DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, SECRETARY
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

GEOLOGIC ATLAS
OF THE
UNITED STATES

LEAVENWORTH-SMITHVILLE FOLIO

MISSOURI-KANSAS

BY

HENRY HINDS AND F. C. GREENE

SURVEYED IN COOPERATION WITH
THE STATE OF MISSOURI

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GEOLOGIC ATLAS OF THE UNITED STATES.

The Geological Survey is making a geologic atlas of the United States, which is being issued in parts, called folios. Each folio includes topographic and geologic maps of a certain area, together with descriptive text.

THE TOPOGRAPHIC MAP.

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

Relief.—All elevations are measured from mean sea level. The heights of many points are accurately determined, and those of the most important ones are given on the map in figures. It is desirable, however, to give the elevation of all parts of the area mapped, to delineate the outline or form of all slopes, and to indicate their grade or steepness. This is done by lines each of which is drawn through points of equal elevation above mean sea level, the vertical interval represented by each space between lines being the same throughout each map. These lines are called *contour lines* or, more briefly, *contours*, and the uniform vertical distance between each two contours is called the *contour interval*. Contour lines and elevations are printed in brown. The manner in which contour lines express altitude, form, and grade is shown in figure 1.

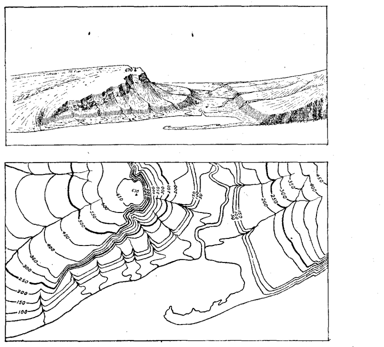


FIGURE 1.—Ideal view and corresponding contour map.

The sketch represents a river valley between two hills. In the foreground is the sea, with a bay that is partly closed by a hooked sand bar. On each side of the valley is a terrace. The terrace on the right merges into a gentle hill slope; that on the left is backed by a steep ascent to a cliff, or scarp, which contrasts with the gradual slope away from its crest. In the map each of these features is indicated, directly beneath its position in the sketch, by contour lines. The map does not include the distant portion of the view. The following notes may help to explain the use of contour lines:

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

2. Contour lines show or express the forms of slopes. As contours are continuous horizontal lines, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines, and project in passing around spurs or prominences. These relations of contour curves and angles to forms of the landscape can be seen from the map and sketch.

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

A small contour interval is necessary to express the relief of a flat or gently undulating country; a steep or mountainous country can, as a rule, be adequately represented on the same scale by the use of a larger interval. The smallest interval used on the atlas sheets of the Geological Survey is 5 feet. This is in regions like the Mississippi Delta and the Dismal Swamp. For great mountain masses, like those in Colorado, the interval may be 250 feet and for less rugged country contour intervals of 10, 20, 25, 50, and 100 feet are used.

Drainage.—Watercourses are indicated by blue lines. For a perennial stream the line is unbroken, but for an intermittent stream it is broken or dotted. Where a stream sinks and reappears the probable underground course is shown by a broken blue line. Lakes, marshes, and other bodies of water are represented by appropriate conventional signs in blue.

Culture.—The symbols for the works of man and all lettering are printed in black.

Scales.—The area of the United States (exclusive of Alaska and island possessions) is about 3,027,000 square miles. A map of this area, drawn to the scale of 1 mile to the inch would cover 3,027,000 square inches of paper and measure about 240 by 180 feet. Each square mile of ground surface would be represented by a square inch of map surface, and a linear mile on the ground by a linear inch on the map. The scale may be expressed also by a fraction, of which the numerator is a length on the map and the denominator the corresponding length in nature expressed in the same unit. Thus, as there are 63,360 inches in a mile, the scale "1 mile to the inch" is expressed by the fraction $\frac{1}{63,360}$.

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

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

The atlas sheets, being only parts of one map of the United States, are not limited by political boundary lines, such as those of States, counties, and townships. Many of the maps represent areas lying in two or even three States. To each sheet, and to the quadrangle it represents, is given the name of some well-known town or natural feature within its limits, and at the sides and corners of each sheet are printed the names of adjacent quadrangles, if the maps are published.

THE GEOLOGIC MAPS.

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

KINDS OF ROCKS.

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

Igneous rocks.—Rocks that have cooled and consolidated from a state of fusion are known as *igneous*. Molten material has from time to time been forced upward in fissures or channels of various shapes and sizes through rocks of all ages to or nearly to the surface. Rocks formed by the consolidation of molten material, or magma, within these channels—that is, below the surface—are called *intrusive*. Where the intrusive rock occupies a fissure with approximately parallel walls it is called a *dike*; where it fills a large and irregular conduit the mass is termed a *stock*. Where molten magma traverses stratified rocks it may be intruded along bedding planes; such masses are called *sills* or *sheets* if comparatively thin, and *laccoliths* if they occupy larger chambers produced by the pressure of the magma. Where inclosed by rock molten material cools slowly, with the result that intrusive rocks are generally of crystalline texture. Where the channels reach the surface the molten material poured out through them is called *lava*, and lavas often build up volcanic mountains. Igneous rocks that have solidified at the surface are called *extrusive* or *effusive*. Lavas generally cool more rapidly than intrusive rocks and as a rule contain, especially in their superficial parts, more or less volcanic glass, produced by rapid chilling. The outer parts of lava flows also are usually porous, owing to the expansion of the gases originally present in the magma. Explosive action, due to these gases, often accompanies volcanic eruptions, causing ejections of dust, ash, lapilli, and larger fragments. These materials, when consolidated, constitute breccias, agglomerates, and tuffs.

Sedimentary rocks.—Rocks composed of the transported fragments or particles of older rocks that have undergone disintegration, of volcanic ejecta deposited in lakes and seas, or of materials deposited in such water bodies by chemical precipitation are termed *sedimentary*.

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

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

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

The surface of the earth is not immovable; over wide regions it very slowly rises or sinks, with reference to the sea, and shore lines are thereby changed. As a result of upward movement marine sedimentary rocks may become part of the land, and most of our land areas are in fact occupied by rocks originally deposited as sediments in the sea.

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

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

From time to time during geologic ages rocks that have been deeply buried and have been subjected to enormous pressures, to slow movement, and to igneous intrusion have been afterward raised and later exposed by erosion. In such rocks the original structures may have been lost entirely and new ones substituted. A system of planes of division, along which the rock splits most readily, may have been developed. This structure is called *cleavage* and may cross the original bedding planes at any angle. The rocks characterized by it are *slates*. Crystals of mica or other minerals may have grown in the rock in such a way as to produce a laminated or foliated structure known as *schistosity*. The rocks characterized by this structure are *schists*.

As a rule, the oldest rocks are most altered and the younger formations have escaped metamorphism, but to this rule there are many important exceptions, especially in regions of igneous activity and complex structure.

FORMATIONS.

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

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

AGES OF ROCKS.

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

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

Inasmuch as sedimentary deposits accumulate successively the younger rest on those that are older, and their relative ages may be determined by observing their positions. In many regions of intense disturbance, however, the beds have been overturned by folding or superposed by faulting, so that it may be difficult to determine their relative ages from their present positions; under such conditions fossils, if present, may indicate which of two or more formations is the oldest.

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

It is many places difficult or impossible to determine the age of an igneous formation, but the relative age of such a formation can in general be ascertained by observing whether an associated sedimentary formation of known age is cut by the igneous mass or is deposited upon it. Similarly, the time at which metamorphic rocks were formed from the original masses may be shown by their relations to adjacent formations of known age; but the age recorded on the map is that of the original masses and not that of their metamorphism.

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

Patterns composed of parallel straight lines are used to represent sedimentary formations deposited in the sea, in lakes, or in other bodies of standing water. Patterns of dots and circles represent alluvial, glacial, and eolian formations. Patterns of triangles and rhombs are used for igneous formations. Metamorphic rocks of unknown origin are represented by short dashes irregularly placed; if the rock is schist the dashes may be arranged in wavy lines parallel to the structure planes. Suitable combination patterns are used for metamorphic formations known to be of sedimentary or of igneous origin. The patterns of each class are printed in various colors. With the patterns of parallel lines, colors are used to indicate age, a particular color being assigned to each system.

The symbols consist each of two or more letters. If the age of a formation is known the symbol includes the system symbol, which is a capital letter or monogram; otherwise the symbols are composed of small letters.

The names of the systems and of series that have been given distinctive names, in order from youngest to oldest, with the color and symbol assigned to each system, are given in the subjoined table.

Symbols and colors assigned to the rock systems.

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

SURFACE FORMS.

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

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

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

THE VARIOUS GEOLOGIC SHEETS.

Areal geology map.—The map showing the areas occupied by the various formations is called an *areal geology map*. On the margin is a *legend*, which is the key to the map. To ascertain the meaning of any color or pattern and its letter symbol the reader should look for that color, pattern, and symbol in the legend, where he will find the name and description of the formation. If it is desired to find any particular formation, its name should be sought in the legend and its color and pattern noted; then the areas on the map corresponding in color and pattern may be traced out. The legend is also a partial statement of the geologic history. In it the names of formations are arranged in columnar form, grouped primarily according to origin—sedimentary, igneous, and crystalline of unknown origin—and within each group they are placed in the order of age, so far as known, the youngest at the top.

Economic geology map.—The map representing the distribution of useful minerals and rocks and showing their relations to the topographic features and to the geologic formations is termed the *economic geology map*. The formations that appear on the areal geology map are usually shown on this map by fainter color patterns and the areas of productive formations are emphasized by strong colors. A mine symbol shows the location of each mine or quarry and is accompanied by the name of the principal mineral mined or stone quarried. If there are important mining industries or artesian basins in the area special maps to show these additional economic features are included in the folio.

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

The geologist is not limited, however, to natural and artificial cuttings for his information concerning the earth's structure. Knowing the manner of formation of rocks and having traced out the relations among the beds on the surface, he can infer their relative positions after they pass beneath the surface and can draw sections representing the structure to a considerable depth. Such a section is illustrated in figure 2.

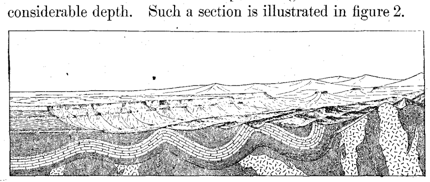


FIGURE 2.—Sketch showing a vertical section at the front and a landscape beyond.

The figure represents a landscape which is cut off sharply in the foreground on a vertical plane, so as to show the underground relations of the rocks. The kinds of rock are indicated by appropriate patterns of lines, dots, and dashes. These patterns admit of much variation, but those shown in figure 3 are used to represent the commoner kinds of rock.

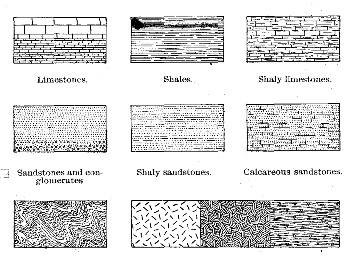


FIGURE 3.—Symbols used in sections to represent different kinds of rocks.

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

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

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

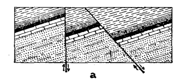


FIGURE 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* or *reverse* fault.

At the right of figure 2 the section shows schists that are traversed by igneous rocks. The schists are much contorted and their arrangement underground can not be inferred. Hence that portion of the section delineates what is probably true but is not known by observation or by well-founded inference.

The section also shows three sets of formations, distinguished by their underground relations. The uppermost set, seen at the left, is made up of sandstones and shales, which lie in a horizontal position. These strata were laid down under water but are now high above the sea, forming a plateau, and their change of elevation shows that a portion of the earth's mass has been uplifted. The strata of this set are parallel, a relation which is called *conformable*.

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

The horizontal strata of the plateau rest upon the upturned, eroded edges of the beds of the second set shown at the left of the section. The overlying deposits are, from their position, evidently younger than the underlying deposits, and the bending and eroding of the older beds must have occurred between their deposition and the accumulation of the younger beds. The younger rocks are *unconformable* to the older, and the surface of contact is an *unconformity*.

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

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

Columnar section.—The geologic maps are usually accompanied by a *columnar section*, which contains a concise description of the sedimentary formations that occur in the quadrangle. It presents a summary of the facts relating to the character of the rocks, the thickness of the formations, and the order of accumulation of successive deposits.

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

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

GEORGE OTIS SMITH,
Director.

May, 1909.

DESCRIPTION OF THE LEAVENWORTH AND SMITHVILLE QUADRANGLES.

By Henry Hinds and F. C. Greene.[1]

INTRODUCTION.

GENERAL RELATIONS.

The Leavenworth and Smithville quadrangles lie between parallels 39° 15′ and 39° 30′ and meridians 94° 30′ and 95° and include an area of 461.7 square miles in northeastern Kansas and northwestern Missouri, comprising parts of Leavenworth and Atchison counties in Kansas and of Platte, Clay, and Clinton counties in Missouri. (See fig. 1.) Leavenworth, the

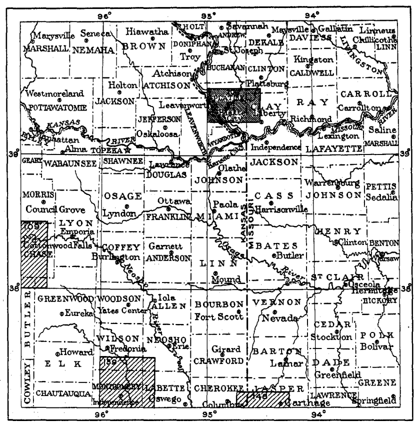


FIGURE 1.—Index map of a part of Missouri and Kansas.
The location of the Leavenworth and Smithville quadrangles (No. 206) is shown by the darker ruling. Published folios describing other quadrangles, indicated by lighter ruling, are Nos. 109, Cottonwood Falls; 148, Joplin district; 159, Independence.

principal city in the area, is on the west bank of Missouri River, in the southwestern part of the Leavenworth quadrangle.

GENERAL GEOGRAPHY AND GEOLOGY OF THE REGION.

TOPOGRAPHY.

The region in which the Leavenworth and Smithville quadrangles are situated includes two main topographic divisions—the Glaciated Plains and the Osage Plains—which have characteristics that bear important relations to past and present conditions in the quadrangles. (See fig. 2.) The Great Plains

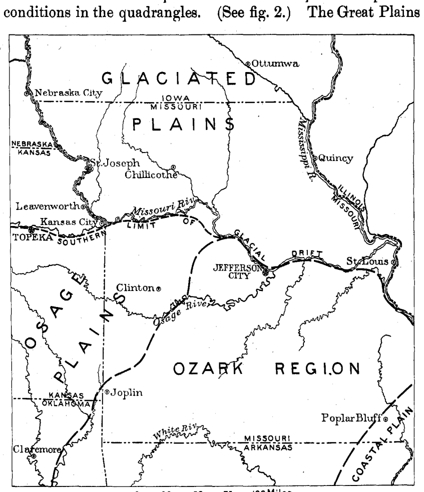


FIGURE 2.—Sketch map of Missouri and surrounding region, showing the major topographic divisions and the southern limit of glacial drift.
The Leavenworth and Smithville quadrangles are in western Missouri and eastern Kansas, as shown in figure 1.

on the west and the Ozark region on the southeast have some features that are also related to the geology of the quadrangles.

[1] Geologic mapping was done in cooperation with Missouri Bureau of Geology and Mines

Glaciated Plains.—The Glaciated Plains is a very large region, including most of the United States north of Ohio and Missouri rivers and extending westward to the Great Plains. It consists in greater part of more or less featureless plains.

In late geologic time glaciers which moved across the country in a southerly direction deposited great quantities of unconsolidated materials, filling many previously existing valleys and in this and other ways greatly modifying the topography of nearly all of the Glaciated Plains. The southern limit of the ice invasions may be roughly placed at Ohio and Missouri rivers, though it lies some distance beyond the present position of the Missouri in northeastern Kansas, eastern Nebraska, and the Dakotas. After the retreat of the ice much of the invaded territory was a nearly level plain in which the drainage was poor because of the obliteration or obstruction of many of the old valleys. In the area reached by the later glaciers, including much of Minnesota, Iowa, Wisconsin, Illinois, and other northern States, the drainage is still poor, and there are numerous lakes and ponds and broad stretches of level prairie. Northeastern Kansas, Missouri north of Missouri River, southern and western Iowa, and eastern Nebraska, though covered by the older glaciers, were not reached by the younger ones, and sufficient time has elapsed since the last ice retreat to permit the development of more extensive drainage lines. East of Chariton River, in Missouri, there are many broad, flat divides, but the uplands west of that stream are rolling and less of the surface remains as it was left by the ice.

The surface of most of the Glaciated Plains lies 500 to 1,500 feet above sea level. The local relief is slight, being less than 100 feet in many places and more than 500 feet in only a few. In northern Missouri and northeastern Kansas the maximum altitude is a little more than 1,200 feet and the local relief is generally less than 300 feet; the greatest local relief is along the escarpment formed by the limestone beds at the base of the Kansas City formation and along Missouri River, where the river bluffs rise to a maximum of about 350 feet above the flood plain.

Along the southern margin of the Glaciated Plains glacial drift was never very thick and much of it has been removed by postglacial erosion. In an irregularly shaped area bordering Missouri and Kansas rivers on the north the drift does not materially affect the topography, and the character of the surface is much like that of the unglaciated region farther south and west. Escarpments are only slightly less conspicuous, divides are not much broader, drainage is well developed, and extensive flat upland prairies are exceptional. The Leavenworth and Smithville quadrangles lie chiefly in this bordering transitional area.

Osage Plains.—In southwestern Missouri, eastern Kansas, central Oklahoma, and northeastern Texas the surface is unglaciated and is called the Osage Plains. The northern part of this area consists of a series of plains separated by escarpments produced by the erosion of gently dipping strata of unequal resistance, belonging to the Pennsylvanian series. The plains commonly conform to the dip of a resistant stratum, so that the combination of plains and scarps is like a huge stairway with each step sloping gently west or northwest, and the top of each escarpment only slightly higher than the top of the one next east of it. As thick limestone beds are more resistant than most of the other rocks exposed each escarpment comprises limestone at or near the top, with less resistant rocks below. The plains are 5 to 30 miles wide and the escarpments 100 to 300 feet high. The principal escarpments from southeast to northwest are those formed by the Henrietta formation and the overlying Hertha to Winterset, Plattsburg to Stanton, and Oread limestone members; several others are only locally developed and hence separate plains that are not so well defined. Many of the characters of the Osage Plains may be seen in the southwestern border of the Glaciated Plains, which includes most of the Leavenworth and Smithville quadrangles.

Great Plains.—Between the Glaciated Plains and Osage Plains and the foot of the Rocky Mountains lie the Great Plains, whose eastern border extends north and south through eastern Kansas and Nebraska, not far from the Leavenworth and Smithville quadrangles. The Great Plains are characterized in general by smooth outlines caused by extensive tabular or rolling areas traversed by the broad shallow valleys of the larger streams. As a whole they slope to the east, away from the mountains, and are higher than the Glaciated Plains and the Osage Plains. The smooth outlines are not universal, however, for lateral drainage has cut many deep, narrow valleys, and in places long escarpments, areas of badlands, and sand dunes have been formed. The relief ranges from 6,000 feet above sea level at the foot of the Rocky Mountains to much less on the eastern border of the province.

Ozark region.—Structurally as well as topographically the Ozark region is a low dome of elliptical outline, occupying much of southern Missouri and northern Arkansas. It is characterized by higher altitude, greater relief, and older outcropping formations than neighboring areas on the west and north. The northeastern part of the region includes the Salem Plateau and the St. Francis Mountains and contains only small patches of Carboniferous rocks; the northwestern border is a smoother area in which Mississippian rocks outcrop. The Ozark region culminates topographically at the south in the Boston Mountains, a long, narrow plateau 2,000 feet above sea level. The part of the region that lies in Missouri, which is less than 1,700 feet in maximum altitude, borders the Glaciated Plains along Missouri River, one of its lowest parts.

DRAINAGE.

Nearly all of the Glaciated Plains lie in the basins of Missouri, upper Mississippi, and Ohio rivers and the Great Lakes. The southern part of the Osage Plains is drained chiefly by Arkansas and Red rivers. The surface waters of the northern part of the Great Plains are tributary to the Missouri and those of the southern part to the Arkansas and other streams. The drainage of the Ozark region is to the Missouri and the Arkansas and through these and smaller streams to the Mississippi. Northern Missouri is drained chiefly by Chariton, Grand, Platte, and Nodaway rivers, all of which flow south into the Missouri. Northern Kansas lies chiefly in the basin of Kansas River, which empties into the Missouri at Kansas City. Southern Kansas lies in the basin of the Arkansas. A small area in east-central Kansas and west-central Missouri is drained by Osage River, which flows east and northeast across the northern border of the Ozark Plateaus to join the Missouri below Jefferson City.

STRATIGRAPHY AND STRUCTURE.

The dominant structural feature of the region is the Ozark uplift in southern Missouri and northern Arkansas, in which the older rocks lie at relatively higher levels than in surround-

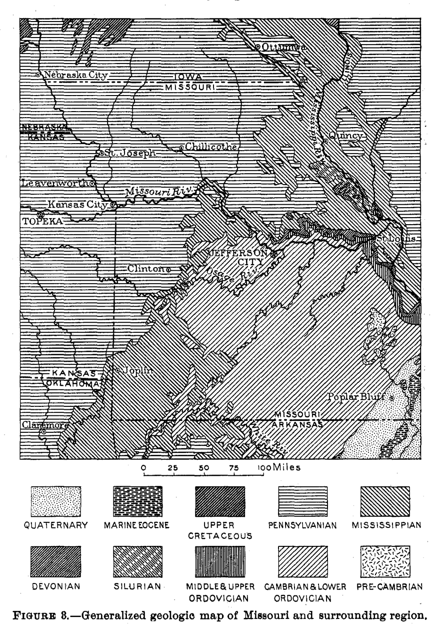


FIGURE 3.—Generalized geologic map of Missouri and surrounding region.
The Leavenworth and Smithville quadrangles are in western Missouri and eastern Kansas, as shown in figure 1. Geology from Geologic map of North America, U. S. Geological Survey, 1911.

ing territory and from which they dip away on all sides. The rocks exposed are chiefly Cambrian and Lower Ordovician limestones, with intercalated sandstone and shale. Pre-Cambrian igneous rocks outcrop in a comparatively small area in the St. Francis Mountains. Small patches of Carboniferous strata are scattered over all parts of the Ozark region, and Silurian and Devonian rocks outcrop at a few places in narrow zones around its border. Mississippian rocks, chiefly limestone, occupy considerable territory in southwestern and northeastern Missouri, in the southeast corner of Kansas, and in a narrow strip near Missouri River in central Missouri. (See fig. 3.)

The older Paleozoic formations dip gently away from the main part of the Ozark region and pass beneath Carboniferous formations on the north and west. The Pennsylvanian series of the Carboniferous system, which contains all the important coal deposits of the region, outcrops in much of northern and western Missouri, in southern Iowa, and in adjacent parts of Kansas and Nebraska. In north-central and northeastern Missouri the beds, broadly considered, lie nearly horizontal, being disturbed only by low anticlines trending northwest and southeast. In west-central Missouri they dip northwest; in northwestern Missouri, west; and in southern Iowa, southwest. These dips, which are commonly less than 10 feet per mile, are continued into Kansas and Nebraska, and the Pennsylvanian passes beneath younger rocks—Permian and Cretaceous—a short distance west of Missouri and Iowa. Cretaceous rocks also cover the Pennsylvanian in part of western Iowa.

The Pennsylvanian series has been divided into several units. The Cherokee shale—the chief coal-bearing formation—is at the base and is overlain successively by the Henrietta and Pleasanton formations of the Des Moines group and the Kansas City, Lansing, Douglas, Shawnee, and Wabaunsee formations of the Missouri group. Owing to the nature of the general dip the Cherokee outcrops in a fairly broad zone around the outer edge of the Pennsylvanian area and dips beneath younger formations to the north and west. In a similar manner each of the other formations outcrops in an arc around the next younger and passes beneath it on the northwest. The Wabaunsee, the youngest formation, appears in Missouri only in Atchison County, in the extreme northwest corner of the State.

In parts of the region the consolidated rocks are covered by unconsolidated glacial deposits, consisting chiefly of clay containing numerous pebbles and bowlders that were brought in from the north by the moving ice. Similar glacial drift covers most of the United States north of Missouri and Ohio rivers. In northern Missouri, near the Iowa boundary, the drift is 400 feet thick in a few places, but as a rule it is much thinner and is less than 100 feet in most parts of Missouri and Kansas.

A mantle of wind-blown loess covers most of the region near Missouri River, especially east and south of that stream. Near the river the loess covers nearly all other formations, but it thins notably within a few miles and is inconspicuous in the greater part of the region. The loess is a sandy silt that lends great fertility to the lands on which it lies.

CLIMATE AND VEGETATION.

The annual rainfall at Kansas City is from 24 to 50 inches, and the average for a number of years during which accurate weather observations have been made is 36.4 inches. The precipitation is fairly well distributed throughout the year but is greatest between April and October, the period when it is most needed. The soils of the region retain moisture well, and droughts are rarely so prolonged as to cause serious damage. The average growing season—the period between the last killing frost in the spring and the first in the autumn—is 181 days. Observed temperatures have ranged from 106° F. in July to —22° F. in February, the mean temperature being 76° during the three summer months and 31° during the winter.

