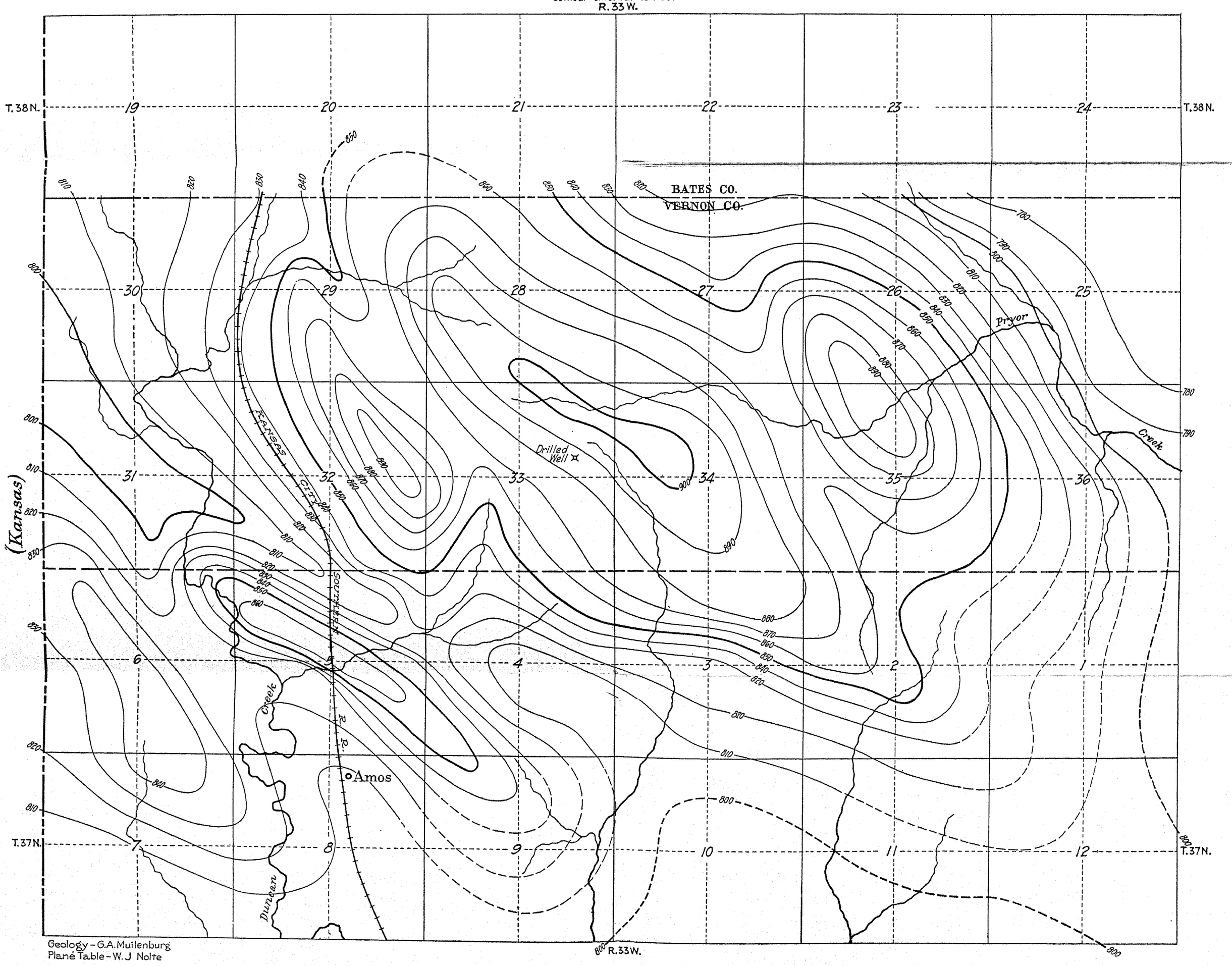
Missouri Bureau of Geology and Mines

Structure Map of Northwest Portion of Vernon County

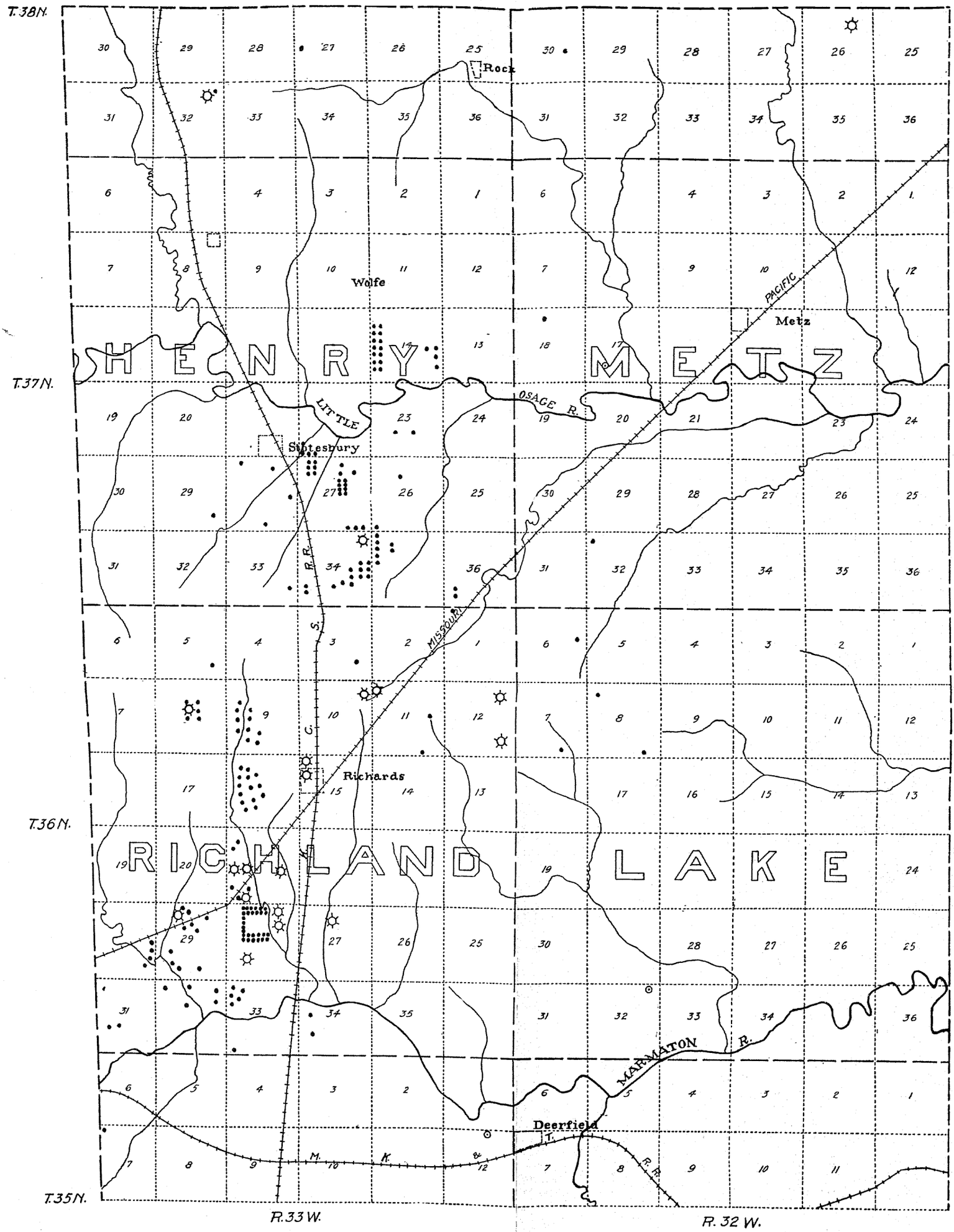
(Contours on base of Pawnee Limestone)

Scale: 2 Inches = 1 Mile

Contour Interval 10 Feet



Geology – G.A. Muilenburg
Plane Table – W.J Nolte



• Wells Producing or Reported in Oil

☼ Gas Wells Producing or Reported in Gas

Map showing drilled oil and gas wells in northwest Vernon County.

THE GEOLOGY *of* VERNON COUNTY

By

F. C. Greene *and* W. F. Pond

Vol. XIX, Second Series

1926

Missouri Bureau of Geology and Mines

Rolla, Missouri

H. A. BUEHLER, *Director and State Geologist*

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LETTER OF TRANSMITTAL.

Bureau of Geology and Mines,
Rolla, Mo., March 1, 1926.

To the President, Governor Sam A. Baker, and the Members of the Board of Managers of the Bureau of Geology and Mines:

Gentlemen: It is my pleasure to transmit herewith a report covering the Geology of Vernon County. The chapters on geography and stratigraphy were prepared by Mr. F. C. Greene; the chapter on economic geology by Mr. W. F. Pond.

Vernon County has a most interesting early history and an introductory chapter on "History and Exploration," prepared by Dr. Edward M. Shepard of Springfield, is included.

Respectfully submitted,
H. A. BUEHLER,
Director and State Geologist.

INTRODUCTION.

EARLY HISTORY AND EXPLORATION.

By

EDWARD M. SHEPARD, Sc. D.

The subject of Geology covers a far wider field than is generally supposed, and the consideration of this branch of science from a historical standpoint merges gradually into archaeology, ethnology, and anthropology. Therefore it is proper that the geological study of any region should take some cognizance of these allied branches of research. In every inhabited part of the world we find abundant evidence of occupation by more than one race of people. In many cases, there has been a series of occupants, each passing through a cycle of settlement, growth and maturity, followed by a gradual decay, migration, or an absorption into the body of some more powerful race.

INDIAN OCCUPATION.

Vernon County is no exception to this rule. When this region was first visited by the white man, the Osage Indians were in occupation. Before them came prehistoric races, namely, the Mound Builders. Representing these are groups of low mounds scattered throughout the eastern and southeastern part of the county, this being, apparently, the western limit of a race of people, evidences of which are so widely found in the Ozark region. These mounds are sometimes so low as to be hardly noticeable, and they are rarely elevated more than two or three feet above the surrounding country. They are often twenty or thirty feet in diameter, usually arranged in irregular groups numbering from half a dozen to fifty or sixty, and standing from one hundred to one hundred and fifty feet apart. They are rarely more than a quarter of a mile away from water, being mostly located in irregular groups, or rows, in the narrow valleys sloping toward springs or water courses. They are seldom found in the broader, lower valleys, either because of the fear of overflow or for the reason that more dense forests covered the river bottoms than now prevail. The original slight eleva-

tion of those mounds has caused them to be often unrecognized, and the agriculturist, by plowing and harrowing, has demolished many of them or greatly reduced their size. They are frequently marked, in a field of grain, as little islands of more luxurious growth.

These small mounds must not be confused with the larger and more prominent buttes in the central and western portion of Vernon County which owe their existence to natural conditions alone, each one of them being capped by hard layers of rock which protect the softer layers below, thus preserving them from obliteration by the elements. Houck[1] says that in Vernon County 148 of these mounds have been catalogued.

	Number
In Twp. 35 N., R. 31 W., as follows:	
Pt. of Sec. 28	29
SE pt. of Sec. 21	23
Middle pt. Sec. 17	22
NW. ¼ Sec. 11	14
SW. ¼ Sec. 12	12
Middle part of Sec. 13	9
In Twp. 35, R. 30, NE. Sec. 28	30
In Twp. 34, R. 31, NW. ¼ of SW. ¼ sec. 23	9
Total	148

These are probably but a small fraction of the mounds that exist in the county. Many counties in the Ozarks contain hundreds of them. The writer estimates that there are probably 10,000 in Greene County alone. They are, without doubt, the remains of human habitations,—the villages of the Mound Builders, which appear to have been composed of circular adobe huts, structures made of mud walls or sun-dried bricks, with thatched roofs, like those of the Mandan Indians described by Lewis and Clark. When these abodes were abandoned, the decay of the thatched roof and the action of the elements soon reduced them to the condition of low mounds, as they appear today. A section of these mounds shows a line of mould at about the level of the ground, indications of the floor of the dwelling, with remains of charcoal often marking the position of the fire-place in the hut which appears to have always been round in shape. The absence of bones, or any human remains, shows that they were not burial mounds. The sun-dried adobe

[1]History of Missouri, Vol. 1, p. 85, footnote 81.

of which they were probably made is further evidenced by the absence of stones or coarser material in them. The general absence of flints or domestic utensils would indicate a people unwarlike and generally low in the scale of civilization.

In other counties, the association of these mounds with shallow ponds,—not the ponds formed by the stoppage of limestone sinks, would seem to indicate the source from which the adobe came. In Greene County, especially, there exists obscure evidence of irrigation ditches running from the higher-located ponds.

In some counties, especially Howell, where the mounds are particularly numerous, the antiquity of the race which left them is indicated by the fact that the mounds outline the location of former streams in shallow valleys where there are now only wet-weather streams and where there are practically no springs. The Big North Fork and Bryant's Fork, tributaries of the White River, have trenched deeply and rapidly, from 300 to 400 feet below the general level of the surrounding country, which has caused the minor streams to leave their surface channels largely to wet-weather streams and seek subterranean drainage, proof of which is seen in the many enormous springs which now rise in the beds and adjacent valleys of the Big North Fork and Bryant's Fork. The numerous Indian mounds along these old stream beds show that the region had been a populous one before the waters had left their surface channels and the springs dried up. The nature of these topographic changes, and the great beds of residual material, from 70 to 90 feet thick, give evidence of the lapse of time since these prehistoric people dwelt on the borders of the now sunken and lost streams. What became of the race, no one knows. It may be that they were driven out by some other tribe, or that some epidemic disease killed them off, but one can only conjecture what may have been the cause of their complete disappearance.

The earliest inhabitants of Vernon County of which we have any written record are the Osage Indians. Marquette, on his autograph map of 1673, locates them, apparently, on the Osage River, where all subsequent writers have placed them in the region now known as Vernon County. Du Tisne, who visited the region in 1719, described the Indians as stout, well-made men who were never so happy as when fighting their enemies. The group of Pahatsi or Great Osages, had its principal village near the mouth of the Marmaton River southwest of its union

with the Osage, in sec. 32, twp. 37, R. 31. In 1825, it was located in the NW. ¼ of sec. 15, T. 37 N., R. 30 W. The Indians moved their villages frequently, for sanitary reasons. Another Osage village, probably that of the Little Osages, was located in the NW ¼ sec. 19, T. 37 N., R. 31 W., first called Balltown and later Little Osage Village.

The Osage tribes had their hunting grounds scattered through the Ozark[1]. Many of their camps, only used when on their Spring and Fall hunting trips, were located on their trail leading to a point on White River near what is now the town of Forsyth. They had a love for scenery, as is shown by the fact that for the burial of their dead they always selected the most sightly positions,—the highest mounds, the tallest bluffs or promontories which commanded broad views of plain and lowland. For example, Timbered Mound, on the west side of the Marmaton, at its juncture with the Osage, was where they buried "White Hair" and many other famous chiefs of their band.

In an environment of natural beauty, with rich soil, a great abundance of pure, clear, cold springs and broad, spring-fed streams, and rivers, with pure air, bounteous rainfall, and a food supply unlimited in quality and abundance, was developed this tribe, the largest, most perfect in physique and the most admirable in character of any of the great Siouan family, and probably of all the North American Indians. Do we not find, in these facts, something suggestive of the physical possibilities presented to the future occupants of this wonderful region. Catlin[2] says that the Osages were the tallest race in North America, either among the red or white men. He states that few were less than six feet in stature and that many were six and a half and even seven feet tall. They were well-proportioned, good-looking, rather narrow in the shoulders, and like most tall men, inclined to stoop. They were one of the few tribes that shaved their heads, and they decorated and painted themselves with great care and some taste. They dressed largely in skins of their own preparing, and adorned themselves with great quantities of wampum, beads, and tinsel ornaments. Washing-

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[1]The origin of the name "Ozark" is given by Fetherstonaugh in his book entitled "Excursions Through the Slave States in 1834 and '35," p. 63. He says: "It was the custom of the French Canadians to abbreviate all their names. If they were going to the Arkansas Mountains, they would say they were going 'aux arcs,' a term which American travelers have converted into 'Ozarks.'"

[2]Catlin's North American Indians, Vol. 2, p. 89.

ton Irving, in his "Tour of the Prairies" says: "The Osage Indians are the finest-looking Indians I have seen in the West."

History tells us that several centuries ago the Osages, with allied tribes, forming one great family called Siouan, after the principal tribe, the Sioux, either migrated or were driven by the Iroquois and other tribes westward from Virginia and North Carolina, making long stops at various points along the Kanawha and Ohio valleys until the Mississippi was reached. While on the way, small bands were here and there left behind, and so they distributed themselves throughout the surrounding country. At the Mississippi, the Siouan band divided, one group, called the Omaha, or up-river group, going north up the river, and the other, the Quapaw (Kwapa), or down-river group, going down the river. The Omaha group again divided at the mouth of the Missouri River, further dividing as they went, into the Osages, along the Osage River, the Kaws (Kansas), who settled on the Kansas River, and the Missouris, along the Missouri River. A reason for these migrations and the separations into different tribes is found in the fact that they were largely dependent upon hunting for food and clothing, and when a village became too large, or its enemies too strong, it was necessary to break up and find new hunting grounds.

About 1802, according to Lewis and Clark, nearly half of the Great Osages, in what is now Vernon County, under a chief named "Big Track," migrated to the Arkansas River. From the same authority we learn that in 1804 the Great Osages numbered about 500 warriors living in a village on the south bank of the Osage River. The Little Osages had about 250 warriors, and the Arkansas band, with about 600 warriors were on the Vermillion River, a branch of the Arkansas. In 1817, Gen. Sibley reported that the Great Osages had 400 warriors and the Little Osages 250. Houck[1] states: The main dependence of these Indians was on hunting, but they raised, annually, small crops of corn, beans, and pumpkins, cultivating them entirely with the hoe, and planting in April. In May they entered upon their summer hunts and returned about the first of August to gather the crops which they had left unhoed and unfenced all summer. Sibley states that each family could save from 10 to 20 bags of corn and beans, besides a quantity of dried pumpkins. On this they feasted, together with their

[1]History of Missouri, Vol. 1, p. 182.

dried meat, until September, when what remained was cached[1], while they set out for the fall hunt, from which they returned about Christmas. From then, until some time in February and March, if the season happened to be severe, they stayed pretty much in their villages, making only occasional hunting excursions, and during that time they consumed the greater part of their caches. In February or March the spring hunt commenced, first the bear and then the beaver hunt. This was continued until the planting time, when they again returned to their villages, planted their crops, and, in May, set out for the summer hunt, taking with them the residue of their corn, etc. Sibley states that these people derived a portion of their subsistence regularly from dried fruits in which the country abounded —walnuts, hazel nuts, pecans, acorns, grapes, plums, pawpaws, persimmons, hog potatoes and several very nutritious roots, all of which they gathered and preserved with care. For a fuller description of Osage people, especially with reference to their villages, the building of their lodges, their government, etc., see "Pike's Expedition." Vol. II, pp. 526-529; Schoolcraft, "Journal of a Tour in the Interior of Missouri and Arkansas in 1818," London, 1821, p. 52; Catlin's "North American Indians," Vol. II, p. 89.

SOVEREIGNTIES AND TREATIES.

In 1541, both De Soto and Coronado, Spanish explorers, who came into this southwest region, claimed for Spain, by right of discovery, the vast territory which included Missouri. What is now Vernon County was probably under the Spanish flag. In 1682, on April 9th, near the mouth of the Mississippi River, Robert Cavalier La Salle took formal possession of the country in the name of the King of France and called it Louisiana, thus bringing what is now Vernon County under the French flag. In 1762, on November 3rd, France ceded Louisiana to Spain, but Spanish authorities did not take possession of Upper Louisiana until May 20th, 1770. This brought what is now Missouri again under the Spanish flag. In 1800, on October 1st, by treaty ratified March 1st, 1801, Spain retroceded Louisiana to France, but Upper Louisiana was not transferred until March

[1]See description of Caches in Halley's Bluff in another portion of this volume. See, also, Pike's Journal, Vol. II, p. 385, and Broadhead, Geological Survey of Missouri, Vol. 1, 1873-4, p. 152.

9th, 1804, coming again under the French flag. In 1803, April 30th, France ceded the province of Louisiana to the United States but Upper Louisiana was not transferred until March 4th, 1804.

On October 10th, 1808, after the Louisiana purchase, the Big and Little Osage tribes made a treaty with the United States at Fort Osage, now called Fort Sibley, about twenty-five miles east of Kansas City, on the Missouri River, by which they ceded to the United States all that portion of southern Missouri lying east of a line extending from Fort Sibley due south to the Arkansas River and north of the Arkansas to its mouth, west of the Mississippi to the mouth of the Missouri, and following that river back to the original starting. For this vast tract, covering practically all of the Ozark Country, the Big Osages were given $800.00 in cash and $1,000.00 in merchandise; while the Little Osages received just half this amount. On June 2nd, 1825, they relinquished all their land remaining in Missouri and Arkansas, and a portion of their Kansas possession, recognizing the right of the United States to use all navigable rivers in what was left of their original territory. For this they were to receive $7,000.00 yearly for seven years[1]. By Act of Congress, July 15th, 1870, the limits of their reservations in the then Indian Territory were established. This reservation consisted, in 1906, of 1,470,058 acres, and in addition the tribe possessed funds in the Treasury of the United States amounting to $8,562,690.00, including a school fund of $119,911.00, the whole yielding an annual income of $428,134.00. Their income from pasturage leases amounted to $98,376.00 in the same year, and their total annual income was, therefore, about $265.00 per capita, making this tribe the richest in the entire United States.

By Act of Congress of June 28, 1906, an equal division of the lands and funds of the Osages was provided for. The population of the tribe at this time, after the division of the tribal lands and trust fund had been provided for, was 1,994.

RECORD OF EARLY TRAVELERS.

In 1541-'42, De Soto, according to the best historians, Bancroft, Shea, Sparks and others, is believed to have penetrated

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[1]See 18th Annual Report, United States Bureau American Ethnology, Part 2, page 676. Handbook of American Indians, United States Bureau of Ethnology, Bulletin 30, Part 2, p. 158.

as far north as Greene County, in what is now Missouri, and there is a tradition that he reached a point near what is now Vernon County, though this is not substantiated. At the same time, 1541, Coronado, starting from Mexico, nearly reached the eastern limits of what is now Kansas, but did not penetrate into what is now Vernon County, as many have tried to show. It is, however, a remarkable fact that these two great explorers, De Soto starting from Florida on the east and Coronado from Mexico in the southwest, should, without the knowledge of either, have been, at one time, within a few days' journey of each other. So we see that the white man was in this region about 50 years before the Cavaliers landed at Jamestown, and about 75 before the Pilgrims landed at Plymouth. As this Ozark region was widely known among the Indians for its salubrious climate and as a famous hunting and fishing ground, it is not strange that early explorers, in their search for gold, should have been led hither by the Indian guides to whom this region meant everything that could be desired. In fact, the early Indians of the Atlantic coast had a regular trail, called "The Indian Warriors' Trail," extending from Virginia westward through southern Missouri to the Rocky Mountains.

The first Caucasian to visit the region now known as Vernon County was Charles Claude Du Tisne, a French Canadian, who, in the summer of 1719, was sent by Bienville, at that time Governor of Louisiana, to explore the interior of the territory that is now Missouri. In September of that year, he reached the Osage Village in the north part of Vernon County. He named the Osage River from that tribe, and he left the first written record pertaining to that region. From 1719 to 1742, it is very probable that what is now Vernon County was visited by some of the numerous exploring parties under the direction of Renault and La Motte (of the famous French Mississippi Company), prospecting for precious minerals. Evidences of their search are found in many of the counties of the Ozarks.

During these years, the Osage and Missouri Rivers were becoming known. The excavations at Halley's Bluff have, by some, been referred to the activities of the above-mentioned explorers; but there is little doubt in the minds of archaeologists but they were originally designed by the Indians or French traders for caches, as before explained. Supposed evidences of old diggings have been reported in the SE. corner of T. 38 N., R.

30 W.; at Howard's Mound; and the SE. corner of T. 37 N., R. 29 W., all in Vernon County.

About 1787, Pierre Chouteau, of St. Louis, under authority of Francisco Crozat, Spanish Governor, was granted permission to build a fort and trading post which was probably located above Halley's Bluff, on the south bank of the Osage. The fort consisted of a stockade and probably one or two block houses and store-houses. It was garrisoned probably by 12 or more men and several small cannon. It had disappeared at the time of the visit of Zebulon Pike in 1806, though a trading station was still maintained there, as Brackenridge, in 1810, stated that $30,000.00 worth of goods were handled there annually. The old fort was called Fort Carondelet, and it attracted a few French settlers who were the first white men to reside in Vernon County or western Missouri.

The first American exploring expedition to enter what is now Vernon County was that of Zebulon Pike. A new edition of his "Journal," published in 1895, in three volumes, and edited by Elliott Coues, contains very full descriptions of the Osage Indians, the Osage River, and the condition of the country at that time. Pike left St. Louis July 15, 1806, and reached the site of Fort Carondelet August 17th of that year. He says that not a vestige of the fort remained, and that the spot was marked only by the superior vegetation. He described the river bank as "one solid bed of stone coal, just below which is a very shoal and rapid ripple, 'Kaw rapids' (where was Colleen, or Colly ford), the head of navigation whence the village of the Grand Osage is nine miles south across a grand prairie."

The direct cause of the settling of Vernon County by Americans was the founding of Harmony Mission, in 1821, in southern Bates County. In 1820, a delegation of Osage Indians visited Washington, and after settling various items of business with the Government, requested that men be sent to their home in the West to teach them the civilization and learning of the white brothers. When this appeal was published abroad, it attracted a great deal of attention. The American Board of Commissioners for Foreign Missions, a Congregational Missionary association, located in Boston, decided to send out missionaries for two stations, one group to the Neosho, or Verdigris Band, in Arkansas, and the other to the Great Osage Band on the Osage River. In 1821, these New England Mis-

sionaries, preachers, carpenters, blacksmiths and farmers, some with wives and children, and a doctor, 13 souls in all, gathered at Pittsburg, Pa., to embark on the dangerous part of their journey along the great rivers of the western wilderness. They were facing greater perils than did the Pilgrim Fathers in crossing the Atlantic in the famous Mayflower. They set out in two pirogues, as it was necessary to use keel boats to work their way up stream. They pushed their way by means of long poles set against the bottom of the river and boatmen's shoulders, and shoved by main force as the men walked a plank fastened to the side of the boat. Where the current was too strong, or the river too deep to admit of poling, the crew frequently had to get out on the bank, and by means of a rope fastened to the boat pull it up stream by sheer strength. Their leader was drowned in the Ohio. Not only were there dangers from the rapids and currents of the great rivers, but they had to pass through the territory of hostile tribes. Floating down the Ohio to its mouth in the Mississippi, toiling up stream in the mighty current to the mouth of the Missouri, thence up the muddy and treacherous Missouri, they fought their toilsome journey to the mouth of the Osage, and in August, 1821, four months after embarking at Pittsburgh, they reached the head of navigation on the Osage at the site of the old Fort Carondelet, and they established their mission on the east bank of the Marais Des Cygnes, six miles north of that point, in what is now Bates County. It would be interesting to follow the struggles of this band of heroes, whose privations were great and whose work was hindered by the bad influence of meddling traders, but the nature of this chapter does not permit.

It was not until 1827 that the affairs of the Mission were wound up, the Government paying $8,000 for the two sections of land which it occupied, and the improvements made by the Mission. This money was turned over to the American Board, at Boston. The members of the Mission were scattered, some returning east and some settling, ultimately, in Vernon and other counties. At this time, nothing remains to indicate the spot on which the Mission buildings stood except a few fruit trees.

In the year 1825 was made the treaty by which the land of the Osages in this region was ceded to the Government and the tribe was removed to a new reservation in Kansas. The

first permanent white settlers in what is now Vernon County were the three Summers brothers who located on the Osage, sec. 22, T. 37 N., R. 32 W., in Metz township, in 1829. Vernon County was organized February 17th, 1851, and named for the Hon. Miles Vernon, of Laclede County.

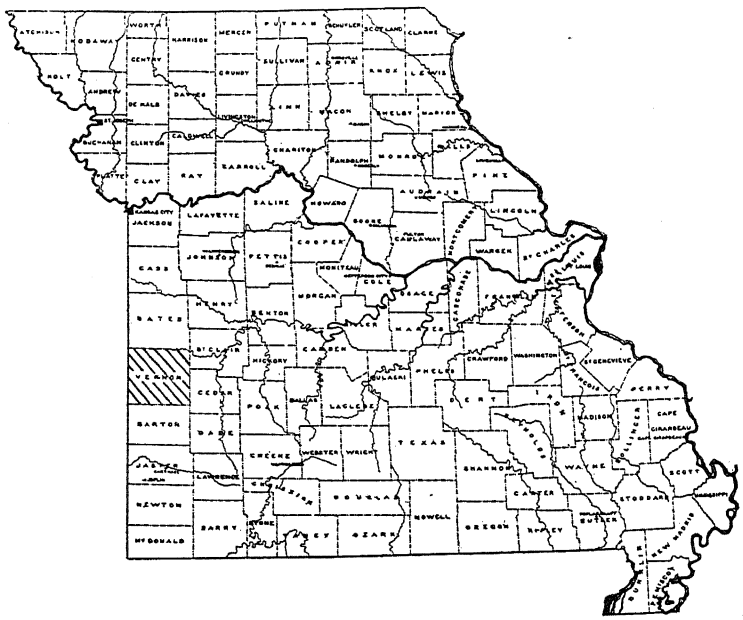


Fig. 1. Location of Vernon County, Missouri.

