of Neva (see fig. 2). Another small anticline is located near the southeast corner of Clear Creek Township, where, on its eastern slope, the rocks are seen to dip 35 feet to the mile to the east instead of having their usual westward dip. This fold, however, is of small extent compared with the folds of the Cottonwood province.

MINERAL RESOURCES.

Shale, limestone, and chert are the three mineral resources of this quadrangle. It is probable that local gypsum beds may also be found within its limits in the upper portion of the Marion formation. The limestones occurring here are used for dimension stones and may be burned to lime. It is not improbable that in connection with the shales they would afford material for cement manufacture.

BUILDING STONE.

Limestone suitable for use in building is found throughout the quadrangle, the most important single horizon being that of the Cottonwood limestone. This is a foraminiferal limestone of very light buff-gray color, appearing white at a little distance. It is of even texture and in many quarries is remarkably free from joint planes. Blocks of the stone 3 feet in thickness and of almost any length and breadth desired may be obtained. It is easily dressed and is durable. The stone contains 85 per cent of calcium carbonate and less than 2 per cent of magnesium carbonate, as is shown by the following analysis, by Dr. S. W. Williston, of rock from the Rettiger Brothers quarry, east of Cottonwood Falls:

Analysis of Cottonwood limestone.

	Per cent.
Calcium carbonate	84.72
Magnesium carbonate	1.75
Oxides of iron and aluminum	3.62
Sulphates	.90
Insoluble	8.52
	99.56

The crushing strength was determined by Dr. Williston to be 6800 pounds per square inch; the weight per cubic foot, 161.6 pounds; the specific gravity, 2.59.

The stone occurs over nearly one-third of the quadrangle and is accessible in many places. Extensive quarries are located near Cottonwood Falls. There are quarries at Strong, Bazaar, Clements, and along Diamond Creek at Hymer. The exposures are such that the rock may usually be obtained with but little stripping. It is well exposed both north and northeast of Clements and up Middle Creek for some distance from its mouth, though very little quarried.

The Cottonwood limestone is the most important dimension stone in the State, and at various places are extensive quarries which afford an excellent opportunity to study the limestone and its overlying shales. Some of the more important quarries are those on the north side of the river between 2 and 3 miles east of Strong, the Lantry & Sons quarry within the limits of that city, and the Fox Creek quarry nearly 1 mile west of Strong. On the south side are those of the Rettiger Brothers and DuChanois & Jones, 2½ miles east of Cottonwood Falls, and the Perrin quarry in Cottonwood Falls, while farther up the river, near Clements, are the quarries of D. Y. Hamill. In the Rettiger Brothers quarry the two layers are clearly shown, with a total thickness varying from 5 to 5½ feet, the lower layer where thickest being 2½ feet, and the upper one 3 feet. In the neighboring quarry of DuChanois & Jones the lower layer is 2 feet 4 inches in thickness, and the upper, which splits in the middle, is 3 feet 2 inches, making the total thickness 5½ feet, the same as in the Rettiger quarry. The quarrymen make three ledges of the stone as worked in W. W. Perrin's quarry in Cottonwood Falls; the lower one, 2 feet 4 inches, the middle layer 1 foot 11 inches, and the top one 2 feet 6 inches, making a total of 5 feet 11 inches. On the north side of the river, near the eastern edge of the quadrangle, the quarry, which did not reach the base of the rock, shows 5 feet 10 inches of the limestone, while just east of Strong the full thickness is shown, the lower layer, 2 feet 1 inch in thickness and the upper 4 feet 3 inches, making the total 6 feet 4 inches. At the Fox Creek quarry the upper 4 feet 8 inches is shown, and at the Robertson bridge, 3½ miles farther up the stream, 5 feet 3 inches is shown. The quarry south of Hymer shows the upper 4 feet 8 inches of limestone, while in the Hamill quarry, near Clements, there are two layers, each 2 feet 8 inches in thickness.