Vegetation is abundant and is essentially the same as in the rest of the famous "corn belt" of the central part of the United States. A very large proportion of the total acreage is under cultivation. Various grasses grow luxuriantly in the pasture lands and the principal farm crops are corn and wheat. There are no extensive forested areas, trees being confined chiefly to the rougher valley slopes and to small "wood lots" that furnish fuel for local use.

TOPOGRAPHY.

RELIEF.

General features.—The Leavenworth and Smithville quadrangles are deeply dissected near Missouri and Platte rivers but contain extensive rolling uplands. The maximum relief in he quadrangles is about 400 feet, the altitude above sea level ranging from less than 740 feet (at low water) where Missouri River crosses the southern boundary of the Leavenworth quadrangle to more than 1,140 feet on the ridge southwest of Leavenworth. The upland surface, broadly considered, slopes slightly to the east, some of the highest points being on the bluffs along the Missouri, one of which (near the center of sec. 33, T. 54 N., R. 36 W.) rises about 340 feet above the flood plain and has the distinction of being one of the highest in northern Missouri. The uplands and the smaller valleys include about 400 square miles and the flood plains of Missouri, Platte, and Little Platte rivers about 62 square miles.

Uplands.—Erosion of the consolidated rocks both before and after glaciation produced more or less conspicuous escarpments capped by limestone and rolling plains on nonresistant rocks. The Oread escarpment, which is a strong topographic feature 150 to 340 feet high in the west third of the Leavenworth quadrangle, forms steep slopes bounding Pilot Knob Ridge and other narrow, irregularly shaped ridges west of the Missouri and the exceptionally high ridge north of Bear Creek and east of the river. Beautiful views of the city of Leavenworth and of the broad valley of the Missouri may be obtained from the tops of these ridges. The escarpment was formed by erosion in the nonresistant shale of the Lawrence shale member, which is protected by the overlying resistant Oread limestone member. East of Bear Creek the escarpment is in part masked by glacial drift. The Plattsburg-Stanton escarpment, which is in places the next conspicuous one southeast of the Oread, is not conspicuous in the quadrangles, because the limestone members at the top of the Lansing formation, which are the resistant beds that govern its position, are topographically low. It is marked by rather steep slopes, however, in the lower part of some of the valleys. The Hertha-Winterset escarpment, the next conspicuous one on the southeast, lies a short distance southeast of the quadrangles. In the part of the south third of the quadrangles in which the highest indurated rocks are massive sandstones in the lower part of the Lawrence shale member the uplands are slightly higher than those that border them on the north.

The topography of a part of the uplands is controlled or considerably modified by the drift. Areas that lie chiefly west of the Missouri and east of the Platte, however, resemble the neighboring parts of the Osage Plains, the small upland streams flowing through shallow valleys with gently sloping sides that grade imperceptibly into the rolling well-drained upland prairies. Most of the triangular area between the Missouri and the Platte has more of the characters that typify the Glaciated Plains. Along the southern border of this area hills of drift rise 100 feet or more above the general level and are prominent features. At no place in this region are flat uplands or tabular divides so common as in northeastern Missouri.

The topography of the territory adjacent to the flood plains of the Missouri owes its character in part to the thick accumulation of loess along the bluffs. The loess east of the river, where it is thickest, forms a ridge which runs parallel to the flood plain and is generally highest within a mile or less of the edge of the bottoms. A similar ridge lies along the bluffs west of the Missouri in places, but it is not so pronounced. Away from the bluffs the ridges are progressively lower and have the appearance of "giant swells of a stormy sea which has been suddenly fixed." Some of the ridges are several miles long and their crests, as seen in profile, are slightly wavy.

The topography, outside of the area of thick loess near the Missouri, has not been affected by loess accumulations, except that it has possibly been made slightly more rolling. A notable feature is the tendency of the roads to wear down to the underlying till where the loess is thin and to make miniature canyons where the loess is thickest.

Valleys.—The valley of Missouri River is by far the largest in the quadrangles, the width of its flood plain ranging from $2\frac{3}{8}$ to $3\frac{5}{8}$ miles and averaging $2\frac{3}{4}$ miles. Along this part of its course and as far south as Kansas City the river has carved a valley that is exceptionally deep in proportion to its width. Above the Leavenworth quadrangle and below Kansas City the valley is wider because there is less resistant limestone in the valley walls and more nonresistant shale.

Bluffs rise abruptly from the edge of the bottom lands except at the mouths of tributaries and near Leavenworth. The bluffs are highest where the valley cuts across the Oread escarpment, rising 340 feet above the flood plain in an eighth of a mile in Missouri and 380 feet in half a mile in Kansas. The bluffs on the east side of the river are in general higher than those on the west side, and their bases, especially those on the east side, have a remarkably straight alignment. West of the river the bluffs are low and inconspicuous from a short distance above Fort Leavenworth south to the mouth of Fivemile Creek. The city of Leavenworth and Fort Leavenworth are built on a rolling plain lying only 50 to 100 feet above the flood plain and bounded on the west by a steep-sided ridge rising about 200 feet higher.

The flood plain of the Platte averages less than a mile wide; the valley is much more irregular than that of the Missouri; and the outline of the bluffs is extremely ragged, more so than in most of the valleys of northwestern Missouri. The Platte, like the Missouri, is carving most of its valley in the quadrangles in resistant rocks. In a few places, however, it has cut across the drift filling of preglacial valleys and broadened its valley considerably. A typical illustration of such broadening is afforded by the Little Platte southeast of Trimble, in the Smithville quadrangle. At two places isolated rock-capped mounds rise in the flood plain. Along the Platte, its larger tributaries, and Bee Creek the stream banks are 10 to 30 feet high, and in many places are bordered by low terraces, locally as many as three.

The smaller valleys, of which that of Bee Creek is the largest, closely resemble the valley of the Platte and exhibit many of its characteristic features, such as the ragged outlines of the flood plains, the isolated mounds, and the moderately high and steep banks. They contain more terraces, however. The smallest valleys, those in which water flows during only part of the year, are commonly steep sided and are carved chiefly in drift and loess. Their chief characteristic is the number and distinctness of the terraces which border them and slope toward the outlet. These terraces are by no means continuous from the heads to the outlets of the ravines, and those which originate near the heads of the hollows commonly merge into the irregularities of the valley sides. Some of the hollows show in profile as many as five or six terraces.

DRAINAGE.

The Leavenworth and Smithville quadrangles lie entirely within the Missouri River basin. Most of their drainage enters Missouri River above its junction with Kansas River, but that of the southwest corner of the Leavenworth quadrangle reaches the Missouri through Kansas River by way of Little Stranger and Stranger creeks, and that of the southeast corner of the Smithville quadrangle flows into the Missouri below Kansas City.

Missouri River flows approximately S. 30° E. across the Leavenworth quadrangle with a gradient of only 0.8 foot per mile. The estimated mean discharge between October 4, 1906, and October 21, 1907, above Kansas River at Kansas City, was 71,030 cubic feet per second, and during the same period the suspended matter passing a given point was 567,500 tons per 24 hours. The channel frequently shifts, and the river often cuts across the necks of meanders and leaves oxbow lakes, sloughs, and marshes to mark its former course. Horseshoe and Duck lakes, as well as the other small bodies of water in the flood plain, lie in abandoned meanders of the river, and the line between Missouri and Kansas marks the site of the channel at the time when the State boundaries were surveyed. The general tendency of Missouri River along the western border of Missouri is to hug its right or west bluff. The water is not deep at normal stages of the river and is given the appearance of boiling by numerous small whirlpools and eddies. The range between high and low water at Leavenworth is 23.8 feet and at Fort Leavenworth, 26.2 feet.

Platte River and its chief tributary, the Little Platte, rank next to the Missouri in importance. Bottom lands are moderately wide and well marked but are rarely marshy, even below Platte City, where the stream gradient is low. The stream banks are 10 to 30 feet high and steep. Numerous meanders have been formed by the Platte and the Little Platte and are very intricate in places. One bend brings water flowing in the main river toward the mouth of the Little Platte within a few feet of water that has already left the Little Platte. At present, the Platte enters Missouri River near Farley, but formerly it did so nearly 12 miles below, near Parkville. When the Missouri is in flood, water is backed up the Platte for many miles.

The principal tributaries of the Missouri are Plum, Salt, Fivemile, and Sevenmile creeks in Kansas, and Bee, Pedee, Bear, and Brush creeks in Missouri. The chief tributaries of Platte River and the Little Platte are Jowler, Prairie, Todd, First, Second, Wilkerson, Dick, and Grove creeks and Camp Branch. All these streams are small and contain very little water during part of the year. Some of them, especially Bee, Plum, and Salt creeks, have fairly well developed alluvial flood plains and small but complex meanders in the lower parts of their courses.

CULTURE.

The Leavenworth and Smithville quadrangles are thickly though not densely populated. Leavenworth, with a population of 19,363 in 1910, is the largest city. Fort Leavenworth with 2,000, Soldiers Home with 4,281, and Lansing with 712, might be properly considered part of Leavenworth. Weston, with a population of 1,019 in 1910, is the only other place with more than 1,000 inhabitants. Outside the towns the population is evenly distributed except on the flood plain of Missouri River, where few people take up permanent residences.

The region is exceptionally well supplied with railroads, both steam and electric, which are so distributed that everywhere in the quadrangles there is at least one within a few miles. The wagon roads follow land lines in the smoother areas and ridges and valleys in the rougher districts near the rivers. At present few of the country roads are graded or macadamized, and the others are not all that could be desired in wet weather. There are splendid roads on the Military

Reservation, and a paved street extends from Leavenworth to Lansing. The Interstate Trail, which crosses the Smithville quadrangle and connects Kansas City with St. Joseph and Des Moines, is also a good road and is an example of what can be done with moderate expenditure.

Agriculture is the principal industry in the quadrangles, but there is considerable manufacturing and coal mining at Leavenworth and at Lansing. The United States penitentiary, the military post, college, and prison at Fort Leavenworth, and the United States Soldiers' Home are within a few miles of Leavenworth. The Kansas State penitentiary is at Lansing. The other towns are chiefly agricultural trading and shipping points.

DESCRIPTIVE GEOLOGY.

STRATIGRAPHY.

GENERAL CHARACTER OF THE ROCKS.

The rocks of the Leavenworth and Smithville quadrangles consist of indurated strata of Pennsylvanian age, overlain in most places by unconsolidated till and wind-blown loess of Pleistocene age and in many places by alluvium of Recent age. Beneath the rocks exposed at the surface there is, as shown by deep borings, a great thickness of older Paleozoic strata resting on a floor of granite. The general character, thickness, and sequence of the formations, both those exposed and those beneath the surface, are shown diagrammatically in columnar and structure sections. (See figs. 4, 5, and 7.) The formations will be described in their order of age, beginning with the oldest.

ROCKS NOT EXPOSED.

SECTIONS.

Many wells that range in depth from 300 to more than 1,100 feet and three wells more than 2,000 feet deep have been drilled in or near the quadrangles. Of the three deep wells one at Leavenworth, Kans., is 2,116 feet deep; another at Bonner Springs, Wyandotte County, Kans., is 2,150 feet deep; and a

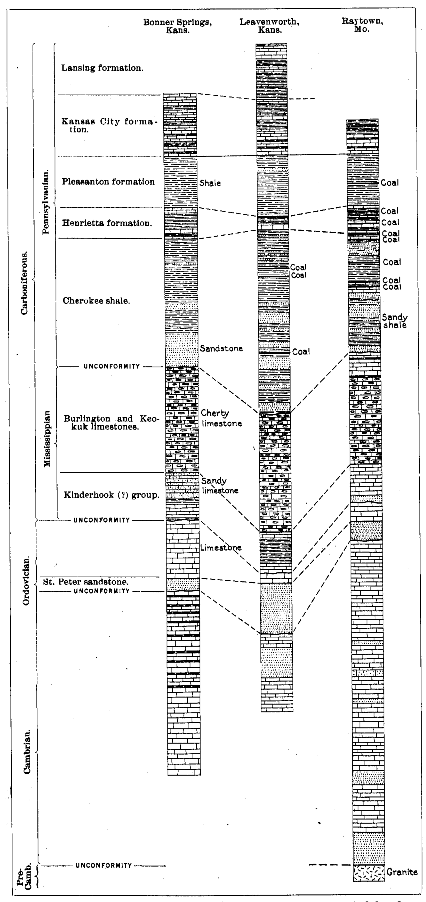


FIGURE 4.—Generalized columnar sections of rocks penetrated by deep wells in and near the Leavenworth and Smithville quadrangles.
Scale: 1 inch=800 feet.

third at Raytown, Jackson County, Mo., near Kansas City, is 2,400 feet deep. (See fig. 4.) No direct paleontologic evidence is available to show the age of the pre-Pennsylvanian strata encountered in the borings, and the lithologic evidence which can be derived from drill records is not commonly sufficient for the differentiation of beds that have no easily recognized characteristics. Correlation of several beds, however, can be made from well to well throughout large areas with a fair degree of accuracy.

The rocks penetrated by the boring near Raytown, Mo., not far from Kansas City, include all of the Paleozoic section present, as well as some of the underlying pre-Cambrian crystalline rocks. The record of the drilling is as follows:

Record of diamond drilling near Raytown, Mo.

	Thickness.	Depth.
Carboniferous system:	*Feet.*	*Feet.*
Pennsylvanian series:		
Kansas City formation:		
Limestone and shale	112	112
Pleasanton and Henrietta formations and Cherokee shale:		
Shale, sandstone, limestone, and coal	638	750
Mississippian series:		
Keokuk and Burlington limestones:		
Limestone, shelly in places, with shale partings	75	825
Limestone, light colored, flinty layers	260	1,085
Kinderhook (?) group:		
Limestone, dark, with shelly layers	100	1,185
Sand, dark reddish	15	1,200
Carboniferous (Mississippian), Devonian, or Ordovician system:		
Limestone, bluish, fine grained, shelly in places	57	1,257
Ordovician system:		
St. Peter sandstone:		
Sandstone, white at top, reddish at bottom	64	1,321
Ordovician and Cambrian systems:		
Limestone, gray and brown	129	1,450
Limestone, shelly and clayey	10	1,460
Limestone, light, coarse, porous	160	1,620
Limestone, shelly	20	1,640
Sandstone, white	16	1,656
Limestone, light, flinty, porous; water disappeared	74	1,730
Limestone, gray, clayey and sandy	20	1,750
Limestone, gray, hard, fine grained	70	1,820
Sandstone, gray, hard, fine grained	15	1,835
Limestone, gritty, porous, crystalline, white and flinty in places	215	2,050
Sandstone, hard, coarse	50	2,100
Limestone, with seams of gray and brown shale	40	2,140
Limestone, dark and light, fine grained	110	2,250
Sandstone, hard, coarse	98	2,348
Pre-Cambrian:		
Granite, determined by microscopic examination of part of the core by the authors	53	2,401

A prospect drilling for oil and gas was made in 1887 at the north edge of Leavenworth, due south of the United States penitentiary and a few rods south of the road which marks the boundary of the penitentiary reserve. The drilling was continued to a depth of 2,116 feet, and a careful record of strata penetrated is said to have been preserved.[1] As the beds of the Pennsylvanian series were noted in greater detail in the shafts and boring at the North mine, a mile distant, only the coal beds in that series are given in the following log:

Log of deep well at Leavenworth, Kans.

[Altitude at surface, about 860 feet.]

	Thickness.	Depth.
Quaternary system:	*Feet.*	*Feet.*
Loam and clay	20	20
Carboniferous system:		
Pennsylvanian series:		
Shale and limestone, some sandstone	700	720
Coal (Bevier)	2	722
Clay and shale	25	747
Coal	2	749
Shale and sandstone, some clay	239	988
Coal	2	990
Shale and sandstone, some clay	185	1,175
Mississippian series:		
Keokuk and Burlington limestones:		
Reported as "hard white sandrock" [probably limestone of Mississippian age]	375	1,550
Kinderhook (?) group:		
Limestone, brown	20	1,570
"Iron pyrites"	5	1,575
Shale, white	75	1,650
Limestone, brown	30	1,680
Ordovician system:		
Joachim (?) limestone:		
Limestone, light gray	30	1,710
St. Peter sandstone:		
Sandstone, gray, hard	102	1,812
Sandstone, "sharp," soft	18	1,830
"Pebble sandrock," white	40	1,870
Ordovician and Cambrian systems:		
"Rock," white, hard [limestone?]	50	1,920
Sandstone, blue to white, soft	90	2,010
Limestone	106	2,116

[1] Jameson, E., Geology of the Leavenworth prospect well: Kansas Acad. Sci. Trans., vol. 11, pp. 37–38, 1889.

The very accurate record of the strata penetrated by the hoisting shaft of the Kansas State Penitentiary coal mine at Lansing, in somewhat condensed form, is as follows:

Log of hoisting shaft of Penitentiary mine at Lansing, Kans.

[Altitude at surface, about 850 feet.]

	Thickness		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Hoisting house floor to top of stone curbing	8	2	8	2
Quaternary system:				
Surface clay and débris	22	3	30	5
Carboniferous system:				
Pennsylvanian series:				
Lansing formation:				
Stanton limestone member:				
Shale and yellow clay	5	0	35	5
Limestone, gray	12	0	47	5
Shale, black, slaty	3	11	51	4
Limestone, blue	2	5	53	9
Vilas shale member:				
Shale, light drab, slaty	23	6	77	3
Plattsburg limestone member:				
Limestone, gray, hard; two very thin clay partings near base	15	8	92	11
Clay, green, and green "marlite" containing limestone nodules	2	4	95	3
Lane shale member:				
Shale, green; contains fossil plants	18	8	113	11
Limestone and shale in thin beds	2	0	115	11
Limestone, brown and gray; two thin shale partings in upper half	14	6	130	5
Shale, light drab; contains thin layer of soft limestone	37	0	167	5
Kansas City formation:				
Iola limestone member:				
Limestone, chiefly light gray, brown at top, dark gray at bottom, hard and compact	18	10	186	3
Chanute shale member:				
Shale, black	10	8	196	11
Limestone; 4 inches of shale near base	4	10	201	9
Shale, gray at top, black and bituminous at base	3	2	204	11
Limestone, brown, hard	1	1	206	0
Shale, gray at top, purple below; contains fossil plants	8	0	214	0
Limestone, gray; has 18 inches of green shale in lower half	10	4	224	4
Shale, gray and purple, very soft	15	6	239	10
Drum limestone member:				
Limestone, drab, cherty; has 3 inches of shale near bottom	10	2	250	0
Cherryvale shale member:				
Shale, gray at top, black below	18	4	268	4
Limestone, gray, hard and compact	2	6	270	10
Shale, gray at top, black at base; has 6 inches of limestone in lower half	4	3	275	1
Limestone, dark gray	1	11	277	0
Shale, dark gray	5	10	282	10
Limestone, light gray, soft	1	7	284	5
Shale, gray and black	1	6	285	11
Winterset limestone member:				
Limestone, gray, blue, and buff; has pockets of chert and two 4-inch partings of shale	25	0	310	11
Galesburg shale member:				
Shale, black and slaty at top, gray at base	5	1	316	0
Bethany Falls limestone member:				
Shale, gray, hard, mixed with large nodules of limestone	5	0	321	0
Limestone, light, porous and sandy, dark gray and hard at base; salt spring at contact of two beds	20	1	341	1
Ladore shale member:				
Shale, black, bituminous; salt spring flowing 50 gallons per hour	2	7	343	8
Limestone, drab; has 8 inches of shale near middle	3	6	347	2
Shale	1	6	348	8
Hertha limestone member:				
Limestone, light gray, soft, shaly; has clay seams	6	0	354	8
Limestone, blue, hard and compact	6	3	360	11
Pleasanton formation:				
Shale, drab, blue, purple, and black	110	0	470	11
Limestone, gray to dark, soft	5	0	475	11
Shale, drab to black; has two 6-inch limestone layers and 1 inch of coal	36	0	511	11
Coal		2	512	1
Clay, underlain by drab shale	9	2	521	3
Henrietta formation:				
Limestone, light brown, top shaly, bottom hard	5	0	526	3
Shale, blue and black	3	9	530	0
Limestone, gray, hard	1	0	531	0
Shale, black	1	0	532	0
Limestone, gray, very hard	3	2	535	2
Shale, blue, drab, and black	7	5	542	7
Limestone, light gray; has 6 inche sof black shale in lower half	5	11	548	6
Sandstone, gray and brown, shaly at top and bottom	8	3	556	9
Shale, black, soft	12	0	568	9
Limestone, brown, very hard, fine grained	3	3	572	0
Shale, black, bituminous	2	6	574	6
Coal, good quality		8	575	2
Clay		6	575	8
Sandstone, gray; contains fossil plants	4	0	579	8
Shale, drab, buff, and black; fossil ferns	5	7	585	3
Limestone, light gray, very hard	4	0	589	3
Shale, drab and green, soft	9	6	598	9
Limestone, light gray, hard	2	2	600	11

Log of hoisting shaft of Penitentiary mine at Lansing, Kans.—Continued.

	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Carboniferous system—Continued.				
Pennsylvanian series—Continued.				
Cherokee shale:				
Shale, black; has 4-inch layer of soft limestone near middle	4	9	605	8
Coal (Lexington); burns well		7	606	3
Clay, drab	5	1	611	4
Limestone, gray	3	3	614	7
Shale, drab	2	3	616	10
Limestone, light gray, in two layers, separated by thin shale parting	4	9	621	7
Shale, black at top, light colored below; has soft limestone at bottom	29	11	651	6
Shale, dark drab to black; has thin layers of limestone in upper half and concretions in lower; much gas	18	7	670	1
Coal; burns well		10	670	11
Sandstone, black, hard; much gas	6	2	677	1
Shale, drab and black, slaty; 2 inches of coal at base; much gas	7	3	684	4
Shale, drab and black, slaty; contains fossil shells and ferns	27	8	712	0
Coal (Bevier, the bed mined)	1	9	713	9

The top of the hoisting shaft of the North mine at Leavenworth is 24 feet above the top of the Lansing formation, and the Bevier coal bed is 709 feet beneath the surface and therefore 71 feet above sea level. The rocks penetrated differ only slightly from those shown in the Lansing record. A prospect shaft was sunk in this mine to a depth of 290 feet below the Bevier coal bed, and a boring 172 feet deep was made in the bottom of this shaft. The record is as follows:

Record of shaft and boring from bottom of North mine, Leavenworth, Kans.

	Thickness		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Coal (Bevier, the bed mined)	2	0	708	10
Clay	2	0	710	10
Limestone	2	6	713	4
Shale, dark, slaty, with 2 inches of coal	4	9	718	1
Limestone	4	9	722	10
Shale	4	4	727	2
Coal	1	4	728	6
Shale, dark; has 8 inches of clay at top	7	9	736	3
Sandstone	3	0	739	3
Limestone	1	6	740	9
Sandstone, light, micaceous	14	6	755	3
Shale	1	0	756	3
Limestone, very hard	2	0	758	3
Clay; has red streaks	5	6	763	9
Shale; contains iron pyrites	16	6	780	3
Sandstone, light	5	5	785	8
Limestone, white	4	10	790	6
Sandstone, variegated	8	2	798	8
Shale, light at top, black at bottom	19	2	817	10
Sandstone, white, soft	7	5	825	3
Shale, in part slaty	4	0	829	3
Sandstone, gray, dark; has black shale near base; contains gas and water	14	7	843	10
Shale, black	7	9	851	7
Sandstone, very hard at top, dark at bottom	30	11	882	6
Shale, black, slaty	6	0	888	6
Coal		5	888	11
Sandstone, hard, seamed with "flint"	6	11	895	10
Shale, black, slaty; contains ferruginous concretions near top; bears streaks of coal	19	11	915	9
Coal		4	916	1
Shale, dark	1	2	917	3
Coal		6	917	9
Parting of iron pyrites		2	917	11
Coal		3	918	2
Sandstone, soft	11	0	929	2
Shale, black, sandy	2	2	931	4
Sandstone, gray at top, dark at bottom, micaceous; contains many plant impressions; bears gas and water	48	4	979	8
Shale, black, slaty; contains fossil plants	12	2	991	10
Coal		10	992	8
Sandstone	4	5	997	1
Coal	2	2	999	3
Clay	1	4	1,000	7
Sandstone, micaceous; contains fossil plants at bottom	21	3	1,021	10
Shale, black	6	7	1,028	5
Coal, impure	2	4	1,030	9
Clay		10	1,031	7
Shale, black, slaty	10	2	1,041	9
Sandstone, whitish, fine grained; breaks easily	5	8	1,047	5
Shale, black, sandy	22	2	1,069	7
Sandstone, white, micaceous, peppered with black specks; contains much water	16	3	1,085	10
Coal	1	0	1,086	10
Sandstone, ripple marked; grades down into dark sandy shale	9	7	1,096	5
Coal, good		5	1,096	10
Sandstone, white; has seam of "flint"	4	1	1,100	11
Shale, in part black and slaty and in part sandy, seamed with "flint"	21	3	1,122	2
Sandstone, black; contains iron pyrites	1	2	1,123	4
Shale, black, slaty		9	1,124	1
Sandstone; contains green fossils	2	6	1,126	7
Shale, black, slaty		4	1,126	11
Coal		6	1,127	5
Shale, black, slaty; burns readily	2	0	1,129	5
Shale, black, sandy, seamed with "flint"; fossil plants	16	7	1,146	0
Sandstone, seamed with flint; has shale partings; contains great volume of water	24	8	1,170	8

The sandstone at the bottom of the boring is stratigraphically near the top of the "hard white sandrock" reported in the Leavenworth deep boring and probably lies near the base of the Pennsylvanian series.