CHAPTER I.

GEOGRAPHY.

Location and Area.

Vernon County lies on the western edge of Missouri about 100 miles south of Kansas City. It is bounded on the north by Bates County, on the east by St. Clair and Cedar Counties, on the south by Barton County, and on the west by Crawford, Bourbon, and Linn Counties, in Kansas. It lies on the western edge of the Ozark region, intermediate between it and the Great Plains region to the west. It is about 28 miles long by 30 miles wide and contains approximately 840 square miles. (Fig. 1.)

Population and Industries.

The population in 1920 was 26,069. Nevada, the county seat and chief city, occupies a position near the center. The population of the different towns according to the 1920 census is given in the following table:

Deerfield	238	Nevada	7,139
Fairhaven	82	Richards	359
Harwood	215	Schell City	596
Metz	210	Sheldon	544
Milo	134	Stotesbury	141
Montevallo	130	Walker	309
Moundville	240		

The chief industries are those relating to agriculture. There are several manufacturing establishments at Nevada but the area is not one of any considerable industrial development. The Joplin zinc-mining district lies a short distance to the south, but has had very little influence on this area. A zinc smelter was operated intermittently at Nevada for some years but has since been torn down. Coal mining has been an important industry and there are large reserves throughout the county. To some extent the clays and shales have been utilized in the manufacture of brick and drain tile and these industries are only limited by market conditions as there is unlimited raw material available. Although practically undeveloped,

there is a possibility of establishing a considerable industry in the production of asphaltic sandstone as this county contains what are considered the most extensive deposits in the State. The shallow oil wells of the western part of the county have not been pumped though the area in which the oil has been found is more extensive than in any other county in Missouri. Shallow gas wells in the same general area have been utilized for domestic purposes.

Railroads.

All of the county, except the southeastern corner, is provided with railroad facilities. The main line of the Missouri-Kansas-Texas R. R. from St. Louis to Texas, crosses it in a northeast-southwest direction, with a branch extending from Walker east to Eldorado Springs. The Kansas City-Joplin line of the Missouri Pacific R. R. traverses the county in a north-south direction, dividing it nearly equally. A branch extends from Rich Hill to Yates Center, Kansas, and another from Nevada to Coffeyville, Kansas. The main line of the Kansas City Southern Ry., to Port Arthur, Texas, traverses the west part of the county within two or three miles of the state line.

Climate.

Vernon County has a mild climate which is in all respects similar to the surrounding region of Eastern Kansas and Western Missouri. The annual precipitation averages 39.8 in. distributed throughout the year the dryest months being November and December with 1.88 and 1.86 inches respectively. May and June which have an average rainfall of 5.40 and 5.11 inches are the wettest months. The snow fall is light and averages 18.8 inches annually. The average date of the latest killing frost in Spring is April 18th, while the earliest frost in Autumn is October 15th. The latest recorded killing frost in the past 20 years was May 9th and the earliest frost was September 26th.

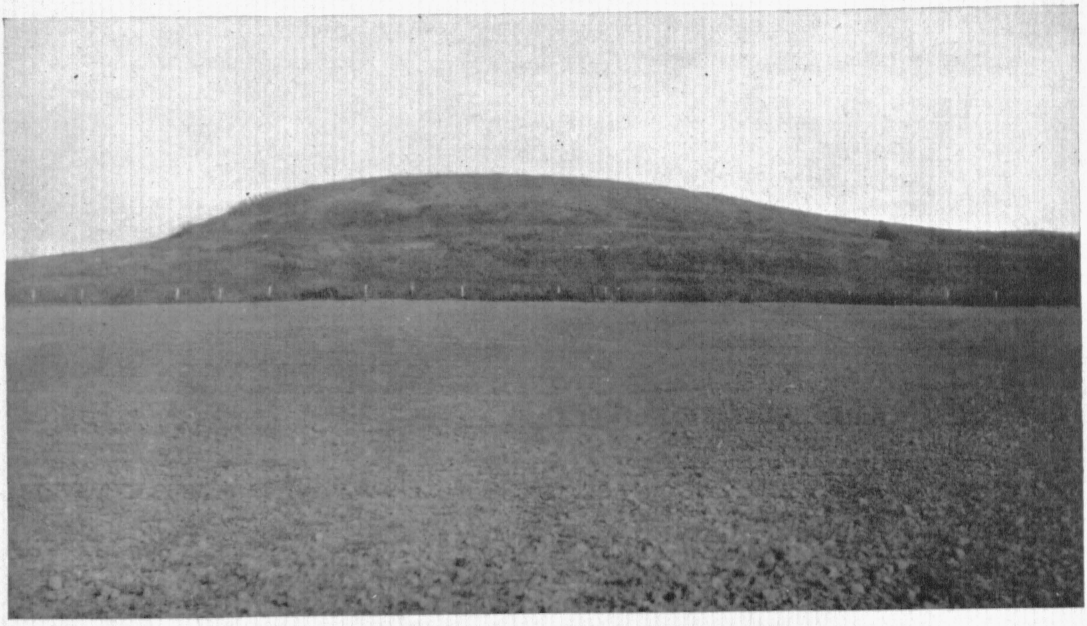
TOPOGRAPHY.

Relief.

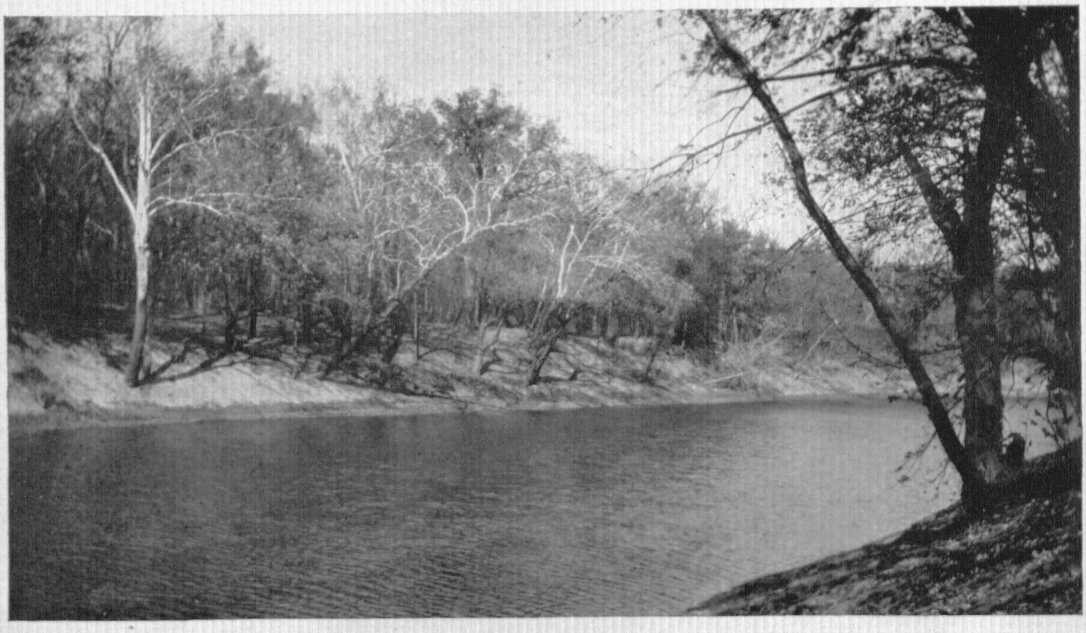
The greater part of Vernon County is a low plain extending from the southwest to the northeast corner. In the northwest and southeast corners are slightly higher areas that slope toward the center, and the central plain itself slopes from an elevation

A. Prairie country north from Howard Mound, Blue Mound in the right distance.

B. Blue Mound and country to the northeast.



A. Blue Mound, from the west.



B. Osage River near Schell City.

of about 850 feet in the southwest to 750 feet in the northeast. The high area in the northwest varies in altitude from 850 to 900 feet, and that in the southeast from 950 to 1,000 feet. Scattered over the central plain are several high mounds, conspicuous features of the landscape for many miles (Plates 1 and 2A). Among them, Walker Mound, Timber Hill, Howard Mound, Blue Mound, and those between Moundville and Bronaugh, are the most prominent.

The lowest point in the county, somewhat less than 700 feet, is at water level on Osage River in the northeast corner, and the highest point, about 1,000 feet, is at the northeast end of Howard Mound, near Fairhaven. The local relief is in places as much as 100 feet, as in the vicinity of Zodiac, Montevallo, and Dederick where the bluffs of Clear Creek and Horse Creek rise about 100 feet above water level.

The following table gives the altitude along the railroads in the county. Those marked on accurate bench marks were established by the U. S. Coast and Geodetic Survey. The remainder are Railroad elevations adjusted to Federal Survey lines.

ALTITUDE AT RAILROAD STATIONS IN VERNON COUNTY.

Town.	R. R.	Feet.	Town.	R. R.	Feet.
Amos	K. C. S.	813	Milo	Mo. Pac.	879
Arthur	Mo. Pac.	767	Moundville	Mo. Pac.	837
Bronaugh	Mo. Pac.	880	Nevada	Mo. Pac. & M-K-T.	862
County Line, 3 mi. south	Mo. Pac.	870	Nassau Junction, 2 mi. southeast	Mo. Pac.	874
Dederick	M-K-T.	798	Richards	Mo. Pac.	836
Deerfield	M-K-T.	784	County line, 4½ mi. SW.	Mo. Pac.	800
Ellis	M-K-T.	832	Rinehart	Mo. Pac.	780
Eve	M-K-T.	810	Schell City	M-K-T.	748
Crossing, 1 mi. east.	K. C. S.	813	Sheldon	Mo. Pac.	924
			Stotesbury	K. C. S.	785
County line, 2 mi. west	M-K-T.	798	Swart	K. C. S.	822
			Wales	Mo. Pac.	837
Harwood	M-K-T.	842	Walker	M-K-T.	847
Horton	Mo. Pac.	776			
Metz	Mo. Pac.	775			

The following are descriptions of the bench marks set by the United States Coast and Geodetic Survey along the main line

of the Missouri Pacific Railroad, taken from U. S. G. S. Bull. 568, p. 156, 1914.

DESCRIPTION OF THE U. S. COAST AND GEODETIC SURVEY BENCH MARKS IN VERNON COUNTY.

	Altitude, feet.
Sheldon, north side of principal street, a brick store owned by Mr. E. Pollard and occupied as harness store by Mr. M. M. Wilson, near west end of sandstone door sill: bottom of square cut, roughly lettered U. S. b. m. (C. & G. S. b. m. XCII)	924.545
Milo, north of principal street of town and east of railroad track, in yard in front of residence of Mr. J. H. Lloyd, near fence on side of yard (post-office is next to Mr. Lloyd's house): limestone post with top surface marked U. S. b. m. (C. & G. S. b. m. XCI)	879.188
Nevada, Missouri-Kansas-Texas Ry. station, brick building with one-half story of stone and stone trimmings, entrance to gentlemen's waiting room, top of first stone step (above platform) next to track: bottom of square cut, with following letters cut nearby: U. S. C. & S. B. M. (C. & G. S. b. m. XC)	862.098
Marmaton Creek, top of stone abutment to Missouri Pacific Ry. (Lexington & Southern Division) bridge over, south abutment near outer (north) edge, east of track and between it and superstructure of bridge: bottom of square cut, roughly lettered U. S. B. M. (C. & G. S. b. m. LXXXIX)	748.155
Horton, opposite railroad station, west of track, front of brick store owned by Mr. Perry Hutchinson and occupied by Rowen & Son, front face of north wall to right in entering doorway leading to second story, in fourteenth course above ground, in corner brick at northeast corner of building, end of copper bolt: center of cross (C. & G. S. b. m. LXXXVIII)	766.219
Arthur, about 1 ½ miles south of, in top of stone abutment to Missouri Pacific Ry. (Lexington & Southern Division) bridge over Little Osage River, on north abutment, west of track and between it and superstructure of bridge, near inner (north) edge: bottom of square cut, roughly lettered U. S. B. M. (C. & G. S. b. m. LXXXVII)	750.392

The Nevada, Butler, Fort Scott and Mound City topographic maps of the United States Geological Survey cover the area of Vernon County. These maps are much generalized, however, and should be considered as reconnaissance maps only.

Drainage.

Most of the drainage of Vernon County is into Osage[1] River, a large tributary of Missouri River with its source in eastern Kansas. Osage River forms part of the north boundary

[1]The Osage above the mouth of the Little Osage is often called the Maraias Des Cygnes River and is officially so named in Kansas.

line of Vernon County. It is joined by Little Osage River in the northwest part of Blue Mound Township. Little Osage River also rises in Kansas, flowing eastward across the northern part of the county. A few miles above the point where it empties into the Osage, it is joined by Marmaton River which flows in a northerly direction across the center of the county.

Tributary to Osage River are Miller, McKenzie, and Coal Creeks, flowing in general to the north. Little Osage receives Reed, Pryor, and Duncan Creeks from the north, and Marmaton River and Hightower Creek from the south. The drainage of the southwestern part of the county is chiefly to the north into Marmaton River by way of Big Drywood and Little Drywood Creeks. Clear Creek with its main branches, McCarty Creek and West Fork drains the southeast part of the county.

Uplands.

The uplands are divided into three distinct plains separated by escarpments. These are, beginning with the lowest stratigraphically, the Springfield plain, the Nevada plain, and the Warrensburg plain. The Nevada plain includes most of the county except a small area in the northwest corner and the isolated mounds farther south and east. The Springfield plain includes a few square miles near Virgil City and Montevallo. It would scarcely merit mention in this report were it not so important in the region to the east and south.

Nevada Plain. The areas shown on the accompanying geologic map as the Cherokee formation and alluvium comprise the Nevada plain; a region of flat or gently rolling country (Pl. 1, A). The edges of the upland contain some hilly land along the streams, especially in the southeastern part of the county, but these strips are surprisingly narrow. The general slope of the Nevada plain is to the northwest, but the slope is steeper in the southeast quarter of the county than elsewhere because of the greater amount of sandstone brought to the surface there by the prevailing northwesterly dip of the rocks (Fig. 2). The lower part of the Cherokee formation is chiefly sandstone and the upper chiefly shale. Consequently, on account of the greater resistance of the sandstone to erosion, the slopes here are steeper than in the areas where shale forms the surface rock.

The area where the upper part of the Cherokee outcrops has been eroded to a flat, nearly level plain, while the lower part,

containing a thick sandstone, produces a higher, more hilly region with a steeper slope to the northwest.

In many places the even surface of the western and northern part of the Nevada plain is broken by mounds which are capped by sandstone or limestone beds in the Cherokee formation. Some of the mounds are capped by limestone of the next higher formation, the Henrietta, and are quite large. They are classed as outlying parts of the Warrensburg plain.

The eastern part of the Nevada plain is beyond the eastern boundary of the County, but along the lower course of Clear Creek, the Clear Creek sandstone escarpment which marks the boundary of the Nevada plain, has receded into Vernon County.

Warrensburg Plain. The Warrensburg plain includes that part of Vernon County shown on the accompanying geological map as the Henrietta and Pleasanton formations. It is separated from the Nevada plain by an escarpment which is one of the most conspicuous features of the region. A short distance back from the escarpment, the Warrensburg plain becomes gently rolling, and in Bates County is quite flat locally. This plain is upheld by the limestones of the Henrietta formation. These dip to the northwest and the surface slopes in general in that direction. On the west it is bounded by another escarpment that does not enter Vernon County.

Springfield Plain. The Springfield plain includes a large part of the western slope of the Ozark region. It is most conspicuous in the region around Springfield, Missouri, and from there west to Joplin. The controlling factor is a thick group of limestones of Mississippian age. As already mentioned, there are a few areas along Clear Creek, near Virgil City and Montevallo from which the Clear Creek sandstone has been eroded, producing a low-lying plain underlain by Mississippian limestone directly, are covered with a few feet of soft shale, These constitute the Springfield plain as found in Vernon County.

Clear Creek sandstone does not rest on the Mississippian directly, but is separated from it by shale so that the western boundary of the Springfield plain is marked by a low escarpment. This is very prominent on the upland just west of Virgil City but in other places merges with the stream bluffs.

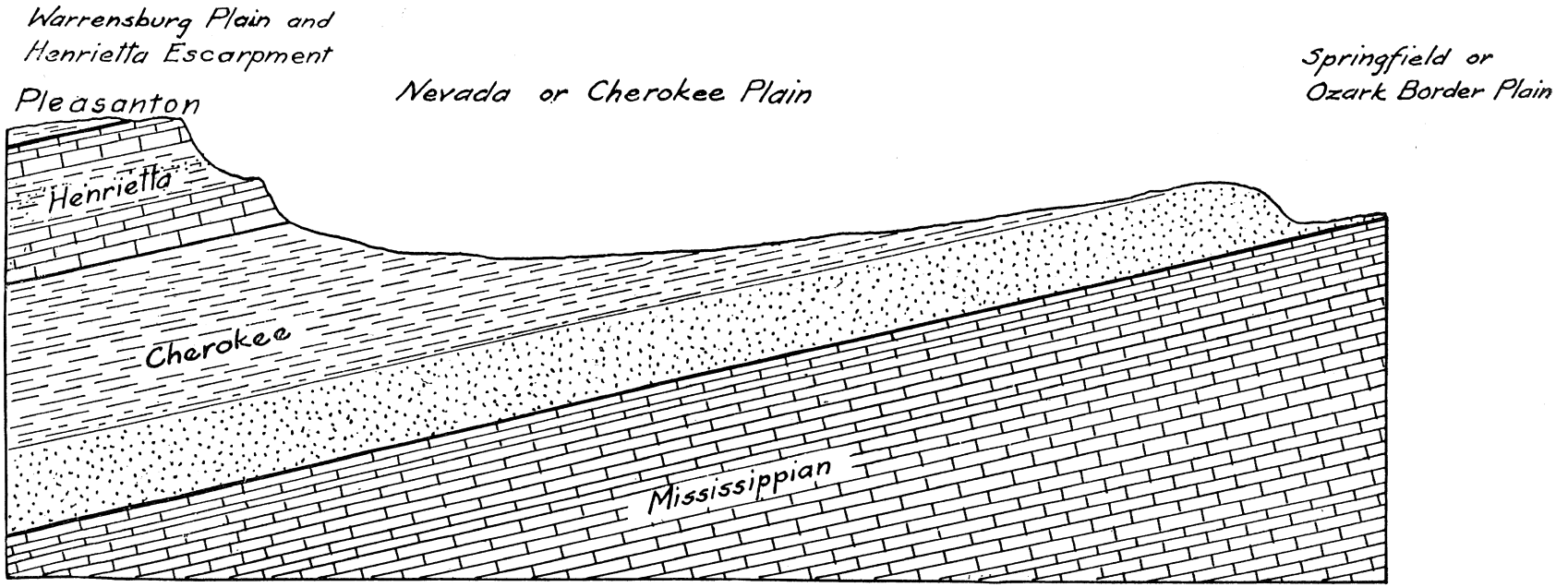


Fig. 2. Diagramatic section across Vernon County from northwest to southeast showing the principal features of the topographic belt and the factors that cause them.

Valleys.

Stream valleys have all the characteristics of valleys in other parts of southwestern Missouri. They are of two types that grade into each other. In the Ozark region the valleys are deep and narrow and the meanders are incised. Farther west, in the prairie country the same valleys become broad and shallow and the streams meander with wide swings.

Osage River with its tributaries, the Little Osage and the Marmaton, is an example of the latter type (Pl. 2, B), though a short distance east it has the characteristics of an Ozark stream. Clear Creek exhibits both types of valley within the boundaries of the county. These are well shown on the accompanying geologic map by the outline of the flood plain.

The channels of the lower streams exhibit another characteristic that is common to the streams of western Missouri and eastern Kansas. The stream banks are high and steep and the channels of even width for long stretches. The flood plains of the larger streams are flat, more or less marshy, and covered with a rank growth of grass or open groves of pin oak trees. In the lower places the soil is black and tenacious, locally known as gumbo.

Special Physiographic Features.

Halley's Bluff. Halley's Bluff is situated on the right bank of Osage River at the south end of a meander in sec. 34, T. 38 N., R. 30 W. Here, on a bench of sandstone about 40 feet above the river under an overhanging cliff of sandstone near the southerly end of the cliff bluff are seven pits and traces or remnants of sixteen more, a total of twenty-three (Pl. 3). Norwood[1], visiting them in 1873, reported twenty-three, six being side by side forming a double row. At present only parts of the outer three of the double row remain, the larger part having either weathered off along an irregular joint plane or been destroyed in searching for supposed mineral. In the sixth pit from the north, the burnt stump of a six-inch oak is probably the remains of the "Red Oak (tree) four inches in diameter," noted by Norwood. The pits are fairly regular in shape being two to four feet in diameter at the top, circular or slightly oval in outline,

[1]Norwood, C. J., in report on Vernon Co., Report of Geol. Surv. of Mo., 1873-74, G. C. Broadhead, 1874, p. 151.

four to five feet deep and are a few inches to two feet larger at the bottom than at the top. They are one to three feet apart and two of them connect at the bottom where the sandstone wall is only four to six inches thick by an opening about a foot in diameter which has probably been made in comparatively recent times as Norwood made no mention of it.

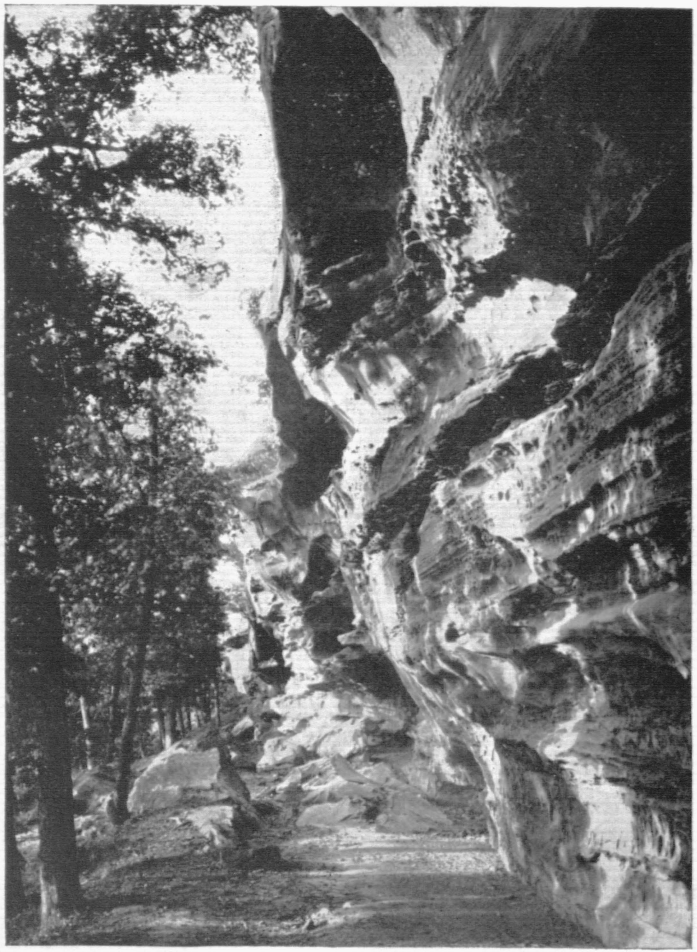
There seems but little doubt that the pits were caches used by the Indians or early traders. Plate 3, figures A and B, are photographs taken in 1922.

A good description of Halley's Bluff as it was in 1804 is given in Eliot Coues' edition of the Zebulon Pike Expedition, volume 2, pages 385 and 386.

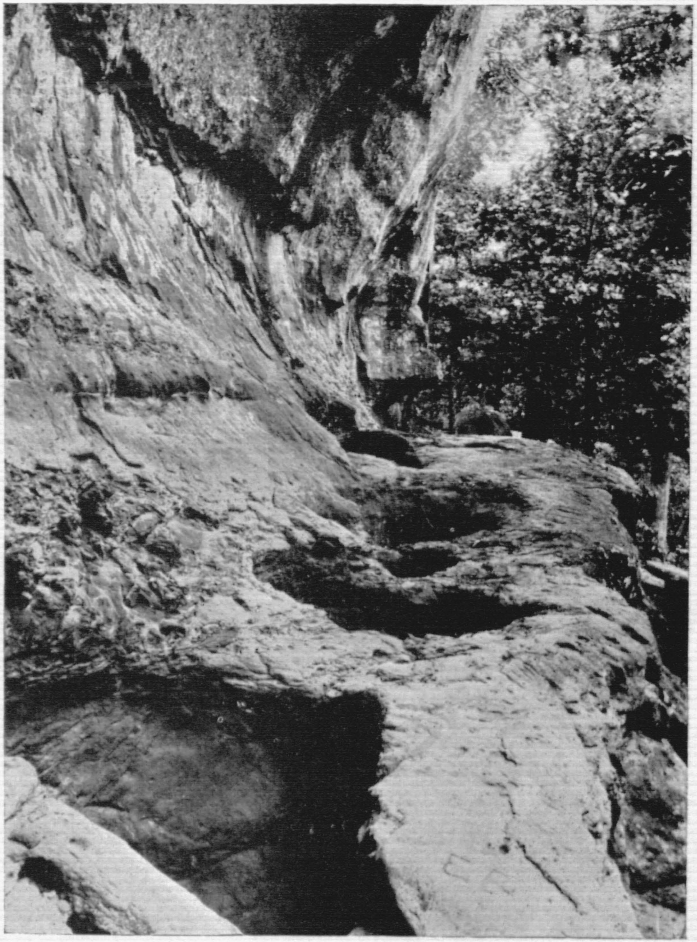
Abandoned Valley Near Montevallo. A large abandoned valley has been traced from a point west of Montevallo northeast to sec. 23, T. 35 N., R. 29. W., where it merges into the Springfield plain. It appears to have been made by McCarty Creek. From where the road crosses this creek just west of Montevallo, the abandoned valley seems to be the northern continuation of the valley of McCarty Creek. The latter, however, turns to the west and is less than one-fourth mile wide, while the abandoned valley is nearly three-fourths of a mile in width. The mean altitude of the valley floor is about 820 feet and of the upland on either side about 900 feet.

Northwest of Montevallo the old valley is occupied by two small tributaries of Clear Creek, both of which flow to the north and leave the west side of the old valley, entering Clear Creek through narrow, steep-sided valleys like that of McCarty Creek. West of Virgil City the east side of the old Valley merges into the escarpment that separates the Springfield and Nevada plains and the west side is not distinct. The valley itself becomes a part of the Springfield plain. It has not been traced into Cedar County, though it is believed to unite with the valley of Clear Creek in the northwest corner of that county.

Marmaton Valley. The Marmaton Valley, from a point near Deerfield to its mouth, is believed to be a departure from the normal type of valleys of the region in that the river flows close to the south and east bluff which is rather steep, while on the north and west side of the valley the rise to the upland is extremely gentle. The usual type as before stated is either broad and flat or deep and narrow. In several places it is difficult to draw the line of separation between upland and bottom land.



A. Differential weathering of Clear Creek Sandstone.



B. Caches of early traders or Indians.

Halley's Bluff, NW. ¼ NE. ¼ sec. 34, T. 38 N., R. 30 W.

Several other streams in this part of Missouri that flow in general eastward, exhibit a tendency to crowd the south side of their valleys, but in none of them is it so marked a feature. This phenomenon cannot be attributed to the dip of the rocks as the latter is to the northwest. In the present work this feature was not investigated beyond the area of Vernon County.

CHAPTER II.

DESCRIPTIVE GEOLOGY.

Stratigraphy.

General Character of the Rocks. The rocks of Vernon County consist of nearly horizontal strata of limestone of Mississippian age; sandstone, shale, and limestone of Pennsylvanian age; and alluvium of recent age. The Mississippian limestone is exposed low down on the bluffs along the larger streams in the eastern part of the county, the Pennsylvanian limestone in the western half and particularly in the northwestern corner of the county, and the shale and sandstone over much of the remainder of the area. Alluvium of greater or less thickness occurs along all the important streams. The more level uplands are nearly everywhere covered by soil that has resulted from the decay of the underlying rocks. Figure 3 is a generalized columnar section of the rocks outcropping in the county.