Stone for building is occasionally obtained from the Wreford limestone, but next to the Cottonwood the Fort Riley is the most important bed for this purpose. This limestone is 40 feet thick and is composed of many layers, a number of which are valuable building and dimension material. The rock is light buff in color, even grained, easily worked, and durable. In it are one or two layers, each about 5 feet thick, one of which is an excellent dimension stone, particularly valuable for basement work. Some layers work up into flagging of any uniform thickness, from 5 inches to 1 foot, and into blocks as large as may be desired. The only locality within this quadrangle at which this rock has been developed to any considerable extent is at Florence, though north of Kansas River it has been much more extensively used. This rock has many good qualities and is widely distributed, and deserves more attention as a building stone than it has heretofore received.

CLAY.

Shales probably suitable for the manufacture of clay products are found in the Elmdale, Eskridge, Garrison, Matfield, and Doyle formations, previously described. One or more of these formations outcrop at almost any given point in the quadrangle except in the northwest and southwest portions. It is probable that in some of the shale beds of the Elmdale formation workable material suitable for local purposes may be found. An examination of the columnar section will show the formations in which shales occur. The areal geology map shows the locations of these formations. In the Garrison formation near Strong, Cottonwood Falls, Neva, Hymer, Clements, Bazaar, and Matfield Green, shales of economic value may be found. The same may be said for the Matfield shales, which, though extensive, are more remote from the places named.

ROAD MATERIAL.

The various limestones and cherts outcropping within the quadrangle afford large quantities of rock suitable for ballast and road making. The Wreford limestone, Florence flint, and the Marion formation, in particular, yield excellent material for these purposes.

The Wreford limestone is 40 feet thick, the upper and lower portions being heavily charged with chert, both in layers and as concretions. No better illustrations of its value as a road material need be cited than the natural macadam road along the ridges where this stone has been disintegrated, and a mantle of the residuary chert forms smooth, gravelly roads, almost entirely free from dust and mud. This rock was extensively quarried for ballast at the Crusher Hill quarry, one mile northwest of Strong. It is also often used in building stone fences, as are most of the limestones of this region. There are frequently layers of good building stone in or near the base of the Wreford limestone. At one locality northeast of this quadrangle it has been used for fence posts with satisfactory results. The area of this limestone in the quadrangle is wide, as will be seen on referring to the areal geology map. It extends from Strong along both sides of Fox and Diamond creeks, up Middle Creek to Elk, and along the bluffs or in the hills on both sides of Cottonwood River from Strong to Cedar Point. It is found also on both sides of South Fork Cottonwood River nearly to its head, and in the extreme southeast corner of the quadrangle at the head of Fall River. In addition to yielding road material, this limestone is important for the water it carries, which issues from its base in springs and in the form of "seeps" along the lower edge of the outcrop. In an exceptionally dry season the lower limit of this rock may easily be distinguished at some distance by the closely cropped green grass, which is so well moistened by the seepage that it furnishes good pastures when regions not thus favored are dried out.

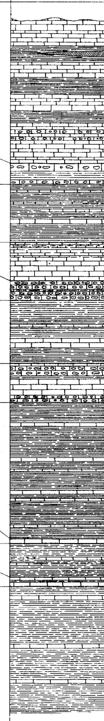
The Florence flint is a stratum of very cherty limestone 20 feet thick, similar to the cherty portions of the Wreford limestone, but of more general distribution over the quadrangle. The chert is both in layers that break into prismatic pieces and in layers of small concretionary nodules. The remarks concerning the use of the Wreford limestone are applicable to this stratum. Its distribution, however, is more general, and it covers much of the eastern three-fourths of the quadrangle. The water resources of this stratum are probably more important than those of the preceding limestone.

The base of the Marion formation is largely made up of limestone. This limestone is usually rather soft, porous, frequently cellular, often contains geodes, and is of a grayish color. The lower part often contains chert concretions and geodes, yet in many places fair building material is found. On Clear Creek it is quarried extensively for ballast and to some extent for building purposes. It forms the surface rock over the northwest and southwest corners of the quadrangle.

April, 1902.

GENERALIZED SECTION FOR THE COTTONWOOD FALLS QUADRANGLE.

SCALE: 1 INCH = 100 FEET.