A test boring for oil and gas by the Tiffany Springs Oil Co., a short distance south of the southwest corner of the Smithville quadrangle, showed the following strata:

Log of well on the Higgins farm (SE. ¼ sec. 8, T. 51 N., R. 34 W.), Platte County, Mo.

[Altitude at surface, about 930 feet.]

	Thickness.	Depth.
	Feet.	*Feet.*
Quaternary system:		
Soil, red, soft	15	15
Carboniferous system:		
Pennsylvanian series:		
Lansing formation:		
Stanton limestone member:		
Limestone, white, hard	13	28
Shale, soft, slaty	5	33
Limestone, gray, hard	5	38
Vilas shale member:		
Shale, black at top, gray below	12	50
Plattsburg limestone member:		
Limestone, gray, hard	18	68
Lane shale member:		
Shale, soft, gray	27	95
Limestone, gray, hard (Farley bed)	20	115
Shale, black, soft	35	150
Kansas City formation:		
Iola limestone member:		
Limestone, gray, hard	35	185
Chanute shale member:		
Shale, gray, soft	15	200
Limestone, white, soft (Raytown bed)	5	205
Shale, gray, soft	15	220
Limestone, gray, hard (Cement City bed)	10	230
Shale, black, soft	20	250
Drum limestone member:		
Limestone, gray, hard	5	255
Cherryvale shale member:		
Shale, black, soft	15	270
Winterset limestone member:		
Limestone, white, hard	20	290
Galesburg shale member:		
Shale, brown, soft	5	295
Bethany Falls limestone member:		
Limestone, white, hard	25	320
Ladore shale member:		
Shale and coal, black, soft	5	325
Hertha limestone member:		
Limestone, gray, hard	10	335
Pleasanton and Henrietta formations and Cherokee shale:		
Shale, gray, soft	100	435
"Gas sand"	12	447
Shale, gray, soft	10	457
Sand, gray, soft	13	470
Shale, gray	20	490
"Oil sand"	10	500
Shale, gray, soft	30	530
"Oil sand," brown, hard	15	545
"Water sand," gray, soft	5	550
Shale, gray and black	180	730
Sandstone, hard	15	745
Shale, gray and black, soft	70	815
Limestone, gray, hard	2	817
Sandstone, dark at top, gray below, hard (probably near base of Cherokee)	23	840

At Smithville a churn drilling for oil and gas was made to a depth of 804 feet. Coal that seemed to warrant further prospecting was found, and a second well was drilled a short distance from the first, the upper 450 feet with a churn drill and the rest with a core drill. The record of the second well is as follows:

Log of second well in the SW. ¼ SE. ¼ sec. 23, T. 53 N., R. 33 W., near Smithville, Mo.

[Altitude at surface, 887 feet.]

	Thickness	Depth.
	Feet.	*Feet.*
Quaternary system:		
Surface material	45	45
Gravel	5	50
Carboniferous system:		
Pennsylvanian series:		
Kansas City formation:		
Chanute shale member:		
Limestone (Raytown bed)	10	60
Shale	10	70
Limestone (Cement City bed)	15	85
Shale, black at base	15	100
Drum limestone member:		
Limestone	10	110
Cherryvale shale member:		
Shale	10	120
Limestone	5	125
Shale	5	130
Winterset limestone member:		
Limestone	30	160
Galesburg shale member:		
Shale, black, slaty	5	165
Bethany Falls limestone member:		
Limestone	20	185

Log of second well in the SW. ¼ SE. ¼ sec. 23, T. 53 N., R. 33 W., near Smithville, Mo.—Continued.

	Thickness.	Depth.
	Feet.	*Feet.*
Carboniferous system—Continued.		
Pennsylvanian series—Continued.		
Kansas City formation—Continued.		
Ladore shale member:		
Shale, black, slaty	15	200
Hertha limestone member:		
Limestone	5	205
Pleasanton formation:		
Shale	110	315
Henrietta formation:		
Limestone	10	325
Shale	5	330
Limestone	10	340
Shale	20	360
Limestone	10	370
Shale	15	385
Limestone	10	395
Cherokee shale:		
Shale	43	438
Sandstone	4	442
Shale	16	458
Limestone	2	460
Shale, light at top, black at base	11½	471½
Coal	3	474½
Fire clay, sandy	4	478½
Shale, sandy	9½	488

At a depth of 730 feet the first well at Smithville reached the top of a light-colored sandstone and continued in it for 74 feet, probably to a point near the base of the Pennsylvanian.

PRE-CAMBRIAN ROCKS.

The core of the Raytown boring has at the base a rather fine grained crystalline rock, composed chiefly of quartz, microcline, biotite, muscovite, and apatite, of the general type that undoubtedly underlies all the sedimentary rocks of this region. Under the microscope it appears to be a granite, possibly somewhat gneissoid.

CAMBRIAN AND ORDOVICIAN SYSTEMS.

The Raytown boring passed through the St. Peter sandstone (Lower Ordovician) and 1,027 feet of limestone and sandstone beneath it. The limestone is probably chiefly dolomite and predominates over the sandstone. Several hundred feet of strata beneath the St. Peter are probably also of Lower Ordovician age. According to the opinion recently expressed by Ulrich, that the lowest sedimentary rocks in this general region are of Upper Cambrian age, the Lower and Middle Cambrian are not represented in the Raytown record.

In the three deep wells in and near the quadrangles there is a sandstone 48 to 160 feet thick that corresponds to the widely distributed St. Peter sandstone in thickness, character, and stratigraphic relations. Its color is reported as gray and white in one well and as white at top and reddish at bottom in the other two. The sandstone is ordinarily composed of loosely cemented, rounded grains of clear quartz, the reddish color being caused by a small amount of iron oxide.

In the Raytown well a 57-foot limestone above the St. Peter sandstone may also be of Ordovician age, though it is possible that it is Devonian or even early Mississippian. In the other two deep wells 30 to 228 feet of limestone overlies the St. Peter, and it may be that at least the lower part of these beds is Ordovician and that the upper part includes younger rocks.

CARBONIFEROUS SYSTEM.

MISSISSIPPIAN SERIES.

Along the northwestern flank of the Ozark region no Silurian and only a thin series of Devonian rocks outcrop, but the Mississippian series is nearly everywhere present and is represented by both the Kinderhook group and the Burlington and Keokuk limestones. All three of the deep wells show 100 to 115 feet of sandstone, shale, and dark limestone of possibly early Mississippian age. The limestone at the top of these beds is probably Kinderhook, but the underlying shale and sandstone may be either Devonian or Kinderhook, probably the latter. It is possible that some of the strata questionably correlated with the Ordovician may be of Devonian or Mississippian age.

The interval between the rocks tentatively referred to the Kinderhook group and the Pennsylvanian series is occupied by 300 to 375 feet of light-colored cherty limestone that corresponds well to the Burlington and Keokuk limestones of the Ozark border. In the Leavenworth deep well a thick stratum that was described by the driller as "hard white sandrock" is probably chiefly cherty limestone, like that usually found at the top of the Mississippian in this region. If, however, the driller's description be correct the "sandrock" would form the lower part of the Cherokee shale, and this shale would be much thicker than in any of the many other borings in neighboring parts of Missouri and Kansas. In several drill records in Missouri, near the quadrangles, the boundary between the Pennsylvanian and the Mississippian series can be easily determined, but in the deep well at Leavenworth and in that southeast of Atchison, Kans., the base of the Pennsylvanian is apparently a hard light-colored sandstone that drillers have sometimes confused with the cherty Mississippian limestone below, making the determination of the boundary difficult.

PENNSYLVANIAN SERIES.

CHEROKEE SHALE.

The Cherokee shale consists of shale and sandstone, with a few thin strata of limestone and several coal and clay beds. It ranges in thickness from 476 to 580 feet, averaging a little more than 500 feet, and lies unconformably on the uneven surface of the underlying Mississippian series. The formation is important economically, as it contains the most valuable coal deposits of the region. No coal has been found below its base.

The portion of the Cherokee shale above the Bevier coal horizon contains several rather persistent beds at its outcrops in north-central Missouri. Rocks that mark the horizons of the Summit and the Mulky coal beds have been identified in many parts of an area of several thousand square miles. In the records of the shafts in the Leavenworth quadrangle these beds can not be identified with certainty, for the section is somewhat different in detail from that in the nearest district in which the Cherokee outcrops. As shown by borings in and near this part of the Missouri Valley, however, the beds penetrated near Leavenworth are fairly persistent throughout rather large areas, and this persistency applies to beds even lower than the Bevier coal, which is about 115 feet below the top of the Cherokee and is well marked by the 30-inch bed of characteristically nodular limestone upon which its underclay rests. Although it can not be identified with certainty in the Smithville borings, the Bevier coal and the characteristic beds just above and below it are much the same at and near Leavenworth as in north-central Missouri.

Many fossil plants have been obtained from these beds in the shaft of the Penitentiary mine at Lansing, and the following species are recorded by White and Sellards; presumably they are from the roof shale of the Bevier coal bed.

Eremopteris solida.	Neuropteris gilmani.
Eremopteris missouriensis.	Neuropteris clarksoni.
Pseudopecopteris obtusiloba.	Linopteris obliqua.
Pseudopecopteris squamosa.	Calamites suckowii.
Mariopteris occidentalis.	Asterophyllites equisetiformis.
Sphenopteris denticulata.	Annularia sphenophylloides.
Sphenopteris pinnatifida.	Annularia stellata.
Pecopteris vestita.	Calamostachys brevifolia?
Pecopteris squamosa.	Sphenophyllum emarginatum var. minor.
Pecopteris villosa?	Sphenophyllum cuneifolium?
Pecopteris unita.	Macrostachia infundibuliformis.
Alethopteris serlii.	Lepidodendron scutatum.
Alethopteris serlii missouriensis.	Lepidodendron clypeatum ?
Callipteridium sullivantii.	Lepidostrobus cultriformis.
Odontopteris papilionacea.	Plintheotheca angularis.
Neuropteris rarinervis.	Rhabdocarpos mammilatus.
Neuropteris vermicularis.	Rhabdocarpos cf. multistriatus.
Neuropteris ovata.	Trigonocarpum schultzianum.
Neuropteris missouriensis.	Cordianthus ovatus.
Neuropteris coriacea.	Cordaicarpon cinctum.
Neuropteris caudata.	
Neuropteris scheuchzeri.	

According to White, this list includes several species not known above the upper Pottsville in other regions. Other species are found only in the lowest Allegheny beds of the Eastern Interior coal field and the Appalachian trough, and still others have a higher range. The flora evidently is not younger than the Brookville flora, the lowest in the Allegheny formation. On the other hand, it might be regarded by some paleobotanists as older. According to the Old World classification, it would appear to fall in the Middle Coal Measures of Great Britain and in the uppermost zone of the Westphalian in Continental Europe. Recent paleobotanic work by White in Missouri has shown that the Bevier coal bed marks approximately the boundary between the Pottsville and the Allegheny formations of the Appalachian basin.

The invertebrate fossils in the following list were collected from the roof shale of the Bevier coal in mines at Leavenworth:

Lingulidiscina missouriensis.	Pustula nebraskensis.
Chonetes mesolobus.	Marginifera muricata.
Chonetes mesolobus var. decipiens.	Spirifer cameratus.
Chonetes verneuilianus.	Composita subtilita.
Productus semireticulatus.	Aviculipecten rectilaterarius.
	Pseudorthoceras knoxense.

HENRIETTA FORMATION.

The Henrietta formation, like the Cherokee shale, underlies a large area in northwestern Missouri and eastern Kansas, including the Leavenworth and Smithville quadrangles. It is distinguished from the Cherokee shale and the overlying Pleasanton formation by the number and persistency of its limestone members, though shale and sandstone form about half its thickness, which in this region is 40 to 80 feet. The character and stratigraphic relations of the formation are essentially the same as those which it possesses in outcrops in northern Missouri.

The Henrietta rests conformably on the underlying Cherokee shale and in most places is overlain conformably by the Pleasanton formation. Erosion that took place during the Pleasanton epoch, however, removed the lower part of the Pleasanton formation in a few places and, less commonly, the upper part of the Henrietta, so that beds of the upper Pleasanton rest unconformably on the Henrietta.

The Henrietta has been divided into three members, which are, beginning with the lowest, the Fort Scott limestone, the Labette shale, and the Pawnee limestone. All three subdivisions can be recognized in most of the borings in these quadrangles, but shale partings in the limestone and limestone lentils in the shale make it difficult to define their limits accurately. The Henrietta is nearly equivalent to the Appanoose formation of the Iowa Geological Survey and is the lower part of the Marmaton formation of the Kansas University Geological Survey.

PLEASANTON FORMATION.

The Pleasanton formation consists chiefly of shale, some sandstone, thin lenses of limestone near the middle, and a few rather lenticular and thin coal beds. In thickness it ranges from 110 to 200 feet and averages about 150 feet. It thins toward the northwest.

Lithologically and stratigraphically the formation here termed the Pleasanton closely resembles the outcropping beds originally grouped under that name in Kansas.[1] The restriction of the name to the upper part of the formation by some geologists appears to be unjustified, as it has been used for years in its original sense in both Missouri and Iowa. As mentioned in the description of the Henrietta formation, there is an unconformity within the Pleasanton, so that sandstone of late Pleasanton age, which is absent from many places, rests in other places on beds of early Pleasanton or even of Henrietta age.

ROCKS EXPOSED.

CARBONIFEROUS SYSTEM.

PENNSYLVANIAN SERIES.

KANSAS CITY FORMATION.

Distribution.—The Kansas City formation outcrops along the creeks near Smithville and on the headwaters of Shoal Creek, in the southeast corner of the Smithville quadrangle. Only the upper half of the formation is exposed at these places (see fig. 5), but the whole of it has been penetrated by several shafts and drillings in other parts of the quadrangles. Between the Leavenworth quadrangle and the vicinity of Kansas City there are many fine exposures of the formation along Missouri River.

Character and thickness.—The formation rests conformably on the underlying Pleasanton formation. It consists essentially of limestone, although it contains much shale and in places some sandstone. The shale is prevailingly blue but in some beds is reddish or greenish. Most of it is of the common argillaceous type, but three layers are of the black slaty variety. The limestones are light gray, blue, and buff, mostly fine grained, and noncrystalline. They range from thin bedded to massive and oolitic, and a few of them are cherty, particularly those in the upper part of the Winterset member. In the detailed log of the Kansas State Penitentiary coal shaft at Lansing, where the formation has about the average thickness, $108\frac{3}{8}$ feet of the total of $193\frac{1}{2}$ feet is limestone. The thickness of the whole formation ranges from 175 to 228 feet in this region and averages about 194 feet.

Subdivisions.—The formation is subdivided on lithologic grounds into the following nine members, in order from the base up: Hertha limestone, Ladore shale, Bethany Falls limestone, Galesburg shale, Winterset limestone, Cherryvale shale, Drum limestone, Chanute shale with Cement City and Raytown limestone beds, and Iola limestone. All these members are persistent and vary only slightly in detail from place to place. The following is a generalized section of the members that outcrop in the quadrangles:

Generalized section of Kansas City formation in Smithville quadrangle.

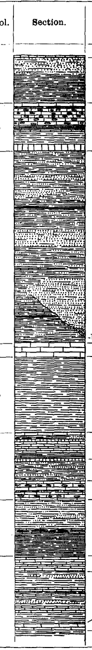
	Feet.
Iola limestone member:	
Limestone, gray, thin bedded	8–14
Shale, blue or gray	½–1
Limestone, even layer; contains fossil sponges	1
Chanute shale member:	
Shale, blue, argillaceous, calcareous at top in places	3–20
Limestone, thin bedded, has shaly partings; a coarse-grained crinoidal layer at base (Raytown bed)	3–4½
Shale, black, slaty where thin but containing dark clayey shale above slaty portion where thick	1–7
Limestone, even layer	½–1
Shale, blue or buff; contains a hard layer of micaceous sandstone in places	10–15
Limestone, gray (Cement City bed)	5–6
Shale, greenish	5–10
Drum limestone member:	
Limestone, gray, oolitic in places	6–8
Cherryvale shale member:	
Shale, blue	9+

The log of the Penitentiary coal shaft at Lansing (pp. 3–4) shows in detail the character of the formation in the Leavenworth quadrangle, where it lies below the surface.

Fossils.—The following invertebrates, collected from the Kansas City formation in the Smithville quadrangle, were identified by G. H. Girty:

Fusulina secalica?	Pustula nebraskensis.
Heliospongia ramosa.	Marginifera splendens.
Lophophyllum profundum.	Ambocoelia planiconvexa.
Conularia crustula?	Spiriferina kentuckyensis.
Cyclotrypa barberi.	Cliothyridina orbicularis.
Fenestella tenax.	Composita subtilita.
Crania modesta?.	Schizodus sp.
Chonetes verneuilianus.	Griffithides sp.
Productus semireticulatus.	

Correlation.—The Kansas City formation is the lower part of the Pottawatomie formation of the Kansas University Geological Survey and includes the upper part of the Coffeyville formation, the Drum formation, and the lower part of the Wilson formation of Schrader in southeastern Kansas. As the result of recent cooperative geologic work in Missouri by the authors it became apparent that the Pottawatomie formation is naturally divisible, both lithologically and paleontologically, into two units, the lower of which was named the Kansas City



System.	Series.	Formation.	Member.	Symbol.	Section.	Thickness in feet.	Character of rocks.	Character of topography. (Obscured in places by glacial drift.)
Carboniferous.	Pennsylvanian.	Shawnee.	Lecompton limestone.	Cs		2+	Buff limestone.	Caps small escarpment of Oread limestone in northwest corner of Leavenworth quadrangle.
			Kanwaka shale.			48	Shale, with sandy shale or sandstone at top and a thin limestone in lower half.	
		Douglas.	Oread limestone.	Cdo		30–60	Four beds of limestone separated by shale. The thick upper limestone contains chert nodules.	Forms, with the underlying shale, the highest escarpment in the region.
			Lawrence shale.	Cdl	Unconformity.	170–300	Over most of the area shale, chiefly drab and sandy, and thin beds of sandstone, limestone, and coal. In the south third of the quadrangles, where it is 300 feet or more thick in places, the lower half is chiefly sandstone and very sandy shale, and in these places it rests unconformably on the Weston shale member or the Stanton limestone member of the Lansing formation.	The thick sandstone at the base in the south third of the quadrangles forms a high upland belt.
			Iatan limestone.	Cdi		0–22	Limestone, gray, massive. Absent in places.	The Iatan and the Weston form an escarpment near Platte City and Camden Point.
			Weston shale.	Cdw		0–100	Shale, blue or drab, argillaceous; thickest at the north. Absent in places in the south third of the quadrangles.	
		Lansing.	Stanton limestone.	Cls		30	Three beds of limestone separated by shale.	Form an escarpment where sufficiently high above the valleys.
			Vilas shale.			20	Shale, blue, in places containing thin sandstone layers.	
			Plattsburg limestone.			20	Limestone, bluish gray, cherty; shaly in middle.	
			Lane shale.	Cll		60	Shale, argillaceous at base, sandy and with some sandstone in upper half. The Farley limestone bed in the middle is very irregular in thickness and lithologic character.	
		Kansas City.	Iola limestone.	Ckc		15	Limestone, gray, thin bedded.	The Iola limestone caps an escarpment in which the underlying limestones form steps or terraces.
			Chanute shale.			55	Shale, with Cement City and Raytown limestone beds.	
			Drum limestone.			7	Limestone, gray; oolitic in places.	
			Cherryvale shale.			9+	Shale, blue.	

FIGURE 5.—Generalized columnar section of the consolidated rocks exposed in the Leavenworth and Smithville quadrangles.

Scale: 1 inch=100 feet.

[1] Haworth, Erasmus, The stratigraphy of the Kansas Coal Measures: Kansas Univ. Quart., vol. 3, p. 274, 1895.

limestone and the upper the Lansing formation.[1] In a subsequent publication[2] the name of the lower unit was changed to Kansas City formation, and the reasons for its segregation and for the names applied to its members were fully explained. The other major and minor subdivisions of the Pennsylvanian series, as used in this folio, were similarly discussed in the same report.

LANSING FORMATION.

Distribution.—The Lansing formation has a wide surface distribution in the two quadrangles. It outcrops on most of Platte River drainage, on Bee Creek to Woodruff, and on the Missouri to points near Weston and Leavenworth. In other parts of the quadrangles it underlies the younger Pennsylvanian formations.

Character and thickness.—The formation is 120 to 146 feet thick, averaging about 130 feet. It lies conformably upon the Kansas City formation and consists chiefly of alternate beds of shale and limestone, the limestone being a few inches to 40 feet thick and comprising less than one-third of the whole. (See Pl. I.) The lower half is known as the Lane shale member and consists of argillaceous shale at the base and sandy shale and sandstone at the top, the whole being about 60 feet thick. Between the two phases, near the middle of this member, lies the Farley limestone bed of highly variable thickness and character.

The upper half of the Lansing formation contains thick beds of limestone and is subdivided into the Plattsburg limestone member at the base, the Vilas shale member in the middle, and the Stanton limestone member at the top. The Plattsburg limestone member is a blue or bluish-gray limestone in regular beds with a few thin partings of dark shale and scattered nodules of chert, the whole being 15 to 25 feet thick. (See Pl. I.) The Vilas shale member is a blue sandy micaceous shale with thin layers of sandstone in places. It is 4 to 24 feet thick, the most common thickness being 20 feet or more in most of the area but decreasing toward the southeast. The Stanton limestone member is about 30 feet thick and is composed of three beds of limestone separated by shale. The lower limestone is a dark, even-bedded rock 2 to 4 feet thick, locally called the "dimension rock;" the lower shale is about 5 feet thick and is in part black and slaty; the middle limestone layer is 10 to 16 feet thick, gray at the base to buff in the upper 3 to 5 feet, and thin bedded and is the ledge usually exposed in bluffs (Pl. IV); the upper shale is 2 to 20 feet thick, argillaceous where thin but sandy where thick; the upper limestone is a gray thin-bedded sandy fucoidal limestone, seldom seen in natural outcrops. Except the upper shale layer, which thickens notably to the southeast, each of these divisions is remarkably uniform over large areas.

Sections.—At Lansing, the type locality, the limestone bed at the top of the formation is 3 feet thick, and the shale which underlies it is 7 feet thick and includes a calcareous sandstone layer near its middle. The rest of the formation is shown in the log of the Penitentiary coal shaft at Lansing, in which the highest limestone stratum is the middle bed of the Stanton limestone member. The Farley limestone bed, which includes practically all the limestone in the Lane shale member, is exceptionally thick in this locality.

The railroad cuts near the Platte River bridge of the Kansas City, Clay County & St. Joseph Railway have furnished exposures in the upper half of the formation that differ somewhat in detail from the section at Lansing.

Section of upper half of Lansing formation 6 miles west of Smithville, Mo.

	Ft.	in.
Stanton limestone member:		
Limestone, gray; has thin shale parting near base	2	8
Shale, greenish and argillaceous at base, sandy above	6	8
Limestone, buff and argillaceous at top, gray and thin-bedded below; buff shaly partings	15	0
Shale, black and slaty in lower half, blue above	5	0
Limestone, blue, even bedded and in four or more layers	3	0
Vilas shale member:		
Shale, blue, sandy	4	6
Plattsburg limestone member:		
Limestone, banded gray, wavy laminae, weathering buff and sandy	1	4
Shale, buff; contains layers and nodules of limestone	8	7
Limestone, bluish gray; has three thin shale partings	12	10
Shale, blue-black at top; contains layers and nodules of limestone in lower half	2	4
Limestone, blue	4	4
	61	8

Owing to the exceptional development of the Farley limestone bed near Lansing, the section of the Lane shale member at that town is hardly typical for most of the quadrangles. The following section, measured in a road near Crows Creek (SE. ¼ sec. 30, T. 53 N., R. 32 W.), shows the normal phase of the member in this region. As the Plattsburg limestone rests upon the highest stratum of the section and the lowest stratum rests upon the Iola limestone, all the Lane shale is known to be represented.

[1] Hinds, Henry, Coal deposits of Missouri: Missouri Bur. Geology and Mines, 2d ser., vol. 11, p. 7, 1912.

[2] Hinds, Henry, and Greene, F. C., Stratigraphy of the Pennsylvanian series of Missouri: Missouri Bur. Geology and Mines, 2d ser., vol. 13, 1915.

Section of Lane shale member 3 miles southeast of Smithville, Mo.

	Ft.	in.
Plattsburg limestone.		
Shale, sandy; has 3 inches of limestone near top	21	3
Limestone, gray, massive; composed of comminuted fossils (Farley limestone bed)	2	0
Shale, argillaceous at base, sandy and with thin sandstone beds near top	36	0
Iola limestone.		
	59	3

Fossils.—Large collections of invertebrates were obtained from the Lansing formation in both quadrangles. The fauna is remarkably varied, including an unusual number of specimens and species from most of the larger zoologic groups. The following list, prepared by G. H. Girty, is not complete, but it shows to some extent the variety of the fauna and some of the more interesting and abundant species. In addition to the species listed, the fauna includes most of the common types of Pennsylvanian brachiopods.