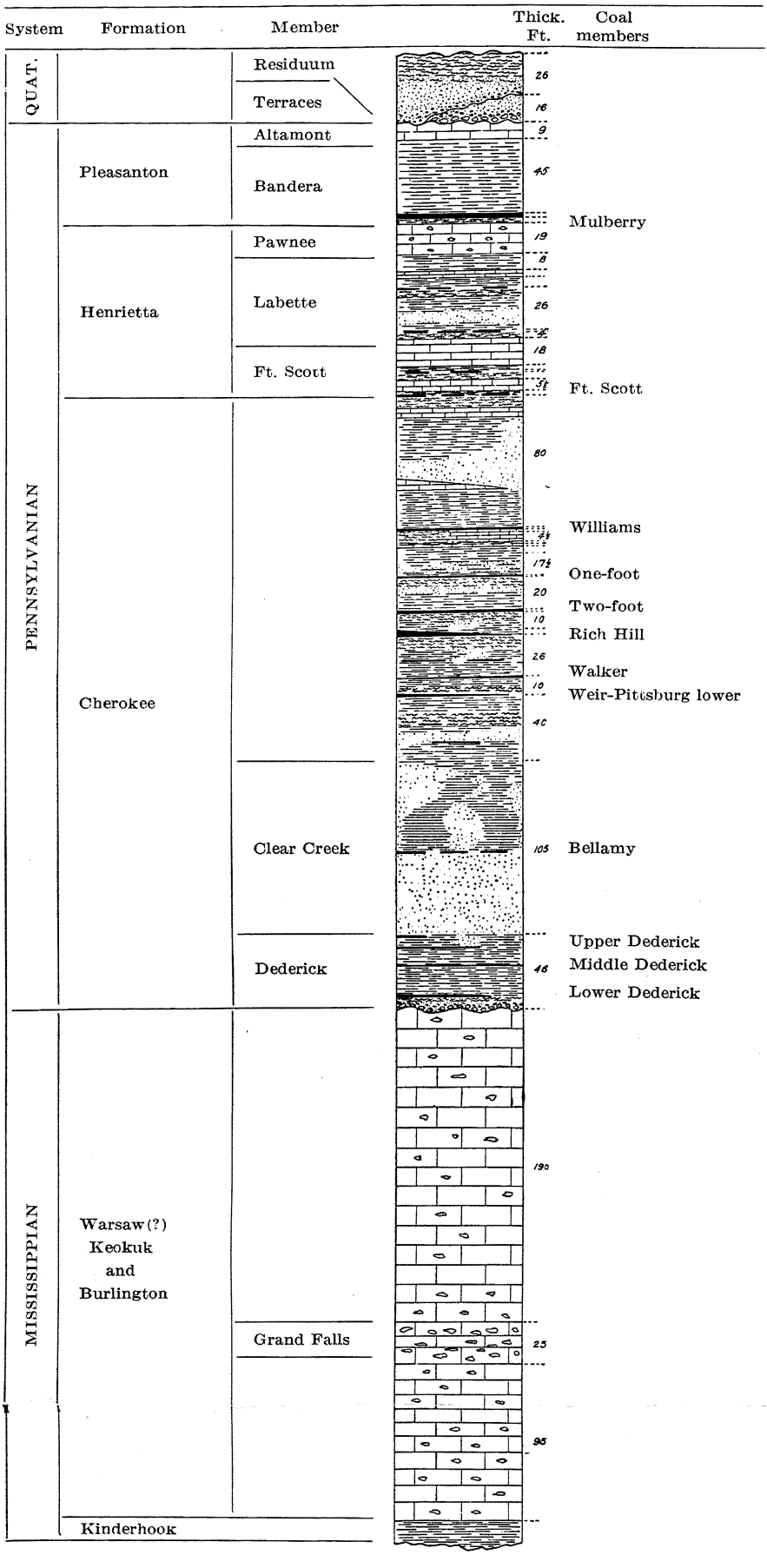
Below the outcropping strata are other Mississippian and older rocks, resting on a floor of granite (see under "Rocks Not Exposed").

MISSISSIPPIAN SERIES.

The Mississippian of the southwestern flank of the Ozark has probably been more thoroughly studied in the Joplin Mining district than anywhere else in the region. As the center of the Joplin district is only 35 miles south of the Vernon County line a summary of the Mississippian section there will serve to introduce the discussion of this series as it exists in Vernon County.

GENERALIZED SECTION OF THE MISSISSIPPIAN SERIES IN THE JOPLIN DISTRICT.

	Thickness, feet.
Chester Group	
Carterville formation	
(1) Shales, shaley limestones, white limestones, some sandstones	0–50



General Geological Section in Vernon County, Missouri.

GENERALIZED SECTION OF THE MISSISSIPPIAN SERIES IN THE JOPLIN DISTRICT—*Continued.*

	Thickness, feet.
Unconformity	
Meramec Group	
Warsaw limestone	
(2) Crystalline limestone with interbedded chert	0–140
Osage Group	
Keokuk limestone	
(3) Gray to brown oolitic limestone (Short Creek oolite)	2–8
(4) Crystalline limestone with interbedded chert	60–100
Burlington limestone	
(5) Limestone, cherty	10–40
(6) Heavy bedded chert with a little limestone (Grand Falls chert)	0–80
(7) Dark blue chert and bluish-gray limestone "Second lime" of drillers (lower Burlington)	125–150
Unconformity	
Kinderhook Group	
Chouteau limestone	
(8) Shaly limestone	20+
Northview Shale	
(9) Dark blue shale	3–13

In Vernon County the Carterville formation is absent so far as known, but the greater part of the Joplin section below the Carterville is believed to be present. From the study of the available drill records the following much generalized section has been compiled.

GENERALIZED SECTION OF THE MISSISSIPPIAN ROCKS ENCOUNTERED IN DEEP BORINGS IN VERNON COUNTY.

	Range in thickness.	Average thickness.
	Feet.	*Feet.*
1 Limestone, cherty	140–205	190
2 Chert, with some limestone (Grand Falls chert)	0–105	25
3 Limestone, in part cherty and dolomitic	35–150	95
4 Shale (Northview)	15–75	35

In the two drill records in which No. 2 is reported 90 and 105 feet thick, respectively, the chert probably includes some of the underlying or overlying cherty limestone.

When the Vernon County and Joplin sections are compared, it becomes apparent that there is a due correspondence. No. 3 of the former section is probably the equivalent of the lower Burlington and Chouteau of the latter; No. 2, of the Grand Falls chert; and No. 1, of the upper Burlington, Keokuk, and Warsaw.

The Mississippian rocks outcropping in Vernon County have been referred to both the Keokuk and Burlington limestones. As the distinction between these formations is largely one of paleontology, the convenient term "Osage group," which includes both, is used here.

Osage Group.

Name and Definition. The name, Osage, taken from the river which flows along the northern edge of the county, was proposed for the Mississippian rocks exposed along its course. According to the present definition, the Osage includes the Burlington and Keokuk, the Chouteau being placed in the underlying Kinderhook group. From a lithologic standpoint, the Warsaw of southwestern Missouri would be placed in the Osage but on the evidence of fossils found in the typical Warsaw along Mississippi River it is placed with the next overlying group, the Meramec.

Distribution and Thickness. The limestone of the Osage group underlies the whole area of Vernon County, but is almost entirely covered by the overlying Pennsylvanian rocks. The latter have been eroded from a few comparatively small areas along the larger streams in the eastern part of the county and even smaller areas near Nevada and Schell City. The outcrop of the Mississippian is shown on the accompanying geologic map.

The average thickness of the Osage group in Vernon County, as determined from well records, is about 310 feet. In most outcrops only the upper 20 to 30 feet is exposed. About 4 miles west of Schell City the residual chert covers the hillside to 105 feet above the level of the Osage River but the greatest exposed thickness of the limestone is only 35 feet.

Topography. Owing to its limited distribution, the Mississippian has no characteristic topography in the area, although the wide, flat-bottomed valleys in the vicinity of Virgil City probably owe their origin to the combined effect of the soft Pederick shale and the harder Mississippian limestone. In-

cidentally, it may be pointed out that this is probably the origin of the flat or slightly undulating landscapes that are characteristic of the Mississippian areas of Cedar, Dade and Bates Counties.

Wherever the Mississippian outcrops it produces chert-covered hillsides and chert-filled subsoil.

Lithologic Characteristics. As a whole the Mississippian rocks are light-colored, usually light gray to bluish gray, cherty and crystalline. The lowest rocks exposed in the county occur at the old Belvoir lime kiln five miles northwest of Schell City, on the south bank of Osage River (SE. ¼ sec. 26, T. 38 N., R. 30 W.). The following section was measured there:

SECTION AT OLD BELVOIR LIME KILN, NORTHWEST OF SCHELL CITY.

		Thickness.
		Feet.
1	Slope to top of bluff covered with residual chert	40
2	Limestone, light gray to nearly white, dense to coarsely crystalline, lower 12 to 15 feet in thick beds with chert nodules, upper part in beds 1 to 2 feet thick, with interbedded chert	35
3	Talus	10
4	Alluvium to water level in river	20
		105

No. 2 is believed to be equivalent to the upper Burlington of the Joplin section. The coarse limestones are made up almost exclusively of weathered fragments and the chert is full of molds of crinoid segments. The cavities in the chert contain an asphalt-like substance and locally the limestone is stained a very dark gray by the same material.

The other outcrops in the county are chiefly higher beds that are probably concealed in the slope in the section given above, and represented by the residual chert. The limestones of these outcrops are not so coarsely crystalline as those of the lower beds. Locally there are three layers of deep brown, fine-grained limestone a foot or two thick, interbedded with gray crystalline limestone. The chert contains many casts of bryozoan forms, the genus Archimedes being especially abundant. At the outcrop northwest of Nevada (sec. 20, T. 36 N,. R. 31 W.) the chert is entirely composed of minute fossil fragments. Plate 4 A shows a characteristic outcrop of the limestone in stream beds.

Geologic Relations. The Osage group probably rests conformably on the underlying Kinderhook, but is overlain unconformably by the Cherokee formation. As will be shown in the discussion of the Cherokee, the lower shale member of that formation is fairly uniform in thickness, indicating that the surface of the Mississippian was comparatively level. This fact is further indicated by the presence in many places of a layer of chert-filled soil at the contact, a soil such as would be found on a more or less level surface of limestone.

Correlation. The general correlation of the Mississippian has already been discussed. All of the outcrops probably come within one hundred feet of the local upper limit of the series.

In the present study no collections were made to determine the fauna in the Mississippian.

PENNSYLVANIAN SERIES.

Des Moines Group.

The Pennsylvanian is a more or less rapidly alternating series of shale, sandstone, limestone, clay, coal, and conglomerate. Of the eight formations of the Pennsylvanian series in Missouri, three are present in Vernon County. In ascending order these are the Cherokee, Henrietta, and Pleasanton formations. The remaining five, the Kansas City, Lansing, Douglas, Shawnee, and Wabaunsee formations outcrop farther northwest, due to the northwesterly regional dip.

The formations represented in Vernon County are not simple lithological units, as each contains several members, some of which have received names. The members themselves contain beds with easily recognized characteristics, which, in some cases, are persistent over a considerable area. The following table shows the present classification:

PENNSYLVANIAN SERIES IN VERNON COUNTY.

Formation.	Member.
Pleasanton	Conglomerate and sandstone. *Unconformity.* Altamont limestone. Bandera shale.
Henrietta	Pawnee limestone. Labette shale. Fort Scott limestone.

A. Mississippian Limestone, NW. ¼ NE. ¼ sec. 36, T. 36 N., R. 29 W.

B. Upland Gravels, SW. ¼ sec. 30, T. 38 N., R. 30 W.

PENNSYLVANIAN SERIES IN VERNON COUNTY—*Continued.*

Formation.	Member.
Cherokee	Shale, sandstone, and coal. Rich Hill limestone. Shale, sandstone, and coal. Vernon or Clear Creek sandstone. Dederick shale.

Unconformity.

Mississippian Series—Limestone.

CHEROKEE FORMATION.

Name and Definition. The type locality of the Cherokee formation is in Cherokee County, Kansas, only a few miles southwest of the area here considered. The Cherokee includes all the beds between the Mississippian limestone, upon which it rests unconformably, and the lower Fort Scott limestone or "Cement Rock." The term Cherokee shale has been applied to the formation and the statement made that it is very irregular. In Vernon County sandstone makes up a large part of the formation, and the character is fairly regular, some thin members being persistent far beyond the boundaries of the county.

Distribution and Thickness. The Cherokee is the surface formation over practically all of Vernon County, except for a few small areas along the eastern border from which it has been eroded, and a few square miles in the northwestern corner where it is overlain by the Henrietta formation. Several drill holes have passed through the entire formation, showing its thickness to be about 375 feet. A composite section, based on nearly two hundred well logs, indicates about the same average thickness. To the west it thickens slightly. At Fort Scott and Pleasanton, Kansas, it is respectively 430 and 442 feet thick. Northward it thins to 324 feet at Amsterdam, and 330 feet at Merwin, Bates County.

Local names have been employed in this report for members of the Cherokee formation to avoid the confusion which would result from using names that are in use in distant areas. The local names have been in use throughout the region for a long time and it would be difficult to have new ones accepted.

In the generalized section which follows, some members are assigned a rather wide range in thickness. Although this is

true as regards a single bed, the vertical interval between two given beds one hundred feet or more apart will not, as a rule, show nearly as much difference as the generalized section may seem to indicate. There appears to be a compensation. For instance, in a group of borings in the vicinity of Timbered Mound (secs. 11 and 14, T. 37 N., R. 31 W.) the interval between the "One-foot" and "Middle" coals is 13 feet to 16 feet, 5 inches; the "Middle" coal is 8 to 16 inches thick, and between the "Middle" and Rich Hill coals the interval varies from 4 feet, 7 inches, to 23 feet. However, the interval between the "One-foot" and Rich Hill Coal beds ranges between 27 feet, 8 inches and 39 feet. Another example is found in the total thickness of beds between the base of the Rich Hill Coal and the base of the Clear Creek sandstone. These beds, comprising approximately one-half of the Cherokee, range in thickness between 170 and 200 feet, a difference of only 30 feet, whereas some individual beds in the interval exhibit a variation in thickness greatly exceeding this amount.

Topographic Expression. The chief characteristic of Cherokee topography is a nearly flat or gently rolling plain, tilted slightly to the northwest. This plain begins at the foot of the Henrietta escarpment and extends southeast. In this area only the larger stream valleys are bordered by bluffs. Rising from the plain are a few ridges and mounds capped by resistant beds (Plates 1 and 2A). Farther away from the Henrietta escarpment where the Clear Creek sandstone is at the surface, the uplands have an undulating or rolling topography and the streams are bordered by broken land. Vertical cliffs of sandstone are common. Along the eastern margin of the county, in places, the basal part of the sandstone, with the underlying shale, has formed a low escarpment, from the foot of which another plain, similar to that in the west-central part of the county, extends to the southeast.

Lithological Character. A generalized section of the formation follows:

GENERALIZED SECTION OF THE CHEROKEE FORMATION IN VERNON COUNTY.

		Variation in thickness.			Total thickness (average).	
		Ft. to Ft.	*In.*		*Ft.*	*In.*
1	Shale, light at top, grading down to black, slaty shale: in places only light shale present, in others only black shale present: where black shale is one foot or more thick, it commonly contains large, rounded concretions of black, impure limestone, which rest on the underlying coal	0	7		2	0
2	Coal (Fort Scott) in places represented by a thin bed of dark shale	0	1	8	2	6
3	Shale and sandstone: at top is a thin bed of clay below which there are in places small and large calcareous concretions or a layer of nodular limestone: the middle and major part varies from a shale with little or no sand to a sandstone: at the base is light or dark shale, the latter locally containing thin beds of dark, impure limestone and septarean concretions. In the western part of the county the thickness of this member is 35 to 55 feet, in the northern part 70 to 85 feet, average probably 65 feet	35	96	6	82	6
4	Coal, known in the Rich Hill District as the "Williams" coal	0	1	6	83	0
5	Clay	0	4	9	84	0
6	Limestone, gray (with Nos. 7 and 8 the Rich Hill lime). At places in the western part of the county it is absent, in others it is represented by as much as 10 feet of limestone nodules imbedded in clay. In the Rich Hill district it is a consolidated gray limestone 2 to 10 feet thick. Near Walker it is about 12 feet thick.	2	12		90	0
7	Shale, usually present between No. 6 and No. 8, where found is nodular to a thickness of 4 or 5 feet: when 6 and 8 are united it is merely a thin, shaly parting	0	5	0	91	0
8	Limestone (the Diamond Rock), dark gray and dense. Commonly 1 to 2 feet thick, entirely absent locally in the Rich Hill district: in the western part of the county, usually overlain by 2-4 inches of limestone much cracked by frost	0	2	0	92	0
9	Shale, a few inches at top buff, remainder black and slaty: in many places contains thin layers and spherical concretions of dark fossiliferous limestone and large rounded concretions. Usually thin or absent where No. 10 is more than 20 feet thick, and as much as 13 feet thick where No. 10 is thin	0	13	0	96	6
10	Shale, light gray, usually sandy where more than 25 feet thick	3	47	0	114	0

GENERALIZED SECTION OF THE CHEROKEE FORMATION IN VERNON COUNTY—*Continued.*

		Variation in thickness.			Total thickness (average).	
		Ft.	*to Ft.*	*In.*	*Ft.*	*In.*
11	Coal (One-foot). Remarkably persistent. Known in different parts of the country as Moundville, Ten-inch, Soapstone, and One-foot coal.	½	2	4	115	0
12	Clay, sandstone and shale: clay at top of sandstone, and shale, blue to black at base: locally a thin coal bed or limestone below the sandstone	7	33	0	135	0
13	Coal, the upper of the two beds mined at Rich Hill where it is known as the Middle coal: it is the Two-foot in the Walker district, and probably the Weir-Pittsburg upper coal of southeastern Kansas	0	2	6	136	0
14	Shale and clay: locally some sandstone is present.	4	28	0	146	0
15	Coal (Rich Hill), 114 to 172 feet below top of Cherokee: thins to southwest	0	6	0	148	0
16	Clay, shale, and sandstone: locally a very thin coal bed is present in the upper part, grades into black, slaty, blocky shale at base	14	35	0	174	0
17	Coal (Walker), appears to be persistent but thins to the southwest: probably the Weir-Pittsburg intermediate of southeastern Kansas	½	2	8	174	6
18	Clay and shale, thickens to southwest	4	32	0	183	6
19	Coal, thin and of little value in most of Vernon County: thickens to the southwest where it is probably the Weir-Pittsburg lower of southeastern Kansas	0		9	184	0
20	Shale, with thin beds of clay, sandstone, and coal. Near Deerfield contains *Conostichus broadheadi*, thickens to southwest	13	65	0	224	0
21	Clear Creek sandstone member, locally subdivided as follows	82	130	0	329	0
	a. Sandstone, or shale and sandstone: contains 0-5 irregular coal beds: thickness 29 to 80 feet, average 55 feet.					
	b. Coal (Bellamy), 0-3 feet.					
	c. Sandstone, generally without shale: thickness 25 to 75 feet, average 50 feet.					
22	Dederick Shale member, locally subdivided as follows	27	65	0	375	0
	a. Shale, blue and sandy or black and slaty: locally a coal bed is present at top: thickness 0-20 feet: average 6 feet, 6 inches.					
	b. Coal, upper Dederick, 0-3 feet, average, 1 foot.					
	c. Clay and blue to black shale: 6-16 feet, average, 10 feet, 6 inches.					
	d. Coal, middle Dederick, 0-1 feet, 5 inches: average, 8 inches.					
	e. Clay and blue to black shale, 8-26 feet: average, 19 feet.					

GENERALIZED SECTION OF THE CHEROKEE FORMATION IN VERNON COUNTY—*Continued.*

	Variation in thickness.	Total thickness (average).
	Ft. to Ft. In.	*Ft. In.*
f. Coal (lower Dederick), 0-3 feet: average 1 foot, 8 inches.		
g. Clay, cherty, locally contains sandstone and conglomerate, rests unconformably on Mississippian limestone, 1-16 feet: average, 6 feet, 6 inches.		

The above section agrees substantially with that of Broadhead[1] except in a few particulars.

The relation of the beds in Vernon County to those in southeastern Kansas is of great interest. The probable correlation of the coal beds in these two districts has been indicated in the above section. Between the Rich Hill-Panama district and southeastern Kansas, outcrops are poor and only a few drill records could be obtained.

The following generalized section is compiled from 16 records of drillings and outcrop observations made near Mulberry, Kansas, and is here inserted for comparison.

GENERALIZED GEOLOGIC SECTION NEAR MULBERRY, KANSAS.

	Thickness.				Average total thickness.	
	Ft.	*In. to Ft.*		*In.*	*Ft.*	*In.*
Henrietta Formation.						
1 Limestone (upper Fort Scott) maximum	..	..	..	..	11	6
2 Shale, black	2	6	5		14	10
3 Coal		5		11	15	5
4 Clay	1	1	2	3	17	
5 Limestone (lower Fort Scott or "Cement Rock")	2		8		22	1
Cherokee Formation.						
6 Shale and "slate"	62		96		102	1
7 Coal (Williams of Rich Hill)	0		1	9	102	8
8 Clay		3		6	103	
9 Limestone (Rich Hill lime)	0		2		104	

[1]Broadhead, G. C., Missouri Geol. Surv., Rept. 1873-74, pp. 60-61, 101-102, 1874.

GENERALIZED GEOLOGIC SECTION NEAR MULBERRY, KANSAS—*Continued.*

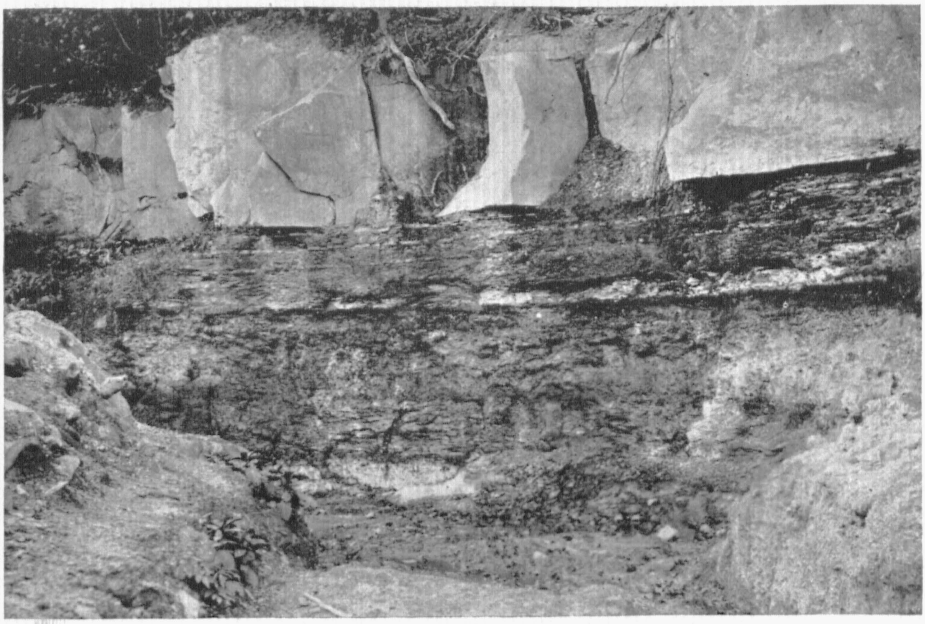
		Thickness.	Average Total thickness.
		Ft. In. to Ft. In.	*Ft. In.*
10	Clay, shale and "slate" containing locally one foot of limestone...	7 15	113
11	Coal (Ten-inch of Rich Hill).....	0 1	113 6
12	Clay and sandstone.....	12 28	135 6
13	Coal (Weir-Pittsburg upper).....	0 1 6	136 4
14	Clay, shale, and sandstone.....	13 27	152 4
15	Coal (Rich Hill of Rich Hill district)	0 1	152 8
16	Clay, shale, and sandstone, grading into black, slaty shale at base..	23 32	182 8
17	Coal (Weir-Pittsburg intermediate)	0 9	183 1
18	Clay, shale, and sandstone.....	11 32	204 1
19	Coal (Weir-Pittsburg lower), the bed mined at Mulberry.....	2 5 3 2	206 11
20	Interval at base of Cherokee reported to be.....	190	396 11
	Total thickness of Cherokee.....	.....	375

The correlation of Nos. 1 to 11 with the Rich Hill section can be made without question. On a basis of succession and position in the formation, coal No. 13 of the Mulberry section correlates with the Middle coal of Rich Hill, No. 15 with the Rich Hill, No. 17 with the Walker coal, and No. 19 with the thin irregular coal below the Walker. The fairly persistent and peculiar sandstone overlying the Middle coal has been found at intervals between the two districts and is believed to be the sandstone over the Weir-Pittsburg upper coal. No. 15 bears little resemblance, however, to the thick bed in the Rich Hill district that is believed to be its equivalent. No. 17 is much thinner than in northern Vernon County but the black, blocky roof "slate" is present in both districts. No. 19 is very much thicker and far more regular and persistent than in northern Vernon County.

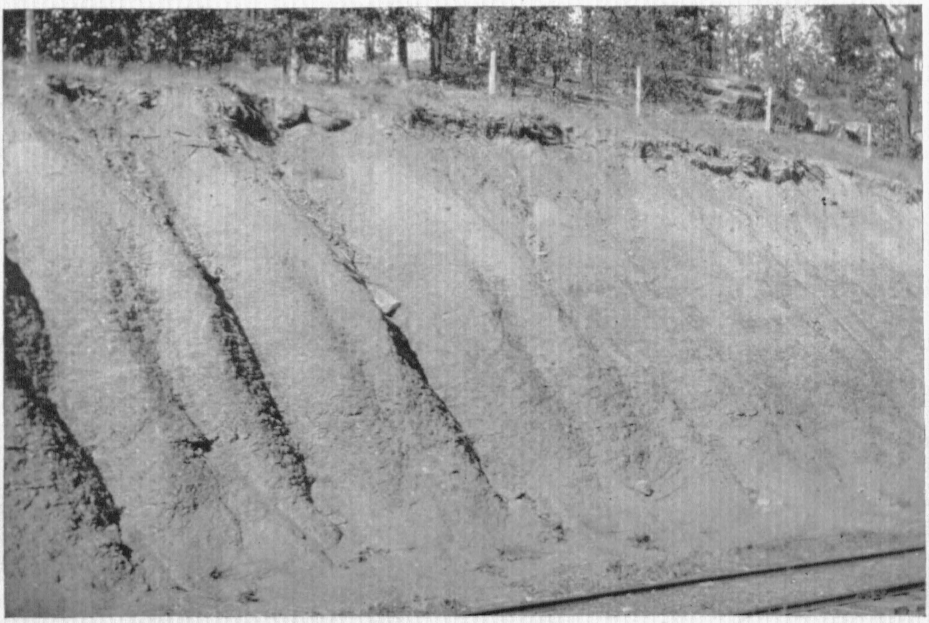
Members.[1]

Dederick Shale Member. (22, a-g.) This is a uniform, widely-present member of the Cherokee formation, for which the name Dederick shale member is here proposed. The best exposures are in the vicinity of Dederick, along the railroad in

[1]Numbers in parentheses immediately after the name of a member refer to the numbers in the generalized section (pp. 37 to 39).



A. Base of Clear Creek sandstone and coal below.



B. Dederick shale near Dederick.

the northern part of sec. 26, T. 36 N., R. 29 W., and in the NE. ¼ SE. ¼ sec. 36, T. 36 N., R. 29 W. (Plate 5, A and B). The upper part is well exposed southwest of Nevada on Birch Branch. The name is not intended to apply to the Cherokee section outside of the area in southwestern Missouri.

In the eastern quarter of Vernon County the Dederick shale outcrops along the bluffs of Horse Creek, Clear Creek, McCarty Creek, Kelton Creek, Osage River, and their tributaries. It also appears above water level along the Marmaton and Little Drywood in the vicinity of Nevada, principally east of the streams. In comparison with the overlying Clear Creek sandstone, it is soft and easily weathered so that it outcrops only in the face of an escarpment. It gives rise to relatively broad valleys floored by Mississippian, or by Mississippian with a thin mantle of the shale remaining on it. Near Virgil City and Schell City the escarpment has receded to some distance from the main drainage lines, producing lowlands from which rise sandstone-capped mounds.

All drill holes in Vernon County of which the Survey has obtained records, show the Dederick shale, and it outcrops wherever the streams have cut down through the overlying sandstone. It is probably safe to assume that the shale underlies the entire Cherokee area in Vernon County and extends an unknown distance to the north and west. It is also present in the southern part of St. Clair County and in the Pennsylvania outliers of Cedar and Dade Counties. To the south it extends across Barton County and is probably equivalent to the beds underlying the Columbus sandstone in southeastern Kansas[1] which is chiefly shale, but includes some sandstone.

The Dederick shale ranges from 27 to 75 feet thick, averaging about 46 feet in 35 measurements. In 25 cases the thickness is within 10 feet of the average.