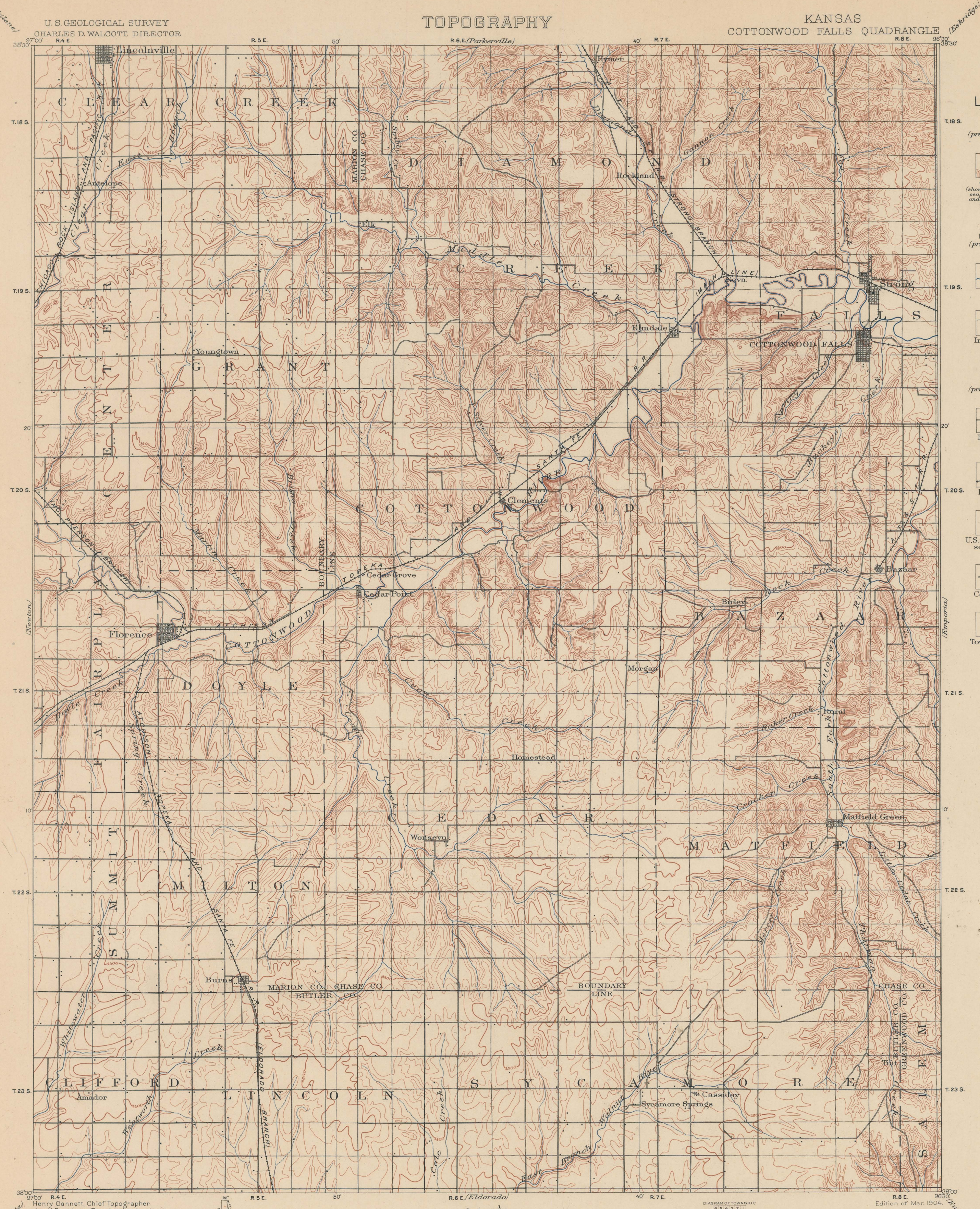
System.	Series.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soils.
CARBONIFEROUS	PERMIAN ?	Marion formation.	Cmr		150±	Soft, cellular, thin-bedded, buff limestones and variegated shales, with gypsum beds in the upper part and with chert and siliceous geodes most abundant in the lower part.	Covers the surface of the western and south-central parts of the quadrangle. Flat or very gently sloping table-lands. Moderately fertile, thin, black soil.
		Winfield formation.	Cw		20-25	Cherty limestone at base, yellowish shale above, and at the top light-gray limestone containing concretions which weather to a reddish-brown color.	Gentle slopes or low escarpments. Soil thin and poor.
		Doyle shale.	Cd		60	Variously colored shale with occasional strata of soft limestone. A limestone 20 feet above the base is conspicuous in places.	Gentle slopes. Thin soil, not very fertile.
		Fort Riley limestone.	Cfr		40	Buff limestones, shaly and thin bedded above, massive below.	Steep escarpments and flat plains. Thin, poor, moist soil; excellent pasture land.
		Florence flint.	Cf		20	Very cherty limestone and layers of chert with a bed of shaly or white cellular limestone near the middle.	Steep escarpments and steep slopes covered with much loose chert. Poor soil.
		Matfield shale.	Cm		60-70	Variously colored shale with some shaly buff limestone, cherty in places, and a thin, light-gray limestone near the middle.	Rather steep slopes. Thin, moist soil, making good pasture land.
		Wreford limestone.	Cwf		40	Light-buff, massive limestone, very cherty at top and bottom, but comparatively free from chert in the middle.	Steep escarpments and terraces with much loose chert. Good pasture land.
		Garrison formation.	Cg		140-145	Alternating gray limestones and variously colored shale (Neosho member). Yellowish, fossiliferous shale (Florena member).	Steep bluffs. Thin soil and good pasture land.
	PENNSYLVANIAN	Cottonwood limestone.	Cc		6	Massive, light-gray to buff-colored, foraminiferal limestone.	Limestone cap of small escarpments.
		Eskridge shale.	Ce		30-40	Variously colored shale with some thin limestones.	Steep slope with fair soil.
		Neva limestone.	Cn		10±	Massive, gray to bluish, porous limestone, very rough on weathered surface.	Prominent limestone ledges in bluffs.
		Elmdale formation.	Ced		130	Yellowish to bluish shale alternating with thin beds of grayish limestone.	Rather steep and terraced slopes. Thin and not very fertile soil on hills, but good pasture land; rich, black soil in valleys.