Heliospongia ramosa.	Pseudomonotis kansasensis.
Lophophyllum profundum.	Myalina ampla.
Fistulipora carbonaria.	Myalina kansasensis.
Cyclotrypa barberi.	Myalina subquadrata.
Enteletes hemiplicatus.	Myalina swallowi.
Derbya bennetti.	Deltopecten occidentalis.
Derbya crassa.	Euphemus carbonarius.
Chonetes verneuilianus.	Bucanopsis meekana.
Productus insinuatus.	Bucanopsis bella.
Edmondia ovata.	Goniospira lasallensis.
Nucula anodontoides.	Metacoceras inconspicuum.
Leda arata.	Phillipsia major.
Monopteria gibbosa.	Bairdia beedei.
Pseudomonotis hawni.	

Correlation.—The Lansing formation corresponds to the upper part of the Pottawatomie formation of the Kansas University Geological Survey and the upper part of the Wilson formation of Schrader in southeastern Kansas. The reasons for its segregation as a formation unit have been mentioned in connection with the correlation of the Kansas City formation.

DOUGLAS FORMATION.

Distribution.—The Douglas formation outcrops over a large part of the Leavenworth quadrangle and in the northwest corner of the Smithville quadrangle. The thick sandstone bed that stretches across the southern third of both quadrangles is also a member of this formation. The Oread escarpment, along which all or most of the formation outcrops, stretches southwest from Leavenworth across Kansas and is one of the notable topographic features of the region.

Character and thickness.—The Douglas formation is 280 to 340 feet thick, averaging about 300 feet. It rests conformably upon the Lansing formation in most places. There is a local unconformity within the formation, however, and in places the oldest Douglas deposits and the top of the Stanton limestone member of the Lansing formation were removed, and beds of late Douglas age replaced them. In some places, therefore, there is a slight unconformity between the two formations.

The formation consists chiefly of shale but has at the top a persistent limestone member, thicker than most limestone beds in the Pennsylvanian series of this region, and in its lower part two limestone beds that are locally conspicuous; in part of the region it contains considerable sandstone. A few thin and rather impure coal beds are more or less regularly interbedded with other beds. The Douglas is subdivided, on lithologic grounds, into the Weston shale member at the base, the Iatan limestone member next above it, the Lawrence shale member above the Iatan, and the Oread limestone member at the top of the formation.

The Weston shale member is as a rule a bluish or drab argillaceous shale, containing ferruginous concretions composed of concentric shells that weather out on exposed surfaces. Its thickness is 55 to 100 feet but appears to increase consistently to the north, not being known to vary more than 10 feet in any square mile of the area.

The Iatan limestone member is a light-gray limestone, in many places filled with large brachiopod shells that are in part replaced by crystalline calcite. (See Pl. II.) In parts of weathered ledges these shells resist weathering and project beyond the matrix, giving the rock the appearance of a cemented "oyster bed"; in other parts the shells or the calcite replacing them goes into solution first, giving the rock a pitted appearance that has caused it to be confused with the limestone conglomerate at the base of the Lawrence shale member. The absence of well-developed bedding planes and the presence of vertical joints cause large blocks to slip down over steep slopes of the underlying shale wherever the Iatan forms an escarpment. At a few places blocks several acres in area appear to have been displaced in this manner. The thickness of the Iatan ranges from 5 to 22 feet, but the change is gradual from place to place.

The basal bed of the Lawrence shale member is 9 to 20 feet thick and resembles the Weston shale. Above this is a thin, more or less lenticular coal bed overlain by a few feet of calcareous shale and shaly limestone that is exceedingly fossiliferous. This is succeeded by thick argillaceous and sandy shale, containing one or two thin beds of limestone, one of which thickens to 22 feet near St. Joseph, where it is known as the Amazonia limestone bed. In a zone 25 to 80 feet below the top of the member one or more thin coal seams are interbedded with shale and shaly sandstone. Above this zone there is generally more or less sandstone and sandy shale to a horizon within 10 or 15 feet of the top of the member. A persistent bed of red clayey shale, grading to white or blue above, marks the upper boundary of the formation. Because of its position on the steep slopes of the Oread escarpment, the Lawrence is rarely well exposed, and the weathering out of the sand grains in the shale has led some observers to believe that it contains more sandstone than it does. The thickness of the Lawrence member, where the Iatan limestone is present, ranges from 170 to 210 feet.

The succession outlined above for the Douglas formation holds true in most but not in all parts of the quadrangles. South of Onemile Creek in Kansas and of latitude 39° 20′ in Missouri a thick deposit of sandstone and sandy shale appears in the lower part of the formation. In this southern area the lower part of the Lawrence shale, all the Iatan limestone, and all or part of the Weston shale were removed by erosion during late Douglas time, and the broad valley thus formed was filled before the deposition of the Oread limestone member with sediments that now form massive sandstones and sandy shales and that locally carry lenses of brecciated limestone near the base. This deposit is more than 100 feet thick in places. It forms part of the Lawrence shale member and is shown on the maps with the same symbol. At Tiffany Springs there are 100 feet of massive brownish-buff sandstone, though ordinarily the massive phase is thinner and sandy shale is intercalated with the sandstone. These beds rest on different parts of the Weston shale in most of the Kansas area and on the thickest ledge of the Stanton limestone in most of the Missouri area. (See Pls. III, IV, and V.) The brecciated limestone consists of small subangular fragments of reddish-buff limestone and shale, a few clay balls, and fragments of fossils, the whole being embedded in a calcareous matrix, 8 feet or less thick, and interbedded with sandstone in places. Limestone of this type outcrops 29 feet above the Stanton limestone near the Santa Fe depot at Leavenworth, 58 feet above the Stanton at the Soldiers' Home, and 15 feet above it near East Leavenworth. The same deposit lies on the Stanton near Lansing, at East Leavenworth, and 2 miles southeast of Nashua. In places there are large concretions of firmly cemented, white calcareous sandstone at the base of the massive buff sandstone. (See Pl. III.)

At the top of the formation is the Oread limestone member, 30 to 60 feet thick. It closely resembles, lithologically, the three upper members of the Lansing formation and has also been confused with the Stanton limestone member. The lowest bed of the Oread member is a blue limestone, 3 to 10 feet thick, that weathers buff or gray. Just above it is a bluish shale ranging in thickness from 7 to 16 feet and underlying a dark, even-bedded limestone that is in two or three layers and about 2 feet thick. (See Pl. VI.) The shale above this limestone is black and slaty in the lower part and bluish above and is 5 to 16 feet thick. The highest bed seen in most exposures of the Oread is a bluish-gray, cherty limestone in layers 3 to 12 inches thick that are separated along wavy bedding planes by buff and shaly material. This limestone is 10 to 35 feet thick and is the "main ledge" of quarrying operations. Above the "main ledge" and separated from it by a few inches to 3 feet of blue shale is the "Waverly flagging," a bed that has a maximum thickness of 4 feet in this region and is a gray, cross-bedded limestone with a splintery fracture and thin interbedded layers of "cone-in-cone." The "Waverly flagging" outcrops in few places and was probably largely removed by preglacial erosion. The lowest limestone of the Oread also is generally concealed, but the "main ledge" is conspicuous and has had a marked effect upon the topography of the region.

Sections.—The following section was measured on the bluffs northwest of Weston:

Section of Douglas formation 3½ miles northwest of Weston, Mo.

	Ft.	in.
Oread limestone member:		
Limestone, gray, weathering buff, cherty, shaly; has wavy partings ("main ledge")	10	0
Concealed	22	0
Limestone, buff, in one bed	5	6
Lawrence shale member:		
Concealed; probably shale	17	6
Shale, red at top, sandy in greater part	44	0
Concealed; fragments of shale and sandstone	94	0
Limestone, sandy, with 1 inch of shale at base		5
Coal, rather shaly	1	2
Shale	13	6
Iatan limestone member:		
Limestone, gray	15	0
Weston shale member:		
Chiefly shale (base not reached)	40	0
	268	1

The following nearly complete measurement of the formation was obtained in the Fort Leavenworth Military Reservation. The Oread limestone member was measured at the United States Military Prison quarry on the north end of Hancock Hill, the Lawrence shale and Iatan limestone at the prison stockade half a mile south of Wade, and the Weston shale at the Fort Leavenworth railroad station.

Section of Douglas formation in Fort Leavenworth Military Reservation, Kans.

	Ft.	in.
Oread limestone member:		
Limestone, light-gray, cherty, irregularly bedded at top, yellowish impure layer at base ("main ledge")	8	10
Shale, blue	2	0
Concealed	23	0
Limestone, dark brown to drab	3	0
Lawrence shale member:		
Interval, chiefly shale; including allowance made for dip	154	0
Shale, dark blue, plastic	3	0
Limestone, in part crystalline, in part subcrystalline and impure	1	5
Shale, indurated, calcareous bands near top	11	0
Coal		7
Shale, blue, slightly sandy	18	0
Iatan limestone member:		
Limestone, light gray, very fossiliferous and much crystalline calcite associated with the fossils	12	0
Weston shale member:		
Shale, drab and light blue, only slightly sandy	35	0
Concealed; probably shale, to top of Lansing formation	27	0
	298	10

Nearly complete measurements of the formation where the Iatan member has been removed were obtained by combining outcrops from Leavenworth west to the Oread escarpment, allowance being made for the dip. In the following section the strata down to and including the 107-foot red and buff sandstone were measured near the northeast corner of sec. 33, west of the city, the next lower stratum was measured in the NW. ¼ sec. 34, and the rest of the section a short distance west of the Santa Fe station at Leavenworth. The lower part of the Lawrence shale is highly variable lithologically near the city, and the base of the member lies at various distances from the base of the Douglas formation.

Generalized section of Douglas formation west of Leavenworth, Kans.

	Ft.	in.
Oread limestone member:		
Limestone, light gray, cherty at top, mostly irregularly bedded ("main ledge")	10	0
Shale, drab at top, black and slaty at base	6	0
Limestone, blue, even bedded, compact ("dimension rock")	1	10
Concealed; probably shale	10	0
Limestone, buff, impure	3	0
Lawrence shale member:		
Shale, argillaceous	12	
Sandstone, gray, calcareous, thin bedded	3	0
Shale, drab, slightly sandy	18	0
Coal, dirty		5
Shale, bluish drab, argillaceous	3	0
Sandstone, buff, argillaceous, very thin bedded	7	0
Shale, drab, sandy at top and bottom	73	0
Sandstone, red and buff, massive at top and bottom, alternating with buff sandy shale in greater part	107	0
Limestone, reddish buff, brecciated, ferruginous, fossiliferous, irregularly bedded with sandstone and grading into sandstone above and below	1–6	0
Sandstone, red, thick bedded	4	0
Weston shale member:		
Shale, dark blue, argillaceous, to top of Lansing formation	25	0
	286	3

Fossils.—The Douglas formation is perhaps the richest faunally in the quadrangles. The collections are numerous and include many species. The list below, prepared by G. H. Girty, is intended to show their variety and some of the more abundant or more interesting types. Many species have been omitted, and the fauna includes, besides those listed, all of the common Pennsylvanian brachiopods. The Douglas fauna closely resembles the Lansing fauna which preceded it and shows the same rich variety of forms. Among the types not yet obtained from the Lansing may be mentioned *Chonetes geinitzianus*, which is abundant, *Tegulifera*, *Bellerophon stevensianus*, *Orestes intertextus*, and *Trepospira sphaerulata*.

Fusulina secalica.	Modiola subelliptica.
Lophophyllum profundum.	Allerisma terminale.
Hydreionocrinus acanthophorus.	Astartella concentrica.
Hydreionocrinus mucrospina.	Bellerophon stevensianus.
Fistulipora carbonaria.	Patellostium montfortianum.
Fistulipora zonata.	Euphemus carbonarius.
Cyclotrypa barberi.	Bucanopsis meekana.
Liopora subnodosa.	Pharkidonotus percarinatus var. tricarinatus.
Enteletes hemiplicatus.	Goniospira lasallensis.
Derbya bennetti.	Phanerotrema grayvillense.
Derbya broadheadi.	Orestes intertextus.
Chonetes geinitzianus.	Trepospira sphaerulata.
Tegulifera kansasensis.	Schizostoma catilloides.
Nucula anodontoides.	Aclisina quadricarinata.
Nuculopsis ventricosa.	Pseudorthoceras knoxense.
Leda arata.	Bairdia beedei.
Monopteria marian.	
Myalina subquadrata.	

Correlation.—The Douglas formation is the equivalent of the "Buxton formation" and the Oread ("Painterhood") limestone of southeastern Kansas, the "Buxton" including the Weston, Iatan, and Lawrence members of the Douglas. The term Douglas has been in use as a Kansas formation name for a long time, but the names applied to the members differ from those most recently employed by the Kansas University Geological Survey.

SHAWNEE FORMATION.

General character.—The Shawnee formation occupies only a very mall area in the Leavenworth quadrangle, having been identified in less than a square mile in the extreme northwest corner. Only the lower portion of the formation remains, the rest having been eroded prior to glaciation. It is probable, however, that patches of the lower part of the formation are concealed beneath glacial drift in a few other places above the Oread escarpment. That part of the formation represented in the quadrangles is shown in the following section, obtained in the hills northwest of Iatan:

Section of lower part of Shawnee formation northwest of Iatan, Mo.

	Ft.	in.
Lecompton limestone member:		
Limestone, buff	2+	
Kanwaka shale member:		
Sandstone and shale, former at top	30	0
Limestone, blue, shaly, ferruginous; weathers buff		6
Shale, poorly exposed	18	0
Douglas formation.		
	50	6

The Shawnee formation is conformable on the underlying Douglas formation. The name Shawnee is that of a county in Kansas a few miles southwest of Leavenworth and has been in use for years. The sandstone in the Kanwaka shale member is the equivalent of the Elgin sandstone of reports on southeastern Kansas.

Fossils.—The following fossils were obtained from the Shawnee in this area and were identified by G. H. Girty:

Fusulina secalica.	Fenestella tenax.
Fusulina sp.	Rhipidomella pecosi.
Lophophyllum sp.	Chonetes granulifer.
Monilipora prosseri?	Marginifera wabashensis.
Fistulipora zonata.	Spirifer cameratus.
Tabulipora distans?	Composita subtilita.

QUATERNARY SYSTEM.

The deposits of Quaternary age comprise bowlder clay and loess, with associated beds of sand and gravel, of Pleistocene age, and alluvial deposits and rain wash of Recent age. They form a blanket covering nearly the whole surface of the quadrangles and nearly everywhere at least partly concealing the underlying indurated strata.

PLEISTOCENE SERIES.

AFTONIAN (?) GRAVEL AND SAND.

Deposits of bowlders, gravel, and sand, found at a number of places in the Leavenworth and Smithville quadrangles east of Missouri River, have been mapped as probably Aftonian. They outcrop in the hills south of Weston, at several places on Murray Branch west of Settles station, in the cuts for the Kansas City, Clay County & St. Joseph Railway 2 miles northwest of Hoover, at the mouth of Crow Creek northeast of Smithville, and east of the Smithville quadrangle on the north side of Camp Branch. (See Pl. VII.) Their distribution and altitude suggest that they were deposited in the bed of an eastward-flowing stream and of one or more of its tributaries. Similar deposits have been found in wells at a few other places in the quadrangles notably 1½ miles east of Trimble. These deposits are apparently related and are tentatively regarded as Aftonian.

No two detailed sections of these deposits are exactly alike, but all resemble one another in character and general relations. The section on the bluff near Weston is as follows:

Section of Pleistocene deposits at Weston, Mo.

	Feet.
Loess, at top of bluff	(?)
Gravel, waterworn and water-laid, with layers of fine gravel and sand; contains many foreign pebbles	4–6
Kansan stage:	
Clay, blue, containing angular bowlders of local limestone—some of them 3 feet in diameter—and many bowlders and pebbles of foreign material	3–4
Aftonian (?) stage:	
Bowlders and gravel and a few thin layers of sand; the bowlders are well rounded, average about 6 inches in diameter, and show no difference in size at different levels; about 70 per cent of them are limestone and are derived chiefly from the Oread escarpment; a few scattered bowlders are of foreign origin and are so thoroughly weathered as to crumble at the touch; the deposit is cemented and in places overhangs, with an especially firm layer at the top; at the base it has a layer of yellow sand a few inches thick	8–10
Pennsylvanian series.	

The supposed Aftonian is not exposed between Weston and the vicinity of Murray Branch, but the absence of outcrops of the Iatan limestone and the uppermost part of the Weston shale in a belt extending from Bee Creek east to Quinn School indicates the probable course of the stream in which the gravel and bowlder bed was deposited. The bed outcrops in a number of places near Murray Branch, but the thickest exposure is in the road north of the creek near the center of sec. 13, T. 53 N., R. 35 W., where there is 35 feet of material like that in the bed of supposed Aftonian at Weston. The Aftonian (?) here rests on the lower 5 feet of the Weston shale. The altitude of its base is 846 feet.

In the railroad cuts northwest of Hoover several beds of bowlders and associated gravel and sand outcrop in what was probably a small tributary of the main stream. Where the road crosses the line between secs. 22 and 27 a bowlder bed 8 feet thick, closely resembling that at Weston, rests on the top of the main ledge of the Stanton limestone at an altitude of about 835 feet. The top of the bowlder bed slopes south and is flanked on the south by a bed of gravel, composed chiefly of firmly cemented foreign pebbles. The beds of the conglomerate dip south, parallel with the upper surface of the bowlder bed. The whole is overlain by drift bowlders. The next cut to the south shows 7 to 10 feet of stratified sand, orange and yellow and with some black bands, resting on the main ledge of the Stanton limestone at the same altitude as that of the gravel in the first cut. Shale outcrops in the northern part of the next cut to the south but is flanked on the south by a bed of partly cemented gravel that resembles that flanking the bowlder bed in the northern cut. Here, also, the beds dip south. The best exposure of the gravel seen in the region is that east of Smithville, near the mouth of Crow Creek, where the following section was measured:

Section of Pleistocene deposits at mouth of Crow Creek.

	Feet.
Kansan stage:	
Clay, lower 2 feet sandy, has few pebbles, and is reddish-brown; the rest is typical blue, red, and drab bowlder clay	25
Aftonian (?) stage:	
Sand, yellow, very fine and powdery; has a few indurated streaks and a 2-inch layer of blue clay 8 inches above base	15
Sandstone, yellow, coarse to fine grained, slightly wavy, in one or two layers about 2 inches thick. Where two layers are present, they are separated by 10 inches or less of yellow sandy clay	½
Sand, mainly reddish brown; has some black streaks and a 2-inch layer of fine white sand. The sand is coarse as a rule and contains some pebbles; cemented in a few places	3
Gravel; contains many chert pebbles and much sand	3
Bowlders, rounded, mostly local limestone but a few are deeply weathered foreign bowlders; the maximum diameter is a foot, but the average is probably less than 6 inches. This stratum forms an overhanging cliff	8
	54½

In one place the half-inch sandstone layer and the beds below form a trough about a foot deep (see Pl. VIII), suggesting crumpling that might possibly have been caused by an overriding ice sheet.

The easternmost outcrop of probable Aftonian bowlders and gravel is in a road half a mile north of Camp Branch, in the eastern part of sec. 9, T. 53 N., R. 32 W., but the exposure is poor and no details were observable.

Beds of possibly the same age as the bowlder deposits outcrop 1½ miles east of Trimble, where Little Platte River crosses a pre-Kansan channel. The following section was measured up the west bank of the stream, where it crosses the line between secs. 19 and 20:

Section of Pleistocene deposits 1½ miles east of Trimble, Mo.

	Feet.
Soil, ash-gray; contains no pebbles; sharply defined from the bed below	1
Kansan stage:	
Clay, brown, crumbly, contains no pebbles	1½
Clay, gray; contains few pebbles	5
Bowlder clay, yellow	3
Aftonian (?) stage:	
Sand, yellow, and brown clay, stratified; contains many small pebbles	5
Clay, like next lower stratum but banded entire length of bank, nearly 100 yards; contains fine gray or yellow sand with deep orange or reddish iron-stained blotches; layers of sand half an inch to 6 inches thick and very regular	21
Clay, gray mottled with yellow, sandy; contains flakes, pipes, and concretions of limonite and some foreign pebbles	14
	50½

There is no paleontologic evidence to establish the age of the supposed Aftonian deposits, but the fact that they invariably lie at the very base of drift believed to be of Kansan age and in fairly low topographic positions shows that they are at least older than the main body of this drift. The coarseness of the constituents and the abundance of limestones similar to those outcropping in the vicinity indicate that the material was transported in rapidly moving water for only comparatively short distances, and the presence of some pebbles of igneous rock of northern derivation means that the streams had access to glacial débris. These facts alone might be taken to show that these deposits were laid down in waters pouring from the front of the advancing Kansan ice sheet, and such may be their origin. But the igneous rocks are so thoroughly decomposed that they were probably derived from a drift sheet older than the Kansan, and the quartzite pebbles that are so characteristic of the Kansan are very rare. The general characteristics, moreover, are much the same as those of certain outcrops in Atchison County, Mo., that contain remains of animals that lived in a warm climate. These facts have led to the tentative suggestion that the deposits just described are of Aftonian age.

KANSAN DRIFT.

Distribution and thickness.—Overlying the Aftonian (?) gravels and extending throughout nearly the whole area there is a deposit of glacial drift which is believed to have been laid down during the Kansan stage of glaciation. A covering of drift was left by the glacier over the entire region but is nearly everywhere concealed by the omnipresent mantle of loess. In some places, especially west of the Missouri, much of the drift has been removed by post-Kansan erosion, but a large part of it still remains on the uplands and in the smaller valleys. Only a few outcrops of till were found along the bluffs of Missouri River, though foreign bowlders are not uncommon.

The drift is thickest where the present divides coincide with preglacial valleys, as in the northeast corner of the Smithville quadrangle, where it is at least 130 feet thick. Elsewhere on the uplands of the Smithville quadrangle it is 40 to 100 feet thick, but it decreases westward and is more than 40 feet thick in few places west of Missouri River. An exceptional thickness was noted 3 miles north of Platte City, where drift appears in place along a road from the top of a mound to the outcrop of the Iatan limestone member, a vertical distance of 120 feet. In the present valleys drift is thin or absent, except in the vicinity of preglacial valleys.

Till.—By far the greater part of the drift is typical till composed of ash-blue joint clay that weathers yellow and contains irregularly distributed pebbles and bowlders. Most of the pebbles and bowlders are angular and consist of limestone and other sedimentary rocks, obviously derived from strata like those outcropping in the region, and igneous and metamorphic rocks that must have been transported hundreds of miles from northern ledges. The most conspicuous and abundant type among these rocks is a red, brown, and variegated quartzite of the kind that outcrops in the vicinity of Sioux Falls, S. Dak. The largest bowlder seen is 9 feet in greatest diameter. The till also contains much concretionary calcareous material in large irregular masses and in smaller nodules arranged along the joints. On drying the clay divides into small angular polyhedrons separated by narrow cracks.

Sand and gravel.—Part of the drift consists of gravel and sand beds—the gravel predominating. These beds and the many isolated bowlders are the coarser components of the till that were left by the erosive agents that carried away much of the finer clay and sand. Their principal constituents are Sioux quartzite, chert, and other notably resistant rocks. The beds are thickest just above and near parts of escarpments that are capped chiefly by the Stanton limestone member in the Smithville quadrangle and by the Iatan member in the Leavenworth. These resistant limestones seem to have acted much like riffles in hydraulic mining. West of Woodruff, above the Iatan escarpment, the gravel beds attain a thickness of 35 feet.

Other beds of gravel and small bowlders lie at the top of the drift on the uplands. They are not more than 6 to 12 inches thick and seem to be confined to places where the Loveland (?) clay and bluish-gray loess are absent and the yellow loess rests directly on typical drift. It is possible that these beds were formed by the removal of the finer material by the wind, much as the "desert pavements" of arid regions are formed.

Loveland (?) clay.—A part of the drift consisting of reddish and whitish clay containing few or no pebbles is found in many places on the uplands where the drift is thick and only at the top of till that is overlain by loess. Such pebbles as are present are very small and of resistant rock. A thickness of 20 feet was observed near Nashua, Mo. (NW. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 26, T. 52 N., R. 33 W.), but this is probably not the maximum. These deposits correspond in every way with the Loveland clay, as described by Shimek,[1] and are tentatively correlated with it. They are probably still-water deposits formed in depressions on the surface of the till.

LOESS.

General features.—The formation having the greatest areal distribution in the quadrangles is the loess, a sandy clay which differs in texture and properties from the other clays of the region. It is spread like a blanket over the entire area of the quadrangles except the flood plains and the bare rock ledges. It is thicker and more sandy on the bluffs of Missouri River than elsewhere, and is thicker on the eastern than on the western bluffs of the river. West of the river it thins notably and is not at all conspicuous above the Oread escarpment; east of the river it thins considerably for 4 or 5 miles and then more gradually to the boundaries of the quadrangles. There are two distinct phases of the loess, the lower thin and bluish gray and the upper thick and yellow or buff-colored.

Bluish-gray loess.—The lower loess appears to be absent from many places near the larger streams but is generally present on the uplands. It is a bluish-gray clay mottled with orange or brown ferruginous stains and contains much fine sand and many vertical brown limonite pipes several inches long and as much as an inch in diameter that were probably formed in concentric layers around plant roots. The greatest observed thickness of this part of the loess is 6 feet, but it is not improbable that it reaches 10 feet in places. At the top it is commonly sharply separated by a thin ferruginous layer or a limonite band from the overlying yellow loess, but at the bottom it grades more or less completely into the Loveland (?) clay, where this is present. Only where the Loveland (?) is absent is its lower boundary fairly clear.

[1] Shimek, B., Geology of Harrison and Monona counties [Iowa]: Iowa Geol. Survey, vol. 20, pp. 371-375, 1910.