Altogether, more than 30 drill holes in Vernon and adjoining counties have penetrated practically the entire thickness of the shale, and most of these show that it is within the normal range of thickness. In cases where it has been reported to be 60 to 75 feet thick the increase is no doubt due to thickening in sinkholes and erosion channels such as are found in drilling in Jasper County to the south. The cherty clay at the base is believed to be pre-Pennsylvanian residual soil.

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[1]Haworth, E., and Kirk, M. Z., The Neosho River Section: Kansas Univ. Quart., Vol. 2, p. 106, 1894.

The Dederick shale consists chiefly of dark blue to black shale. The coal beds are underlain by clay, and locally sandstone, conglomerates, and ferruginous limestone appear at the base. The black shale contains numerous thin bands and plates of dark, impure iron carbonate (see Plate 5, A). In the eastern part of Vernon and in the neighboring counties, Cedar, Dade, and Barton, the Dederick shale contains valuable coal beds. The upper Dederick coal (No. 21-b) has been mined near Nevada and along Clear and Kelton Creeks. In places it is as much as 3 feet thick.

In the southwest corner of sec. 8, T. 35 N., R. 31 W., at an abandoned quarry or pit on the south side of Birch Branch, near Nevada, the upper part of the Dederick shale shows the following section:

SECTION OF UPPER PART OF THE DEDERICK SHALE NEAR NEVADA.

		Thickness.	
		Ft.	*In.*
1	Sandstone (Clear Creek), massive with 8-10 inches of iron ore conglomerate at base	8	0
2	Shale, black, slaty, with 2 or 3 bands of impure iron carbonate	4	6
3	Coal (upper Dederick)		10
4	Clay, light at top, grading down to hard, black, slaty shale	6	0
5	Coal (middle Dederick), hard, slaty		1–5
6	Clay, light gray, hard, sandstone, grading into clayey sandstone	2	0

About four miles south of Dederick on the south bank of Clear Creek (where it crosses the line between secs. 15 and 22, T. 35 N., R. 29 W.) is the following section:

SECTION OF DEDERICK SHALE ABOUT FOUR MILES SOUTH OF DEDERICK.

		Thickness.	
		Ft.	*In.*
1	Sandstone (Clear Creek)	15+	
2	Concealed	15	
3	Shale, black, with iron carbonate	10	
4	Coal		3
5	Shale, black		2
6	Sandstone grading up to shale which is 6 to 12 inches thick	5	
7	Chert conglomerate	2	
8	Coal		1
9	Clay, gray, becoming darker toward the top: contains scattered angular chert pebbles	2	
10	Clay and concealed to water level	5	
	Total below Clear Creek sandstone	39	6

Less than 100 feet to the east the Mississippian extends 10 feet above water level, or about to the top of the conglomerate. If Nos. 4 and 8 are the middle and lower coal beds of the member, the conglomerate constitutes a departure from the normal succession, a feature to be expected where slight irregularities existed in the surface of the Mississippian.

The following table shows in condensed form, sections of the Dederick shale determined from drill holes at different places in and near Vernon County.

SECTIONS OF DEDERICK SHALE IN AND NEAR VERNON COUNTY

	Liberal.		Swart.				Mound-ville.		Bron-augh.		Stotes-bury.		Horton.	
	Ft.	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*
A. Interval from base of Clear Creek ss. to top of coal.....	6	0	5	4	..	.	4	0	6	0	5	0	11	0
B. Coal (Upper Dederick).....		2		6		5		11		9	2	0		6
C. Interval...	9	4	12	2	13	4	7	0	12	7	14	0	16	0
D. Coal (Middle Dederick).....		6	1	4	1	4		8		8	1	0	1	0
E. Interval...	17	6	17	11	18	7	25	2	16	6	8	0	14	10
F. Coal (Lower Dederick)		8	2	6	2	5	2	5	2	4	3	0	..	..
G. Interval to Mississippian....	8	4	4	9	7	2	3	10	2	8	10	0	13	6
Total...	42	6	44	6	43	3	44	0	41	6	43	0	57	8

The Dederick shale appears to be contemporaneous in age with that over the Jordan coal of Henry County which has furnished many species of fossil plants. This flora has been made the subject of a monograph[1] to which the reader is referred.

Dr. White has collected some material from the Dederick shale about 4 miles west of Schell City but the collection has not as yet been studied.

Invertebrate fossils have been found at only one place. The dump of the strip pit in the SE. ¼ sec. 20, T. 36 N., R. 31.

[1]White, David, Fossilflora of the Lower Coal Measures of Missouri: U. S. Geol. Surv. Mon. 37, 1899.

W., contains several species which appear to have come from just above the coal.

Clear Creek Sandstone Member. (21, a-c.) This member was named by Broadhead[1] from the outcrops on Clear Creek. It is probably the sandstone in southeastern Kansas to which the name Columbus[2] was applied and it may be the "Bartlesville sand" of the mid-continent oil fields. It is equivalent to the Graydon sandstone and conglomerate as described by Shepard in Vol. 12, 1st ser., p. 124 of the reports of the Missouri Geological Survey.

The Clear Creek member includes all the beds from the top of the Dederick shale member to a horizon about 105 feet above it.

The sandstone underlies the entire Cherokee area of the county except the small portion where the Dederick shale is at the surface. It outcrops at intervals along Big Drywood and along the entire course of Little Drywood and north along the Marmaton between Nevada and Horton, and it also extends from Horton to the Balltown bridge (sec. 18, T. 37 N., R. 31 W.).

North of Little Osage River in secs. 30 and 31, T. 38 N., R. 30 W., it outcrops over a small area. Near Horton the sandstone dips below the Marmaton and does not outcrop along the south side of the Little Osage above its junction with the Osage. About one mile east of the junction, however, it appears above water level (sec. 34, T. 38 N., R. 30 W.), and from this point to a place near Harwood the Clear Creek sandstone gives rise to a peculiar topographic feature, a low, west-facing bluff, caused by the monoclinal flexure of the sandstone. This feature disappears in the vicinity of Harwood probably because the dip becomes less pronounced in that region. The sandstone outcrops up to the head of the fork of Clear Creek and caps the divide southeast of Nevada. For a few miles north, south, and east along the divide near Milo, it is buried beneath the overlying shale.

East of the line roughly located above, the Clear Creek sandstone is within a few feet of the surface or at the surface. Along all the branches of Clear Creek it outcrops conspicuously, the basal division (21-c) in many places forming steep cliffs.

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[1]Broadhead, G. C., Mo. Geol. Surv. Rept., 1873-74: 1874, pp. 69, 100, 122.
[2]Haworth, E., and Kirk, M. Z., Kans. Univ. Quar., Vol. 2, 1894, p. 106.

In the vicinity of the main drainage lines, the country is broken, but a very short distance back from them it becomes level or gently rolling. In some places the level areas extend to the very edge of the cliff. Large patches of barren rock, some nearly an acre in size, are quite common along the edge of the upland in the Clear Creek sandstone region. In a few places the sandstone forms overhanging cliffs as at "Cave Hollow" (lot 7, NW. ¼ sec. 6, T. 34 N., R. 29 W.) and at Halley's Bluff (Pl. 3).

Out of 23 drill holes in or near Vernon County that have penetrated the entire thickness of the Clear Creek sandstone, 20 showed a thickness of from 82 to 130 feet, averaging 105 feet. In three cases the records were not kept with enough detail to permit the determination of the upper contact, although the base was well marked. Eight of the records show only sandstone, 91 to 127 feet thick, but in 4 of these drillers noted the contact between the two divisions by difference in lithology. The lower division ranges between 25 and 75 feet in thickness, averaging 50 feet, and the upper between 30 and 80 feet, averaging 55 feet, giving the average total mentioned above as 105 feet.

In outcrops the lower division of the Clear Creek sandstone appears as a massive or thin-bedded, brown sandstone with much crossbedding. The color of the unweathered rock varies from nearly pure white through light yellowish, bluish gray, yellow, brown, and red to brownish black. Where it contains asphaltum it varies from gray to black according to the degree of saturation.

Most of the sandstone is fine-grained but somewhat coarser than the average Pennsylvanian sandstone, and mica is a common constituent. Conglomeratic texture due to different sized sand and gravel grains was noted. As a rule it is only moderately well cemented and can be broken readily. At the surface it is usually more strongly cemented than in the interior, due to concentration of iron oxide. Locally the sandstone is hard enough for building purposes and buildings made of it have stood for years. The basal beds, as a rule, are well adapted for walls and foundations and have been quarried at many places. At the south-facing cliff in secs. 7 and 8, T. 36 N., R. 31 W., there are large, rounded concretions which are comparatively hard, due to the large amount of calcium carbonate they contain. Asphaltum, which is sometimes present, almost invariably increases the toughness of the rock. The exposed surface of the sandstone is usually case hardened.

The contact of the Clear Creek sandstone with the underlying Dederick shale is usually sharp (Pl. 5 A.), in fact in many places where the contact can be seen, the base of the sandstone conglomerate composed of material derived from the underlying shale. Locally fragments and thin irregular streaks of coal are abundant, but in these places the conglomeratic texture is not so pronounced. Where the conglomerate is exposed in natural outcrops, the soluble iron carbonate has disappeared leaving a cellular mass of very ferruginous sandstone containing casts of the dissolved material. The conglomerate is not more than a foot or two thick and in places is entirely absent.

Above the basal conglomerate the lower division of the Clear Creek varies from thin, shaly, to massive-bedded sandstone, in general more thickly bedded from the base upward and from east to west. In drill holes at Walker and in outcrops near Dederick, the lower 2½ to 5 feet consist of rather thin beds of hard, light gray, ripple-marked sandstone, the lowest part of which contains locally the conglomerate mentioned above. The beds are as much as 18 inches thick, but although they can be traced along the bluffs for many feet they eventually pinch out. They furnish a good quality of building stone. The next higher beds consist of sandy shale, shaly sandstone, or thinly bedded sandstone, 15 to 25 feet thick. On Milton Creek in sec. 22, T. 36 N., R. 32 W., flagging was formerly produced from this horizon. To the south and west the lower division loses this thin-bedded, shaly aspect, as already mentioned.

The top of the basal division is in places marked by a bed of coal (here termed the Bellamy Coal), which, on the divide between McCarty and Clear Creeks, is sufficiently thick to be of local value. It is mined about one mile west of Bellamy, and also at places from 2 to 4 miles northeast. It ranges from a mere hard streak to 3 feet thick and not uncommonly contains a 3 to 6-inch shale parting.

The roof of the Bellamy coal in the Bellamy district consists of light gray to white, crossbedded sandstone, with usually very little or no cementing material. Because of this, it is not well exposed except in recently-worked strip pits. In other places the roof of the coal and the upper beds in the upper division of the Clear Creek range from clay to indurated sandstone, but in general they are easily weathered and do not form extensive outcrops. Logs of drill holes that have passed through this portion indicate rapidly changing conditions during deposition,

and consequently no two sections of the upper division (21-a) are the same except those in which it is reported to consist entirely of sandstone.

In many places the sandstones of the Clear Creek member carry oil and asphaltum, and in the western part of the county the principal supplies of oil and gas appear to come from these beds.

Shale and Coal Member (9-20): Above the Clear Creek, extending to the Rich Hill lime (No. 8 of the generalized section), the Cherokee consists of alternating beds of shale, coal, and clay having an average thickness of 132 feet. Near the base the shale shows a *Conostichus broadheadi* zone, which is especially noted near Deerfield. The coals serve as markers and are therefore described in some detail in their relation to the intervening strata.

Weir-Pittsburg (Lower) Coal (19): The southeastern Kansas Coal field, in which this is the most important bed, is known to extend within two miles of the southwest corner of Vernon County. It is reported of workable thickness in secs. 30 and 31, T. 34 N., R. 33 W., as shown by drilling. The Survey has obtained records of five other borings in this township, four near Swart and one near Bronaugh, and in three of these the Weir-Pittsburg bed is five to nine inches thick. In the northern and western parts of Vernon County drilling shows that it is very thin or absent, although its horizon can usually be detected. The roof of the coal is commonly shale, although in places it is nearly all sandstone.

The coal bed ranges from 4 to 32 feet below the next higher coal, the interval averaging about 9 feet in Vernon County and increasing to the southwest. Near Mulberry, Kansas, the coal lies 165 to 208 feet below the top of the Cherokee, averaging about 185 feet. The interval increases from east to west. In northwestern Barton and southwestern Vernon counties the Weir-Pittsburg coal lies from 59 to 64 feet above the Clear Creek sandstone member, according to four drill records. In the same four records, it is 184 feet to 203 feet above the Mississippian, averaging about 190 feet.

Walker Coal (17): Coal No. 17 in the generalized section, and No. 18 of Broadhead's section, is stripped on many farms near Walker and is here named the Walker coal bed. It is very persistent and underlies most of the divides in the western third of the county. In the Rich Hill-Panama district it is 8 to 32

inches thick, averaging about 20 inches, but to the southwest it thins to less than 8 inches, and in places is altogether wanting.

Its chief characteristic is the black, blocky, thickly laminated and well-jointed roof slate which is ½ to 5⅓ feet thick, averaging about 3 feet.

As already mentioned, the Walker coal is believed to be equivalent of the Weir-Pittsburg intermediate, a thin but persistent bed with the same kind of roof that lies next above the thick coal of southeastern Kansas.

The interval between the Walker and Rich Hill coal beds is 14 to 35 feet, averaging about 26 feet. Between the underlying clay of the Rich Hill coal beds and the black slate overlying the Walker coal, there is shale or sandstone with locally a thin bed of coal.

Rich Hill Coal (15): The Rich Hill coal is of greatest commercial importance in R. 31 W., north of the Little Osage River, and in one or two square miles near Timbered Mound. From the Vernon County line the field extends to Rich Hill and beyond into Bates County. The Rich Hill coal extends south and west from this field into Kansas but is usually thin and of no value. The thick coal in the mounds near Harwood may also be at the Rich Hill bed.

In the district centering about Rich Hill, a large number of prospect holes have been drilled through the Rich Hill coal, and the Survey has obtained records of 147 of them. In 19 of these borings the coal was absent. In the remaining 128, it ranges between 2 inches and 6 feet, with an average of about 2½ feet. The average for the county is about 2 feet. Between the Rich Hill and the Middle coal are beds of clay and shale, ranging from 5 to 28 feet thick and averaging 10 feet. Where the interval is small, the material is chiefly clay, but where it is large, it consists of clay above and shale below. Locally there is some sandy shale or sandstone. The roof of the coal consists of black, slaty shale, clay, or black, fossiliferous limestone, known respectively as "slate," "white bat," and "black bat," but near Harwood and in a few other places, it is sandy shale or sandstone.

The Rich Hill coal lies 114 to 172 feet, averaging 146 feet, below the top of the Cherokee. Usually the interval is within 10 to 15 feet of the average. The interval between the Rich Hill coal and the Mississippian below ranges from 211 to 240 feet, averaging about 225 feet.

Middle or Two-foot Coal (13): The upper of the two principal coal beds in the Rich Hill-Panama district is known as the Middle coal and has been stripped in many places. It occurs in the mounds near Walker where it is known as the Two-foot coal. Between Rich Hill and the southwestern corner of the county and on into Kansas, where it appears to be the Weir-Pittsburg upper coal, it is fairly persistent although in many places too thin to mine.

Although locally absent, the Middle coal is usually found where the overlying strata have escaped erosion, and has a thickness of 2 to 30 inches, averaging about 12 inches. In the Rich Hill-Panama district it was found in 137 of 169 drill holes that passed through the horizon. It averaged 13 inches in thickness.

The Middle coal is usually underlain by a thick bed of clay. The interval to the overlying One-foot ranges from 8 to 33 feet, averaging about 20 feet. As a rule, it consists of thin, distinct beds of shale forming the roof of the lower coal. The roof shale is a black, slaty variety, locally grading into black, impure, fossiliferous limestone which rests directly on the coal, or the common "soapstone" shale, or in a few places, sandy shale. In the Rich Hill-Panama district the shale contains irregular concretions of gray ferruginous limestone that weather to a reddish brown. Locally a thin coal bed is present and a thin bed of fossiliferous limestone was observed in a few places.

The sandstone above the roof shale is gray or nearly white, hard, fine-grained and from 1 to 4 feet thick. In some places it is quite distinct from the beds above and below it, but in others it grades through sandy shale into them, and locally only sandy shale is present. Because of the comparative hardness, this sandstone caps many mounds and ridges in the southwestern quarter of the county and in the district northwest of Walker, between the Missouri-Kansas-Texas Railroad and Little Osage River. Between the sandstone and the One-foot coal there is a persistent bed of clay.

Variations from the above section are not uncommon. In places the underclay of the One-foot coal extends down to within a few feet of the Middle coal. In a few drill holes limestone is reported at the horizon of the sandstone and in others it is reported that light or dark shale is found.

One-foot Coal (11): The name One-foot is a modification of the name "foot" coal, used for this bed in the mounds north-

west of Walker where it has been extensively stripped. In other parts of Vernon County other names are used. In the Rich Hill-Panama district drillers term it the Ten-inch or Soapstone coal, and near Moundville it is known as the Moundville coal. The One-foot coal is a very persistent bed extending over a large area in the northern and western parts of the county and numerous openings, mostly strippings, have been made in it along the line of outcrop which is shown on the accompanying geologic map. The accuracy of this line depends more or less on the local relief and in the flat districts in the west-central part of the county it is only approximately correct.

The range in thickness given in the generalized section, 6 inches to 2⅓ feet, is somewhat misleading, as the One-foot coal is probably the most uniform member of the formation in the county, and the normal thickness in any given region is usually close to the county average of one foot as implied by the name. In the mounds near Walker it is in many places 10 to 15 inches; in the northwestern part of the county, 10 to 18 inches; and in the west-central part, 12 to 28 inches. In the Rich Hill-Panama district the Ten-inch coal was found in every drill hole that passed through its horizon.

At Moundville and near Eve, the coal is increased by the addition of one or two coal beds separated by thin clay or shale partings. The extra beds are believed to be lenses coming in below the main bed although they may be merely splits from it. At Moundville the section is as follows[1]:

SECTION OF BROWN SHAFT, MOUNDVILLE.

		Thickness.	
		Ft.	*In.*
1	Limestone, light blue, compact	1	6
2	Shale, drab, sandy	14	
3	Shale, dark blue, hard	8	
4	Coal	2	4
5	Clay	1	
6	Coal, 8 inches to	1	
7	Clay	2	
8	Coal, in part cannel, not mined, 12 to 28 inches, average	1	4

Near Eve the clay between the upper two benches is 4 to 10 feet thick and the bottom coal is much thinner.

[1]Hinds, Henry, Coal Deposits of Missouri: Mo. Bur. Geol. and Mines, 2nd ser., Vol. 11, 1912, p. 414.

The One-foot coal rests on an underclay wherever it is found in Vernon County and is overlain by drab or gray shale. In general the roof shale (10) is homogeneous but it contains scattered concretions that weather into thin concentric layers. It also contains some pyrite and this causes the shale to take on a light buff color when it weathers. Where the shale is more than 25 feet thick, the upper part is sandy and locally it is indurated into a sandstone. The shale ranges in thickness from 3 to 47 feet. It is thinnest in the west central part of the county and thickens to the south and northeast. The line between T. 38 N., R. 32 W., and T. 38 N., R. 31 W., marks a rather abrupt change in thickness. Practically all drill records and outcrops west of that line show less than 20 feet of this shale and those to the east show more than 20 feet. However, this generalization does not altogether hold true, as, for example, in sec. 13, T. 38 N., R. 32 W. (Bates County), where, in 18 borings, this shale was found to range from 20 feet to 41 feet.

Above the roof shale is a bed of black, slaty shale (9) that contains, near the base, flattened, spherical concretions of black, impure limestone up to 3 feet in diameter (Pl. 6, B). Near the top there are usually 1 to 3 thin layers of dark, dense, fine-grained, fossiliferous limestone between which the shale is lighter in color and calcareous. In the west-central part of the county the top of the shale is marked by a layer of peculiar, buff concretions which resemble in external form the clinker derived from the burning of certain coals.

The thickness of the black shale is irregular. Where the underlying gray shale approaches the minimum thickness, the black shale reaches the maximum of 13 feet, and where the gray shale approaches the maximum, the black shale is thin or absent.

Rich Hill Limestone (6-8): The name Rich Hill Lime is in common use in the Rich Hill-Panama district and is accordingly adopted in this report. It is probably the member to which Gordon[1] applied the name "Ardmore" limestone in the Bevier district of northern Missouri. In the western part of Vernon County the name Diamond Rock is used because of the tendency to break into diamond-shaped or rhomboidal blocks. The upper part has also been called "cement rock."

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[1]Gordon, C. H., A report on the Bevier Sheet: Mo. Geol. Surv., Vol. IX, 1st ser., pt. 2, 1896, Sheet Rep. No. 2, 1893, p. 20.

The Rich Hill limestone is present in one of its various forms whenever this part of the formation has escaped erosion. Its outcrop extends intermittently across the country from Walker to Bronaugh and uninterruptedly a few miles to the northwest. In the mounds near Walker it is from 5 to at least 12 feet thick, and in the Rich Hill-Panama district, from 2 to 11 feet, averaging 7 feet in 81 drill records. For the western part of the county, in which the upper part is a mass of unconsolidated nodules, no generalization can be made. Here the diamond rock is persistent and from 1 to 2 feet thick, but the bed above it varies from a calcareous clay to an argillaceous limestone up to at least 10 feet thick.

The lower part of the Rich Hill limestone, the Diamond Rock, is much the same wherever it outcrops. It is commonly a single bed one to two feet thick, weathering to a buff color and is more or less jointed. The major joints trend N. 4°—10° W. (magnetic), about 1½ to 3 feet apart and the ledge is broken at right angles to these along joints that trend N. 54°—60° E. (magnetic), forming long monolithic rhombohedral blocks (Pl. 6, A).

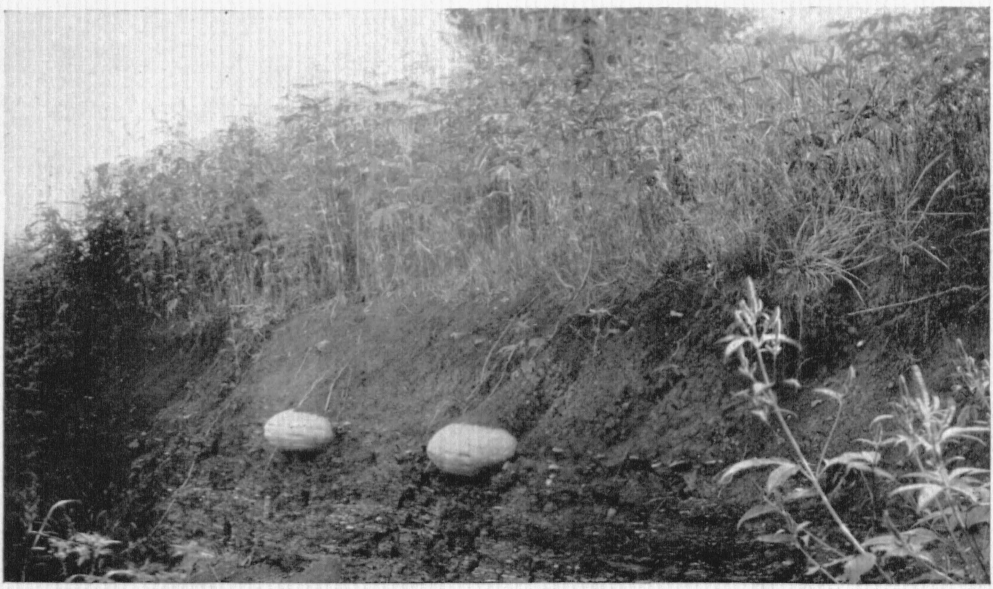
On the interior the Diamond Rock is a dark bluish-gray, compact, fine-grained and fossiliferous limestone. *Squamularia perplexa* is the characteristic fossil. In the west-central part of the county there is a 2-inch layer above the main bed that weathers into small fragments. In the vicinity of Walker, the Diamond Rock is rather siliceous and weathers into an impure tripoli.

The upper part of the Rich Hill limestone is gray, nodular, concretionary, and unevenly bedded. Locally some of the beds are very fossiliferous and the great thickness at Walker is largely due to the presence of *Chaetetes milleporaceous*.

In the Rich Hill region the limestone is rather cherty and in places, especially in road outcrops, the only indication of its presence is the chert. The limestone grades through a mass of nodules embedded in clay, into the under clay (5) of the Williams coal, and, as already stated, the upper part of the bed becomes nodular in the western part of the county.

Williams Coal (4): The name, Williams, in common use among the drillers in the Rich Hill-Panama district, is adopted in this report. It is probably the Bevier coal of northern Missouri. The Williams coal ranges from 2 to 18 inches in thickness, averaging about 6 inches. It lies about one foot above the

A. The "diamond rock" near Eve, showing typical jointing.



B. Limestone concretions in shale above the one-foot coal.

Rich Hill limestone. Exceptionally the coal rests directly on the limestone but usually there is an underclay (5), locally up to 4¾ feet thick, between coal and limestone. The roof shale is usually black and contains one or more thin layers of black, impure, fossiliferous limestone and locally, septarian concretions. The following section was measured in the railroad cut between Stotesbury and Richards.

SECTION IN RAILROAD CUT BETWEEN STOTESBURY AND RICHARDS.

		Thickness.	
		Ft.	*In.*
1	Shale, dark below, gray above, estimated	30	0
2	Shale, dark gray to black, with 3 or 4 bands of limestone like that below, but less fossilferous, harder, and more ferruginous. The bands can be traced for many feet along the sides of the cut	5	0
3	Limestone, black, crystalline, fossiliferous, shelly, 2 inches to		3
4	Shale, black, with septarian concretions of gray, fine-grained limestone	4	
5	Limestone, black, fossiliferous, ½ inch to	0	9
6	Coal (Williams)	0	11
7	Clay, light, with locally 1 or 2 black coaly streaks	2	0
8	Clay with limestone nodules, to bottom of cut	2	0
	Total about	45	

Upper Shale Member (3): The beds included in this member comprise everything between the Williams coal and the Fort Scott coal. There is very little doubt but that this member is the equivalent of that to which Gordon applied the name Lagonda sandstone and shale in the Bevier district of northern Missouri.[1]

The upper member of the Cherokee formation outcrops in the mounds and escarpments extending from near Moundville to Harwood. It occupies most of the area shown on the map between the horizon of the One-foot coal and the top of the Cherokee.

The thickness ranges from 38 to 96 feet, averaging about 80 feet and increases in general from the west-central part of the county eastward. In the western part it ranges from 35 to 65 feet and in the Rich Hill region from 68 to 96 feet, averaging

[1]Gordon, C. H., A report on the Bevier Sheet, Mo. Geol. Surv., Vol. IX, 1st ser., pt. 2, 1896, Sheet Rep. No. 2, 1893, p. 19.

84¾ feet in 32 drill records. As shown in the generalized section near Mulberry, Kansas, it also thickens to the southwest, averaging about 80 feet there.

From the dark shale at the base it grades through gray shale to sandy shale to sandstone, but in the upper few feet clay predominates. The sandstone varies from the fine-grained, shaly type to a type comparatively coarse for Cherokee sandstone. Locally conglomerate is exposed along the State line west of Stotesbury, consisting of a sandy, ferruginous matrix from which the soluble material has been removed. Where the shale is less than 55 to 60 feet thick the sandstone is commonly absent, although sandy shale may be present.

Near the top the sandstone or sandy shale grades rather abruptly into clay that locally contains nodules, vertical or horizontal plates, or beds of concretionary, argillaceous limestone. The latter is most typical near Amos Station and consists of a layer of gray, nodular limestone 2 feet thick, 1½ feet of clay with limestone nodules, and 8 inches of dark gray limestone. This thickness is greater than the normal and in places there is practically no calcareous material.

Fort Scott Coal (2): The names, Fort Scott, or Rusty, have long been used and owe their origin to the color of the coal along the outcrop and for some distance back from it. The discoloration is due to the oxidation of iron sulphide. The Fort Scott coal is believed to be the equivalent of the Mulky coal of Lafayette and Saline counties and of the Macon City bed in Macon County.

The area and outcrop of the Fort Scott coal is practically coextensive with that of the Fort Scott limestone, but there are many places in which the coal is altogether absent or too thin to be of commercial importance even locally. The maximum thickness noted in Vernon County is 20 inches and the usual thickness is only 13 to 14 inches.

The floor of the Fort Scott coal is clay and the roof a black, slaty shale (1), one to seven feet thick. In the lower part of the roof shale there are large spherical concretions of black, impure limestone, locally very fossiliferous, that rest on, or project into the coal. The limestone contains a large amount of pyrite in the outer layer of about one inch. In some cases near the outcrop the nodules are found to have a limonitic shell and are hollow, being partly filled with brown mud. Some are said to contain water. It is thought that surface waters penetrating the nodules leach out the limestone and oxidize the pyrite to a

limonite which, being only slightly soluble remains as a shell. The shell becomes cracked at some stage in the process and fine clay is carried in with the water and becomes stained with small amounts of iron. At the top the shale is lighter in color, calcareous, and weathers to a deep buff.