CHARLES S. PROSSER,
Geologist.

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

TOPOGRAPHY

KANSAS
COTTONWOOD FALLS QUADRANGLE



LEGEND

RELIEF
(printed in brown)

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

DRAINAGE
(printed in blue)

Streams

Intermittent streams

CULTURE
(printed in black)

Roads and buildings

Railroads

U.S. township and section lines

County lines

Township lines

Henry Gannett, Chief Topographer.
Jno. H. Renshawe, Topographer in charge.
Control by R. U. Goode.
Topography by H. S. Wallace.
Surveyed in 1895.

TRUE NORTH — MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1900.

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.

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

Edition of Mar. 1904.

U. S. GEOLOGICAL SURVEY
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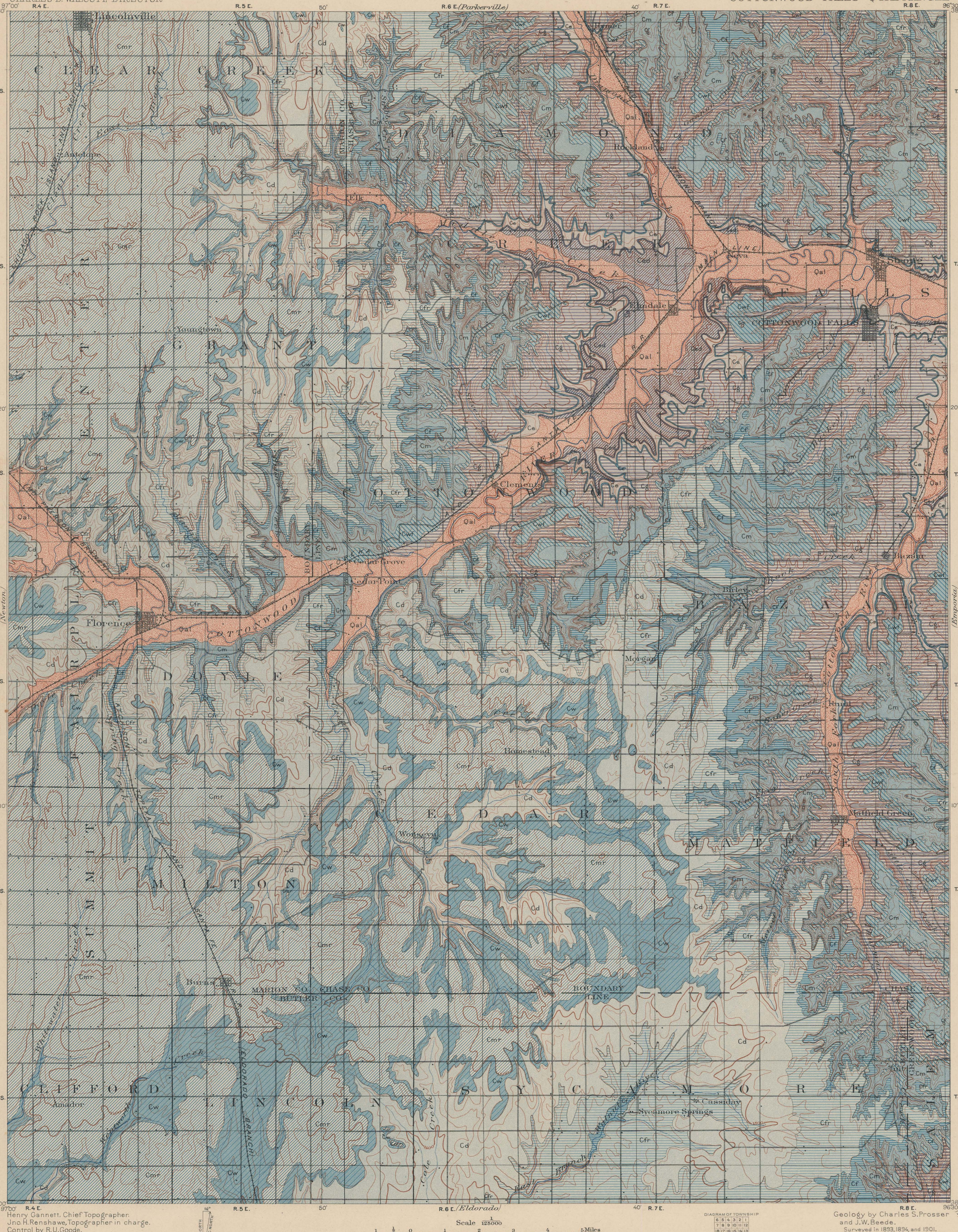
AREAL GEOLOGY

KANSAS
COTTONWOOD FALLS QUADRANGLE



LEGEND

SEDIMENTARY ROCKS

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

QUATERNARY

Recent

Qal — Alluvium *(in flood plain of Cottonwood River and its larger branches)*

CARBONIFEROUS

Permian series ?

Cmr — Marion formation *(thin-bedded limestone and shale, with gypsum in upper part)*

Cw — Winfield formation *(cherty limestone, yellowish shale, and light-gray concretionary limestone)*

Cd — Doyle shale *(variously colored shale with occasional thin strata of limestone)*

Cfr — Fort Riley limestone *(shaly and massive buff limestone)*

Cf — Florence flint *(mainly very cherty limestone)*

Cm — Matfield shale *(variously colored shale with some buff limestones)*

Cwf — Wreford limestone *(massive buff limestone, very cherty near the top and bottom)*

Pennsylvanian series

Cg — Garrison formation *(alternating gray limestones and variously colored shales, with yellowish fossiliferous shale at base)*

Cc — Cottonwood limestone *(massive, light-gray, foraminiferal limestone)*

Ce — Eskridge shale *(variously colored shale)*

Cn — Neva limestone *(massive, porous, gray limestone)*

Ced — Elmdale formation *(yellowish to bluish shales alternating with thin and thick beds of grayish limestone)*

⚒ Quarries, *building stone and ballast*

Henry Gannett, Chief Topographer.
Jno. H. Renshawe, Topographer in charge.
Control by R. U. Goode.
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Surveyed in 1895.

APPROXIMATE MEAN DECLINATION 1900.

Scale $\frac{1}{125000}$

Contour interval 20 feet.
Datum is mean sea level.

Edition of April 1904.

Geology by Charles S. Prosser and J. W. Beede.
Surveyed in 1893, 1894, and 1901.

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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
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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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76	Austin	Texas	25
77	Raleigh	West Virginia	25
78	Rome	Georgia-Alabama	25
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

* 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.