The bluish-gray loess seems to be the same as that termed post-Kansan loess by Shimek.[2] In these quadrangles it seems to contain no fossils nor other decisive evidence of age, but its stratigraphic relations, distribution, thinness, and weathered surfaces are strongly indicative of a comparatively old age.

Yellow loess.—Overlying the bluish-gray loess or, where that is absent, resting on Loveland (?) clay, Kansan drift, or Pennsylvanian rocks, is the yellow or buff loess, the most conspicuous surface deposit in most of the region. As it is younger than all other sediments except the alluvium and lies like a mantle over practically the whole area, it is in contact with all older sediments, being separated from the drift in places by a thin gravel zone and from the bluish-gray loess by thin ferruginous bands. Only the thicker deposits are shown on the map by a distinct symbol, much of the thinner loess being mapped with the Kansan drift and that covering Pennsylvanian rocks on valley sides not being represented at all.

This loess is a light-yellow or buff sandy clay, sufficiently coherent to stand in vertical faces in road, stream, and railway cuts. It contains calcareous white or cream-colored concretions a foot or less in diameter, the larger ones being hollow, with cracks radiating from the cavity into the walls. In places the vertical faces of the yellow loess show well-developed columnar jointing due to shrinkage, and a few exposures show indistinct banding along lines that are apparently parallel to the surface upon which the loess was deposited. (See Pl. X.) On steep slopes the jointing causes the loess to slip downward, or at least facilitates the process, giving hillsides a stepped or terraced appearance.

The thickness of the yellow loess varies with its distance from the Missouri River bluffs, being thickest on the bluffs themselves, and thicker on the east than on the west side of the river. In places east of the river it is thin or wanting on the western slopes of hills and 10 or 15 feet thick on the eastern slopes, and even where farthest from the river is at least 4 or 5 feet thick. The thickness on the bluffs east of the river, estimated along lines perpendicular to the surfaces on which the loess rests, ranges from a thin film to probably 80 feet, the maximum being on the hilltops. On the western bluffs, the maximum is probably not more than 40 feet.

Origin.—At one time there was much diversity of opinion among geologists as to the origin of the loess, some contending that it was deposited by winds and others that it was formed by great floods resulting from the melting of glacial ice. Unanimity of opinion has not yet been reached, though many observers are now agreed that the loess is chiefly a wind deposit and that water has played only a very subordinate part, if any, in its last transportation and deposition. These writers believe that it requires a wide stretch of the imagination to conceive of conditions under which the yellow loess in these quadrangles could have been laid down in water, whereas there are many cogent reasons for believing that practically all of it was deposited by winds. Moreover, the distribution and the differences in coarseness in different parts of the region lead inevitably to the conclusion that at least a large part of the yellow loess has a direct connection with Missouri River and was blown up from its bars and alluvial plains by westerly winds. The amount of silt available for distribution is almost unlimited, as the sediment-laden Missouri quickly replaces any material taken from its shores.

Another problem about which there is much difference of opinion is the age of the yellow loess. It overlies the Kansan drift and is therefore later than Kansan. Its presence in considerable quantity low down on valley slopes, much of it in situations to which it was evidently blown, shows that at least part of it was carried to its present position after most of the present stream dissection had been accomplished. The upland loess may, of course, have been deposited at an earlier date. From evidence derived principally from localities in eastern Iowa it is believed that most of the loess, at least in that region, was formed subsequent to the post-Kansan glacial stage commonly known as the Illinoian and before the advent of the last or Wisconsin glacier. There are, however, deposits of loess of several different ages, and even now loess is being deposited in favorable localities. It has been suggested that the dust storms that now often sweep over the Missouri River flats result in the accumulation of loess near the river. The determination of the time when the deposition of the loess ceased in this region, or whether it has ceased, awaits further study.

Fossils.—The loess is fossiliferous in many places, especially near Missouri River, being rich in snails and other mollusks that Shimek has shown[3] to be largely land forms that probably lived in a climate very similar to that of the present. The following were collected at Weston and identified by W. H. Dall:

Succinea lineata.	Pyramidula cronkhitei.
Pupoides procera.	Pyramidula alternata.
Bifideria armifera.	Zonitoides arboreus.

[2] Idem, pp. 376-386.
[3] Idem, pp. 395-399, 404-405.

RECENT SERIES.

TERRACE DEPOSITS AND WASH.

In some abandoned meanders along Platte River and the Little Platte there are terrace gravels covered at the surface by deposits whose origin is probably to be referred largely to rainwash. The principal areas of terrace and wash deposits of this character are shown on the geologic map of the Smithville quadrangle. They are probably composed of coarser material than the neighboring alluvium, but as there are no well records nor exposures that give the requisite information their character and depth are not known. Other colluvial or wash deposits occur throughout the area, particularly at the bases of valley slopes, but their areal extent is small and their boundaries indefinite.

ALLUVIUM.

Most of the larger streams have flood plains built up by the deposition of silt and fine sand during flood stages. This alluvium is of two more or less distinct types, one in the wide bottom lands of Missouri River and the other along smaller streams. Both have been well described in the report on the soil survey of Platte County,[4] as follows:

The alluvial soils of the area come from two principal sources. The first is wash from the loess mixed to a very small extent with wash from the residual soils and deposited in the flood plains of all the smaller streams. Soils formed from this material belong to the Wabash series. When the alluvial soils come so directly from the loess as they do in this area they often differ from the upland loess but little in color, texture, or crop value. In places, however, the sandier material has been sorted out and deposited, usually near the stream channel, while in other places the clays and silt have been deposited, thus forming heavy soils, which have often become more intractable and apparently heavier on account of lack of drainage.

Alluvial soils of the second class are found in the flood plain of the Missouri River and have been formed from material brought down and deposited by that stream. Like the Wabash soils, they vary in texture from very light, fine sand to heavy clay. Their principal distinguishing characteristic is the sandy or light silty character of the subsoil underlying the heavier surface soils. These soils belong to the Sarpy series. Near the bluffs bordering the Missouri River flood plain, and especially where small streams enter it, considerable areas are covered by soils which are a mixture of the Wabash and Sarpy series. The Wabash characteristics usually predominate at the surface near the stream channel, while the Sarpy characteristics are found in the subsoil. Farther from the streams the two materials are more thoroughly mixed.

The difference between the two types is probably due to the fact that the alluvium of any stream is derived from material washed from the surface of its drainage basin and that only a comparatively small part of the Missouri basin is coated with loess, whereas the basins of small streams in these quadrangles are almost entirely covered by it. Under the loess-derived part of the alluvium along many of the larger creeks there are slabs of limestone and flattened pebbles. In the smaller creeks and branches there is usually a stiff blue gravel-bearing clay that once formed the stream bed.

The alluvium in all the valleys except that of the Missouri lies in one or more benches, the lowest forming the stream banks, which at one place are as much as 27 feet high. In many places on the large streams there are two to four of these benches and in the hollows there are even more—all composed of the rewashed loesslike material.

Borings in the valley of Missouri River commonly penetrate a considerable thickness of valley filling. At St. Joseph bedrock was found at a depth of 53.4 feet in a boring that started at water level. In South St. Joseph a number of wells have been drilled to a depth of 80 feet before striking rock; and at Atchison and Leavenworth borings 57 feet deep failed to reach the bottom of the alluvium. (See fig. 6.) At Quindaro,

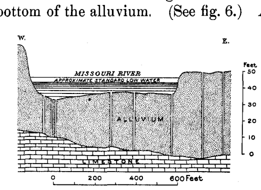


FIGURE 6.—Cross section showing thickness of alluvium deposited by Missouri River at Leavenworth, as determined by borings. After Missouri River Commission.

Kans., bedrock lies at a depth of 100 feet and near Randolph, Mo., at 107 feet.[5] It is probable that bedrock is about 100 feet below the general level of the flood plain in the Leavenworth quadrangle. The flood-plain deposits grade in general from coarse material at the bottom to finer sand and silt at the top, though coarse sand and bowlders are found in the present river channel in dredging operations.

[4] Sweet, A. T., Dunn, J. E., and Vanatta, E. S., Soil survey of Platte County, Mo.: U. S. Dept. Agr. Bur. Soils Field Operations, 1911, Advance sheets, p. 17.
[5] The authority for most of the data is Bingham, Capt. T. A., Report on borings in the Missouri River valley: Chief Eng. U. S. Army Rept. for 1890, pt. 4, appendix 20, pp. 3375-3390, 1891.

The Missouri received the drainage of the part of the last, or Wisconsin, ice sheet that occupied northwestern Iowa, southwestern Minnesota, the Dakotas, and Montana, and also the waters from numerous Rocky Mountain glaciers of the same age, so that it probably brought down great quantities of sediment during and following that ice invasion. It is probable that the deeper valley filling accumulated at that time, though the upper part is probably recent, as the stream now seems to be aggrading. Most very large rivers flow over considerable valley-filling alluvium, however, because at a certain stage in ordinary drainage development the tributaries carry more sediment than the main stream is able to transport.

STRUCTURE.

STRUCTURE CONTOURS.

Delineation.—For the delineation of structure by means of contours an easily recognizable reference stratum, whose position can be determined at many points by means of outcrops or borings, is chosen. The altitude and dip of its surface are determined at as many points as possible, and points of equal altitude are connected by lines on the map just as topographic contour lines are drawn. In some places the altitude of the reference stratum is observed directly in outcrops, mines, or wells, and in other places it is calculated from observations on some other recognizable stratum, for generally the layers of stratified rock are approximately parallel and the average interval between any two may be determined. Thus, if a stratum above the reference layer is found, its altitude above sea level at the point of discovery may be determined and the altitude of the reference stratum or key rock at that point may be calculated by subtracting from the altitude of the stratum discovered the average distance (or the nearest measured distance) between the two. If the outcrop of a bed below the reference stratum is found the average distance is added, thus giving the approximate altitude at which the reference layer would lie if it were present.

Use.—On the geologic maps of the Leavenworth and Smithville quadrangles structure contours are drawn at vertical intervals of 20 feet on the base of the Plattsburg limestone member of the Lansing formation as a key stratum. In order to determine the depth from the surface to the base of this limestone at any point crossed by a structure contour it is only necessary to subtract the altitude shown by the structure contour from the surface altitude shown by the brown surface contours on the topographic base. Between structure contours the altitude of the limestone is intermediate between that shown by the contours on each side. Similarly the depth or altitude of any other stratum may be determined by adding or subtracting the vertical interval between the limestone and that stratum, this interval being taken from the stratigraphic sections and the discussions accompanying them.

In addition to showing the depth and altitude of any stratum structure contours necessarily delineate the main features of the structure and the direction and steepness of the dip in each locality. The dip in feet per mile can be read directly from the map; the dip in degrees can be calculated but is generally so small in this region as to be of no practical value. Undulations of less amplitude than the contour interval can not be shown.

Accuracy.—Errors in delineating structure may arise from inaccurate determination of the altitudes of outcrops, shafts, and borings, from insufficient data, and from irregularities in stratigraphic intervals.

On the topographic maps of the Leavenworth and Smithville quadrangles the interval of the surface contours is 20 feet, and bench marks are numerous. With the aid of these maps it is possible to carry hand-level lines from points of known altitude to most of those whose altitude is desired, and errors arising from inaccurate determination of altitudes are so small as to be of minor importance.

Where there are few outcrops of indurated strata and few wells, borings, or shafts that have penetrated beds whose stratigraphic horizon is known, it is obviously impossible to delineate the structure accurately. However, outcrops are numerous in all parts of both quadrangles, except in the Missouri River bottom lands, and some information from wells and shafts is available, so that data of this character may be considered ample.

The most likely source of error in this region is variation in the stratigraphic section. Except in districts in which the Plattsburg limestone outcrops or has been reached by borings or shafts its altitude is estimated from that of strata outcropping either above or below it, this estimation being based on the stratigraphic intervals determined in localities as nearly adjacent as possible. In most parts of the quadrangles outcropping strata are not separated from the Plattsburg by long or variable stratigraphic intervals, and consequently few errors are apt to be made. Where the only outcropping rocks belong in the upper part of the Lawrence shale member or in higher stratigraphic units, however, the contours may be 20 to 50 feet in error, for the thickness of the Douglas formation is rather irregular.

STRUCTURE OF THE LEAVENWORTH AND SMITHVILLE QUADRANGLES.

The dominant structural feature of the quadrangles is a gentle dip of about 12 feet per mile in a direction slightly north of west, modified by a series of very low anticlines and shallow synclines, whose axes trend northwest and southeast. (See fig. 7.) Dips are so slight in most of the region that they can be detected only by comparing altitudes of strata at points more or less widely separated, but in a few very small areas of more marked disturbance they range from a few degrees to as much as 20°.

The anticlines—arches along which strata are relatively higher than on either side—are low and irregular; most of them are short, and their axial lines, if projected, would pass into territory without special structure, or even into synclinal areas. A well-defined anticline crosses the northern part of the Smithville quadrangle from Camp Branch northwest to the Chicago, Rock Island & Pacific Railway west of Swamp School, where it dies out. Another anticline extends from Smithville north of west to Settles station and thence northwest to the Platte Valley School, plunging to the northwest and dying out near the bluffs east of the Missouri. Shorter anticlines lie 2 miles south of Smithville, southeast of Nashua, and south of Platte City. Broad, shallow synclines commonly separate anticlinal areas, but few of them are strong. The sharp, narrow synclines at East Leavenworth and southeast of Farley are probably associated with faulting.

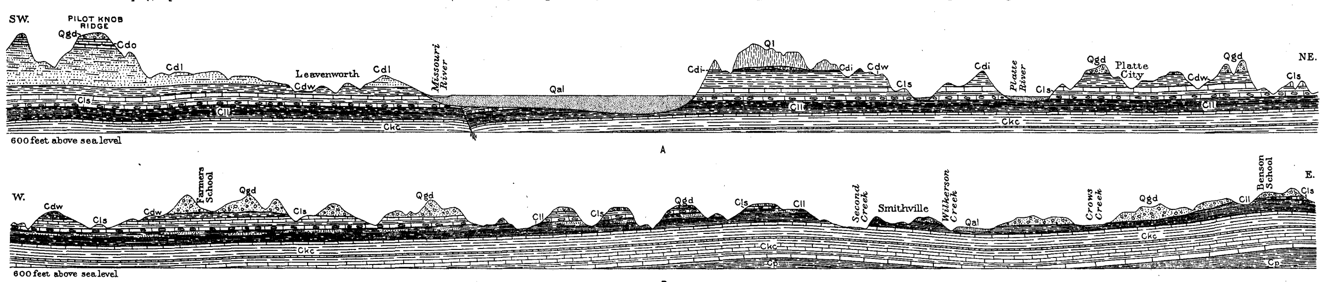


FIGURE 7.—A, Structure section across the Leavenworth quadrangle, passing northeast through Leavenworth and Platte City. B, Structure section across the Smithville quadrangle, passing through Smithville.

Qal, Alluvium. Ql, Loess. Qgd, Glacial drift. Cdo, Oread limestone; Cdl, Lawrence shale; Cdi, Iatan limestone; and Cdw, Weston shale. (The last four are members of the Douglas formation.) Cls, Lansing formation above the Lane shale member. Cll, Lane shale member of the Lansing formation. Ckc, Kansas City formation. Cp, Pleasanton formation. Horizontal scale same as that of geologic maps, approximately 1 inch equals 1 mile; vertical scale 10 times the horizontal.

The general westerly dip is interrupted in several structural terraces where the strata lie nearly flat. One notable terrace includes a large area in the southwestern and south-central parts of the Smithville quadrangle, and a smaller one embraces the territory south and southwest of Leavenworth.

Abnormally steep and irregular dips, probably closely associated with faults that are not well exposed, were noted in several small areas. The greatest disturbance is 2 miles southeast of Farley, in the S. ½ sec. 35, T. 52 N., R. 35 W., where the strata dip as steeply as 20° from both sides toward a medial line, and on Shoal Creek, near the south line of sec. 33, T. 52 N., R. 32 W. Dips are sufficiently strong to be evident to the eye in the small syncline between Iatan and Weston, in the NW. ¼ sec. 33, T. 54 N., R. 36 W.

The Bevier coal bed commonly lies nearly level in the Leavenworth coal mines but is slightly broken and otherwise disturbed in a few short and narrow synclines. The largest of these synclines was first encountered in the North mine many years ago, at a point nearly under the middle of the river and northeast of the shaft. The coal dipped from both sides at a nearly uniform inclination of 1 foot in 4 feet toward a broken and faulted zone, the width of the syncline being 750 to 800 feet and the depth in the center 100 feet. About 700 feet southeast of this place an entry from the southwest encountered a nearly vertical, slickensided fault face (see fig. 7, A) and was driven horizontally across dipping beds for 167 feet. At the end of this tunnel a boring was made, and the coal was found at a depth of 43 feet. About 1,800 feet southeast of the place first described the mine workings passed around the end of the fault across a narrow syncline about 30 feet deep. Evidently this structural feature is a short fault which passes into a syncline at each end. The only evidence of disturbances at the surface are gentle southerly dips between the North mine shaft and the mouth of Corral Creek and a shallow syncline near East Leavenworth, which is probably in line with the faulted zone in the mine.

The tensions to which the rocks have been subjected are indicated by the jointing that is common in the limestones. The most numerous and best-developed joints are those striking about N. 62° E., though others striking N. 3° W. are only slightly less distinctive. There are also two minor sets, affecting chiefly the thick beds of limestone, one striking approximately N. 45° E. and the other N. 45° W. Joints are most conspicuous and most closely spaced in the thin, even-bedded limestone members and are shown to best advantage in the "pavements" in stream beds, where the top of a limestone stratum has been swept bare by running water. (See Pl. IX.)

GEOLOGIC HISTORY.

PALEOZOIC ERA.

EARLY PERIODS.

At the beginning of the Paleozoic era the quadrangles and neighboring areas were part of a great land mass and probably remained above sea level until after the middle of the Cambrian period, during which time the region was undergoing erosion. The available data indicate that the resulting topography was of considerable relief and that the general altitude was somewhat greater than that of many neighboring areas. As the Cambrian sea advanced over the region, the higher lands at first remained as islands while sedimentation took place about their borders.

Before the end of the Cambrian period the area included in the quadrangles was almost wholly submerged, though the St. Francis Mountains and perhaps other highlands in the same general region still remained above the sea as islands. Through the remainder of the Cambrian and well into the early part of the Ordovician period intermittent sedimentation was going on, the process being occasionally interrupted by relatively short intervals of emergence and erosion. During most of the time conditions were favorable for the deposition of limestone, but at the first submergence much coarse sand was deposited and subsequently thinner beds of sand accumulated. The widespread deposit which formed the St. Peter sandstone was laid down under conditions which are not certainly known but which may have been due to a combination of the action of wind and water.

How long after St. Peter time the region continued to receive sediments is uncertain, the deposits that may have been laid down from then until the Carboniferous period being now represented by only a few hundred feet of strata. It is probable, however, that the region was subjected to subaerial erosion through a large portion of the later Ordovician and the Silurian and Devonian periods. Beds that were deposited between the close of early Ordovician time and the beginning of Kinderhook time are exposed at only a few places on the northwestern border of the Ozark region. Farther north, at Nebraska City, Nebr., more than 1,300 feet of strata were deposited during the same interval.

CARBONIFEROUS PERIOD.

Mississippian deposition.—At the beginning of Mississippian time, or possibly during later Devonian time, the sea again invaded the region and remained more or less continuously during the first half of the Mississippian epoch. Most of the deposits of this interval now form limestones, but some argillaceous muds were brought in at the beginning of the submergence.

Late Mississippian and early Pennsylvanian erosion.—After the deposition of a great thickness of limestone the sea withdrew from a large district north and west of the Ozark region at or near the close of the Mississippian epoch. The land thus laid bare stood at least 200 to 300 feet above the level of the neighboring seas, and agents of subaerial erosion soon began to excavate valleys and lower the general surface. Erosion continued well into the Pennsylvanian epoch, until much of what is now the central Mississippi basin was reduced to a more or less featureless lowland covered with residual soils and chert fragments and pitted with sink holes and shallow depressions in the easily soluble limestones. When erosion ended in the region near Leavenworth, there were comparatively high land areas in what is now southeastern Nebraska and central Kansas, in the Ozark region, and in a strip extending north from the Ozarks into northeastern Missouri.

Pennsylvanian deposition.—While this erosion was taking place, an arm of the Pennsylvanian sea was slowly advancing from the southwest over the lowland in eastern Kansas and northwestern Missouri toward central Iowa. Residual materials left on the old land surface were washed away from some places and concentrated in others, so that deposits of white, red, or brown sand, angular fragments of chert, black clay, and other materials accumulated in the shallow waters. Coal-forming plants began to grow in favorable situations, only to be covered by mud, silt, and sand in the shifting waters. Later the irregularities of the old surface were smoothed over and conditions became more uniform. Plant life existed simultaneously over wide stretches when the shallow seas temporarily withdrew, and marine organisms flourished at other times when the land stood slightly below sea level—the plants furnishing the peats that are now coal and the marine organisms the shells and tests that are now consolidated with calcareous muds to form limestone. Such conditions existed only for short intervals, however, for during most of the time sand and clay were being brought into the seas or heaped in estuaries and on coastal plains.

At some stage before the Pleasanton epoch, probably late in Cherokee time, the Pennsylvanian seas reached their maximum extent and covered much of the present Ozark region. Late in Pleasanton time differential warping raised the Ozark region and shifted the seas back to the northwest. During the remainder of Pennsylvanian time warping continued intermittently, interrupted by intervals of general stability, at first prolonged but gradually becoming shorter. During the intervals of stability widespread shallow seas favorable to animal life existed in the region now forming parts of Kansas, Missouri, Iowa, and Nebraska. Plants grew in relatively small swamps, which disappeared before very thick masses of peat had time to accumulate. During the intervals of warping, conditions were similar to those during the first invasion of the Pennsylvanian sea. At times, especially during the Douglas epoch, the sea withdrew far enough to allow subaerial erosion to act more or less vigorously on the soft, newly formed sediments, in which it cut shallow channels, which were filled with sand and mud when the sea again advanced. The exact conditions under which the channels were made and filled are, however, imperfectly understood.

The sea finally retreated beyond the region here considered. The land covered with Pennsylvanian sediments was subjected to erosion and was probably tilted to the northwest near the end of the Paleozoic era.

MESOZOIC ERA.

Erosion by streams and other denuding agents continued throughout most of the Mesozoic era. In other regions prolonged erosion base-leveled large areas and was followed by earth movements that rejuvenated the streams, but such phenomena have left no definite record in the area under discussion. Late in the Mesozoic, in the Cretaceous period, deposition took place in western Iowa and farther west, but there is no evidence that sediments were then deposited in western Missouri and northeastern Arkansas.

CENOZOIC ERA.

TERTIARY PERIOD.

The erosion which characterized the Mesozoic era continued during the Tertiary period. In other areas there are evidences of earth movements that resulted in the retardation or acceleration of erosive processes, but in this region little remains to show the details of the geologic history. The topography which had been developed at the end of the Tertiary was probably not essentially different from that which existed at the beginning of Kansan time and which has been largely preserved beneath deposits of glacial till. This topography was much like that of the plains of southwestern Missouri and southeastern Kansas at the present time, and though the escarpments were not very high the contrast between them and the intervening plains was much more marked than it is now. The Oread escarpment lay slightly east of its present position and the Iatan escarpment a short distance east of the Oread, extending south nearly to the upland formed by the sandstone in the Lawrence shale in the southern part of the quadrangles. East of the Iatan escarpment and north of the sandstone upland an extensive plain occupied most of the Smithville quadrangle and was traversed by at least two eastward-flowing streams. The valley of one has been identified as far west as Weston, and traces of it that may be seen at intervals across the quadrangles indicate that its gradient was greatest just east of Weston and averaged 5 feet to the mile. The other preglacial valley crossed the northeast corner of the Smithville quadrangle and seems to have been wider and deeper than the one near Weston. (See fig. 8.) There were other small valleys in the quadrangles, but their exact positions are not definitely known. Kansas River was probably at that time a large stream that occupied a valley on or near the site of its present channel and that of Missouri River east of Kansas City.

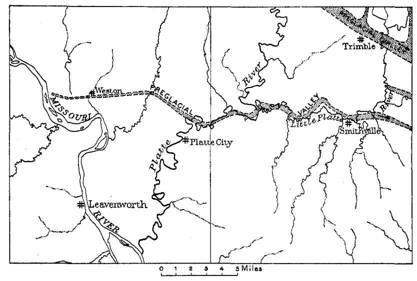


Figure 8.—Sketch map of the Leavenworth and Smithville quadrangles showing present streams and probable preglacial valleys (dotted areas).
The arrows indicate probable direction of preglacial drainage.

There is no evidence that a large valley occupied the site of the present Missouri River valley above Kansas City before the Kansan ice invasion. The small eastward-flowing pre-Kansan stream at Weston, nearly 150 feet above the present Missouri River, and the character of the alluvial material deposited in it seem to prove the nonexistence of a deep Missouri River valley in Tertiary time. The recession of the Oread escarpment near Kansas River, compared with the narrow gap through which the Missouri crosses the same escarpment, indicates that Kansas River is older than that part of the Missouri. The high, straight bluffs and lack of well-developed lateral drainage lines in the Leavenworth quadrangle may also mean that this part of the Missouri Valley is comparatively young.

QUATERNARY PERIOD.

PLEISTOCENE EPOCH.