The horizon of the Fort Scott coal was passed through in 30 drill holes in the Rich Hill-Panama region and in 15 of these the coal and black roof shale were found. In one the shale was present but the coal absent; and in 15, both the coal and shale were absent. If this proportion is typical, the coal is probably absent in about one-half of the area included within its outcrops.

HENRIETTA FORMATION.

Name and Definition. The name Henrietta is derived from a post office, in Johnson County, Missouri. As defined by Marbut[1], the formation includes three members which, in ascending order, are the Fort Scott limestone, the Labette shale, and the Pawnee limestone. As the type localities of these members are in the vicinity of Fort Scott, Kansas, and only a few miles from Vernon County, it may be said that the formation is typically exposed in Vernon County. It is segregated from the Cherokee and Pleasanton because of the greater amount of limestone it contains. In addition, it outcrops in a distinct and continuous escarpment, limited to the southeast and to the northwest by the more level Cherokee and Pleasanton plains.

Distribution and Thickness. The main outcrop of the Henrietta formation is confined to the northwest part of the county, but that it formerly extended some distance beyond is shown by the outliers near Walker and Moundville. The distribution is shown on the accompanying geologic map.

The thickness ranges from 88 to 112 feet as shown by drill records which have penetrated the entire formation. The average thickness, based on many measurements, is about 100 feet divided as follows: Fort Scott member, 24 to 40 feet, averaging 31 feet; Labette shale, 39 to 61 feet, averaging 50 feet; and Pawnee limestone, 15 to 23 feet, averaging 19 feet.

Topographic Expression. The lowest member of the Henrietta, the Fort Scott limestone, forms a low, but well-marked, escarpment overlooking the flat Cherokee plain, and is a con-

[1]Marbut, C. F., Reports on areal geology: Mo. Geol. Surv., 1st ser., Vol. 12, pt. 2, 1898, p. 33.

spicuous feature of Vernon County topography. Near Metz the escarpment is particularly low and treeless, but to the southwest it becomes more pronounced and the crest is covered with timber or shrubs. Along the edge of the escarpment there is usually a luxuriant growth of prickly pear cactus (*Optemia*). South and east of the hills capped by the limestone, there are numerous mounds capped by the sandstones in the upper member of the Cherokee. These rise in places almost as high as the Fort Scott escarpment.

The Labette shale forms a rolling topography north and west of the Fort Scott escarpment and, in contrast to the rough, rocky roads over the Fort Scott limestone, makes smooth roads.

The Pawnee limestone, under normal conditions, also produces an escarpment, but in the Pawnee area of Vernon County, the structure is so much more pronounced than usual, that the characteristic escarpment is lacking and a rolling to hilly landscape has been produced.

Characteristics. The Henrietta formation is characterized by the fact that about one-half of it is limestone. Of the remainder, about one-half is sandstone and the other half is shale, clay and coal. The following is a generalized section based on the records of prospect holes in the Rich Hill district of Bates County, and in Bourbon County, Kansas.

GENERALIZED SECTION OF THE HENRIETTA FORMATION IN VERNON COUNTY, MO., AND THE SURROUNDING REGION.

		Thickness.	Average total.
		Feet.	*Feet.*
1	Limestone (Pawnee), gray, cherty, thick-bedded.....	15–22	19
2	Shale (top of Labette), gray to black.....	4–14	27
3	Limestone, gray, fine-grained, weathers to deep buff.	0–7	32
4	Shale, gray to black, clayey to slaty: locally a thin, slabby limestone is present: interval irregular....	1–15	38
5	Coal, not persistent.....	0–½	38
6	Clay, shale, sandstone, and shale in descending order. The greater part is sandstone and the shale above and below it commonly grades into the sandstone. In places this sandstone rests directly on the upper Ft. Scott limestone.....	12–43	64
7	Coal, rather persistent except where replaced by the sandstone above.....	0– 1	65
8	Clay (base of Labette), becoming calcareous at base...	0–11	69
9	Limestone (upper Fort Scott), major part gray, thin-bedded, but becomes buff and argillaceous toward top and bottom.....	12–23	87

GENERALIZED SECTION OF THE HENRIETTA FORMATION IN VERNON COUNTY, MO., AND THE SURROUNDING REGION—*Continued*

		Thickness.	Average total.
		Feet.	*Feet.*
10	Shale, buff and calcareous at top, lower part black, slaty, and hard, layer of limestone at base	1– 7	90
11	Coal, not persistent	0– 2	91
12	Clay	0– 8	95
13	Limestone (lower Fort Scott or Cement Rock), gray, massive, vertical joints prominent	2–20	101

Members.

Fort Scott Limestone. As shown in the generalized section, the Fort Scott limestone consists of a lower limestone, the Cement Rock, a layer of clay, a non-persistent coal, overlain by black, slaty shale and an upper limestone, the "Twenty-foot Lime" of the drillers.

The lower Fort Scott ranges from 2 to 20 feet thick, averaging about 6 feet. In the west-central part of the county and at Fort Scott, Kansas, it is bluish-gray, weathering to deep buff, fine-grained, argillaceous, and massive. At the top it grades into light gray, nodular material that does not change color upon weathering. Fossils increase in number from top to bottom. The ledge is cut by vertical joints and the blocks thus formed, when exposed in artificial excavations, tend to round off at the corner. The thickness is usually close to the average.

To the north and east the thickness becomes irregular and the character of the rock more variable. The lower part consists of large, rounded blocks with nodular shale and limestone in the interstices, and the upper part is a light gray limestone, the surface of which is marked by nodes of harder, dark gray material. The lower Fort Scott possesses hydraulic properties and was formerly burned to natural cement at Fort Scott, Kansas.

Between the two Fort Scott limestones is a coal horizon. The underclay is 8 feet thick in some places, but in others the roof shale of the coal rests on the upper surface of the lower Fort Scott and the coal is absent. The average thickness of the clay is about 4 feet. The coal has a maximum thickness of 2 feet in the southwestern part of the county in the mounds near

Swart and Moundville, and probably averages 1¼ feet in that district. It has been stripped along much of its outcrop. In the greater part of the area, however, its maximum thickness is 6 inches and in the Rich Hill-Panama district it was found in only 6 of the 27 wells that penetrated the horizon. The roof shale of the coal ranges from 1 to 7½ feet in thickness, averaging about 3½ feet. The lower part is commonly hard, black, blocky, slaty shale, with small, gray, spherical or button-shaped concretions. Locally however, there is between the "slate" and coal a layer of gray, calcareous, fossiliferous clay, and still more rarely, a thin layer of limestone. Near the top the shale becomes softer and grades up through black to gray clay shale, and at the top is calcareous with locally one to three layers of buff-weathering limestone that perhaps should be considered a part of the upper Fort Scott limestone. One of these layers has a clinker-like appearance and is fairly persistent.

The upper Fort Scott is from 12 to 23 feet thick, averaging about 18 feet. In the Rich Hill-Panama region it is known as the "Twenty-foot Lime." Where it caps mounds or escarpments, as it does in many places, the upper part has been removed by erosion.

Aside from the buff ledges at the base, the greater part consists of gray limestone in even layers 2 to 6 inches thick at the base, and irregular ledges 1 to 15 inches thick higher up. The bedding planes are wavy and marked by buff shaly material and the individual layers tend to become buff toward the top and bottom. The middle part of each layer is rather fossiliferous, the fossils appearing in cross-section as curved planes and irregular areas of calcite in the dark-gray, dense, fine-grained matrix. The lower two to three feet weather back faster than the overlying part. In the upper part, the coral, *Chaetetes milleporaceous*, is very abundant. There are many small vertical fractures that cross only individual layers and cause vertical breaks, as well as two sets of vertical joints that cut the whole ledge. These are approximately at right angles and strike about N. 45° E., and N. 45° W. (magnetic).

At the top of the upper Fort Scott there is an irregular thickness of nodular and argillaceous limestone that weathers buff, and locally a thin bed of gray limestone composed almost exclusively of *Fusulina sp.* and segments of crinoid stems.

Labette Shale. The Labette shale consists of sandstone, clay, shale, and one or two beds of limestone, and contains two

coal horizons. It is 39 to 61 feet thick, averaging about 50 feet. At the base there is a bed of clay that grades down into the argillaceous material at the top of the Fort Scott limestone. This clay has a maximum thickness of 11 feet and averages 4 feet, but in a few places where the sandstone in No. 6 of the generalized section rests directly on the upper Fort Scott, the clay and overlying coal and shale are absent. This coal appears to be rather persistent otherwise and is from 2 to 12 inches thick, averaging 4 inches. It is overlain by various kinds of shale, chiefly black, and as much as 11 feet thick in places. Locally a thin layer of gray, slabby limestone occurs a few inches above the coal.

Above the shale is a persistent and widespread sandstone from 1 foot to 34 feet thick. The sandstone varies from massive and cross-bedded to thin-bedded and shaly or calcareous. Where it outcrops in the bed of the creek in the NE. ¼ NE. ¼ sec. 31, T. 38 N., R. 33 W., it is very thinly-bedded and calcareous, and contains numerous impressions resembling the hoof prints of a horse, but probably of vegetal origin and possibly belonging to the genus *Taonurus*. The sandstone becomes shaly at the top and the shale grades upward into the underclay of a coal bed (No. 5 of the generalized section).

The coal at this horizon is thin and non-persistent, averaging less than 2 inches thick. It is marked by shale and "slate" ranging from 1 foot to 15 feet thick and averaging 6 feet. The "slate" occupies the upper part of the interval and is usually about one foot thick in the outcrops near Amos although it is reported to be as much as eight feet thick in drill records.

About eight feet below the top of the Labette shale is a limestone that varies from a thin, shaly layer to a bed seven and one-half feet thick, averaging about five feet. Where good exposures are found it is brown, fine-grained rock, in even layers. The distinguishing characteristic is the amount of finely disseminated calcite that gives the rock a sandy appearance. In Bates County it contains many *Fusulina*.

The shale at the top of the Labette ranges from 4 to 14 feet, averaging about 8 feet thick. It is chiefly a gray, clayey shale, but locally it is black and slaty at the top and sandy in the lower part.

Pawnee Limestone. This member occurs only in the northwest corner of the county. The distribution is shown on the accompanying geological map. The area of outcrop is for the

most part a rolling prairie and exposures are rare. The boundary in places is doubtful. In other places the Pawnee has been assumed to be present when the limestone (No. 3 of the generalized section) near the top of the Labette shale outcrops, as the average interval between the two limestones is only 8 feet.

So far as can be determined from present data, the thickness of the Pawnee in Vernon County ranges between 15 and 22 feet, with an average of 19 feet. There are places where the thickness is greater, as in Bates County, where it is nearly 40 feet thick.

The Pawnee is a light gray, fine-grained, heavy-bedded, fossiliferous, and cherty limestone. It is readily soluble, a fact that probably accounts for the scarcity of outcrops in certain areas. Although it appears to be fairly pure, it has a comparatively high iron content and the resulting soil is consequently stained a deep red. The chert is light gray, slightly lighter than the limestone and in freshly exposed surfaces is rather calcareous. Like the limestone, the chert is fossiliferous, suggesting metasomatic replacement, although small patches of chalcedonic silica are common.

The upper part of the Pawnee limestone is a mass of the coral *Chaetetes milleporaceous* and its thickness in a given area depends largely on the abundance of this coral. In the bed of the creek in NW. ¼ NW. ¼ sec. 29, T. 38 N., R. 33 W., there are large rounded knobs of *Chaetetes*.

PLEASANTON FORMATION.

Name and Definition. The Pleasanton formation takes its name from Pleasanton, Kansas, a town about 10 miles northwest of the northwest corner of Vernon County. At the type locality the Pleasanton embraces a number of thick beds of shale and sandstone and thinner beds of limestone, clay, and coal that form a marked lithologic and topographic contrast with the underlying Henrietta formation and the overlying Kansas City formation.

Distribution and Thickness. Three small patches of Pleasanton outcrop in the northwest corner of the county and are shown on the accompanying geologic map. The three aggregate less than two square miles. The presence of two of the areas is due entirely to structure and a large part of the third has been preserved by favorable structural conditions. The Pleasanton area

in Vernon and Bates counties is marked by a large number of strip pits in the Mulberry coal.

At the type locality the Pleasanton is about 200 feet thick. In Vernon County only the lower 60 feet remain. The nearest point at which the whole section occurs is at Rock Mound, near Hume, Bates County.

Topography. The lower part of the Pleasanton (Bandera shale member), the only part that occurs in two of the three localities, is so soft and easily weathered that it produces only a rolling or undulating plain. In the third locality (secs. 25 and 26, T. 38 N., R. 33 W.), the Altamont limestone member forms a low but distinct escarpment, best seen where the road between the two sections mentioned crosses it.

Lithologic Characteristics. The Pleasanton formation in the northwest part of Vernon County and the southwest part of Bates County contains only four beds comprising two members as shown in the following section.

GENERALIZED SECTION OF THE LOWER PART OF THE PLEASANTON FORMATION IN AND NEAR VERNON COUNTY.

		Average thickness.	
		Ft.	*In.*
1	Limestone (Altamont), about	9	0
2	Shale (top of Bandera), 35 to 53 feet thick	45	0
3	Coal (Mulberry)	2	6
4	Clay (base of Bandera)	3	6
		60	0

The Mulberry coal is commercially important in the southwest corner of Bates County, and has been opened wherever it occurs in Vernon County, but has not been extensively mined. The area in secs. 29 and 30, T. 38 N., R. 33 W., probably could be profitably worked by steam shovels since the coal undoubtedly extends southward from Bates County where there are extensive strip pits in this bed.

The roof shale is not exposed in Vernon County but from outcrops and drill records in southern Bates County it is known to consist chiefly of gray, homogenous clay shale (soapstone of drillers). At the type locality in Kansas the upper part of the Bandera shale contains the Bandera flagging and in Bates

County, Missouri, the upper part is in places quite sandy. North of Osage River a limestone lens appears a few feet above the Mulberry coal and is persistent over a large area in the southern part of Bates County.

The Altamont limestone is a gray limestone about 9 feet thick. The lower part is somewhat nodular and argillaceous; the upper part is fine-grained, compact, moderately fossiliferous, and heavy-bedded. The fossils are partly replaced by calcite and there are also small irregular masses of this material.

WALKER CONGLOMERATE AND SANDSTONE.

Name and Definition. The name here used for this formation is merely tentative and is used for convenience only, until the formation can be definitely correlated. It includes the unconformable conglomerate near Walker and the coarse sandstone into which it grades. Although there is no direct evidence, the indirect evidence indicates that the formation is of Pennsylvanian age.

Distribution and Thickness. The Walker formation has been found at only one place, the crest of the ridge which extends to the northwest on Walker Mound (sec. 8, T. 36 N., R. 30 W.). The outcrop is about four-fifths of a mile long and very narrow. About 20 feet of the material is in place at the northwest end of the outcrop. The conglomerate rests on the shale above the Williams coal.

Topography. The part of Walker Mound that is capped by the sandstone is higher than the remainder, which is capped by the Rich Hill limestone. The difference in height, therefore, represents the thickness of the conglomerate and sandstone plus the 10 to 15 feet of shale, coal, and clay overlying the Rich Hill limestone and underlying the conglomerate. The ridge capped by the sandstone is treeless and was probably a prairie even before the advent of the white man.

On top of the ridge the sandstone is cut by vertical joints into large polygonal blocks, which in general are higher at the margin than in the middle 3 or 4 inches. The joints are irregular in direction and do not correspond in strike with the joints in the other Paleozoic formations.

Lithologic Characteristics. The formation consists of conglomerate at the base, very coarse sandstone above, and coarse sandstone at the top, the three types of rock grading into each

other. At the base is a very coarse conglomerate consisting chiefly of limestone pebbles derived from the Rich Hill limestone, with a liberal sprinkling of angular to sub-angular quartz pebbles, the largest an inch in diameter, and a few pebbles of igneous rock. The quartz varies from dark gray to pink. There is a small quantity of limonite, which, however, may have been formed in place. The cementing material is a ferruginous sand. When the conglomerate weathers, the soluble limestone is removed and the matrix becomes soft, freeing the quartz and other pebbles with which the hillside below the outcrop of conglomerate is covered.

Above the basal conglomerate, the formation consists of angular quartz grains held together by brown ferruginous cement. The size of the quartz grains decreases from the base upward, so that the upper part of the formation consists of coarse brown sandstone.

Geologic Relations. The Walker conglomerate rests unconformably on the lower part of the upper shale member of the Cherokee formation. As no unconformity exists within this member, nor in or between any of the higher stratified formations in Vernon County, the conglomerate at Walker is certainly younger than Pleasanton. The exact age cannot be determined as there is no evidence in Vernon County that the Walker formation was ever overlain by other strata.

Correlation. The Walker formation is different lithologically from any of the other Pennsylvanian sediments in the State, and, as its geologic relations are so indefinite, the problem of correlation is difficult. The Warrensburg sandstone channel[1] has been traced southward to a point near Lewis Station, Henry County, about 50 miles northeast of the Walker locality, and the floor of the channel in which the sandstone was deposited is known to rise with reference to the base of the Henrietta formation at the rate of 1.4 to 2 feet per mile to the south. The rate of rise, or, in other words, the gradient of the old stream bed, decreases to the south. Near Lewis Station the approximate bottom of the channel is 77 feet below the base of the Henrietta, and the base of the deposit at Walker is about 30 feet below the same horizon, a rise of 47 feet in 50 miles, or about what could be expected if the Walker formation was deposited in the same channel as was the Warrensburg sandstone.

[1]Hinds, Henry, and Greene, F. C., Stratigraphy of the Pennsylvanian series in Missouri: Mo. Bur. of Geol. and Mines, 2d ser., Vol. 13, 1915, pp. 95-97.

The source of the igneous material in the basal conglomerate has been sought for its bearing on the problem. The Graydon sandstone of Lawrence, Greene, Polk, and adjoining counties contains quartzite pebbles but none of quartz. The Dakota sandstone and the Tertiary of Kansas contain quartz pebbles, but if the Walker deposit is of Cretaceous or Tertiary age, other similar deposits should occur in eastern Kansas and no such deposits have been found. Similarly, if the quartz was derived from the St. Francois Mountains of southeastern Missouri, geologic work in the western part of the Ozark region should have revealed intervening deposits containing quartz pebbles, but none have been found so far as known.

Another possible source is in the Arbuckle Mountain region of Oklahoma, where there are rocks which contain both quartz and chert. Furthermore, the Seminole conglomerate[1] of the Coalgate quadrangle of Oklahoma, an area lying between the Arbuckle Mountain region and Vernon County, is seemingly quite similar lithologically to the Walker conglomerate. It also appears to have similar stratigraphic relations and rests on rocks that are believed to be only slightly higher or younger than those on which the Walker deposit rests. This would be expected if the Seminole conglomerate was deposited in the southern continuation of the Walker or Warrensburg channel.

From Missouri River south to near Lewis station, Henry County, the deposits in the Warrensburg channel form a practically continuous outcrop. South of Lewis station the conglomerate, supposing that it did continue south to the Arbuckle region, has been found in but two localities as mentioned above. The reason for this is apparent. South of Lewis station, the material in which the supposed channel was cut is chiefly a soft and easily eroded shale not at all favorable to the preservation of the old channel. North of Lewis station the formations contain many limestones which have resisted erosion and preserved the channel and sandstone filling.

A summary of the evidence given above indicates, therefore, that the Walker conglomerate and sandstone is the southern continuation of the Warrensburg channel sandstone of late Pleasanton age and that the channel in which these deposits are formed, was carved by a stream flowing in general to the north.

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[1]Taff, J. A., Coalgate folio (No. 74), Geol. Atlas U. S., U. S. Geol. Survey 1901, p. 4.

Paleontology. No fossils have been found in the Walker formation except a few in the fragments of limestone included in the basal conglomerate, and, as these were derived from older formations, they throw no light on the age or origin of this formation.

UPLAND GRAVELS.

There are apparently two types of upland gravels in Vernon County, probably of different origin. These do not include the pebbles of Walker Mound, which have already been mentioned and whose source is apparent, nor the residual chert of the Pawnee, Rich Hill, and Mississippi limestones.

The first type is the angular chert usually found embedded in the surface clay in many places in the county not immediately underlain by chert-bearing formations. This chert is common in the western part of the county, resting on the Diamond Rock and scattered through the surface clay. The deposits resting on the Diamond Rock have largely lost the clay by a sluicing process. The same type of chert has been found as far east as secs. 26 and 35, T. 36 N., R. 30 W. This chert is believed to have come from the cherty limestone that formerly extended much farther east. Solution played a large part in the removal of the limestone and the contained chert has been gradually lowered to its present position. As explained in another part of this report there are areas in the county which have been reduced to their present level by gentle wash that would not carry fragments of chert to any great distance from the place where it was first freed from the matrix.

The second type consists of the pebbles on the upland bordering Osage River, obviously transported, rounded, and deposited by water. Pebbles of this character were noted in the SW. ¼ sec. 30, T. 38 N., R. 30 W. (Pl. 4, B), and on the hills northwest of Schell City. The altitude ranges between 750 and 815 feet. At most, the gravels are now a superficial covering not exceeding 2 to 3 feet in thickness. They consist chiefly of chert, but quartz is not uncommon. The larger pebbles are angular but the edges are rounded. The smaller ones are more or less rounded. These gravels seem to be identical with those occurring in the Joplin district[1] and to the Tertiary gravels

[1]Smith, W. S. T., and Siebenthal, C. E., Joplin District folio (No. 148), Geol. Atlas U. S., U. S. Geol. Survey, 1907, p. 7.

found in Greene County[1] and correlated with the Lafayette gravels of Tertiary age.

Whatever the ultimate source of the gravels along Osage River in Vernon County may have been they were evidently deposited in their present position by the river. The height to which the gravels extend, the maximum being more than 100 feet above water level, indicates clearly the old age of the deposits, for they must have been deposited when the river was at a much higher level than now. Criteria for a closer correlation have not been found in Missouri in the area examined, and it appears to the writer that a correlation with Cretaceous, Tertiary, Pleasanton, or Recent deposits elsewhere has no basis.

RECENT SERIES.

Alluvium.

The main areas of alluvium in Vernon County are shown on the accompanying geologic map (Pl. 14) and, as may be seen, it covers a fairly large part of the total area of the county. There are two types of alluvium, a silty loam, and a clay, the latter known locally as gumbo. The first type occupies the smaller valleys and the higher parts of the large flood plains, usually close to the river banks; and its surface may be either nearly flat or gently undulating. The gumbo occupies the lower part of the larger flood plains and its surface is practically flat. Its characteristic position is in the low lying belt between the bluffs and the slightly higher land bordering the river banks. Usually the gumbo is covered with a rank growth of tall, coarse grass but pin-oak and pecan trees form open groves in many places.

At the heads of the smaller streams, where there are no flood plains, alluvium is absent, but most of the streams of the area have formed narrow flood plains to within a few miles of their source, owing to the softness of the rocks. Alluvium covers the flood plains from the upper to the lower ends, increasing in thickness towards the lower end.

The maximum thickness of alluvium occurs along Osage River in the northeast corner of the county where it is at least 26 feet thick.

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[1]Shepard, E. M., Areal Geology: Mo. Geol. Survey, 1st ser., Vol. 12, pt. 1, 1898, p. 142.

Broadhead describes the material encountered in digging a well at Papinsville, Bates County, as follows.[1]

RECORD OF WELL DUG AT PAPINSVILLE, BATES COUNTY.

		Thickness.	
		Ft.	*In.*
1	Yellow clay	31	
2	Blue clay and gravel		4
3	Sandy stratum, enclosing a tooth of horse, extinct species	Thin	
4	Gravel bed, the pebbles mostly rounded and some adhering together; mostly siliceous associated with fragments of coal and iron ore	5	
	Total, more than	36	4

If the tooth noted in No. 3 is correctly identified the lower part of this alluvium may be of Pleistocene age.

Slope Wash.

Wash is accumulating along the foot of nearly all the gentle slopes in the area except those that are being actively undercut by streams. In but one area, however, is the accumulation of sufficient size to warrant mapping it. In the northeastern corner of the county between the low bluffs of Mississippian limestone and the alluvial flats of the Osage is a terrace-like feature that appears to be composed of slope wash. The river for many years has occupied the northern part of its flood plain, thus allowing uninterrupted deposition along the foot of the south bluff.

Soil.

The uplands with few exceptions are covered by residual soil. The limestone escarpments are barren of soil and it is thin or absent for some distance back from the edge of the escarpment in many places. The vertical or nearly vertical cliffs of sandstone are, of course, barren, as are also the peculiar upland outcrops of the Clear Creek sandstone. Road cuts across some of the narrow divides capped by sandstone show that much of the residual soil is less than two feet thick.

[1]Broadhead, G. E., The geology of Bates County, Missouri; Mo. Geol. Surv. Report, 1873-1874, 1874, p. 157.

Numerous drill holes scattered over the county record from one foot to 35 feet of residual soil averaging about 10 feet. In general, the soils resulting from the weathering of limestone are the thinnest, those from soft shale the thickest, and those from sandy shale and sandstone come between the extremes.

ROCKS NOT EXPOSED.

General Features. In the region east of Vernon County the Ozark uplift brings to the surface strata which in Vernon County lie deeply buried. The columnar sections (Pl. 7) give the general succession as known to underlie the southern half of the State and show the relative position of the thick quartzite horizon encountered in the Rinehart well. Cuttings from comparatively few complete records have been obtained in the territory of Vernon or adjoining counties, the most complete record in the Survey being the Beamer well at Lamar for which cuttings were sent approximately every 5 feet.

The character and correlation of the Mississippian formation have been discussed in earlier pages of this report. While the Devonian, Silurian and Upper Ordovician are well developed along the eastern flanks of the Ozark region, there are no strata in the area of outcrop east of Vernon County that can be assigned to these series. If they were deposited originally, erosion has subsequently removed them. Frequently, at the base of the Mississippian and overlying the Jefferson City, a thin patchy sandstone is encountered. This may be the Sylamore of basal Mississippian age, or possibly remnants of sandstone in the Devonian or St. Peter sandstone if the Ordovician formation was deposited in the region. These factors have not been determined in the present report.

Mississippian Limestones: Beneath the Cherokee sandstones and shales, the drill encounters the relatively hard, light-colored, more or less cherty Mississippian limestone. A number of deep wells have passed entirely through it showing a thickness of 239 to 350 feet, averaging about 310 feet.

Northview Shale. All of the deep wells that have penetrated the Mississippian limestone reached a shale, believed to be the Northview. This is reported as blue shale, "soapstone," "shale and lime," "slate," etc. In nine wells it ranges between 15 and 75 feet in thickness, averaging 35 feet. In a well near Dederick it is reported to be 120 feet thick but this is probably an error

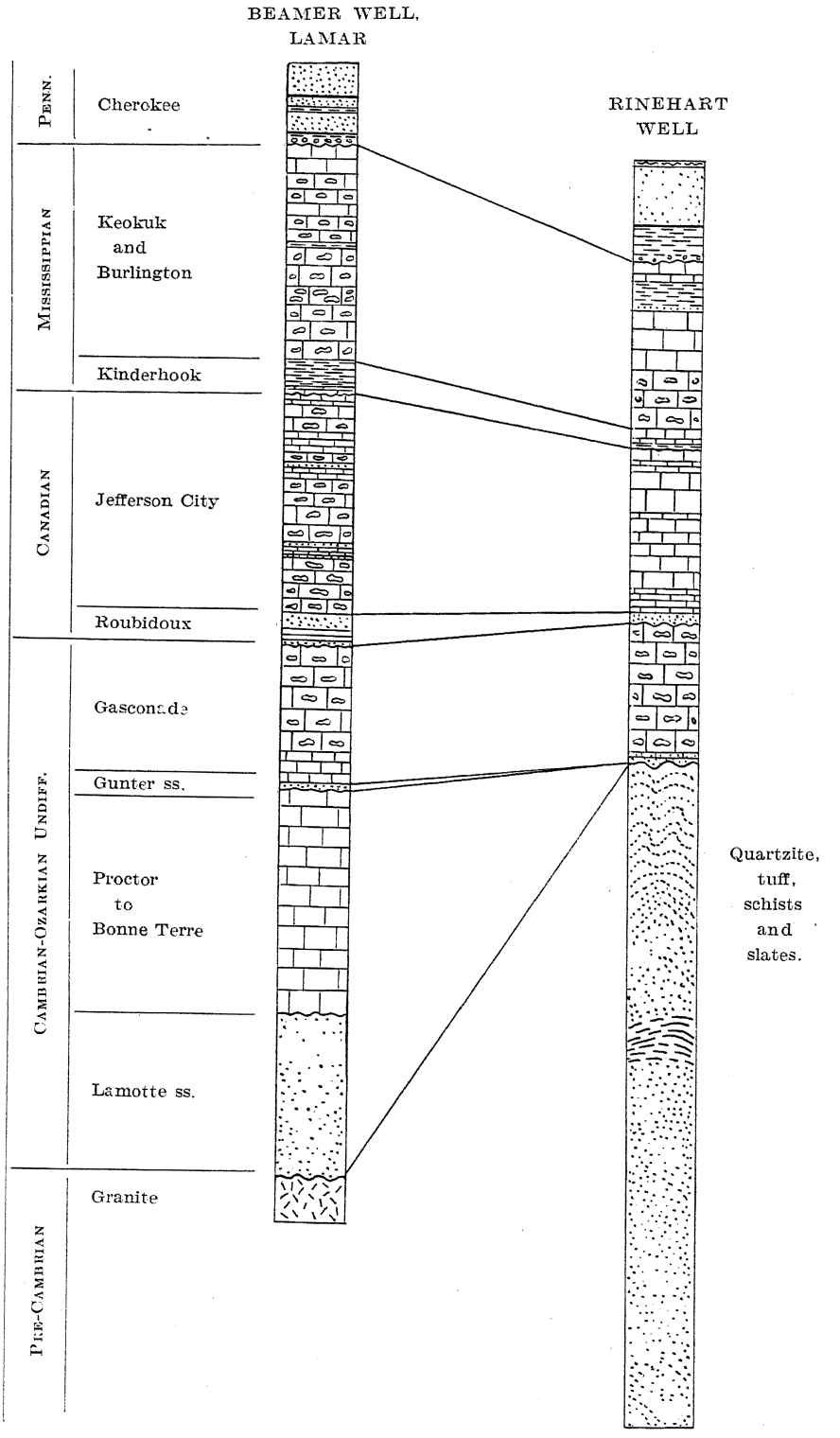


PLATE 7.