Pre-Kansan time.—During the Pleistocene epoch a series of remarkable climatic changes caused at least four great continental glaciers to invade the northern States from centers of accumulation in Canada. The ice invasions were separated by intervals during which the climate was fully as warm as it is at present. Each great glacier transported quantities of clay pebbles and bowlders which it left behind when it melted and which now form the greater part of the surficial deposits of the glaciated area. Only the second glacier, that of the Kansan stage, is thought to have reached the Leavenworth and Smithville quadrangles.

Although the first great ice sheet, that of the pre-Kansan or Nebraskan stage, may not have reached the quadrangles, pebbles derived from the drift it left in neighboring areas were carried in by streams and mixed with bowlders and pebbles from local limestone ledges to form the gravels referred to the Aftonian (?) interglacial stage.

Kansan time.—The warm climate of Aftonian time gave place to a prolonged cold interval during which the Kansan glacier advanced across the quadrangles well into Kansas in a direction shown by rock striae to have been slightly west of south. This ice sheet also covered nearly all the region north and east of Missouri River and considerable adjacent territory west of that stream. When the Kansan glacier finally melted it left great accumulations of bowlder clay that largely filled the valleys and formed a plain of slight relief sloping to the southeast. Depressions in the surface of the drift that filled with water became ponds or lakes in which may have been deposited the fine silt and clay now known as the Loveland clay. Other continental glaciers invaded part of the northern States after the Kansan stage, though the Leavenworth and Smithville quadrangles were never again covered by glacial ice.

Loess accumulation.—Before erosion had dissected the surface of the Kansan drift to any extent a thin blanket of bluish-gray loess was deposited thereon by winds. This was followed by an interval of erosion in which much of the present drainage was developed. It is probable that some wind-blown material was deposited more or less continuously while post-Kansan erosion was in progress, but much of the upland yellow loess may have been accumulated during a comparatively short interval. A maximum accumulation of loess may have immediately followed or accompanied one of the glacial intervals, for transportation by wind would be particularly efficacious when vegetation was sparse and winds exceptionally strong. Late in the Pleistocene and even during the Recent epoch loess continued to be blown from the Missouri River flats and deposited on higher lands and that previously deposited was shifted from place to place.

Development of present topography.—The great quantities of drift spread over the region by the Kansan glacier filled up the valleys and destroyed most of the old drainage system. A new system began to develop after the retreat of the ice and was governed in its initial stages by the slope of the drift surface, which in northern Missouri was generally to the southeast. In the region near the limit of Kansan glaciation, including the Leavenworth and Smithville quadrangles, the escarpments were not completely obliterated, and the preglacial sandstone upland in the southern part of the quadrangles was sufficiently high to cause the young Platte River to swerve to the west. It is possible that the Missouri assumed its present position during a temporary halt of the retreating ice front, when the river, swollen by great volumes of water from the melting ice, may have flowed along the margin of the glacier and eroded rapidly.

RECENT EPOCH.

From the end of Kansan glaciation to the present the deepening and extension of the valleys has been continuous, though hastened or retarded at intervals by slight regional earth movements and by climatic changes, especially those accompanying the later ice invasions in regions not far distant. Missouri and Platte rivers, Bee Creek, and other fairly large streams cut through the drift and into solid rock, making relatively larger valleys where unconsolidated deposits are deepest.

After Missouri River had cut nearly 100 feet below the level of its present channel it began to fill the bottom of its valley by dropping part of its load. The river probably began to aggrade near the end of the Wisconsin glacial stage, when the great volume of water derived from the melting glacier on the north decreased and the amount of sediment carried in suspension was great. After this the normal extension of the upper part of the river's basin continued to add to the load to be transported. There are strong indications that the Missouri is now not only depositing the ordinary flood-plain alluvium during high water but is also actually raising the level of its channel by aggradation. Within the last 50 years Missouri River has become an almost unnavigable stream, with rapidly shifting bars and shallow channel. The fertile loess on its borders is being stripped of its forest and sod covering by the ax and the plow, and the rapid erosion of the loess which soon follows is adding an extra load of sediment to the already overburdened river.

The erosion of many of the valleys has resulted in the formation of some incised meanders, which may not have been inherited from an old peneplain. It is possible that the explanation is to be sought in the effects of alternating layers of unequally resistant rock. Where a stream flowing on shale or drift cuts down to a resistant limestone, erosion is checked and a local reduction to base-level takes place above the limestone outcrop. The stream crosses the limestone as a small waterfall or rapids, and beyond it cuts rapidly into the underlying shale. As the cascade or rapids works its way upstream along the meandering course developed in the shale an incised meander is developed and is strengthened as the valley is lowered by continued erosion. This action is illustrated by the profile of a stream of this character which is shown in figure 9.

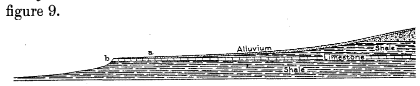


Figure 9.—Diagrammatic profile of stream bottom showing rapids or small cascade (b) below outcrop of thin resistant limestone bed and low gradient (a) above it.
By recession of rapids at b meanders which had developed in the stream on the low-gradien section above the cascade are cut below the general surface and become incised meanders.

Loess accumulation has only slightly modified the topography developed by erosion, its chief effects being to soften the outlines of hills and slopes near the Missouri and to increase the height of the river bluffs, especially those east of the stream. Loess has also appreciably narrowed the mouths of the valleys of very small streams flowing into the Missouri, so that several of the small valleys resemble amphitheaters with narrow outlets through the river bluffs. The slumping of loess on valley slopes has given a few of them a stepped or terraced appearance, and the contours of some slopes have doubtless been slightly affected by the washing of loess toward their bases.

ECONOMIC GEOLOGY.

The mineral resources of the Leavenworth and Smithville quadrangles include coal, shale and clay, building and road stone, limestone and cement material, sand and gravel, surface and underground water, and soils. Oil and gas occur also, at least in small quantities.

COAL.

Outcropping coal beds.—The only coal beds that appear at the surface are thin and comparatively unimportant layers in the Douglas formation. A persistent coal bed, 12 to 20 feet above the Iatan limestone member, is less than a foot thick where exposed on lower Plum and Salt creeks, in the United States military prison stockade, and in the bluffs above Kickapoo. Two miles below Iatan (NW. ¼ NW. ¼ sec. 33, T. 54 N., R. 36 W.) it is 14 inches thick. On Salt Creek, a mile west of Sentinel Hill (SE. ¼ SE. ¼ sec. 17, T. 8 S., R. 22 E.), it consists of about a foot of clean coal and 6 inches of very dirty coal. A short slope marks the spot where it was formerly mined a little for local trade. A zone of thin coal beds lies 25 to 80 feet below the Oread limestone member, but all of those exposed are less than a foot thick. There is some coal in the Douglas formation in the sandstone area of the south third of the quadrangles. A 10-inch coal bed that outcrops 2½ miles southeast of Farley (southwest corner sec. 36, T. 52 N., R. 35 W.) led to the sinking of a shaft that is said to have penetrated 2 feet of coal dipping at a high angle. Some coal was once mined for local sale from a 14-inch bed 2 miles northwest of Nashua (SE. ¼ SE. ¼ sec. 17, T. 52 N., R. 33 W.).

The exposed coal beds are too thin to be of much economic importance, but slightly thicker deposits may lie under cover in the Douglas formation. More than 50 years ago at least 10,000 tons was taken from a bed 18 to 24 inches thick on Little Stranger Creek below Boling, not far from the southwest corner of the Leavenworth quadrangle. More recently considerable coal has been mined about 2 miles south of Atchison from a bed of good quality 16 to 20 inches thick that lies 25 feet below the Oread limestone member.

Coal beds beneath the surface.—As a result of his geologic work in Missouri Maj. F. Hawn became convinced that a coal bed mined extensively in that State lay about 700 feet beneath Leavenworth. He organized a company and began drilling in 1860 in the southeast corner of the Fort Leavenworth Military Reservation, but the bed now mined at a depth of 707 feet was not reached until 1865. In 1870 the shaft of what is now known as the North mine was sunk and operations began.

The bed mined occupies the same stratigraphic horizon as the one from which a large output is obtained in Macon, Randolph, and other counties in Missouri and to which the name Bevier bed is applied in reports of the Missouri Geological Survey. As shown by mining operations at Leavenworth, Richardson, Lansing, and Brighton, the Bevier bed has a remarkably uniform thickness, averaging 22 inches. (See fig. 10.) The same bed is 22 inches thick south of Atchison, only 8 miles northwest of Iatan; 21 inches at Saxton, near St. Joseph; 23 inches at Stewartsville, 19 miles north of Mecca; and 21 inches at Randolph, 11 miles south of Nashua. The Bevier bed therefore has a wide regional distribution and probably underlies the greater part of the Leavenworth and much of the Smithville quadrangles. It was not found in churn drilling at Smithville and may be wanting or very thin in other places, especially in the eastern part of the region. The Bevier bed lies at an average distance of 620 feet below the base of the Plattsburg limestone member of the Lansing formation at Leavenworth and Lansing, and its altitude in any locality can be approximately determined by subtracting 620 feet from the altitude of the Plattsburg shown by the structure contours on the geologic maps. Its depth below the surface can then be calculated by subtracting the altitude so determined from the surface altitude indicated by the brown surface contours on the topographic maps. The interval between the Plattsburg limestone and the Bevier coal is not uniform, however, owing chiefly to differences in the thickness of the Pleasanton formation. In the drilling at Atchison this interval is only 535 feet; a mile north of Weston it is about 600 feet; and 2 miles southwest of Platte City it is 645 feet.

In the Lansing shaft (see p. 3) and the North shaft at Leavenworth six and five coal beds, respectively, were found above the Bevier bed, chiefly in the Cherokee shale, but the thickest measured only 14 inches. Shafts were sunk at the North mine to a total depth below the surface of 999 feet and a boring made to an additional depth of 172 feet, until the entrance of great volumes of water caused it to be abandoned. (See p. 4.) A deep well at Leavenworth south of the United States penitentiary was carried below the top of what is undoubtedly pre-Pennsylvanian limestone, so that it is certain that all the coal-bearing strata have been explored. (See p. 3.) A summary of the coals follows:

Summary of coal beds in Leavenworth shaft and borings.

	Thickness.	Depth.
	Inches.	*Feet.*
Henrietta formation:		
"Upper Fort Scott"	8	567
Cherokee shale:		
Lexington	12	598
Coal	6	617
Coal	6	640
Coal	14	663
Bedford	6	677
Bevier (bed mined)	24	709
Coal	16	728
Coal	5	889

Summary of coal beds in Leavenworth shaft and borings—Continued.

	Thickness.	Depth.
Cherokee shale—Continued.	*Inches.*	*Feet.*
Coal	18	918
Coal	10	993
Coal	26	999
Coal	28	1,031
Coal	12	1,087
Coal	5	1,097
Coal	6	1,127
Aggregate thickness	197	

The total thickness of coal found in beds at least 14 inches thick at Leavenworth was 108 inches. As shown by actual experience in European and American fields bituminous coal beds as thin as 14 inches can be profitably mined under favorable market and mining conditions at depths even greater than those at which coal will be found anywhere in this region. One coal bed was 18 inches thick and 25 feet below the Bevier coal bed in the Home mine sump, 16 inches thick and 30 feet below the Bevier in the Brighton sump, and 12 inches thick near Atchison. Although beds below the Bevier horizon thicken and thin somewhat irregularly, the results of the Leavenworth prospecting operations may be taken as a fair index of the coal resources of at least the Leavenworth quadrangle. The following coal summary of the boring made 2 miles south of Atchison, only a few miles northwest of the northwest corner of the Leavenworth quadrangle, also has a bearing on this region:[1]

Coal beds 14 inches or more thick in Atchison deep boring.

	Thickness.	Depth.
Cherokee shale:	*Inches.*	*Feet.*
Bevier	22	801
Coal	36	1,126
Coal	28	1,190
Coal	15	1,199
Aggregate thickness	101	

The total thickness of coal in the Atchison boring, including thin beds, was 177 inches. The top of the Mississippian series, below which there is no coal, was reached at a depth of 1,315 feet, 1,359 feet below the base of the Oread limestone member of the Douglas formation. The 3-foot coal bed at a depth of 1,126 feet is the same as an impure 28-inch bed at a depth of 1,031 feet at Leavenworth and is the one in which mining operations were conducted at the Atchison deep shaft.

The only deep prospecting in the Smithville quadrangle was made with a churn drill at Smithville to a depth of 804 feet, nearly to the base of the Pennsylvanian series. Coal beds and other strata were not carefully noted and the chief economic value of the drilling lay in a reported discovery of coal that caused a second hole to be made with a churn drill to a depth of 450 feet and with a core drill to a further depth of 488 feet. Three feet of coal are reported found in the second drilling at a depth of 474 feet. (See p. 4.) This coal bed lies at an altitude of about 363 feet, 457 feet below the top of the Kansas City formation, the upper member of which outcrops near Smithville, and 517 feet below the horizon of the Plattsburg limestone member of the Lansing formation, indicated by the structure contours on the geologic map. This bed appears to be in the upper part of the Cherokee shale, but its exact stratigraphic position is not clear. It does not seem to be correlated with thick coal beds in other parts of this general region and its reported thickness may not be maintained under a large territory. The discovery is an important one, however, as the depth of the coal is by no means prohibitive and the locality is close to excellent markets.

Borings in neighboring territory, some of which have been mentioned, throw some light on the probable coal resources of the Smithville quadrangle. One boring 6 miles west of Kearney, only 2 miles east of the Smithville quadrangle, reached the Mississippian at a depth of 1,022 feet, 941 feet below the Plattsburg limestone. Coal beds were not carefully noted, but what is apparently the Bevier was found 554 feet below the Plattsburg limestone. Several borings at Randolph penetrated an average of 100 inches of coal, of which 50 inches were in beds 14 to 21 inches thick and the remainder in thinner layers. All carefully recorded drill logs in this part of Missouri show at least two or three coal beds 14 to 36 inches thick in the Cherokee shale, and these will undoubtedly become of considerable economic importance in the future.

Mines and mining conditions.—Five large coal mines have been in active operation in the Bevier bed at Leavenworth, Richardson, and Lansing, and another was worked for a time at Brighton. The three mines of the Home-Riverside Coal Co. are on the banks of Missouri River. The North mine, or No. 3, is at the southeast corner of the military reservation, north of Leavenworth. The shaft was sunk in 1870 and the mine was not abandoned until July, 1913. The Home mine, or No. 1, is in the southeast corner of the city, three-quarters of a mile below the Terminal Bridge. The shaft of the Riverside mine, or No. 2, is a mile south of the Home shaft. At these mines the coal lies 707 to 713 feet below the tops of the shafts. The Carr shaft at Richardson (NW. ¼ SW. ¼ sec. 18, T. 9 S., R. 23 E.) is 685 feet deep. The mine on the north side of the penitentiary at Lansing, operated by the State of Kansas with convict labor, is 713 feet deep. The mine at Brighton, where the Bevier bed is 811 feet deep, has not been operated for several years but may be reopened.

[1] Detailed record published in Mineral Resources of Kansas for 1900 and 1901, pp. 34–44, 1902, and in Kansas Univ. Geol. Survey, vol. 9, pl. 106, 1908.

All the mines are large, the total annual production being about 300,000 tons, and are equipped with powerful steam hoisting engines and improved machinery of other kinds. The Penitentiary and the Home-Riverside mines are exceptionally well managed and equipped. The Penitentiary mine is a model of cleanliness, having whitewashed brick walls and brick pavements near the pit bottom, and is brightly lighted with 100 incandescent and a number of arc lights. Owing to the long-continued activity of the mines in operation, all except the Carr shaft having been sunk previous to 1890, the working faces are half a mile to a mile from the shaft bottoms. The Home-Riverside workings have been driven under and beyond the Missouri and a large part of the product is now obtained in Missouri. The long-wall plan of mining is followed, but the roof is not sufficiently strong to permit the use of a face track. Mining machines have not proved a success; the coal is cut by hand and need seldom be wedged. Props are placed 3 to 4 feet apart and at the same distance from the face. Few timbers are required in the entries, as the roof arches itself and remains firm even after many years of exposure. Gas is sufficiently plentiful to necessitate careful inspection of working places but not to prohibit the use of naked lights. Many of the entries are so dry as to need occasional sprinkling, but a few thousand gallons of water accumulate in the sumps daily. As much as 40,000 gallons were removed daily from the North mine, most of it coming from the old shaft and drill hole that was made near the pit bottom. This abundance of water in the lower Cherokee shale would be a serious handicap in attempting to mine beds much below the Bevier bed.

The Bevier bed consists of alternate bright and dull streaks of hard bituminous coal, with irregularly placed streaks and lenses of pyrite ("sulphur") and a little white gypsum scale in thin plates. Its average specific gravity is 1.283, so that 1 cubic foot yields 80 pounds 3 ounces, or a trifle more than 1 bushel. Where the bed averages 22½ inches thick, therefore, it contains 3,256 tons to the acre. There are no persistent partings of noncombustible matter, though in some workings a very thin layer of pyrite or of mother coal lies 10 to 14 inches above the bottom of the bed. There is no well-defined vertical cleavage except that governed by the position of the working face. "Bells" and "horsebacks" interrupt the regularity of the bed in a few places, and there is one large fault with accompanying steep dips in the North mine. (See p. 9.) The greater part of the roof is a firm dark-drab shale ("slate") of excellent stability, but two other types of material overlie the coal in comparatively small areas. One, known as "sulphur top," occurs in thin lenses of considerable lateral extent and is a pyritiferous shale full of shelly sandstone layers, very hard when fresh but slacking quickly on exposure. The other, termed "sandstone top," is a calcareous sandstone generally lying about 17 feet above the coal and approaching it only along ancient channels; where it is only a short distance above the coal the intervening "slate" will not stay up. Under the coal are 2 to 18 inches of clay, averaging 9 inches, beneath which is a limestone with a characteristically uneven upper surface. (See fig. 10.) In many rooms the underclay is taken up and the limestone affords an excellent foundation for props and gob walls. As a whole, mining conditions are good.

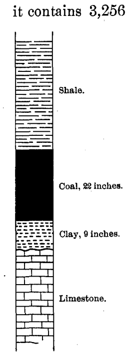


FIGURE 10.—Section of coal bed mined at Leavenworth and Lansing, Kans.

Markets.—The Leavenworth and Smithville quadrangles occupy an enviable position so far as coal markets are concerned. With the exception of a little coal obtained near Atchison no mining of importance is prosecuted along Missouri River between North Dakota and the Lexington and Richmond districts in Missouri. Indeed, no mining is carried on in Nebraska, northern Kansas, or northwestern Missouri that is more than barely sufficient to supply the local needs of very small districts. No coal outcrops that is likely to become a strong competitor of the thicker and more persistent beds in the Cherokee shale, which are nearer the surface in the Leavenworth and Smithville quadrangles than they are farther north and west.

Much of the product of the mines now being operated is used in the large public institutions at Leavenworth or is sold to the city trade; the rest is shipped to points north and west and to Kansas City. About one-fourth of the output is nut and slack and the rest lump and mine run. All coal from the Penitentiary mine is used by Kansas State institutions. During recent years the demand for coal in Kansas and neighboring States has been lessened by the large supplies of natural gas piped to the larger cities, including Leavenworth. The supply of gas is rapidly decreasing, however, and the coal industry is receiving a corresponding stimulus.

Coke is made from Bevier coal in a small beehive oven at the Kansas State Penitentiary. The product is rather light and uneven in quality and contains considerable sulphur. It is used in the prison for cooking and at the State brick plant for drying brick.

Chemical analyses.—Two mines at Leavenworth and one at Lansing were sampled by Mr. Albertson in 1911, vertical channels being cut across fresh faces and the product ground, quartered, and hermetically sealed in the mine, according to the methods adopted by the United States Geological Survey and the Bureau of Mines. The following table contains the analyses of the composites of three samples from each mine:

Chemical analyses of Bevier coal from Leavenworth quadrangle.

[Samples taken by M. Albertson in 1911. Analyses made by the Bureau of Mines.]

Mine.	Laboratory No.	Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
				Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
Penitentiary mine, Lansing	12844	8.6	A	11.1	35.5	40.7	12.70	3.99	5.30	60.72	1.13	16.16	6,145	11,070
			B	2.7	38.9	44.5	13.90	4.36	4.75	66.43	1.24	9.32	6,725	12,110
			C	....	39.9	45.8	14.29	4.49	4.58	68.30	1.27	7.07	6,915	12,450
			D	....	46.6	53.4	....	5.24	5.34	79.69	1.48	8.25	8,070	14,520
North mine, Leavenworth	12848	9.0	A	12.1	35.4	36.4	16.07	4.77	5.16	56.54	1.07	16.39	5,675	10,220
			B	3.3	38.9	40.1	17.66	5.24	4.57	62.13	1.18	9.22	6,235	11,230
			C	....	40.3	41.4	18.27	5.42	4.34	64.29	1.22	6.46	6,455	11,620
			D	....	49.3	50.7	....	6.63	5.31	78.66	1.49	7.91	7,895	14,210
Home mine, Leavenworth	12852	9.1	A	12.0	35.2	39.1	13.70	4.41	5.31	58.94	1.09	16.55	5,955	10,720
			B	3.2	38.7	43.0	15.07	4.85	4.78	64.84	1.20	9.31	6,550	11,790
			C	....	40.0	44.4	15.56	5.01	4.52	66.94	1.24	6.73	6,765	12,180
			D	....	47.4	52.6	....	5.93	5.35	79.28	1.47	7.97	8,010	14,420

A, As received; B, air dried; C, moisture free; D, moisture and ash free.

SHALE AND CLAY.

Shale suitable for drain tile and building and paving brick is abundant and well distributed in the quadrangles but has been commercially developed only on the west side of Missouri River and chiefly by public institutions. Sewer pipe, terra cotta, and other clay products could also be made from some of the shale. The Weston shale member of the Douglas formation and the Vilas shale member of the Lansing formation appear to afford the best material, and the Weston is well situated for advantageous stripping at a number of points along its eastern outcrop and near Missouri River. The Lane shale member of the Lansing formation and the lower part of the Lawrence shale member of the Douglas formation can also be used in many places, and the upper part of the Lawrence member is available where not too sandy. Fairly good common red brick and tile could be made from loess that can be easily obtained on nearly all the uplands and slopes, and certain products can be improved by mixing loess with shale from the Pennsylvanian formations named above. The gumbo clays of the river bottoms are available for burnt-clay ballast, though quantities of clinker, shale, and stone suitable for road beds can also be obtained from the huge dumps of the coal mines. Much of the shale in the Cherokee and other Pennsylvanian formations does not outcrop but could be mined from the coal or other shafts.

The only privately owned shale pit is that of the Leavenworth Vitrified Brick Co. in South Leavenworth. At the top of the section in the pit there is 20 feet of very sandy shale lying on 10 to 15 feet of reddish-buff massive micaceous sandstone. Below the sandstone is 24 feet of dark-blue to drab shale containing two 5-inch layers of ferruginous limestone and a few small concretions. Nine feet of material, probably shale, lying between this and the top of the Stanton limestone member of the Lansing formation, is concealed. The shale, mixed with a little sandstone, is burned to a light-yellow or dark-red paving brick, natural gas being used for heat. The product is sold locally and the production follows the demands of the market.

The Lane shale member is mined at a depth of 115 feet at the Kansas State Penitentiary at Lansing and is hoisted through the air shaft of the coal mine. The mine section includes 15 feet of shale at the bottom, overlain by 2 feet of sandstone and this by 3 feet of clay and limestone nodules. The roof is a strong, thick limestone. Rooms are made 20 to 25 feet square. The lower 8 feet of shale is mined first, the upper shale staying up until the pillars are pulled and all falls. The limestone nodules are removed at the penitentiary brick plant and the rest of the material is mixed and made into red building brick, pavers, and hollow building blocks. The eight down-draft kilns are said to have a daily capacity of 40,000 bricks.

A clay shale 6 feet thick, lying at a depth of 540 feet in the penitentiary shaft, is said to have made good fire brick that were used in the kilns. The penitentiary brick plant was at one time supplied with material from an outcrop of the Vilas shale member, 23 feet thick, in a pit half a mile northeast of the prison. This shale is said to produce a fine buff-colored brick.

Paving bricks were formerly made from shale lying a few feet above the Stanton limestone member in a pit near the power house at the Soldiers' Home. This shale produced a good brick, but Hay states that the linear dimensions contracted one-eighth in burning, necessitating considerable care.

The shale pit in the hillside in the western part of the United States Penitentiary Reserve (SE. ¼ SE. ¼ sec. 22, T. 8 S., R. 22 E.) is in 47 feet of drab to blue plastic clay shale, lying in and 70 feet below the top of the Lawrence shale member. There is 5 inches of coal near the top, and the whole is capped by a thin calcareous sandstone. Thin sandy streaks furnish the proper proportion of sand for excellent brick. The material is burned within the prison walls and the red brick and paving brick produced are used at the institution. The plant contains a complete outfit for the manufacture of stiff-mud brick, including dry pan, pug mill, auger machine, automatic cutter, re-press machine, and waste heat drier. Two kilns for pavers are said to have a capacity of 120,000 bricks each.

At the United States military prison stockade, half a mile below Wade, a blue, slightly sandy clay shale, lying between the Iatan limestone member of the Douglas formation and the coal bed 18 feet above it, and 12 feet of blue clay shale under-lying the Iatan are made into red brick, which are used in the prison buildings. The brick plant is complete though small.

STONE.