Sections showing stratigraphy of Rinehart and Beamer wells.

especially as the overlying limestone was very much thinner than normal.

In Cedar County,[1] where the Northview shale outcrops, it has a thickness of 44 feet and includes some sandstone at the top as it does in a well near Bellamy, Vernon County.

CAMBRO-ORDOVICIAN FORMATIONS.

Jefferson City Formation: It is believed that in general the Northview shale rests directly on the Jefferson City dolomite which is of Ordovician age.

The Jefferson City formation is reported in well logs as "lime," "flinty lime," "sandy lime," "blue flint," etc. From observations elsewhere it is known to be rather cherty. The underlying Roubidoux formation consists of alternating beds of sandstone and dolomite and as the Jefferson City contains layers of sandstone in the basal part, it is difficult, if not impossible, in some cases to differentiate between the two formations. The Jefferson City formation ranges in thickness between 218 and 318 feet, averaging in 10 wells 262 feet. With the underlying Roubidoux, it furnishes the water of the flowing wells of Vernon and surrounding counties.

Roubidoux Formation: As already mentioned the Roubidoux consists of alternating layers of sandstone and dolomite and is not distinctly different from the overlying Jefferson City. However, by averaging six of the eight available logs of wells that have gone through it, the following section was obtained:

SECTION OF ROUBIDOUX FORMATION IN VERNON COUNTY WELLS.

	Average thickness.
	Feet.
Sandstone, 9 to 10 feet	10
Dolomite, 20 to 50 feet	39
Sandstone, 12 to 23 feet	19
	68

In two other wells, it is reported as a single bed of sandstone, in one 35 feet thick and in the other 12 feet thick. The apparent

[1]Broadhead, G. C., The Geology of Cedar County; Mo. Geol. Survey, Rept. 1873-74, 1874, pp. 62-76.

uniformity of some of these sections and the discordance of others may or may not be due to the drillers' determinations of the material encountered.

The Roubidoux is almost certain to yield an abundant flow of "sulphur water," which in the vicinity of Nevada rises to an elevation of about 790 feet above sea level.

Gasconade Formation: Wells drilled for water seldom go more than 50 or 100 feet into the Gasconade, but some of the oil and gas prospects have penetrated a considerable thickness of dolomite below the Roubidoux. A well nine miles south of Nevada passed through 425 feet of dolomite which probably includes the Gasconade and some lower formations. The well at Rinehart penetrated 300 feet, and the one at Fort Scott, Kansas, 345 feet of dolomite below the Roubidoux. At Lamar, in the next county south of Vernon, 700 feet of rock, chiefly dolomite, belonging to the Gasconade and older formations, was encountered.

Older Rocks: In the Lamar well, after passing through the dolomites mentioned above, a sandstone, 195 feet thick was found. This is probably Lamotte as it rests on red granite at a depth of 1,850 feet. A well drilled in the south part of Nevada at the packing plant, entered red or pink granite at a depth of 1,880 feet, but no record was obtained of the rocks that were found above.

In the Rinehart well, the Gasconade rests on a dark-gray to red ferruginous quartzite at the surprisingly shallow depth of 1005 feet. The rock appears to have been highly metamorphosed as most of the cuttings show no evidence of the original grains, although other samples show rounded grains apparently water-worn. There are few well records from which to draw conclusions, but it appears that this quartzite, which is probably of pre-Cambrian age, formed an area of considerable relief prior to the deposition of the Lamotte sandstone and the overlying dolomite.

There are about 900 feet of sedimentary rocks between the Roubidoux and the granite at Lamar, whereas at Rinehart there are but 235 feet between the Roubidoux and the quartzite. The Rinehart well is similar to the well drilled at Fort Scott, Kansas, which the driller reports 345 feet of gray and white limestone (Gasconade dolomite) resting on 110 feet of "gray sand." Although cuttings have not been seen the latter certainly suggests the quartzite.

The following is the record of the Rinehart well:

RECORD OF NEVADA OIL AND GAS COMPANY WELL, NEAR RINEHART, SE. ¼, NE. ¼, SEC. 31, T. 37N., R. 32W.

	Thickness.	Depth.
PENNSYLVANIAN SYSTEM:		
No record (reported chiefly shale and sandstone)	170	170
MISSISSIPPIAN SYSTEM:		
Keokuk-Burlington formation:		
Limestone, light gray; shale, black; chert; pyrite	30	200
Shale, dark gray, sandy; sandstone; chert; limestone; pyrite	48	248
Sandstone, gray; shale, dark; chert; fragments of limestone	3	251
Limestone, light gray, crystalline, with stylolites; chert	188	439
Kinderhook formation:		
Chouteau Limestone:		
Limestone, dolomitic, granular, brown, dense to finely crystalline; chert	30	469
Northview Shale:		
Shale, bluish gray, calcareous	5	474
ORDOVICIAN SYSTEM:		
Jefferson City formation:		
Dolomitic limestone, bluish gray, fine-grained	15	489
Chert, light to dark blue; some gray dolomitic limestone	25	514
Shale, gray, calcareous; some dolomitic limestone	16	530
Dolomite, gray, very argillaceous ("cotton rock")	37	567
Dolomite, hard, oolitic chert	183	750
Roubidoux formation:		
Sandstone, fine-grained, angular to rounded, frosted, with some dolomite, chert	20	770
OZARKIAN SYSTEM:		
Gasconade formation:		
Dolomite, light gray, bluish gray, finely crystalline; light gray, bluish gray chert	205	975
Dolomite, light gray, finely crystalline; chert; fragments of tuff; green quartzite; pyrite	15	990
Dolomite, light gray, finely crystalline; chert; quartz, angular and rounded, frosted grains; fragments of quartzite; green tuff; pyrite	5	995
Sandstone, fine to medium, angular to rounded frosted grains, with dolomite; green tuff, quartzite, chert, pyrite	10	1005
PRE-CAMBRIAN SYSTEM: (?)		
Quartzite, colorless, pink, green, lavender, micaceous, pyritic; tuff, altered, green fine-grained; sandstone, fine to medium, angular to rounded frosted grains	5	1010
Quartzite, white, pink, lavender, red, micaceous; pyrite; magnetite	45	1055
Quartzite, as above; tuff, green	4	1059
Tuff, altered, green, fine-grained; with quartz, feldspar, sericite, epidote, tremolite (?), magnetite; glass	5	1064

RECORD OF NEVADA OIL AND GAS COMPANY WELL, NEAR RINEHART, SE. ¼, NE. ¼, SEC. 31, T. 37N., R. 32W—*Continued.*

	Thickness.	Depth.
Quartzite, colorless to pale green; tuff, green, fine-grained	10	1074
Tuff, green, fine-grained; white ash (?)	5	1079
Quartzite, white to pink, pyrite	35	1114
Quartzite, dark red	4	1118
Quartzite, colorless, pink, red, green	12	1130
Quartzite, light and pink; tuff, green; ash, white.	73	1203
Tuff, green, dense, micaceous; quartzite; ash, white; pyrite	6	1209
Quartzite, colorless to pink	11	1220
Tuff, green, dense, micaceous; quartzite, colorless; ash, gray; pyrite	32	1252
Slate (schist?) dark green, fine-grained, micaceous, quartzitic, with pyrite, chalcopyrite	67	1319
Quartzite, colorless to pink; slate	6	1325
Tuff, green; quartzite, colorless to pink; ash, white	26	1351
Quartzite, colorless to light gray, with muscovite, chlorite, pyrite, hornblende, magnetite; fragments of tuff and slate	164	1515
Tuff, green, fine-grained, micaceous	48	1563
Quartzite; tuff; pyrite	22	1585
Tuff, green, micaceous	7	1592
Quartzite, colorless to pink; muscovite, chlorite; tuff, green; ash, white	106	1698
Tuff, light green, dense to fine-grained, micaceous: pyrite; ash; quartzite	54	1752
Quartzite; tuff; mica (sericite), chlorite, pyrite; ash	137	1889
Quartzite, colorless; muscovite, chlorite; small amount tuff	90	1979
Quartzite, colorless; tuff, light green, fine-grained; ash; chlorite	39	2018

GEOLOGIC HISTORY.

Pre-Pennsylvanian: The geologic history of Vernon County is essentially that of southwest Missouri. The formations exposed at the surface are only a part of those formed during Pennsylvanian time. Consequently they represent but a very small fraction of the geologic history of this part of the country. The record of all preceding events that led up to the time represented by the surface formations, is covered up and is unknown except for occasional fragments obtained by drilling, and the information supplied by far distant outcrops.

The Archean granites which are exposed in southeast Missouri, and which underly the Ozark region are encountered in deep drill holes in Vernon County. This granite mass was for a long time a land area and was subject to erosion processes, comparable perhaps to those of today. After a long period of erosion which resulted in a highly irregular and rough topography the area became submerged in part and a considerable thickness of sandstone and shale was deposited in the depressions. How long this lasted or how widespread the submergence was, are questions that cannot be definitely answered. In all probability the time involved was great. After this period of submergence came a period of dynamic disturbance accompanied by emergence so that a land mass was again formed. The formations composing this land area were more or less altered and metamorphosed during the period of diastrophism, resulting in a change from sandstones and shales to quartzites and slates. These are occasionally encountered in deep drillings. The region remained a land mass for a great length of time during which it is probable that most of the earlier formed sediments were removed by erosion and the granite basement again laid bare. Erosion in time lowered the surface and a down-warping of the land caused the sea to advance thus submerging the region a second time.

This second advance of the sea probably occurred in the middle Cambrian epoch and continued into the Ordovician. On account of the irregularity of the old land surface this sea varied greatly and quartzite hilltops remained as islands. Around these, coarse, poorly assorted sandstones or even conglomerates were laid down, which in turn were buried by thick beds of limestone, sandstone, and shale.

Early in Ordovician time an uplifting of the land left the region again as a land mass, so that when it was again submerged the St. Peter sandstone was laid down unconformably on the old land surface. At the time the St. Peter sandstone was deposited widespread submergence prevailed, since this formation is encountered over an exceedingly large area in the eastern Ozark region and elsewhere. After this period of deposition it seems likely that there were several advances and recessions of the sea during which thick beds of limestone, sandstone, and shale were laid down, but these and the St. Peter have been to a large extent removed by erosion during subsequent periods, so that now only isolated patches of them are encountered.

The record of Silurian and Devonian time is far from complete. Whether a land mass was present in the vicinity of Vernon County, or whether it was a sea whose sediments have been almost entirely removed by erosion cannot be determined. At any rate only a very small thickness of sediments that have been doubtfully referred to these periods are known and it seems likely that the land mass at that time conformed very nearly to the present distribution of Cambro-Ordovician rocks or perhaps extended even farther west.

Mississippian time began with a widespread submergence of the land. It seems probable that nearly all of the Ozark region was covered at this time, as remnants of Mississippian rock have been found in a great many places. The earliest sediments are mostly shales representing mud and sand washed off from the land into the shallow water. As the sea continued to advance, the water cleared and limestone was formed, characterized almost everywhere by an abundance of chert and fossils. From drill records and information obtained where rocks of this age are exposed, it appears that the latter part of Mississippian time is marked by a recession of the sea, when erosion went on and the later rocks were laid down on an uneven surface, which was in many instances covered with a layer of chert fragments derived from weathering of the earlier limestone.

Pennsylvanian. At the close of the Mississippian there was an erosion interval of considerable length when a considerable thickness of the upper beds were removed and a fairly level plain produced. During the next period of subsidence the land probably remained at or near the critical level. There were repeated changes of land and sea as is shown by the numerous coal beds found interbedded with sandstones, shale and limestones of the Pennsylvanian series. The advances and withdrawals of the sea left numerous low-lying swamps in which dense vegetation flourished under the influence of a moist tropical climate. Vegetation continued to accumulate over the area forming vast peat bogs, gradually filling up the marshes and swamps and later becoming buried by sand and mud. Protected from rapid decay by this cover a gradual change took place and in time the coal beds were formed. That there were several oscillations of land and sea during Cherokee time is shown by at least five widespread coal beds and a number of others of less extent.

At the close of Cherokee time conditions changed somewhat and thick beds of limestone with abundant fossils, thin beds of

sandstone and shale, and a thin coal bed, were laid down in succession after which came another period of limestone deposition marking the close of the Henrietta epoch. Then in the shallow Pleasanton sea, shales and sandstones were deposited until a crustal movement again produced an area of land extending a considerable distance north and south of what is now known as Vernon County. This area was drained by a large stream flowing north to the present Missouri River. Large deep channels were cut in the newly formed sediments by this stream and its tributaries and with subsequent subsidence these were filled and remnants remain only here and there to tell the story. The Walker formation described in previous pages seems to occupy a part of one of these old channels.

With the subsidence of the land at this time, conditions again became favorable for the formation of limestone and continued throughout much of the Kansas City epoch. Life was abundant in the sea as is shown by the large number of fossil remains found entombed in the rocks. At intervals the land must have been near the critical level producing swamps in which vegetation accumulated as shown by thin seams of coal and black carbonaceous shale. These intervals were of short duration however, as the coal is nowhere of any great thickness.

Throughout the remainder of Carboniferous time this region was probably under water and more sediments were laid down but by the close, when the Ozarks were again uplifted, the seas withdrew from the region and it has probably been land ever since.

Post-Pennsylvanian: It seems likely that throughout the remainder of the Paleozoic era and the Mesozoic era, this part of the country was subjected to erosion. There is nothing to show that during this great length of time the sea ever advanced as far as western Missouri. Continued erosion caused more or less complete peniplanation during this time.

Throughout the Tertiary and Quaternary erosion continued and the present topography was developed. The great glacial epoch seems to have had little influence on this part of the country. The ice sheets never advanced as far south as this and the effect of the frigid climate cannot be determined. Many of the streams probably reached base level and after that, the present flood plains were produced.

The "scarped" plains, of which Vernon County is a part, were formed as a result of unequal erosion in gently dipping

beds of hard and soft rock. Erosion removes the softer ones at a greater rate than those more resistant, consequently the latter will stand out in escarpments normal to the direction of dip. Away from this escarpment in the down-dip direction will be formed a plain with a gentle slope where the softer rocks have been removed. The width of this plain will depend upon the dip of the beds and their thickness. Due to unequal erosion by streams the escarpments are not always regular, but more often are cut by long "V" shaped re-entrants, where streams have cut down through them.

Erosion is at present going on as may be seen by the great amount of mud and sand carried by the streams during high water. Gullies developed in cultivated fields and cutting of banks of streams are evidence that there is a continual process of tearing away of the land surface, the material being carried away to the sea and there used in extending river deltas and coast lines. It has been calculated that the entire Mississippi Valley is being lowered by erosion at the rate of one foot in about 3,840 years. This shows how slowly the form of the earth's surface changes and what long periods of time are consumed in reducing a land surface to nearly sea-level by erosion. This also explains why the geologist marks time by the millions of years.

Should disintegration of the underlying rocks and removal of the resulting soil continue for a long period the Mississippi Valley with all its branches would eventually be reduced to a low, nearly level, plain. If in the meantime there should be slow sinking of the land surface the ocean would advance up the valley and all its tributaries and sediments would be deposited on the old land surface. On the other hand an elevation of the land or a sinking of the sea-level would result in adding much land surface along the coast line and an increase in the rate of erosion due to the greater slopes of the rivers and consequently faster current.

CHAPTER III.

ECONOMIC GEOLOGY.

W. F. Pond.

The mineral resources of Vernon County are non-metallic, the more important being coal, clay, oil and gas, asphaltic sandstone, stone and underground water.

Other than the production of coal and the utilization of shales and clays in the manufacture of brick and drain tile, there is practically no development of these resources. At the present time considerable attention is being directed toward the use of the asphaltic sandstone in road construction. If this material proves satisfactory, there is the possibility of developing an important industry, as the most extensive deposits in the state occur in this area.

The following pages describe briefly the occurrence of the various natural materials that may be utilized in a commercial way.

COAL.

Vernon County has produced considerable coal, chiefly from the thick deposits of the Rich Hill-Panama district. From 1900 to 1910 the average annual production was 133,360 tons.[1] In 1910 the production dropped to 24,032 tons, and since then it has fluctuated considerably, the average output being approximately 57,000 tons. In 1923 the production was only 7,824 tons.

The above figures do not include the entire tonnage mined as there are many small strip pits and mines in operation at times of coal shortage which do not report.

Panama has been the most active coal mining center and most of the production has come from there, although with the increasing price of coal more attention is being paid to the thinner beds in other parts of the county. Small quantities are sold locally at numerous pits and at a few drifts and shafts, there

[1]Hinds, Henry, The coal deposits of Missouri, Mo. Bur. of Geol. and Mines, Vol. 11, 2d ser., p. 409, 1912.

being hardly a section in the county but has a deposit within a few miles.

The distribution of the "One-foot" or Moundville coal, which is probably the most generally mined in the county, is shown on the geological map by the dashed line of outcrop. All known pits, shafts and slopes are also shown by the indicated symbols.

All slope and shaft mines are worked by the room and pillar method, shooting from the solid, the roof being considered too weak to permit the use of the long-wall method. The latter has been tried in the Panama and Rich Hill districts but without success.

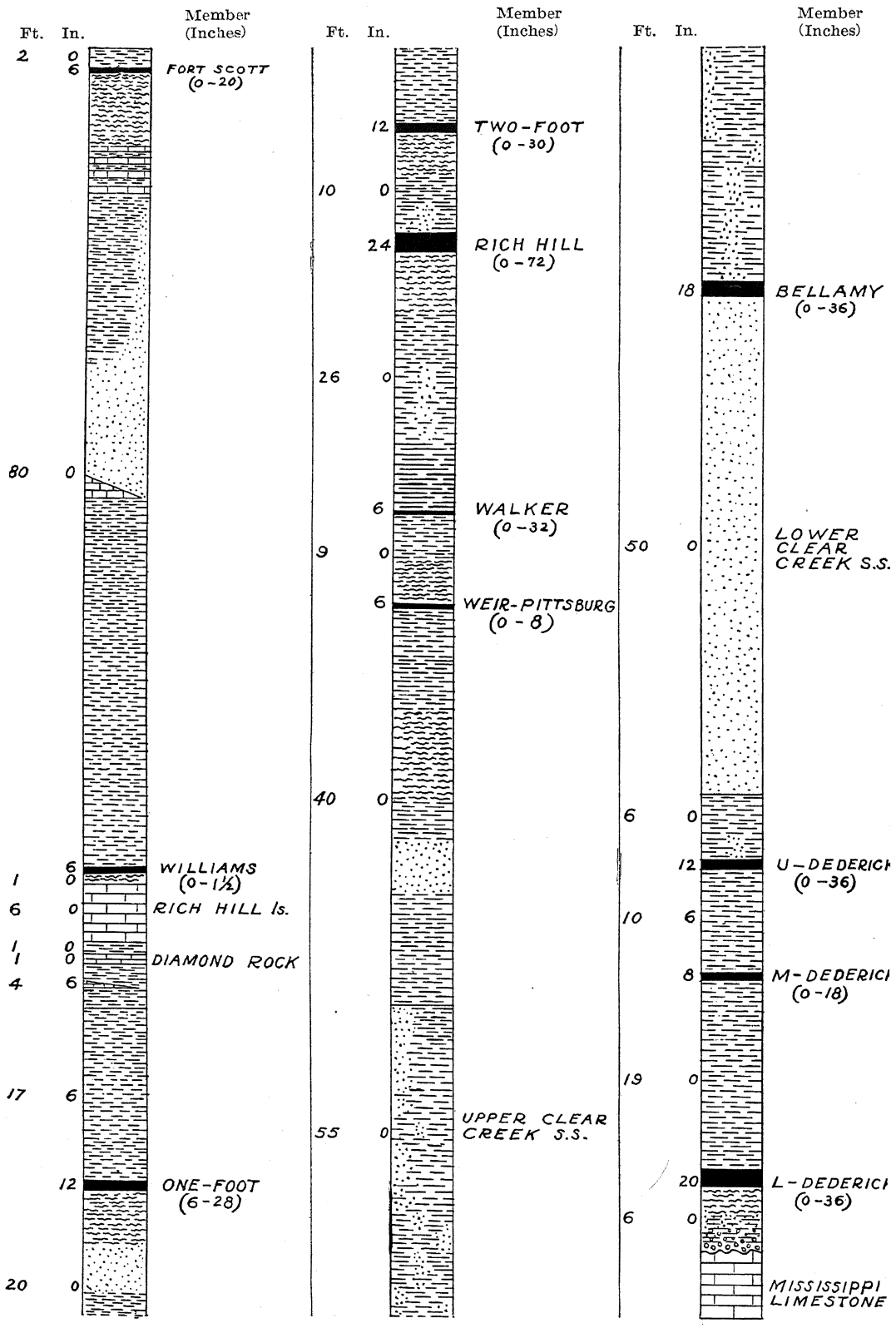
Most of the coal mined is from strip pits, the larger by steam shovel (Pl. 8, B) and the smaller by horse scrapers (Pl. 8, A). In all of those now operating the coal is loaded onto wagons by hand. In nearby areas in Barton and Bates counties, and in Kansas, stripping by steam shovel is carried on in large scale operations and the coal is loaded by small steam shovels. The largest stripping operations around Panama were operated in this manner. For small steam shovel pits one-yard and two-yard shovels are used while in the largest operations four-yard and six-yard shovels are worked. Loading shovels are of one-ton or two-ton size, loading onto cars of two or three tons capacity on 42-inch gage tracks.

A rough figure for power stripping operations is one foot of overburden to one inch of coal. This will vary somewhat according to the nature of the overburden and the area available. If the overburden is small the coal may have weathered and become "dead" unless the overlying rock is particularly impervious to water. The price is accordingly low and mining seldom pays. The maximum thickness of overburden which can be removed profitable is about 35 feet. Where thicker than this the long booms on the shovels make them top-heavy and difficult to manage.

Stripping by steam shovel has not received the amount of attention in Vernon County which it deserves. Many of the pits being stripped by horse scrapers could be operated with steam shovels thus increasing to a considerable extent the area of stripping and lowering costs. It is probable that there are considerable areas not yet developed in which large scale stripping operations might be profitable. Careful prospecting by drilling will outline these areas as the demand for coal increases. The

A. Horse-scraper coal pit.

B. Steam-shovel coal pit.



Sections showing relative positions of coal beds.
(Second and third columns are continuations of the first.)

stratigraphic relation of the various coal seams has been discussed in the chapter on geology. Many of the seams are quite persistent but vary in thickness and are not workable over much of the area. The following is a brief description of the beds in descending order, their relative position being shown graphically on Plate 9. The Mulberry coal which is 105 feet above the Fort Scott is not shown.

Mulberry Coal: This coal is mined extensively in Bates County where it is 30 to 36 inches thick. In the extreme northwestern part of Vernon County it is present in much of the area shown as being underlain by the Pleasanton formation, and probably averages 30 inches thick.

It is underlain by about four feet of clay which rests on the Pawnee limestone and is overlain by shale. Where the overburden is thick enough to protect the coal it should be of good quality. It deserves more attention and prospecting for steam shovel stripping. Most of this area is accessible to the Kansas City Southern Railway.

Fort Scott Coal: The Fort Scott coal in Vernon County has a maximum thickness of 20 inches with an average of 13 to 14 inches. It is underlain by clay and has a roof of black "slaty" shale one to seven feet thick in the lower part of which are large gray limestone nodules. The coal has been mined on the mounds southwest of Eve and west of Swart.

One-foot Coal: This bed, also known as the Moundville coal, while varying in thickness from 2 to 28 inches, is very persistent at about 12 inches—hence its name. In the west central part of the county it is split by a clay seam that thickens to several feet near Eve. It is overlain by drab to gray shale and underlain by light gray clay. This bed is mined at Walker Mound, near Metz and Stotesbury, and there are extensive strippings in it near Bronaugh and Moundville.

Middle Rich Hill (Two-foot) Coal: This bed is mined almost continuously around Walker Mound and to the northeast. It ranges from 18 to 26 inches thick, is underlain by thick clay and has a black "slaty" shale roof. In the Panama district the thickness and associated rocks are about the same.

Rich Hill (lower) Coal: This has been the most important bed in the county. In the Panama district a thickness of up to six feet has been mined over areas of several hundred acres each and it has been found of workable thickness for small strippings as far south as Walker and Moundville. It is over-

lain by hard black shale with a little black limestone in places. A gray clay underlays the coal.

Walker Coal: The Walker coal is mined in many places near Walker where it ranges from 16 to 36 inches in thickness. It is overlain by 2 to 5 feet of black, blocky "slaty" shale and underlain by gray clay. This bed is also stripped to a small extent in the north central part of the county where it is somewhat thinner.

Weir-Pittsburg, Lower, Coal: The only workings in this bed are in the extreme southwestern part of the county where it is 20 to 24 inches thick underlain by gray clay and roofed by 4 to 5 feet of black shale. It is found in drill holes to the north but is less than 10 inches thick. It is mined in northwestern Barton County also.

Bellamy Coal: This bed occurs at about the middle of the Clear Creek sandstone although there are several thin coals in the upper part of that formation which may thicken locally and be confused with the Bellamy. The characteristic associations are heavy sandstone, in places shaly, both above and below the coal, with a thin shale or "bone" seam near the middle. The coal is mined west and northeast of Bellamy and west of Schell City. It thickens to as much as three feet locally, though outside of the districts in which it is mined it is thin or absent.

Dederick Coals: The coal beds called the Upper, Middle and Lower Dederick in this report are persistent throughout the county although of commercial thickness in only a few places. The principal regions in which the coal has been mined are northwest of Nevada and from Schell City to south of Dederick. The thickness seldom exceeds 16 inches. However basins occur in which the coal thickens as shown by the Burford drilling and shaft southwest of Dederick where the coal averages nearly three feet thick. The beds are usually roofed by black "slaty" shales though a thin limestone is in places found immediately above the upper and lower beds.

Two analyses made by the United States Geological Survey in co-operation with this Bureau, together with eight made in the laboratory of the State Survey, are given on page 100.

Detailed Areal Descriptions.

Amos: North of Amos there have been several strippings in the area underlain by the Pleasanton formation which contains the Mulberry Coal three to six feet above the Pawnee limestone—the top of the Henrietta. It is some years since any of them have been worked but a good description of the overlying clay-shale is given under the discussion of the Mulberry Coal on page 61. Just over the line in Bates County in the SW. ¼ sec. 22, T. 38 N., R. 33 W., a small pit has been opened which shows the following section:

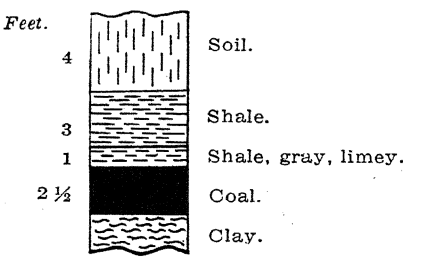


Fig. 4. Mulberry coal, SW. ¼ sec. 22, T. 38 N., R. 33 W.

The coal is somewhat weathered owing to the thin overburden, but having a thicker cover nearby should be of good quality. This area is within two miles of a railroad and is favorable to steam-shovel operations. The Mulberry coal probably underlies much of the area shown as Pleasanton on the map and systematic prospecting would no doubt indicate areas suitable for steam-shovel operations.

Metz: Seasonal strip pits have been opened in the coal below the "Diamond Rock." In the SW. ¼ SW. ¼ sec. 8, T. 37 N., R. 32 W. the coal is reported 15 inches thick, overlain by 7 feet of shale and one foot of limestone. In the SW. ¼ SW. ¼ sec. 2, there was 30 inches of coal at 84½ feet depth. At another place the following was recorded:

DRILLING TWO MILES NORTHEAST OF METZ.
(NW. ¼ NE. ¼ sec. 11, T. 37 N., R. 32 W.)

	Thickness.		Depth.	
	Ft.	*In.*	*Ft.*	*In.*
Soil	10		10	
Shale, sandy	20		30	
Shale	9	4	39	4
Coal		8	40	
Clay	2		42	
Shale	3		45	
Shale, black, "slaty"	2		47	
Coal	1	6	48	6
Clay	10		58	6
Shale	9	6	68	
Limestone, full of shells	2		70	
Shale	4		74	
Coal		3	74	3
Clay	12	9	87	
Shale, black, "slaty"	2		89	
Coal (Rich Hill)	2	8	91	8
Clay		5	92	1

Three miles north of Metz (SE. ¼ sec. 34, T. 38 N., R. 32 W.), on Reed Creek, a bed of coal 10 to 16 inches thick outcrops in the banks of the Creek and is mined for domestic consumption by local residents. It is a hard "peacock" coal and is valued highly for use in threshing machines. It is the "One-foot" coal as shown on the map.

Stotesbury: East and southeast of Stotesbury the coal beneath the "Diamond Rock" has been mined by seasonal strip pits. The bed is from 12 to 14 inches thick and considerable coal has been obtained by removing 6 feet or less of overburden, consisting largely of shale.

The following is a record of the oil and gas well drilled just east of Stotesbury, on the south bank of the Osage.[1]

[1]Shepard, E. M., Underground water resources: U. S. G. S. Water Supply Paper, 195, 1907, p. 125.

RECORD OF OIL WELL NEAR STOTESBURY.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	9	9
Cherokee shale:		
Shale	20	29
COAL	3	32
Shale, in part blue	58	90
"Black sand" and blue shale	30	120
Limestone	5	125
Shale, in part blue	12	137
COAL	3	140
Sandstone and shale	30	170
Shale, in part "slaty"	35	205
Shale, black and blue, and sandstone	20	225
Shale	18	243
Limestone	2	245
Shale, sandy	15	260
Sandstone, fine-grained, micaceous	5	265
Shale, gray and black, with some sand	5	270
Shale, carbonaceous, sandy at base	8	278
Mississippian formation (lower limit of coal):		
Limestone, gray, in part cherty	67	345

Richards: Small strippings have been opened near Richards on the coal below the "Diamond Rock." Southeast of town (SE. ¼ SE. ¼ sec. 15) a 14-inch bed overlain by 8 feet of shale has been stripped for local consumption. On the high ridge between Richards and Stotesbury, the Fort Scott bed and the conspicuous limestone above it outcrop. The coal, however, rarely exceeds one foot in thickness.

Eve: The coal just below the "Diamond rock" occurs north and east of Eve. An upper bed is present in a high mound north of town. It is above the "Diamond rock" as shown by the following section.

OUTCROP ON MOUND NORTH OF EVE.

		Ft.	*In.*
1.	Limestone, light gray to buff (Upper Fort Scott) more than	6	
2.	Interval including black, "slaty" shale and 6 inches of COAL.	6	
3.	Limestone, buff, massive (lower Fort Scott)	5	
4.	Shale, black, "slaty"	4	
5.	COAL (Fort Scott)	1	2
6.	Concealed	61	
7.	Limestone, dark blue, breaks in diamond-shaped flags ("Diamond rock")	1	
8.	Shale, black, "slaty"	3	6

OUTCROP ON MOUND NORTH OF EVE—*Continued*.

		Ft.	In.
9.	Limestone, dark blue		6
10.	Shale	3	
11.	Limestone, dark		6
12.	Shale, black, "slaty," with large and small limestone concretions	5	
13.	Shale, light drab, sandy	5	
14.	Shale, bluish-black	2	
15.	COAL, average	1	4

On the upland south and southwest of Eve, the Fort Scott "red" coal, outcrops in many places. It was formerly stripped extensively 1½ miles southwest of town and is now utilized at a number of pits. The coal is 12 to 20 inches thick and is in demand for domestic use. The roof is 40 inches of black, "slaty" shale that grades upward to one foot of drab clay. On the clay is a massive limestone, the Lower Fort Scott, that weathers buff and is about 5 feet thick. Owing to difficulty in handling the limestone, stripping is not carried far back from the outcrop.

In 1923 the C. B. Jenkins Coal Company opened a pit in the NW. ¼ NW. ¼ sec. 20, two miles southwest of Eve. A steam shovel stripped the overburden and the coal was sold entirely to local trade. The coal, which is the Fort Scott, is 12 to 16 inches thick, underlain by at least four feet of light gray clay and overlain by four feet of blue to black "slate," with many concretions of black limestone resting on or dipping into the coal; hardpan with many flat boulders which are residual Lower Fort Scott limestone; and four to six feet of soil.

A small fault was found in this pit near the north end. As the shovel worked towards the south the coal started to rise and after rising about two feet it suddenly broke off and was picked up again two feet higher. In the west edge of the bank the crumbled shale could be seen showing an overthrust from the southwest. The strike of the fault as nearly as could be worked out from the small exposure is north 30° west, and the dip 25° southwest.

In 1925 the shovel was moved about a mile southwest where the same bed was stripped on both sides of the road in sections 19 and 30. The coal averaged about 14 inches thick and the associated rocks were similar.

A drilling at Eve is said to have penetrated 4 feet of coal at a depth of 100 feet, or at about the horizon of the Rich Hill

bed. This report was not confirmed and additional drilling should be done to determine the possibilities.

In the NW. ¼ sec. 10, T. 35 N., R. 33 W., on land of Tom Weekly, The George Mining Company of Fort Scott, Kan., has stripped by horse scrapers, six to ten feet of overburden to a 12 to 14-inch bed which is probably the Moundville or One-foot. This bed thins to the west as is shown by only 8 to 12 inches of coal in a small pit one-half mile to the northwest. Eight to ten feet lower another bed 18 to 20 inches thick was mined to a small extent. The coal was loaded by hand and hauled to the Missouri-Kansas-Texas Railroad and the Kansas City-Southern Railway at Eve.

Swart: The Fort Scott coal is stripped for local consumption on the small mounds northwest and southwest of Swart and shows much the same characteristics as at Eve. On the flat prairie country between Eve and Swart coal outcrops in very few places and is commonly less than 14 inches thick.

The Fort Scott Coal & Mining Company is stripping with a one-yard steam shovel in the SW. ¼ sec. 33, T. 35 N., R. 33 W., and across the road to the south, about two miles north of Swart. The coal is loaded onto wagons by hand and shipped to Kansas City from a side track on the Missouri-Kansas-Texas Railroad. Mr. H. W. Todd, Field Manager, reports the following compiled section for the pit and underlying ground.

SECTION AT FORT SCOTT COAL & MINING COMPANY'S PIT TWO MILES NORTH OF SWART.

		Feet.	*Inches.*
1.	Soil	1	6
2.	Slate		1
3.	Limestone, blue weathering yellow		5
4.	Slate, black, blocky, with black limestone in streaks and nodules	5	
5.	Slate, gray	4 to 9	
6.	COAL, hard, with pitchy streaks	1	1
7.	Fire clay, gray and hard, with nodules of limestone	6	
8.	Shale, white	1	
9.	COAL, persistent		2 to 4
10.	Fire clay	1	6
11.	Shale, soft and dark		
12.	Slate, black and hard, crowding out overlying shale (No. 11) to the southeast	8	
13.	COAL, thin seam to 22", rather persistent at		15½
14.	Interval	16 to 18	
15.	Limestone	1	
16.	COAL		10
17.	Interval	8 to 10	
18.	COAL, varies, pinching both from top and bottom, may run to 3 feet		

Numbers 6 and 13 are the beds mined, the lower being stripped only outside the area in which the upper coal is not weathered. Towards the west the overburden becomes too thick to be removed economically.

Mr. Todd furnishes the following analysis of the upper bed, from a full cut of the seam. The sample was taken and the analysis reported by the Fuel Agent of the St. Louis and San Francisco Railroad.

	Per Cent
Moisture	2.82
Volatile combustible	38.28
Fixed Carbon	51.35
Sulphur	2.57
Ash	6.55
B. T. U., original sample	14430
B. T. U., dry coal	14849

Three miles southwest of Swart in the northwest corner of section 7, near the state line, the Garland Coal Company is stripping what is believed to be the Moundville coal. It averages 12 inches thick, ranging from 8 to 16 inches. The coal is overlain by 6 inches to 3 feet of blue sandy slate and gray shale and then by about 4 feet of black "slate" with "kidney stones" of black limestone. Operations began in 1923.

In the extreme southwest corner of the county in sec. 31, T. 34 N., R. 33 W., extensive stripping was carried on years ago on the west side of a north-south ridge which extends south into Barton County and a short distance north into sec. 30. The old pits are completely overgrown and no section could be made. Coal "bloom" may be seen in the road along the north side of section 30 but the weathering is too deep to determine the thickness without digging a pit. In the next section south, in northwest Barton County, a large steam shovel stripping extending the entire north-south length of the section on top of the mound has been completed in recent years in a bed which is probably the Weir-Pittsburg lower and shows the following:

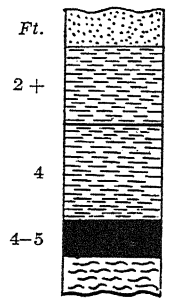


Fig. 5. Coal in sec. 31, T. 34 N., R. 33 W.

As this is the highest point in this part of the county and the general dip is westerly there is no possibility of the presence of this bed elsewhere in this region, except under the small extension of the ridge to the north.

Bronaugh. In an area of about 2 square miles in secs. 17 and 20, at and near Bronaugh, the "Diamond Rock" outcrops in the upland and a coal bed lies a short distance below it. This coal bed is stripped over a small area in an outlier two miles southeast of town (SW. ¼ SW. ¼ sec. 28, T. 34 N., R. 32 W.), where the following was measured:

		Ft.	*In.*
1.	Limestone, drab, clinks, jointed, weathers in slabs		6
2.	Interval, including black, "slaty" shale	8	
3.	Shale, light drab, with small ferruginous concretions	6	..
4.	Shale, light bluish-gray	2	
5.	COAL, 12 to 18 inches	1	6
6.	Clay	..	..

Just northwest of Bronaugh in the south half of section 18, two beds are being stripped by the Bainter Coal Company in the SW. ¼ and the B-E-L. Company in the SE. ¼. The section is as follows:

SECTION NORTHWEST OF BRONAUGH.

		Feet.	*Inches.*
1.	Soil and brown weathered shale	1 to 4	
2.	Shale, light brown clayey with 6 to 8 inch "kidney limestones"	2	
3.	Shale, black, blocky and slaty	5	
4.	Shale, gray	9 to 10	
5.	COAL		10 to 14
6.	Clay, gray and covered	6 to 8	
7.	Coal "bloom"		1–4
8.	Clay, gritty, in places fine, light gray, plastic	3 to 4	
9.	Shale, yellow	4	
10.	Shale, black, slaty	5	
11.	COAL		15–16
12.	Clay, gray, gritty	4+	

These would seem to be the Moundville coal and the Middle coal of the Rich Hill district.

Between Bronaugh and Moundville, about a mile west of the railroad (secs. 6 and 7, T. 34 N., R. 32 W.) is a high mound or ridge about two square miles in extent. On the top of the mound a bed corresponding to the upper coal at Fort Scott is stripped occasionally. Because of the thick overlying limestone, it is not stripped far back from the outcrop and most of the available deposit has been utilized. In recent years a 13-inch bed that outcrops around the base of the mound has been a larger producer. The relations between the two beds are as follows:

		Ft.	*In.*
1.	Limestone, light gray, thinly and irregularly bedded, forms top of mound	3	
2.	Clay	1	
3.	Shale, black, "slaty," with small concretions in upper half, black in lower half	2	10
4.	COAL, stripped	1	2
5.	Interval, by barometer, about	70	
6.	Limestone, dark blue, jointed	1	
7.	Interval, probably including COAL by barometer, about	30	
8.	Sandstone, light brown, calcareous		8
9.	Shale, light and sandy at top, black and "slaty" at base	7	8
10.	COAL, stripped	1	1
11.	Concealed	13	
12.	Limestone, dark blue, laminated, more than		4
13.	Shale	2	
14.	COAL, streak	..	..

Moundville. At and around Moundville 12 small mines have been worked supplying local trade and shipping small quantities of coal from a thick bed which apparently lies at the Rich Hill horizon and is about 150 feet lower stratigraphically than the coal capping the mound near Bronaugh. Over half of these started during the strike of 1922 and most of them were abandoned as soon as the coal shortage was over. The 25-foot shafts of A. S. Brown and D. K. Perkins are in the northwest corner of the town, and the 30-foot shaft of W. J. Smith is a short distance beyond (NW. ¼ SW. ¼ sec. 34). North and south of town within the area shown by the outcrop on the map are seven more shafts, one strip pit and one slope. The coal is hard and contains pyrite in lenses. The roof is good, except near the rather common "horse-backs" and "rolls" in the roof. The latter are 2 to 12 feet wide and cut out part of the coal in places.

BROWN SHAFT AT MOUNDVILLE.

	Ft.	*In.*
Limestone, light blue, compact	1	6
Shale, drab, sandy	14	
Shale, dark blue, hard	8	
COAL	2	4
Clay	1	
COAL		8–12
Clay	2	
COAL, in part cannel, not mined, 12 to 28 inches, average	1	4

At the Perkins mine only the top bench, 16 inches thick, was mined, though the two lower benches are said to be the same as at the Brown shaft. At the Smith shaft the bottom bench is reported to be 3 feet thick. This basin of thick coal, which is little more than a mile wide from east to west, has been removed by erosion a short distance north of Moundville and is not known to extend more than two miles south of town.

Just southwest of Moundville the Lavery Coal Company is stripping the Moundville coal near the center of lots 8 and 9 in section 5. The overburden ranges from about ten feet to a thickness too great for the shovel to handle, the limit of the shovel being about 27 feet. The coal averages 28 inches thick, varying from 26 to 32 inches. The coal is hauled by teams to a spur track on the Missouri Pacific Railroad in the south part of the tract. Shaking screens with round holes 1¾ and 3 inches in diameter are used and three sizes—slack, nut, and lump are shipped. The first car was loaded March 26, 1923, and operations are expected to last five or six years or more.

Northeast of Moundville in and near section 26 several drill holes put down by John A. Storz of Nevada in the summer of 1924 showed four beds of coal. The upper 100 feet or so of the holes was in the Clear Creek sandstone with the Bellamy coal showing about six inches thick. The three coals in the Dederick shales were found averaging 12, 10, and 24 inches, respectively, from the upper to the lower coal. The lower coal is underlain by "coal, slate and iron" up to two feet, nine inches in thickness. As would be expected, the beds thicken to the south as the Moundville basin is approached. The log of the most southerly hole is as follows:

LOG OF G. G. MITCHELL NO. 2 WELL IN NW. CORNER, SW. ¼ SE. ¼, SEC. 26, T. 35 N., R. 32 W.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	8	8
Sand rock	4	12
Sand rock saturated lightly with asphalt	18	30
Sandy shale (base of Clear Creek sandstone)	41	71
Black slate (top of Dederick shale)	6	78
COAL (upper Dederick)	1	79
White clay	3 ½	82 ½
Black slate	9 ½	92
COAL (middle Dederick)	1 ½	93 ½
White clay	3 ½	97
Blue slate	10	107
COAL (lower Dederick)	2 ¼	109 ¼
COAL, slate and iron	2 ¾	112
White clay	3	115
Lime	1	116

Drilled May 7, 1924, by John A. Stortz, Nevada, Mo. More drilling was planned to the west in section 27.

Two miles west of Moundville is the stripping of A. H. Franks (Lot 9 NW. ¼ sec. 6) in a bed that is, perhaps the same as the one stripped around the base of the mound farther south.

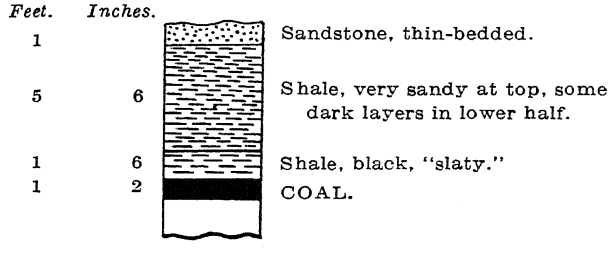


Fig. 6. Franks stripping west of Moundville.

Nevada. West of the State Hospital a number of small strippings and slopes have furnished a limited supply of coal which has found a ready market in Nevada. The beds are in the Dederick shale member and average 12 to 15 inches thick. At a stripping and slope opened by Jordan and Kennedy of Nevada, lessees, Wight Estate, fee, in the NW. ¼ NW. ¼ sec. 32, T. 36 N., R. 31 W., the following section was measured:

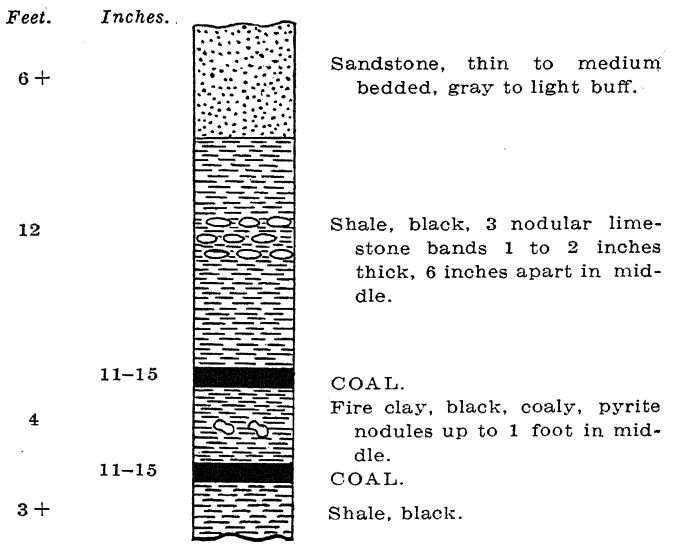


Fig. 7. Coal section west of State Hospital, Nevada.

In the SW. ¼ sec. 35, T. 35 N., R. 32 W., a drill hole just south of the railroad is reported to have found 3 feet of good coal at 165 feet depth. No confirmation could be obtained.

Horton. Five miles southeast of Horton, near Ketterman (NE. ¼ SW. ¼ sec. 30, T. 37 N., R. 30 W., and elsewhere), a 2-foot bed of coal is occasionally stripped for local use. Above it at least 3 feet of black, "slaty" shale and black limestone in thin, flat lenses lies in places directly on the coal. Miners say this bed has much the same characteristics as the upper Rich Hill of the Panama district. It is possible that basins of thicker coal lie below it at the lower Rich Hill horizon.

Northeast of Horton, near the mouth of Marmaton River on Timbered Hill, stripping was formerly done and several shafts sunk, in one of which (NW. ¼ NW. ¼ sec. 14, T. 37 N., R. 31 W.) 12 inches of coal is reported to have been found at a depth of 22 feet, 18 inches at 38 feet, and 42 inches at 60 feet. The last named appears to be the lower Rich Hill, the bed so extensively mined a few miles farther north. Because of lack of transportation facilities, no mining has been done there in recent years.

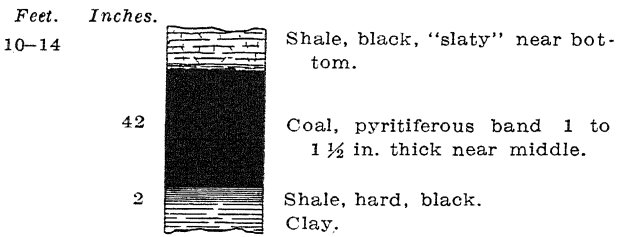
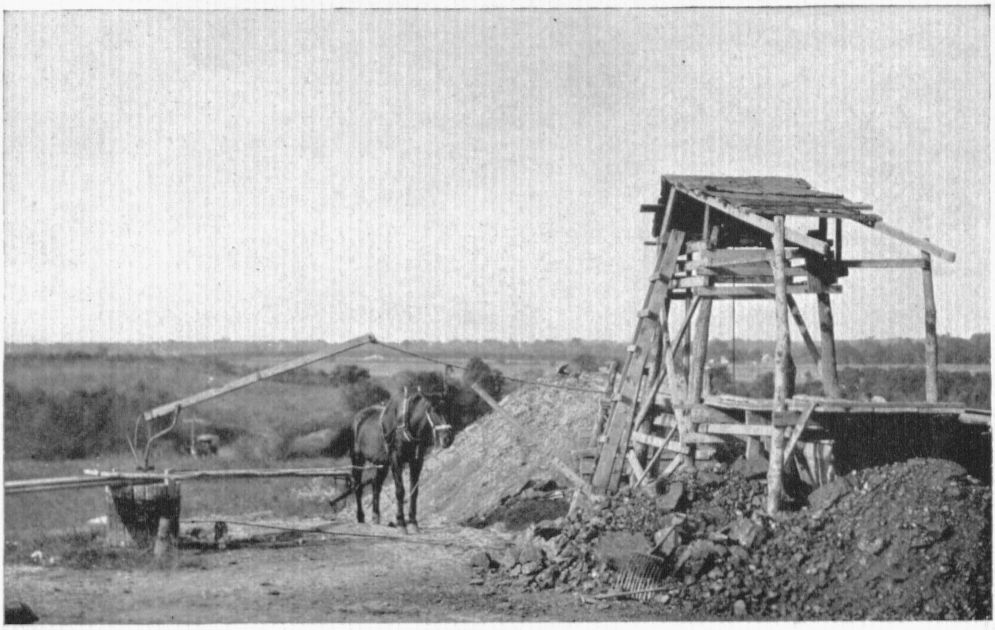


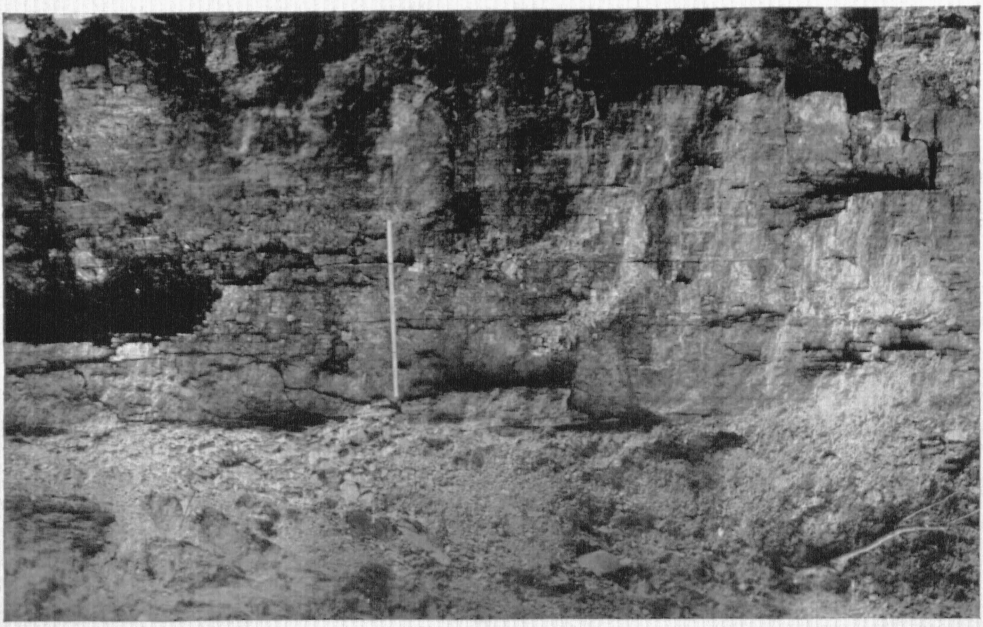
Fig. 8. The lower Rich Hill coal bed at Timbered Hill.

Arthur, Panama, and Carbon Center. Between the bottom lands of the Little Osage and the Bates County line, for 2 or 3 miles on both sides of the railroad from Rich Hill to Nevada, is the southern continuation of the Rich Hill field. From this area some of the largest producers in the State formerly shipped coal and the country is pitted with large abandoned strippings. Most of the readily available deposits have been exhausted and the present production is comparatively small. In the strip pit and shaft of the Jones Coal Company, 1½ miles northeast of Arthur (NW. ¼ NW. ¼ sec. 4, T. 37 N., R. 31 W.), now worked out, the lower Rich Hill bed was 4 to 6 feet thick and the roof a firm black shale except in local areas of "white top." In places thin limestone lenses rested on the coal or lay 3 feet above it. The upper Rich Hill coal is 6 to 12 feet above the lower and is regularly 18 inches thick. This basin of thick coal is said to have included 400 acres. From the Jones strip pit to an old shaft one-fourth mile south, the dip is at least 150 feet.

In the center of the same section the Perry-MacMahon Coal Company has stripped a large area underlain by both veins worked at Rich Hill. The upper is 2 feet thick with an average of 10 to 12 feet of overburden and the lower, 3 to 5½ feet thick, about 10 feet lower (Pl. 10, B). Over 75 acres have been stripped and there still remains a small area available. Stripping was done with a 5-ton shovel, the coal being loosened with small shots of black powder and dynamite and loaded onto a narrow gage railroad by a small steam shovel, hauled to the tipple in the west central part of the section and there loaded at a spur from the Missouri Pacific Railroad. The plant was closed at the beginning of the strike, April 1, 1922, and has not been started up since.



A. Horse-hoist coal mine near Schell City.



B. Perry-McMahon strip-pit near Panama showing five-foot face of coal. (Rule is two feet.)

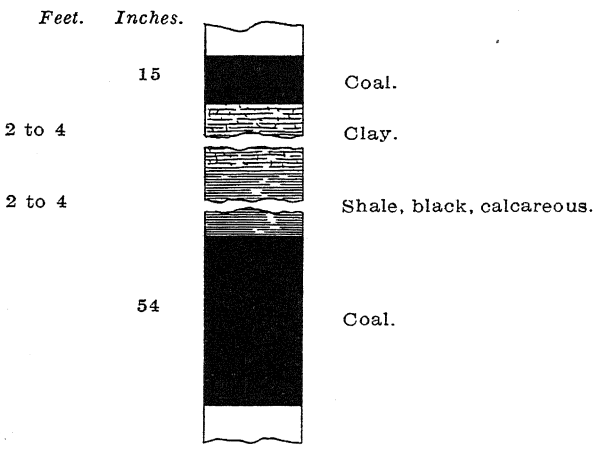


Fig. 9. The Rich Hill coal beds at Carbon Center.

Schell City. Coal is mined for local trade at a number of places north and west of Schell City. The Maus stripping, a short distance north of town (NE. ¼ NE. ¼ sec. 33), works a thick coal, which has the following section in the De Tallante stripping 1 mile to the northwest (middle of E. ¼ SW. ¼ sec. 28):

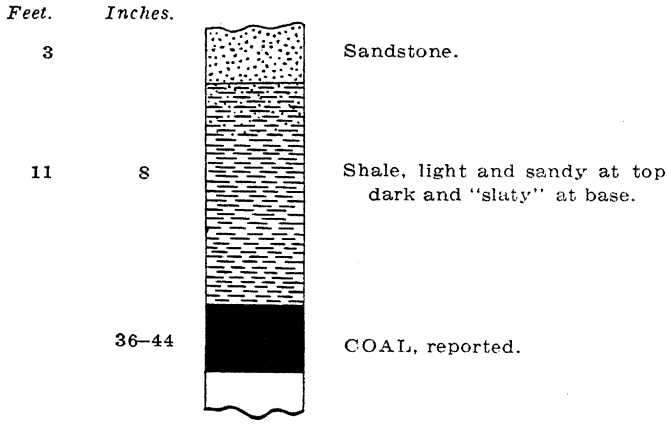


Fig. 10. De Tallante coal strip-pit west of Schell City.

Across the road from the De Tallante pit the John Hardy shaft on land of Fred Maus, SW. ¼ SE. ¼ sec. 28, is reported to go through about 6 feet of sandstone, 12 feet of blue-black shale to 32 to 36 inches of coal, usually 32 inches, underlain by fire clay. The coal is fairly hard and of good quality.

A group of strippings 1 mile southwest of Schell City (E. ½ sec. 5, and SW. ¼ sec. 4) show coal 15 to 18 inches thick overlain with sandstone and conglomerate. The sandstone cuts down into the coal locally. C. S. Curtis has a pit in the SW. ¼ SW. ¼ sec. 4, which shows about 24 inches of good coal under 10 feet of varied shales. There is a one to two-inch streak of "bone" about eight inches from the top and the coal dips slightly to the southwest. Considerable water comes in from below the coal but not too much to be easily handled. This pit and adjoining land would make a good steam shovel proposition as the overburden is not very great for the thickness of coal, and the transportation facilities are good.