Crushed stone suitable for road material and for concrete can be easily obtained in the quadrangles. The Oread and Iatan limestone members of the Douglas formation, the Stanton and Plattsburg limestone members of the Lansing formation, and the Iola limestone member of the Kansas City formation—all furnish abundant material. Good building stone is not so common, though all these limestone beds commonly contain at least one building ledge 1 foot to 3 feet thick. The thick massive sandstone outcropping in much of the southern third of the quadrangles is rather soft but might be sufficiently strong when properly seasoned. The best ledges for building stone are the two "dimension rocks," one forming the lower division of the Stanton limestone and the other a part of the Oread limestone. These beds split along one or two planes to form thin, even pieces that are excellent for foundations, sills, curbing, and walls. Parts of the old walls of the United States military prison were made from blocks obtained from the outcrop of the Iatan limestone in the vicinity and appear to be durable.

Outcrops of thick limestone beds are so extensive that the location and operation of quarries is governed chiefly by local fluctuating demand. Quarries have been opened at many points along the outcrops of the limestone beds. Much of the rock is broken by hand, though there are a few small crushers. Nearly all the upper part of the Oread limestone has been removed from parts of the ridges on the United States Penitentiary and Fort Leavenworth reservations. The chief production recently has been from the Oread limestone on Pilot Knob and the hills west of Leavenworth, the United States Penitentiary Reserve, Government Hill, and Hancock Hill; from the Iatan limestone at the United States military prison stockade and near Weston; and from the Stanton limestone west of Lansing, at Tracy, and at Platte City. The Wyandotte Construction Co. has opened two large temporary quarries 8 miles west of Smithville, where a 15-foot ledge of the Stanton limestone is crushed for use on the roadbed of the new electric line.

LIME AND CEMENT.

Nearly all the limestone beds are sufficiently pure to yield a good grade of high calcium lime. The chert in some beds must be removed before they can be used, but it is not abundant except in the upper part of the Oread member. The main ledge of the Stanton limestone is burned in a small kiln at the Kansas State Penitentiary, and the Oread limestone is used at the United States military prison stockade.

Many of the limestones and shales of the region could be combined in such proportions as to make a good grade of Portland cement, and they occur in many places where the stripping would not be excessive. Moreover, this region, especially along Missouri River, is well situated as regards the very important factors of cheap fuel, good transportation facilities, and adequate markets. The following analyses[1] show the suitability of the Stanton and Iatan limestones and the intervening Weston shale for the manufacture of Portland cement. Analyses of the Stanton limestone from Lansing and Soldiers' Home are essentially the same as those cited below, though slightly lower in magnesium carbonate.

Analyses of limestones in the Leavenworth quadrangle.

No.	Silica (SiO_2).	Alumina (Al_2O_3) and iron (Fe_2O_3).	Calcium carbonate ($CaCO_3$).	Magnesium carbonate ($MgCO_3$).	Moisture (H_2O).	Total.
1	2.77	1.70	90.70	4.20	0.11	99.48
2	2.82	4.03	87.86	4.82	....	99.53
3	6.56	1.35	87.06	5.01	....	99.98
4	2.49	.95	95.59	.25	.13	99.39
5	6.22	1.20	90.86	1.58	....	99.86
6	4.75	1.70	91.23	2.26	....	99.84
7	4.94	1.25	91.75	1.55	....	99.49
8	3.19	1.04	95.05	1.20	....	100.78

1. Ledge at base of bluff at Weston, Mo. (Stanton limestone member).
2. Ledge 18 feet thick at Weston, Mo. (Iatan limestone member).
3. Cherty ledge at top of hill at Iatan, Mo. (Oread limestone member).
4. Ledge at base of bluff north of depot at Iatan, Mo. (Iatan limestone member).
5. Ledge at base of bluff a mile south of Iatan, Mo. (Iatan limestone member).
6. Lower 3 feet exposed in ledge at base of bluff 2 miles south of Iatan, Mo. (Iatan limestone member).
7. Ledge at base of bluff 2 miles south of Iatan, Mo. (3 feet of stone above No. 6, Iatan limestone member).
8. Upper 7 feet of ledge at base of bluff 2 miles south of Iatan, Mo. (Iatan limestone member).

Analyses of shale from Weston shale member of Douglas formation near Iatan, Mo.

	1	2
Silica (SiO_2)	61.54	60.20
Alumina (Al_2O_3)	20.83	20.05
Ferric oxide (Fe_2O_3)	4.05	4.95
Lime (CaO)	.85	1.69
Magnesia (MgO)	.82	.93
Alkalies	3.23	......
Water (H_2O)	....	1.35
Loss on ignition	9.24	8.89
	100.56	98.06

1, 2. Beds underlying the lower ledge of limestone at Iatan, Mo.

SAND AND GRAVEL.

Only a little sand can be obtained from the beds of the creeks and small streams, and few of the scattered deposits at the base of the Pleistocene are so situated as to be available. A cut on the new electric railroad, 6 miles west of Smithville (SE. ¼ sec. 22, T. 53 N., R. 34 W.), exposed 6 to 10 feet of sand that could be obtained by moderate stripping.

The Dresser Sand Co. dredges a clean, fairly even grained quartz sand for general building purposes from the bottom of the Missouri near Leavenworth. The constant shifting of the deposits necessitates frequent moving of the dredge, so that sand of the required degree of fineness may be obtained. At times the river bed is swept clean of sand for considerable distances, and the dredge must be taken several miles up or down river.

Little gravel in the region is suitable for road metal or concrete work. Small deposits lie in some stream beds, and parts of the glacial till are very pebbly, but the cost of obtaining gravel in quantity would be prohibitive. Most of the pebbles and bowlders in the Aftonian (?) beds are too large for use.

OIL AND GAS.

Since the discovery and exploitation of oil and gas in the Kansas and Oklahoma fields some attention has been turned to the possibilities of northwestern Missouri and northeastern Kansas. The greater part of the output of the producing fields comes from the Cherokee shale in places where its stratigraphic relations, lithologic character, and structural features differ very little from those that characterize it in the region of the Leavenworth and Smithville quadrangles. Drilling that has already been done in this region has not yet resulted in the discovery

[1] Buehler, H. A., Lime and cement resources of Missouri: Missouri Bur. Geology and Mines, vol. 6, 2d ser., pp. 188–189, 1907.

of very large accumulations of oil or gas, though enough has been found to encourage prospectors greatly.

With the possible exception of structural terraces that interrupt the general westerly and northwesterly dip in the southern part of the Smithville quadrangle and the southwestern part of the Leavenworth and of small anticlines there are no structural features in the quadrangles that are particularly favorable to the accumulation of oil and gas. As the deep-lying formations are saturated with water, any oil or gas that may be present is most likely to gather in structural terraces and anticlines, areas in which the upward passage of oil or gas in dipping porous beds is interrupted. These features are indicated by the structure contours on the geologic maps and are briefly described under "Structure of the Leavenworth and Smithville quadrangles." Analogy with the producing fields of Kansas indicates that accumulations are most apt to lie above the top of the Mississippian series.

In 1915 a boring was made to a depth of 1,033 feet about a mile north of Weston (SW. ¼ NE. ¼ sec. 2, T. 53 N., R. 36 W.) and another to a depth of 955 feet about 2 miles southwest of Platte City (N. ½ sec. 3, T. 52 N., R. 35 W.). Neither well produced oil or gas, and both were located near the end of the axis of an anticline. These results do not necessarily condemn other parts of the anticlines.

A well 2 miles southeast of Tiffany Springs (SE. ¼ SE. ¼ sec. 1, T. 51 N., R. 34 W.) was abandoned at a depth of 480 feet. Another 25 feet distant was continued to a depth of 600 feet, and several barrels of oil are said to have been baled from a depth of 590 feet, apparently from the lower part of the Pleasanton formation. A well 2½ miles southwest of Tiffany Springs (SE. ¼ sec. 8, T. 51 N., R. 34 W.) was completed in 1911 after penetrating 840 feet of Pennsylvanian rocks. At depths of 530 to 545 feet, in either the lower part of the Henrietta formation or the top of the Cherokee shale, a powerful flow of gas is reported to have been found in a sandstone. Two wells were then drilled to the same sand a short distance farther south (NE. ¼ sec. 17) and a powerful flow of gas resulted. It is reported that the gas is to be piped to Parkville. These wells are all on a large structural terrace, other parts of which appear to offer equally favorable conditions, so far as structure is concerned. A little oil and considerable gas are reported from 540 to 815 feet at Maywood station, halfway between Leavenworth and Kansas City, and gas has been found at a number of other places farther south of the quadrangles.

No oil or gas is reported to have been found in the first Smithville well, which was abandoned at a depth of 804 feet in white sandstone that probably lies near the base of the Pennsylvanian. Some oil and gas are said to have been found in the second Smithville well at depths less than 500 feet. The deep well bored for oil near the United States penitentiary at Leavenworth in 1887 did not furnish conclusive information, as precautions were not taken in time to shut off the great quantities of water encountered. The rope is reported to have been saturated with petroleum when drilling was progressing in the Ordovician system at a depth of 1,802 feet, and gas was present in small quantities, as the well would overflow for several minutes after being agitated with the sand pump. The shafts and borings at the North mine at Leavenworth penetrated nearly all the Cherokee shale without finding notable amounts of gas or oil. Here, also, great quantities of salt water gave much trouble.

WATER RESOURCES.

Surface waters.—Systematic studies of the flow of streams and the collection of hydrometric data in the Missouri River basin have been conducted by the United States Geological Survey since 1888. Records obtained at the gaging station on Missouri River near Kansas City, Mo., from April 1 to December 31, 1905, show that during that period the flow of the Missouri at that point varied from 16,200 second-feet in December to 236,000 second-feet in July, and that the total run-off for the period was 38,900,000 acre-feet.[1] No records of the flow of Platte River and other streams in the Leavenworth and Smithville quadrangles have been collected by the Survey. Power was formerly obtained for small gristmills on the smaller streams in this area, but low stream gradients and insufficient flow during periods of low water seem to have precluded the installation of large water-power plants.

[1] U. S. Geol. Survey Water-Supply Paper 172, p. 35, 1906.

Missouri River is important both as a source of water supply and as a receiver of sewage. The city supply of Leavenworth is pumped from the river, passed through three settling basins containing graded fragments of crushed limestone, and then forced to a distributing reservoir on Pilot Knob. Though the water supply of Fort Leavenworth is taken from the Leavenworth city plant, it is purified by sand filtration before being used. Water for the Kansas State Penitentiary is forced from the river to a reservoir back of the bluffs by a pumping plant a mile east of the institution and is filtered through sand. Complete removal of the great quantity of suspended matter carried by the river water renders filtration difficult and expensive. The water when freed from its mud is hard and high in sulphate and can be distinctly improved by softening before being used in boilers. The following figures show the average composition of the river water at Kansas City, Kans., above the entrance of Kansas River and only a few miles below Leavenworth:

Average chemical composition of the water of Missouri River at Kansas City, Kans., 1906.[2]

[Parts per million.]

Suspended matter	2,032
Silica (SiO_2)	37
Iron (Fe)	.73
Calcium (Ca)	62
Magnesium (Mg)	18
Sodium and potassium (Na and K)	44
Carbonate radicle (CO_3)	0.0
Bicarbonate radicle (HCO)	202
Sulphate radicle (SO_4)	135
Nitrate radicle (NO_3)	2.2
Chlorine (Cl)	13
Total dissolved solids	426

Ground waters.—Small springs of clear cold water are common throughout the sandstone area in the southern part of the quadrangles and at many points along the base of outcrops of the Stanton limestone member of the Lansing formation and the Iatan limestone member of the Douglas formation. A peculiar perennial spring issues near the top of the small mound a short distance southeast of Fairholme. Several mineral springs that flow from the sandstone in the Douglas formation in the southern part of the Smithville quadrangle have aroused interest among health seekers, those at Tiffany Springs being the best known. According to Schweitzer,[3] these waters are chalybeate and deposit iron on exposure to the air and the escape of their free carbon dioxide. They contain also much calcium and magnesium. The flow of Crystal Spring (NE. ¼ sec. 3, T. 51 N., R. 34 W.) is said to be 100 gallons an hour.

Good water of moderate mineral content can be obtained at moderate depths in most parts of the region, and very hard, highly mineralized water is very abundant at greater depths. The average depth of 156 farm wells about which data were collected in the Leavenworth quadrangle is only 43 feet. It is somewhat difficult to obtain water on the hills bordering Missouri River, especially east of the stream, where the loess is exceptionally thick, and many farmers in that district use rain-water cisterns. Water is most abundant near the base of the unconsolidated surface deposits and in the limestones and sandstones. Wells in shale ("soapstone") are not reliable.

Shafts and wells that have penetrated deep-lying strata find much water. A small flow, now used for drinking on the premises, comes from the Vilas shale member of the Lansing formation at a depth of 60 feet in the Home coal shaft at Leavenworth.[1] Great quantities of mineralized water were found in the Cherokee shale in the shafts and boring at the North mine at Leavenworth, especially in sandstone strata lying 757, 853, 1,000, and 1,084 feet, respectively, below the Plattsburg limestone member of the Lansing formation, the altitude of which is shown by the structure contours on the geologic map. As this water contains much common salt, it is termed "ocean spray" and was used for several years in a large swimming pool in Leavenworth. It contains 15,717 parts per million of chlorine, 9,296 of sodium and potassium, 541 of calcium, 232 of magnesium, 43 of silica, 36 of sulphate, and 8.4 of iron.[4]

[2] U. S. Geol. Survey Water-Supply Paper 236, p. 79, 1909.

[3] Schweitzer, Paul, Mineral waters of Missouri: Missouri Geol. Survey, vol. 3, pp. 132, 133, 159, 1892. Analyses of the Rogers Spring, in the southeastern part of the Smithville quadrangle, are given on p. 145, and of the Crystal Spring at Tiffany Springs on pp. 166 and 232. Analyses of Crystal Spring and the neighboring Artesian Spring are also given in U. S. Geol. Survey Water-Supply Paper 102, pp. 437-438, 1904.

Great quantities of strongly mineralized water were also found in the Leavenworth oil boring. The first flow of salt water was from a depth of 550 feet (above the Bevier coal horizon), and a stronger flow came at 1,150 feet, in the lower part of the Cherokee shale. Five streams within the next 500 feet brought the water within 100 feet of the top of the well. A strong flow at 1,700 feet, probably in Ordovician rocks, contained so much sulphur that it destroyed 500 feet of hemp cable. After penetrating the St. Peter sandstone, the base of which was at a depth of 1,870 feet, 1,755 feet below the Plattsburg limestone member, there was so much water that the well was abandoned at a depth of 2,116 feet. For a week 200 gallons per minute were pumped out of the well without reducing the level of the water 5 feet.[5]

SOILS.

The soils of the quadrangles constitute a very important mineral resource and may be separated according to origin into three broad divisions—glacial and loessial soils, alluvial soils, and residual soils.

The glacial and loessial soils cover by far the greater part of the area, and, as the material of glacial derivation is covered by at least a thin layer of loess nearly everywhere except above the Oread escarpment in Kansas, their character is determined chiefly by that of the loess. These soils range from light yellowish brown to brown or almost black and are smooth to the touch. They are of almost uniform texture, both in vertical section and over large areas, though somewhat coarser and more sandy near the Missouri River bluffs than elsewhere. The distribution and thickness of the loess has already been described (p. 8). Loess soils are among the most productive in the United States, and the present prosperity of this region is largely due to their presence.

The alluvial soils are confined to the flood plains of the principal streams and, next to the loess soils, are the most fertile. As already mentioned (p. 8), these soils are of two types—one found along the smaller streams and differing only slightly from the loess soils from which it is chiefly derived, and the other forming the surface of most of the Missouri River flood plain. The second type has a considerable range in color and composition, comprising sand, sandy loam, and considerable dark-gray to yellowish-brown silty clay that is heavy and tenacious and difficult to handle. Under favorable conditions, however, most of the alluvium gives fair yields of corn and wheat.

The residual soils are confined to the areas in which Pennsylvanian rocks outcrop. They result from the weathering of the Pennsylvanian formations upon which they lie and derive their character from them. Where the Lawrence shale member outcrops in the southern third of the quadrangles it consists of massive sandstone and sandy shale and has produced a soil of rather low fertility. Soils derived from weathering of shale and limestone are more productive, though in places too stony for cultivation. Not all the area mapped as Pennsylvanian is characterized by typical residual soils, however, for considerable loess and some glacial till cover them in some places and have modified them in many others.

May, 1915.

[4] Analyses published in U. S. Geol. Survey Water-Supply Paper 273, p. 125, 1911, and in Kansas Univ. Geol. Survey, vol. 7, pp. 152, 206, 1902.

[5] Jameson, E., Geology of the Leavenworth prospect well: Kansas Acad. Sci. Trans., vol. 11, pp. 37-38, 1889.

U.S. GEOLOGICAL SURVEY
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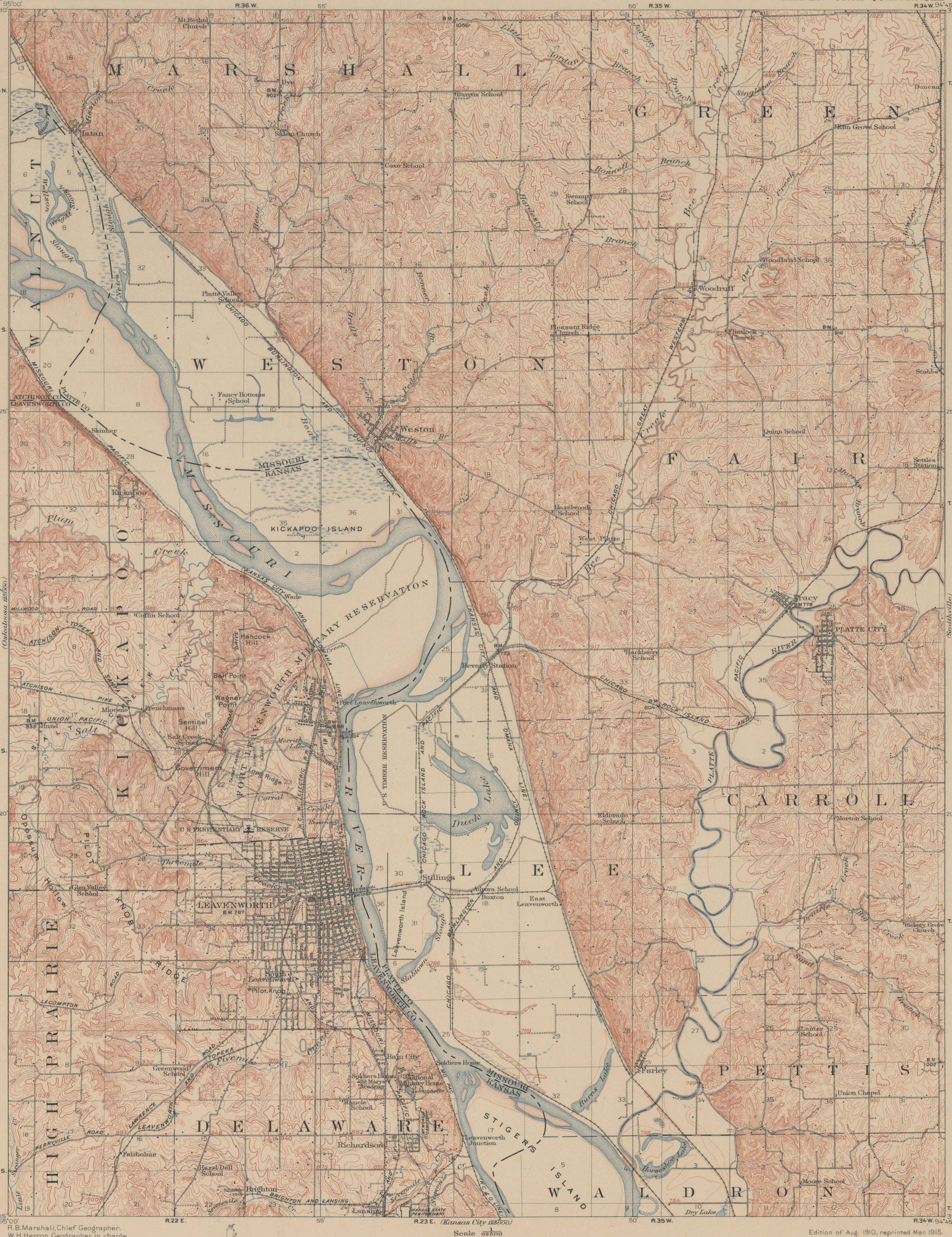
TOPOGRAPHY

MISSOURI–KANSAS
LEAVENWORTH QUADRANGLE



R. B. Marshall, Chief Geographer.
W. H. Herron, Geographer in charge.
Topography by Glenn S. Smith, Arthur Stiles, J. G. Staack, and L. B. Roberts.
Control by Geo. T. Hawkins, S. K. Atkinson, and Missouri River Commission.
Surveyed in 1906–1908.

APPROXIMATE MEAN DECLINATION 1906.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.
Datum is mean sea level.

Edition of Aug. 1910, reprinted Mar. 1915.

LEGEND

RELIEF
printed in brown

Altitude *above mean sea level instrumentally determined*

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

Depression contour

River sand

DRAINAGE
printed in blue

Streams

Intermittent streams

Lake or pond

Intermittent lake

Marsh

CULTURE
printed in black

Roads and buildings

Church or schoolhouse and cemetery

Private or secondary roads

Railroad

Electric railroad

Bridges

U.S. township and section lines

State line

County line

Township line

Reservation line

City, village, or borough line

Triangulation station

Bench mark *showing precise altitude*

AREAL GEOLOGY

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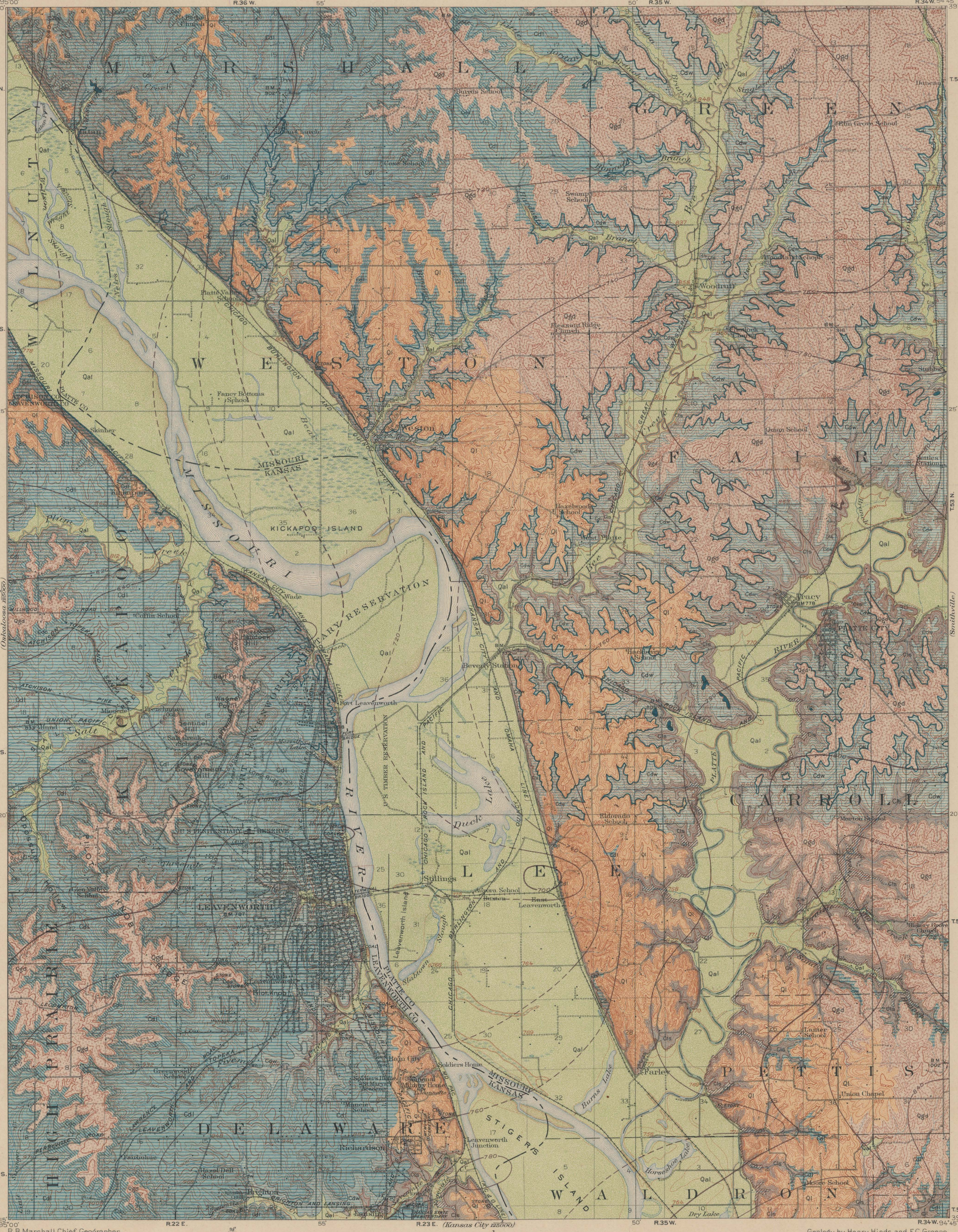
GEORGE OTIS SMITH, DIRECTOR

STATE OF MISSOURI
BUREAU OF GEOLOGY AND MINES
H.A. BUEHLER, DIRECTOR AND STATE GEOLOGIST

MISSOURI–KANSAS
LEAVENWORTH 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 series

Qal — Alluvium *(in flood plains of present streams)*

Pleistocene series

Post-Kansan

Ql — Loess *(buff to gray, fine-grained silt; overlies all older formations nearly everwhere but only thicker deposits mapped; boundaries indefinite)*

Kansan stage

Qgd — Glacial drift *(bowlder clay overlain by thin loess of post-Kansan age; small patches not mapped; boundaries indefinite)*

Aftonian? stage

Qig — Interglacial deposits *(stratified gravel, bowlders, and sand in pre-Kansan valleys; exposed only at Weston and on Murray Branch)*

CARBONIFEROUS

Pennsylvanian series (Smithville)

Missouri group

Cs — Shawnee formation *(chiefly shale and shaly sandstone, Kanwaka shale member, with thin Lecompton limestone member at the top, not separately mapped)*

Cdo, Cdl, Cdi, Cdw — Douglas formation *(chiefly shale and sandstone with limestone beds near middle and at top)*

Oread limestone member, Cdo *(thick-bedded cherty limestone with two interbedded shale beds)*

Lawrence shale member, Cdl *(shale and sandstone with several thin beds of limestone and coal; south of Leavenworth chiefly sandstone, regarded as a channel deposit, which locally rests unconformably on Lansing formation)*

Iatan limestone member, Cdi *(gray massive limestone)*

Weston shale member, Cdw *(blue or drab argillaceous shale)*

Cls, Cll — Lansing formation *(limestones and shales, interbedded, the upper three members mapped together as Cls)*

Stanton limestone member *(limestones with two interbedded thin shales)*

Vilas shale member *(blue shale with sandstone layers)*

Plattsburg limestone member *(cherty limestone, shaly in middle)*

Lane shale member, Cll *(shale, with some sandstone in upper half and irregular limestones in middle)*

Note: *The mapped Carboniferous formations are concealed in places by loess, thin glacial drift, or both.*

ECONOMIC AND STRUCTURE DATA

800 — *Structure contours on base of Plattsburg limestone member of Lansing formation* *(lines dashed where exact position is doubtful; contour interval 20 feet; datum, mean sea level)*

COAL — *Coal mine shafts*
STONE — *Limestone quarries*
Brick-shale pits
(2116) — *Deep boring for oil and gas* *Depth indicated in feet*

Economic data: *The entire quadrangle is probably underlain by one or more workable coal beds in the Cherokee shale at depth of 560 feet or more. The mapped Carboniferous rocks include limestone and sandstone beds suitable for building and other purposes; shale available for brick and other ceramic products; and limestone suitable for lime and cement manufacture. Sand for building purposes is obtained from the bed of Missouri River. Loess suitable for brick making is plentiful on the uplands.*

R.B. Marshall, Chief Geographer.
W.H. Herron, Geographer in charge.
Topography by Glenn S. Smith, Arthur Stiles, J.G. Staack, and L.B. Roberts.
Control by Geo. T. Hawkins, S.K. Atkinson, and Missouri River Commission.
Surveyed in 1906-1908.

TRUE NORTH — MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1906.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.
Datum is mean sea level.
Edition of July 1915.

Geology by Henry Hinds and F.C. Greene, assisted by Maurice Albertson.
Surveyed in 1911.

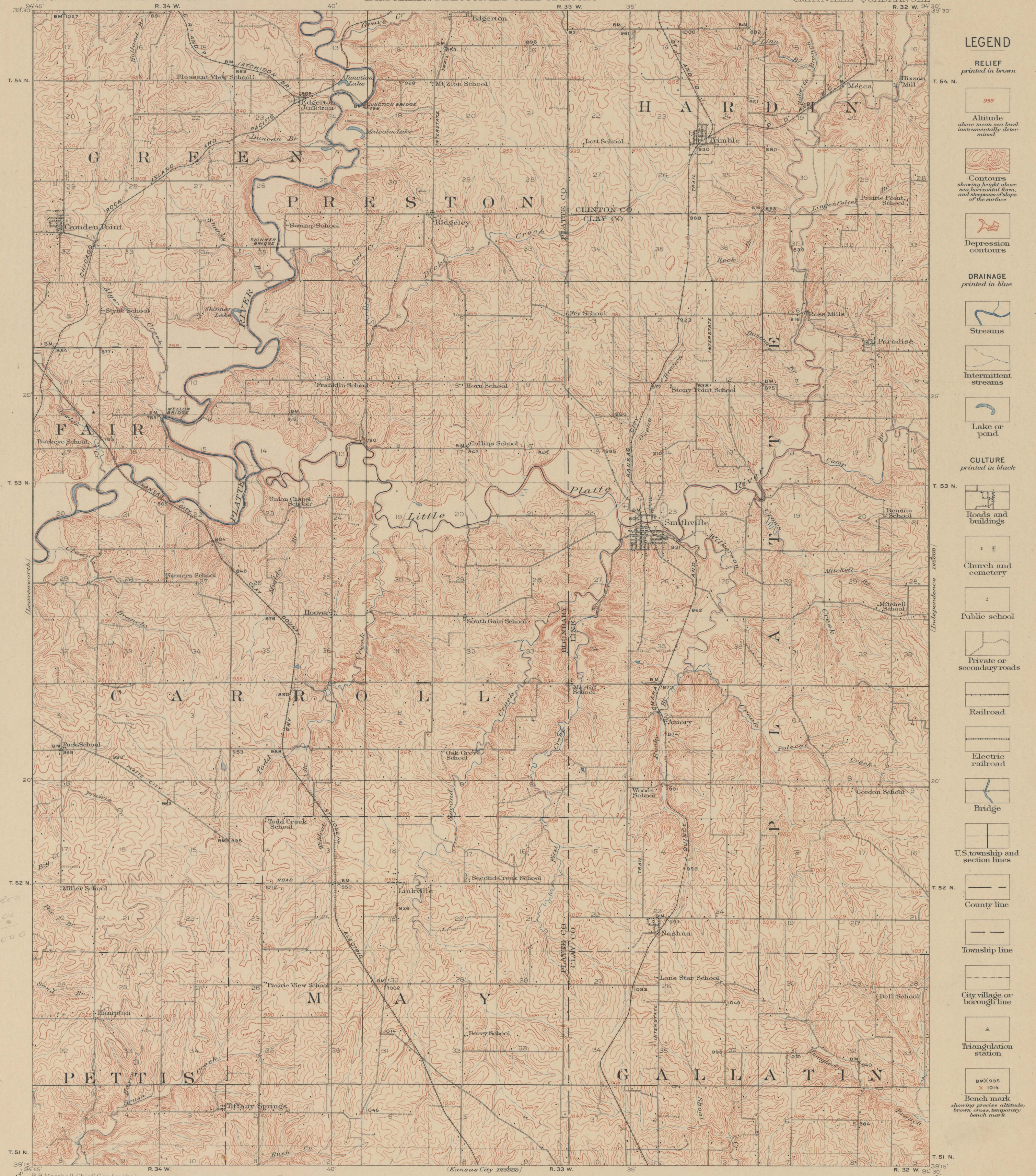
SURVEYED IN COOPERATION WITH THE STATE OF MISSOURI.

TOPOGRAPHY

STATE OF MISSOURI
BUREAU OF GEOLOGY AND MINES
H. A. BUEHLER, DIRECTOR AND STATE GEOLOGIST

U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

MISSOURI
SMITHVILLE QUADRANGLE



R. B. Marshall, Chief Geographer.
W. H. Herron, Geographer in charge.
Topography by H. H. Hodgeson, P. W. McMillen, and J. B. Leavitt.
Control by Geo. T. Hawkins, J. R. Ellis, P. W. McMillen, and J. B. Leavitt.
Surveyed in 1912.

SURVEYED IN COOPERATION WITH THE STATE OF MISSOURI.

APPROXIMATE MEAN DECLINATION 1912.

Scale $\frac{1}{62500}$

Contour interval 20 feet.
Datum is mean sea level.

Edition of April 1914, reprinted April 1915.

AREAL GEOLOGY

STATE OF MISSOURI
BUREAU OF GEOLOGY AND MINES
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U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

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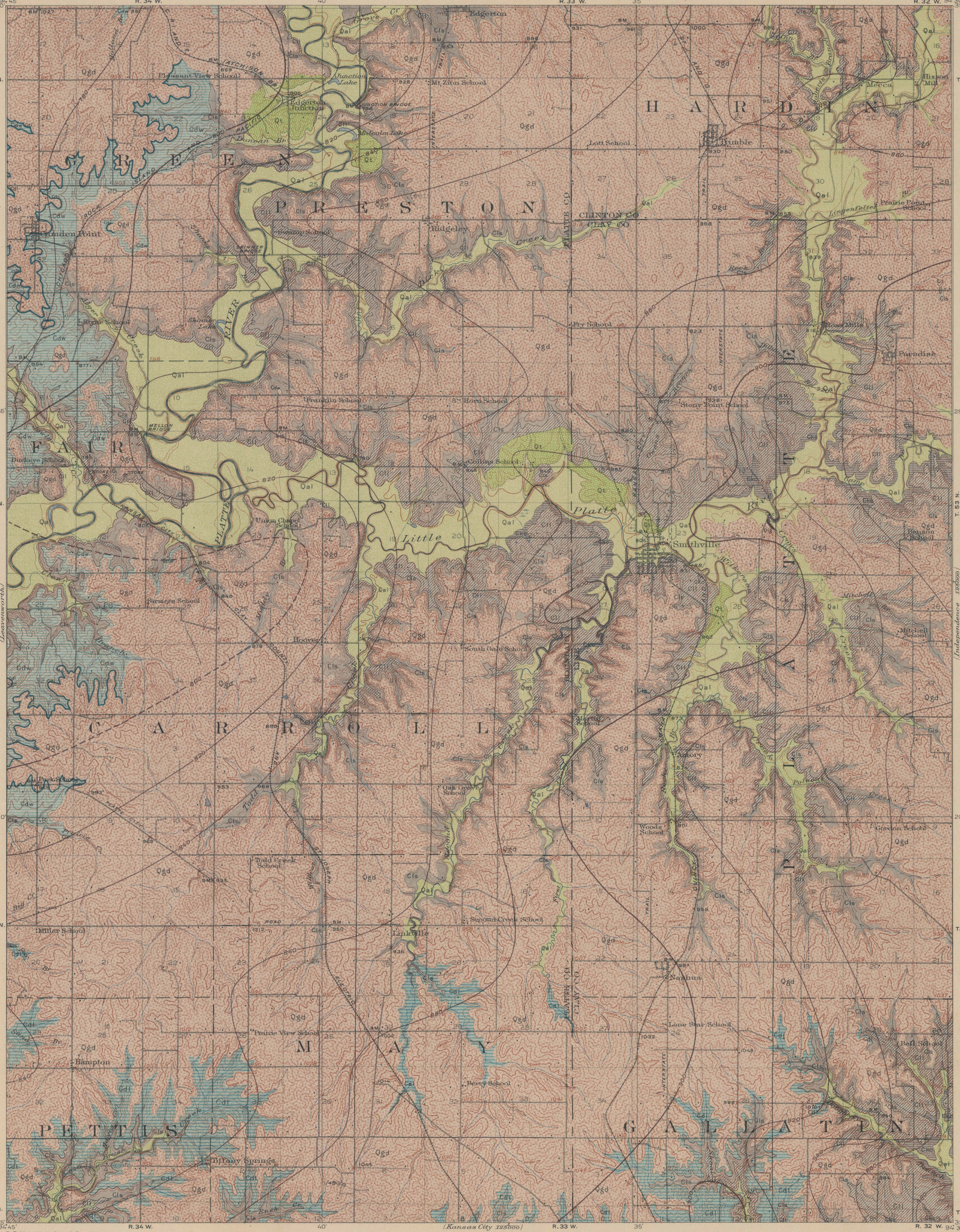

LEGEND

SEDIMENTARY ROCKS

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

QUATERNARY

Recent series

Qal — **Alluvium** *(in flood plains of present streams)*

Qt — **Terrace deposits and wash** *(gravel and wash occupying terraces and slopes of abandoned stream meanders)*

Pleistocene series

Kansan stage

Qgd — **Glacial drift** *(bowlder clay overlain by thin loess of post-Kansan age; boundaries indefinite)*

Aftonian? stage

Qig — **Interglacial deposits** *(stratified gravel, bowlders, and sand in pre-Kansan valleys; exposed only northwest of Hoover and at mouth of Crows Creek)*

CARBONIFEROUS

Pennsylvanian series — Missouri group

Cdl, Cdi, Cdw — **Douglas formation** *(chiefly shale and sandstone, with limestone bed near middle)*

Lawrence shale member, Cdl *(exposures chiefly sandstone and sandy shale, regarded as channel deposit, which locally rests unconformably on Lansing formation)*

Iatan limestone member, Cdi *(gray massive limestone)*

Weston shale member, Cdw *(blue or drab argillaceous shale)*

Cls, Cll — **Lansing formation** *(limestones and shales interbedded; the upper three members mapped together as Cls)*

Stanton limestone member *(limestones with two interbedded thin shales)*

Vilas shale member *(blue shale with sandstone layers)*

Plattsburg limestone member *(cherty limestone, shaly in middle)*

Lane shale member, Cll *(shale, with some sandstone in upper half and irregular limestones in middle)*

Ckc — **Kansas City formation** *(limestones and shales interbedded; members not separately mapped)*

Iola limestone member *(thin-bedded limestone)*

Chanute shale member *(shale with two limestone lentils)*

Drum limestone member *(thin limestone oolitic in part)*

Cherryvale shale member *(thin blue shale)*

Note: *The mapped Carboniferous formations are concealed in places by loess, thin glacial drift, or both.*

ECONOMIC AND STRUCTURE DATA

900 — *Structure contours on base of Plattsburg limestone member of Lansing formation (contour interval, 20 feet; datum, mean sea level)*

STONE — *Limestone quarries*

(480) — *Deep borings for oil, gas, or coal. Depth indicated in feet*

Economic data: *Most of the quadrangle is probably underlain by one or more workable coal beds in the Cherokee shale at depth of 390 feet or more. The mapped Carboniferous rocks include limestone and sandstone beds suitable for building and other purposes; shale available for brick and other ceramic products; and limestone suitable for lime and cement manufacture. Loess suitable for brick making is plentiful on the uplands. Mineral springs issue from sandstones in southern part of quadrangle.*

R.B. Marshall, Chief Geographer.
W.H. Herron, Geographer in charge.
Topography by H.H. Hodgeson, P.W. McMillen, and J.B. Leavitt.
Control by Geo. T. Hawkins, J.R. Ellis, P.W. McMillen, and J.B. Leavitt.
Surveyed in 1912.

SURVEYED IN COOPERATION WITH THE STATE OF MISSOURI.

TRUE NORTH — MAGNETIC NORTH — 9°
APPROXIMATE MEAN DECLINATION 1912.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.
Datum is mean sea level.
Edition of July 1915.

Geology by F.C. Greene,
assisted by Maurice Albertson.
Surveyed in 1912.

SURVEYED BY THE STATE OF MISSOURI.

ILLUSTRATIONS

PLATE I.—LANSING FORMATION, INCLUDING PLATTSBURG LIMESTONE MEMBER, WHICH APPEARS IN TWO LEDGES IN MIDDLE OF CLIFF.
Near mouth of Ninemile Creek, Lansing, Kans.

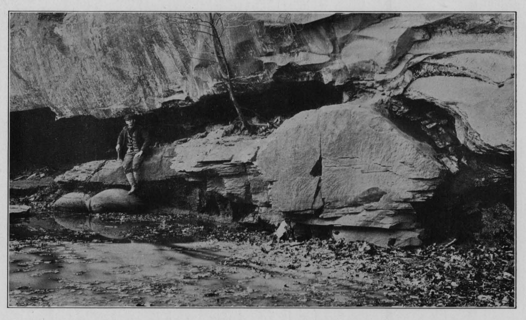

PLATE III.—MASSIVE SANDSTONE AT BASE OF LAWRENCE SHALE MEMBER OF DOUGLAS FORMATION.
Concretions at stream level are characteristic of the basal part of the sandstone. One mile southeast of Linkville, Mo.

PLATE VI.—LOWER PART OF OREAD LIMESTONE MEMBER OF DOUGLAS FORMATION.
In road cut on Government Hill, northwest of Leavenworth, Kans.

PLATE VIII.—CRUMPLED AFTONIAN (?) INTERGLACIAL DEPOSITS DISTORTED PROBABLY BY BEING OVERRIDDEN BY KANSAN GLACIER.
Crow Creek, east of Smithville, Mo.

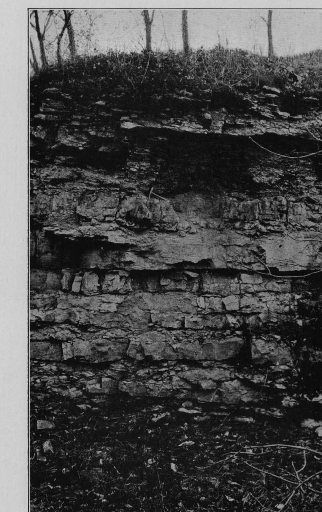

PLATE IV.—MAIN LEDGE OF STANTON LIMESTONE MEMBER OF LANSING FORMATION OVERLAIN UNCONFORMABLY BY BRECCIATED LIMESTONE BEDS AT BASE OF LAWRENCE SHALE MEMBER OF DOUGLAS FORMATION (ABOVE HAMMER).
Two miles southeast of Nashua, Mo.

PLATE IX.—JOINTING IN FARLEY LIMESTONE BED IN LANE SHALE MEMBER OF LANSING FORMATION.
Exposed in bed of brook in southwest corner of Smithville quadrangle, Mo.

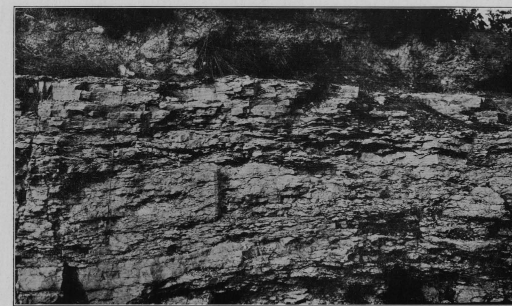

PLATE II.—IATAN LIMESTONE MEMBER OF DOUGLAS FORMATION.
Very thin bedded shaly limestone in railroad cut at Iatan, Mo.

PLATE V.—BASAL SANDSTONE OF LAWRENCE SHALE MEMBER, WHICH HERE RESTS UNCONFORMABLY ON WESTON SHALE MEMBER OF DOUGLAS FORMATION.
Pit of Leavenworth Vitrified Brick Co., Leavenworth, Kans.

PLATE VII.—INTERGLACIAL BOWLDER BED OF PROBABLE AFTONIAN STAGE.
Near Weston, Mo.

PLATE X.—CLIFF OF LOESS SHOWING CHARACTERISTIC COLUMNAR JOINTING AND INDISTINCT HORIZONTAL BANDING.
Railroad cut near Beverly, Mo.

No.*	Name of folio.	State.	Price.†
			Cents.
‡1	Livingston	Montana	
‡2	Ringgold	Georgia-Tennessee	
●3	Placerville	California	
‡4	Kingston	Tennessee	
●5	Sacramento	California	
‡6	Chattanooga	Tennessee	
‡7	Pikes Peak	Colorado	
‡8	Sewanee	Tennessee	
‡9	Anthracite-Crested Butte	Colorado	
‡10	Harpers Ferry	Va.-Md.-W.Va	
●11	Jackson	California	
‡12	Estillville	Ky.-Va.-Tenn	
‡13	Fredericksburg	Virginia-Maryland	
‡14	Staunton	Virginia-West Virginia	
‡15	Lassen Peak	California	
‡16	Knoxville	Tennessee-North Carolina	
‡17	Marysville	California	
‡18	Smartsville	California	
‡19	Stevenson	Ala.-Ga.-Tenn	
20	Cleveland	Tennessee	5
‡21	Pikeville	Tennessee	
‡22	McMinnville	Tennessee	
23	Nomini	Maryland-Virginia	5
‡24	Three Forks	Montana	
‡25	Loudon	Tennessee	
‡26	Pocahontas	Virginia-West Virginia	
‡27	Morristown	Tennessee	
‡28	Piedmont	West Virginia-Maryland	
‡29	Nevada City Special	California	
‡30	Yellowstone National Park	Wyoming	
‡31	Pyramid Peak	California	
‡32	Franklin	West Virginia-Virginia	
‡33	Briceville	Tennessee	
‡34	Buckhannon	West Virginia	
‡35	Gadsden	Alabama	
36	Pueblo	Colorado	5
‡37	Downieville	California	
‡38	Butte Special	Montana	
‡39	Truckee	California	
‡40	Wartburg	Tennessee	
‡41	Sonora	California	
42	Nueces	Texas	5
‡43	Bidwell Bar	California	
‡44	Tazewell	Virginia-West Virginia	
‡45	Boise	Idaho	
‡46	Richmond	Kentucky	
‡47	London	Kentucky	
‡48	Tenmile District Special	Colorado	
‡49	Roseburg	Oregon	
‡50	Holyoke	Massachusetts-Connecticut	
‡51	Big Trees	California	
‡52	Absaroka	Wyoming	
‡53	Standingstone	Tennessee	
‡54	Tacoma	Washington	
‡55	Fort Benton	Montana	
‡56	Little Belt Mountains	Montana	
‡57	Telluride	Colorado	
‡58	Elmoro	Colorado	
‡59	Bristol	Virginia-Tennessee	
‡60	La Plata	Colorado	
‡61	Monterey	Virginia-West Virginia	
62	Menominee Special	Michigan	5
‡63	Mother Lode District	California	
‡64	Uvalde	Texas	
65	Tintic Special	Utah	5
‡66	Colfax	California	
67	Danville	Illinois-Indiana	5
68	Walsenburg	Colorado	5
‡69	Huntington	West Virginia-Ohio	
‡70	Washington	D. C.-Va.-Md.	
‡71	Spanish Peaks	Colorado	
‡72	Charleston	West Virginia	
‡73	Coos Bay	Oregon	
‡74	Coalgate	Oklahoma (Ind. T.)	
75	Maynardville	Tennessee	5
‡76	Austin	Texas	
‡77	Raleigh	West Virginia	
78	Rome	Georgia-Alabama	5
‡79	Atoka	Oklahoma (Ind. T.)	
‡80	Norfolk	Virginia-North Carolina	
‡81	Chicago	Illinois-Indiana	
‡82	Masontown-Uniontown	Pennsylvania	
‡83	New York City	New York-New Jersey	
84	Ditney	Indiana	5
85	Oelrichs	South Dakota-Nebraska	5
86	Ellensburg	Washington	5
87	Camp Clarke	Nebraska	5
88	Scotts Bluff	Nebraska	5
89	Port Orford	Oregon	5
90	Cranberry	North Carolina-Tennessee	5
91	Hartville	Wyoming	5
92	Gaines	Pennsylvania-New York	5
93	Elkland-Tioga	Pennsylvania	5
‡94	Brownsville-Connellsville	Pennsylvania	
95	Columbia	Tennessee	5
96	Olivet	South Dakota	5
97	Parker	South Dakota	5
98	Tishomingo	Oklahoma (Ind. T.)	5
99	Mitchell	South Dakota	5
100	Alexandria	South Dakota	5
101	San Luis	California	5
102	Indiana	Pennsylvania	5
103	Nampa	Idaho-Oregon	5
104	Silver City	Idaho	5
105	Patoka	Indiana-Illinois	5
106	Mount Stuart	Washington	5
107	Newcastle	Wyoming-South Dakota	5
108	Edgemont	South Dakota-Nebraska	5
109	Cottonwood Falls	Kansas	5
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‡111	Globe	Arizona	
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114	De Smet	South Dakota	5
‡115	Kittanning	Pennsylvania	
116	Asheville	North Carolina-Tennessee	5
117	Casselton-Fargo	North Dakota-Minnesota	5
118	Greeneville	Tennessee-North Carolina	5
119	Fayetteville	Arkansas-Missouri	5
‡120	Silverton	Colorado	
‡121	Waynesburg	Pennsylvania	
122	Tahlequah	Oklahoma (Ind. T.)	5
123	Elders Ridge	Pennsylvania	5
124	Mount Mitchell	North Carolina-Tennessee	5
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‡127	Sundance	Wyoming-South Dakota	
‡128	Aladdin	Wyo.-S. Dak.-Mont	
‡129	Clifton	Arizona	
‡130	Rico	Colorado	
‡131	Needle Mountains	Colorado	
‡132	Muscogee	Oklahoma (Ind. T.)	
‡133	Ebensburg	Pennsylvania	
‡134	Beaver	Pennsylvania	
‡135	Nepesta	Colorado	
136	St. Marys	Maryland-Virginia	5
137	Dover	Del.-Md.-N. J	5
‡138	Redding	California	
‡139	Snoqualmie	Washington	
‡140	Milwaukee Special	Wisconsin	
‡141	Bald Mountain-Dayton	Wyoming	
‡142	Cloud Peak-Fort McKinney	Wyoming	
143	Nantahala	North Carolina-Tennessee	5
‡144	Amity	Pennsylvania	
‡145	Lancaster-Mineral Point	Wisconsin-Iowa-Illinois	
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‡151	Roan Mountain	Tennessee-North Carolina	
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‡153	Ouray	Colorado	
‡154	Winslow	Ark.-Okla. (Ind. T.)	
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