Four miles west of town there are several drifts and shallow shafts belonging to A. Meyers (N. ½ SW. ¼ sec. 36, T. 38 N., R. 30 W.) and other drifts belonging to F. M. Cox and Wm. Duncan (SW. ¼ SW. ¼ sec. 36). The following was measured in one of the shafts:

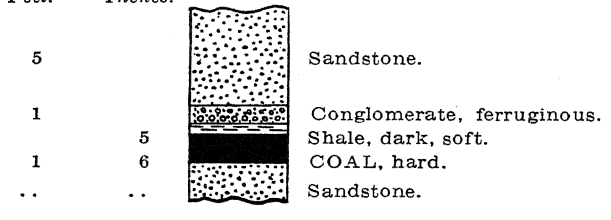


Fig. 11. Coal section, sec. 36, T. 38 N., R. 30 W.

I. L. Luther whose shaft is at about the middle of the section in a small draw reports 33 feet of sandstone over 40 inches of coal with 3 inches of "bone" near the middle. The coal is underlain by two inches of soft shale which is underlain by sandstone. The coal is hard and of good quality.

These deposits are not far above the base of the Coal Measures as is shown by outcrops of Mississippian limestone 40 feet above the Osage, west of Belvoir, and only 1½ miles north of the mines, and at Colley Ford. Farther up the Osage, at Halley's Bluff, 20 inches of coal has been stripped on the river bank. The roof is sandy shale and about 30 feet above it are 30 to 40 feet of buff to gray sandstone. The Mississippian probably lies only a short distance below the river at this point.

Five miles southeast of Schell in secs. 24, 25 and 26, T. 37 N., R. 29 W., there are a few pits which show 10-16 inches

of fair coal with black shale both above and below, and sandstone about 10 feet above. That in the NW. ¼ SW. ¼ sec. 24 is quite extensive and a shaft has been put down where the overburden is thicker just to the northwest. The coal dips to the southwest fairly steeply. The coal is either the upper or lower Dederick and probably both. There are considerable possibilities for steam shovel operations in the vicinity except for the distance from a railroad.

Harwood. Stripping and some underground work are done 2 or 3 miles southwest of Harwood at the Rich Hill or lower horizons. The following mines were visited:

Name.	Location.			Operation.	Thickness.	Roof.
	Sec.	*T. N., R. W.*			*Inches.*	
W. M. Smith, lease						
C. E. Moore, fee	NW, SW, 31	37	29	Slope and strip.	26–30	Sandstone
F. Y. Ewing.	NE, NE, 36	37	30	Strip	26–30	Sandstone
F. Y. Ewing.	SW, NW, 36	37	30	Shaft and strip.	20–42	sh then ss
John Hardy, lease						
I. M. Hart, fee	SW, SE, 25	37	30	Slope	27	
Mayberry	SE, SE, 26	37	30	Strip		

On the south side of the road, near the Mayberry pit, the following section was recorded:

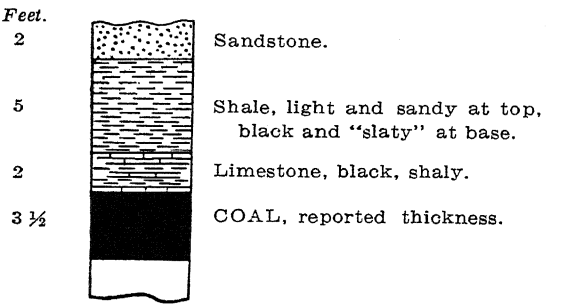


Fig. 12. Coal near Mayberry pit.

About two miles southwest of Harwood in the NW. ¼ NE. ¼ sec. 1, T. 36 N., R. 30 W., a small pit has been opened which exposes an unusual thickness of coal. The pit was worked by C. N. Walker, lessee. When visited in October, 1922, the

deposit was practically worked out. The pit is about 75 feet north-south by 20 to 25 feet east-west and the coal had a steep dip to the west-southwest. About two feet of coal was still exposed along part of the east side where the lens pinched out at the top, and the west side and floor showed that it had pinched out at the bottom on that side. The south face was still exposed and showed interbedding or small lenses of soft sandstone scattered through the top of the coal. The coal is reported to have averaged about eight feet thick in the middle. Owing to the thin overburden—three to six feet of soil and clay over much of the area—the coal had weathered and was not of first class quality. The pit was partly filled with water and practically none of the edge of the deposit was visible, but from the great thickness and small extent it seems probable that it was a pocket rather than a thickening of a continuous bed. It lay at the Rich Hill or somewhat lower horizon.

Walker. In the mound northwest of Walker are the two beds of coal shown in the following section:

SECTION TWO MILES NORTHWEST OF WALKER (NW. ¼ SEC. 8, T. 36 N., R. 30 W.)

	Ft.	*In.*
Sandstone, coarse, massive, and conglomerate	15	
Concealed	26	
Limestone, lower 2 feet blue, weathering buff, upper part mottled gray, thin-bedded	10	8
Shale, drab, clayey	1	9
Limestone, blue, weathers to buff-colored rhomboids		9
Shale, drab, calcareous at top	1	3
Shale, black, "slaty"	1	9
Shale, light drab	15	2
COAL, weathered	1	
Shale, upper 30 feet light drab, bottom 5 feet black and "slaty," grading into black bituminous limestone at base	35	
COAL (Rich Hill)	2	
Clay		

The upper coal, 12 to 15 inches thick and very clean, is stripped on every farm on the mound. The lower bed underlies the surrounding prairie also, and has been stripped at many places in the northern part of T. 36 N., R. 30 W. Its thickness varies from 18 to 30 inches. Attempts have been made to mine it from drifts in the mound but the black limestone forming the roof has a tendency to fall.

In the west end of Walker Mound on the south side of the road, on land of J. Q. Thompson, a small stripping was opened

on the lower bed in the spring of 1922. The pit shows the following:

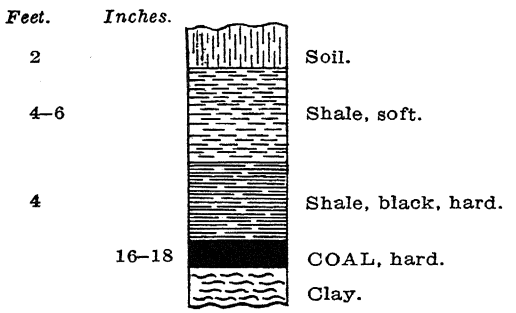


Fig. 13. Coal in J. Q. Thompson pit.

It is necessary to blast the capping of shale before removing with horse scrapers. The coal is good quality and is marketed in Nevada.

The same bed outcrops in the road near the northwest corner of section four and is being stripped in a small pit nearby, the section being as follows:

	Feet.
Soil	2
Clay, yellow, weathered	4
Shale, black	4
COAL	1½
Clay	

In the east center of sec. 35, T. 37 N., R. 30 W., Moss & Moss of Nevada, lessees, have stripped what is probably the same bed. The pit is about 250 feet N-S, by 60 to 75 feet E-W, the overburden being 8 to 10 feet, and the coal 22 inches at the north end and 36 inches to the south. The coal is overlain by four to six feet of hard black shale which yields readily to heavy plowing. This would make an excellent steam shovel proposition as the overburden is not great in comparison to the thickness of coal and a loading track could be put on the railroad not over 1½ miles away. It is probable that other equally good deposits will be found in the vicinity.

Sheldon. A basin of coal 3 to 3½ feet thick was formerly stripped between Milo and Sheldon (NE. ¼ SE. ¼ sec. 2) on the Ferry farm, but nothing has been done there for many years. Ten feet or more of sandstone lies on the coal in places. On

J. L. Maxwell's place (NE. ¼ NE. ¼ sec. 16, T. 34 N., R. 31 W.) 30 inches of coal with sandstone cover have been reported found in a well. This region seems to be worthy of thorough prospecting as the relief is not great and the coal fairly thick. Deposits favorable for steam shovel operations are likely to be found and the Missouri Pacific Railroad running through the center of the area makes transportation readily available.

Five miles northeast of Sheldon, on Clear Creek and near Bellamy, several mines supply a large territory, though the output is small. The coal beds, which are less than 100 feet from the base of the "Coal Measures," appear to thicken only locally and to be absent in many places. At the bottom of the Clear Creek bluffs (NE. ¼ SW. ¼ sec. 16), in the drift of J. A. Lowe, the roof is excellent and the beds dip 10° SW.

COAL AT LOWE DRIFT.

	Ft.	*In.*
Sandstone, yellowish-white, massive	40	
Sandstone, with shale partings	10	
COAL, fair	1	
Shale, carbonaceous, thickness variable		2
COAL, good	1	6
Shale, carbonaceous	1	
Clay, light blue, sandy, hard	1	

What is probably the same bed, though lying at a higher level, has been mined in many small drifts and slopes on the land of F. Baker (SE. ¼ SE. ¼ sec. 16). The coal contains non-persistent shale partings and one that is fairly regular. In one place there is only 13 inches of coal, but the following is the typical section:

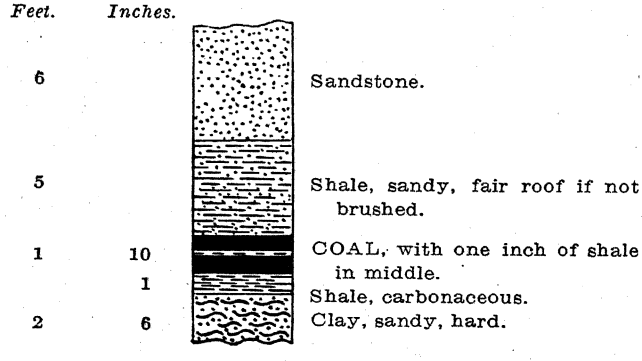


Fig. 14. Coal section at Baker drift.

At the R. W. Shepard slope, a short distance east (SW. ¼ SW. ¼ sec. 15), the coal bed and roof are the same as at Baker's.

One-half mile west of Bellamy (NW. ¼ sec. 23, T. 34 N., R. 29 W.), there is 18 inches of coal with a sandstone roof and a 3-inch parting of shale. Two miles northeast of the village (SW. ¼ SW. ¼ sec. 7 and vicinity), strippings have been made in 12 to 18 inches of excellent coal, on which lies 12 feet of yellowish-white, massive, crossbedded sandstone. Other exposures of thin coal beds appear farther down McCarty Creek.

Along the upper reaches of McCarty Creek in secs. 30 and 31, T. 34 N., R. 29 W., coal is reported with a thickness of 1½ to 3 feet in the Dederick shales. Although the region is eight miles from a railroad prospecting might prove the presence of beds of sufficient thickness and extent and with thin enough overburden to be worked by steam shovel and pay the extra cost of transportation. The beds are at any rate notable reserves and should be kept in mind for future development.

Dederick. Three and a half miles southwest of Dederick P. R. Burford has drilled out and started development of a thick basin in the lower Dederick coal seam. A shaft 85 feet deep reaches the coal at 74 feet depth finding it 34 to 36 inches thick. Ten drill-holes are reported as finding the coal over an area ½ mile east-west by 1½ miles north-south, with a thickness of about 30 inches to the north and 40 inches to the south. An analysis of the coal is given on page 100. The coal is overlain by 13 feet of black shale and underlain by 9 inches of black shale, and at least 6 feet of gray hard clay.

About 27 feet north of the shaft and again 25 east a northwesterly trending fault was found with a down-throw of about 2 feet on the northwest side.

The Middle Dederick coal was apparently absent but the upper bed was found at 43 feet, being one foot thick.

Coal Analyses. The following proximate analyses give a general comparative value to the various beds mined in the county. Nos. 5 and 9 were made in the United States Bureau of Mines laboratory.

These analyses show that the Vernon County coals average above those of the rest of the state which run 11,027 B. T. U. as received and 12,641 B. T. U. on a moisture-free basis. The different beds are much alike in their heating value. These

are all good grade bituminous coals, most of them having a high heat value.

ANALYSES OF COALS FROM VERNON COUNTY, MO.

Abbreviations—Moist =Moisture: Vol. =volatile combustible matter: F. C. = fixed carbon: S. =Sulphur: B. T. U. =British thermal units: a =as received: b = Moisture free.

	Bed.	Moist.	Vol.	F. C.	Ash.	S.	B. T. U.	
1 a.	Fort Scott....	1.93	39.74	49.40	8.92	3.57	13,655	
b.	.....	.....	40.52	50.37	9.10	3.64	13,924	
2 a.	One-foot.....	2.58	36.92	53.55	6.95	3.62	13,646	
b.	.....	.....	37.89	54.97	7.13	3.72	14,007	
3 a.	One-foot.....	5.57	33.76	52.90	7.77	4.65	12,802	
b.	.....	.....	35.75	56.02	8.23	4.29	13,557	Average.
4 a.	One-foot.....	2.40	35.10	53.00	9.50	3.78	13,217	13,031
b.	.....	.....	35.96	54.30	9.78	3.87	13,542	13,608
5 a.	One-foot.....	6.50	32.61	50.83	10.06	4.95	12,458	
b.	.....	.....	34.88	54.36	10.76	5.29	13,324	
6 a.	Two-foot.....	2.09	37.56	52.08	8.27	3.43	13,426	
b.	.....	.....	38.36	53.19	8.45	3.50	13,713	
7 a.	Two-foot.....	2.08	42.33	45.44	10.15	5.60	13,412	Average. 13,164
b.	.....	.....	43.23	46.41	10.37	5.77	13,697	13,430
8 a.	Two-foot.....	1.74	24.98	59.50	13.77	2.92	12,655	
b.	.....	.....	25.42	60.55	14.01	2.97	12,879	
9 a.	Rich Hill.....	6.02	35.94	43.37	14.67	5.84	11,842	
b.	.....	.....	38.24	46.15	15.61	6.21	12,602	
10 a.	Lower.....	3.43	32.02	52.90	11.65	4.63	12,755	
b.	Dederick.....	.....	33.16	54.78	12.06	4.79	13,208	

1. C. B. Jenkins Coal Co. NW. ¼ NE. ¼ sec. 19, T. 34 N., R. 33 W.
2. B. E. L. Coal Co. SE. ¼ SE. ¼ sec. 18, T. 34 N., R. 32 W.
3. T. H. Prewitt. NE. ¼ NE. ¼ sec. 17, T. 36 N., R. 30 W.
4. Lavery Coal Co. Lot. 9 NW. ¼ sec. 5, T. 34 N., R. 32 W.
5. Moundville, northwest corner. U. S. Bureau of Mines analysis.
6. Fort Scott Coal & Mining Co., lower bed. Lot 10 NE. ¼ sec. 6, T. 34 N., R. 33 W.
7. B. F. Mays. NW. ¼ NE. ¼ sec. 17, T. 36 N., R. 30 W.
8. Bainter Coal Co. SW. ¼ SE. ¼ sec. 18, T. 34 N., R. 32 W.
9. Panama, two miles south. U. S. Bureau of Mines analysis.
10. Burford Coal Co. SW. ¼ sec. 7, T. 35 N., R. 29 W.

OIL AND GAS.

General. The presence of many seepages of oil and oil saturated sandstone has been known for many years and with the finding of small amounts of oil and gas in wells drilled for water supplies and the activity in the oil fields in Kansas, there has naturally been a keen interest in the possibilities of finding oil and gas in commercial quantities locally. There have been a few wells producing gas for lighting and heating in farm houses, the well on the farm of J. M. Turly in the NE. ¼ sec. 34, T. 37 N., R. 33 W., being the earliest known, it having been in use since 1909. The pressure is reported to be about 40 to 45 pounds per square inch. The oil from natural seepages and from shallow dug wells has for years been used for greasing farm implements and machinery.

The accumulation of oil and gas in rocks has resulted from the slow decomposition of organic matter, probably both vegetable and animal, and the subsequent migration of the resulting oil to porous rocks known as reservoirs—usually sandstone. If the rocks have been warped or folded the oil or gas may be trapped in domes, terraces or anticlines (elongated domes), or in synclines or troughs if there is no water present to float the oil. These reservoirs must have a tight capping (usually shale or tight limestone) to prevent the oil from escaping. Where the oil bearing rocks are exposed at the surface the oil will be evident as "seepages" or as bituminous deposits resulting from the dissipation of the lighter parts of the oil into the air.

In consequence of the manner of origin of the oil and gas and its method of accumulation there are four conditions necessary to the formation of pools of commercial size: (1) an organic source, which betrays its character by the residual bituminous matter present, as in a dark gray or black shale; (2) a porous reservoir such as a sandstone or fractured limestone; (3) an impervious cap to retain the oil, usually a shale or tight sandstone or limestone; (4) warping of the rocks to create favorable structure for accumulation of large pools.

In Vernon County these conditions are present in the upper formations of Pennsylvanian age—bituminous shales, porous sandstones, shale covering for the sandstones, and gentle warping of the rocks. Below the Cherokee, as shown in the discussion of "Rocks Not Exposed," conditions are not favorable for the accumulation of commercial amounts of oil or gas,

there being no bituminous shales to furnish a source for the oil. In some of the deep wells schistose rocks have been found resembling shales but they are very old rocks, probably pre-Cambrian in age, which have been subjected to great pressure and heat and any oil which may have been present would have been driven off. There are present porous reservoirs, shales which might serve as cap rocks, and probably favorable structure but all of these are of no avail lacking a competent source. Drilling for oil and gas should stop as soon as the underlying Mississippian limestone is reached.

In the past few years it has become more and more certain that some of the oil and gas production of Kansas and Oklahoma is coming from rocks of Mississippian or even Devonian or Ordovician age, all of them older than, and consequently beneath the Pennsylvanian if present. The Mississippian formations producing oil to the west of Missouri are probably of Chester or Kinderhook age and if ever present in Vernon County have been practically completely removed by erosion. As shown in the discussion of the Joplin section, there are only small residual patches of the Chester present there: the largest not over a mile in extent, much too small to have any influence on the presence or absence of oil and gas. That part of the Kinderhook favorable for oil or gas has also been largely removed, the nearest occurrences being patches in southern Newton and Greene Counties where it is too thin to be of commercial importance. During the past few years, the production from the lower sands in Kansas and Oklahoma have been considered as upper or middle Ordovician the horizon being comparable in general to strata occurring above the St. Peter Sandstone.

It has also been shown in the sections on "Rocks Not Exposed" and on the Joplin region that there is no Devonian or "Trenton" (Ordovician age) of importance underlying the Mississippian in Vernon County. Any hopes held forth of finding oil or gas in Mississippian, Devonian or "Trenton" formations in this county or surrounding regions is not based on accurate geological knowledge.

Structure. The regional dip of the Pennsylvanian rocks is about ten feet to the mile in a west-northwesterly direction, caused by the Ozark uplift to the southeast. This dip is so slight as not to be discernible to the eye. Locally slight dips may often be seen but these are often due to irregularities in deposition or slight warping which may die out within a hundred

feet. The only safe way to test for the presence of structure for oil work is with the plane table and alidade, running accurate levels and traverses between different outcrops of the same key bed. There has been considerable gentle folding on a larger scale in the county and in places dips as high as ten degree may be seen. The structure sheet, plate 12, shows a number of small anticlines in the northwestern corner of the county. This is the general type of closed structure which should be sought for as a basis for drilling. It is probable that the exposures of Mississippian limestone in the eastern part of the county and about two miles northwest of Nevada are due to elevation of these formations by warping. There is also evidence of doming near Belvoir.

Oil Sands. Most of the wells in oil have found it in the Clear Creek sandstone. This member has been tentatively correlated with the Bartlesville sandstone of Oklahoma (p. 44), but too much dependence should not be placed on this fact in estimating the possibilities of finding oil or gas as the county is a long distance from the producing regions. Some showings have been found in higher sands, probably in No. 16 of the generalized section of the Cherokee formation. There are seepages from exposed outcrops of sandstones in the higher Henrietta formation but the thickness and depth in Vernon County is too small to give hope of any commercial production.

Developments. About two hundred wells have been drilled for oil in the northwestern part of the County (see Plate 13), most of which are reported to have found oil or gas. Exploration started about 1900 but the most intensive drilling campaign was during the years 1920 and 1921, chiefly in townships 36 and 37 north, range 33 west and adjoining townships. Practically all of the land in the northwestern part of the County is under lease.

The Missouri Oil and Development Co., drilled several wells in secs. 27 and 28, T. 37 N., R. 33 W. in 1901 getting about 30 feet of oil sand at about 140 feet. No production has been reported. The top of the sandstone is about 138 feet above the base of the Cherokee which would place it in the upper part of the Clear Creek sandstone. The oil is reported to have a gravity of about 22° B., and a small proportion of gasoline. The log of their No. 1 well is as follows:

RECORD OF WELL NO. 1, MISSOURI OIL AND DEVELOPMENT CO. NE. ¼ NE. ¼ SEC. 28, T. 37 N., R. 33 W.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	9	9
PENNSYLVANIAN SYSTEM		
Cherokee formation.		
Soapstone	20	29
Coal	3	32
Soapstone	13	45
Sandstone and blue shale	20	65
Soapstone and black sand	22	87
Soapstone and blue shale	3	90
Black sand and blue shale	30	120
Limestone	5	125
Soapstone and blue shale	12	137
Coal	3	140
Oil sand and shale	30	170
Slate and soapstone	35	205
Black and blue sandy shale and sandstone	20	225
Soapstone and shale	18	243
Limestone	2	245
Sandy shale	15	260
Fine-grained micaceous sand	5	265
Gray and black shale with some sand	5	270
Micaceous, carbonaceous shale	5	275
Carbonaceous, sandy shale	3	278
MISSISSIPPIAN SYSTEM:		
Keokuk-Burlington limestone:		
Limestone, cherty	7	285
Limestone, gray, cherty	5	290
Limestone, shaly, some soapstone	5	295
Limestone, gray, cherty	50	345

In the SE. ¼ sec. 27, T. 37 N., R. 33 W., and in the SW. corner of sec. 26 and NE. corner of sec. 35 is a group of nine wells owned by the Minneapolis Oil and Refining Co., which struck gas at 125 to 147 feet in a fine gray sandstone, and found oil in a sandstone at 180 to 216 feet with shale between the two sands and a black shale under the lower. No. 9 of the generalized section of the Cherokee formation is exposed in a gulch in the southwest corner of sec. 26, placing the pay sands in the Clear Creek sandstone. A sample of the oil tested 17.9° B. at 60° F. It had been standing in an open tank for ten days so may have been somewhat lighter when fresh. In the NE. ¼ SE. ¼ sec. 34 of the same township, the Hufty-Smith interests drilled four wells in 1920 of which the following log is typical.

RECORD OF TURLEY NO. 1., NE. ¼ SE. ¼ SEC. 34, T. 37 N., R. 33 W.

	Thickness.	Depth.
	Feet.	*Feet.*
Surface	10	10
Cherokee Formation:		
Limestone, black	10	20
Oil sandstone	5	25
Limestone, white	15	40
Soapstone	40	80
Limestone	5	85
Soapstone	25	110
Limestone, black	10	120
Soapstone	30	150
Limestone	10	160
Soapstone, blue	45	205
Shale, blue	75	280
Oil sand, black and brown	35	315

It is difficult to account for so much limestone in the upper part of the well unless there is a local increase in the lime content of some of the shales. The sand is probably the lower part of the Clear Creek, the upper part becoming more shaly in this region.

The Hufty-Smith interests have about 35 wells altogether, scattered over T. 36 and 37 N., R. 33 W. The following reported log is typical of a group drilled about 1920 in the SW. ¼ NW. ¼ sec. 14, T. 37 N., R. 33 W.

RECORD OF WELL NO. 6, SW. ¼ NW. ¼ SEC. 14, T. 37 N., R. 33 W.

	Thickness.	Depth.
	Feet.	*Feet.*
Surface	10	10
Cherokee:		
Soapstone	10	20
Black limestone	5	25
Blue soapstone	15	40
White soapstone	30	70
Coal	5	75
Blue soapstone	35	110
White shale	20	130
Oil sand	2	132
Shale	8	140
Limestone	5	145
Blue shale	45	180
Oil sand	20	200

This well started at about the elevation of the Moundville coal which throws the oil sand into the Clear Creek. There has been no production up to the present date.

The Sho Me Oil and Refining Co. has a group of wells in and near the SW. ¼ sec. 9, T. 36 N., R. 33 W., and started the erection of a refinery early in 1922. This has not been completed and the property has apparently been abandoned.

The Pecos Valley Oil Co., of Los Angeles, California, have 28 wells on the pump on the Lowrie lease in the E. ½ NW. ¼ and the W. ½ NE. ¼ sec. 28, T. 36 N., R. 33 W., and 14 wells to the south in secs. 28 and 33. They have three 100-bbl. and three 50-bbl. tanks on the Lowrie lease and report having shipped 1,200 barrels of oil. A sample of oil from one of the tanks tested 19.7° B. at 60° F. Mr. R. C. Andre, manager of the company, believes the oil lies in a syncline with a north-south trend as he says there is little water in the pay sand which rises both to the east and west of the central part of the lease. The logs of the wells were not available. There are two gas wells in the northeast corner of the Lowrie lease. The Vernon Oil and Refining Co., a subsidiary of the Pecos Valley Oil Co., built a 300-barrel refinery on a spur of the Missouri Pacific Railroad in the northwest corner of sec. 28 and started operations about October 1, 1922. The plant was closed down soon after and has not been operated since. The log of the water well at the refinery, drilled in the Spring of 1922, supplied by Mr. Andre, follows:

RECORD OF WATER WELL OF VERNON OIL AND REFINING CO., NE. CORNER SEC. 28, T. 36 N., R. 33 W.

	Thickness.	Depth.
	Feet.	*Feet.*
Surface	5	5
Cherokee:		
Clay, yellow	15	20
Shale, blue	5	25
Lime, black	5	30
Shale, white	80	110
Shale, black	25	135
Shale, white	25	160
Lime, brown and shale; show of gas	5	165
Shale; (top of Clear Creek)	10	175
Shale, black	15	190
Shale, white	15	205
Oil sand, light brown, coarse with scum of oil	1	206
Heavy flow of water, slightly brackish	39	245

"Small quantity of water at 40 feet cased off with 42 feet of 8 ¼-inch casing. 172 feet of 6 ¼-inch casing set at 172 feet makes perfect shut-off with both strings leaving all possible oil-bearing formations between the two casings."

The Moundville coal has been stripped in the north-central part of the section and allowing for the difference in elevation it is evident that the oil sand reported is in the upper part of the Clear Creek sandstone and the water sand at the bottom of the hole is the lower Clear Creek member. The brown limestone reported at 160 feet is not known to outcrop anywhere. It is apparently a local variation in the top of the Clear Creek or in the bottom of the overlying shale. It is also reported in wells in secs. 14 and 34, T. 37 N., R. 33 W., where it is gray.

Where found it should serve as a good marker for the top of the Clear Creek sandstone.

A shallow well drilled in the SW. ¼ SW. ¼ sec. 28, T. 36 N., R. 33 W. struck flowing sulphur water, the elevation of the well being about 770. No log is available.

None of the oil wells of the district have been given a systematic test so that it is impossible to say what the production will be. One well was pumped separately for ten days during which it averaged about five barrels per day and the operator believes the well will settle down to a production of about two barrels per day. The oil so far as reported and seen is a heavy black oil. The gravity is said to run from 16° B. to 22° B., only one well reporting higher, that being 26.2° B. from a well drilled by C. Roy Hathaway, Trustee, in sec. 36, T. 37 N., R. 33 W. The gasoline content of the oils is low.

MINNEAPOLIS OIL AND REFINING CO. (MO. BUR. GEOL. & MINES ANALYSES, 1922).

Source of Sample—SW. cor. sec. 26, T. 37 N., R. 33 W.	
Specific gravity at 60° F.	.947
Degrees Baume, at 60° F.	17.91
Color—Black.	
Odor—Asphaltic.	
Viscosity-Engler No. at 100° F.	66.85
Water and B. S.	Trace
Sulphur	Present
Flash point (closed Tagliabue)	240° F.
Burning point (closed Tagliabue)	272° F.
Carbon residue (Conradson)	9.32 %
Heating value (calculated)— 18650 + 40 (Be—10) b. t. u. per pound	18,966
In original sample.	
Asphaltene	8.76 %
Petrolene	91.05 %
Soluble in CS^2 (total bitumen)	99.81 %
Carbene	None.
Paraffin wax	1.10 %

MINNEAPOLIS OIL AND REFINING CO. (MO. BUR. GEOL. & MINES ANALYSES, 1922)—*Continued.*

In Residue above 300°C. in vacuo	
Asphaltene	47.39 %
Petrolene	2.00 %
Total bitumin	49.39 %
Carbene	None.
Paraffin wax	None.
Carbon residue (Conradson)	50.55 %

CRUDE PETROLEUM. FRACTIONAL DISTILLATION BY U. S. BUREAU OF MINES—HEMPEL METHOD. (ELECTRIC HEATER.)

Distillation at atmospheric pressure.

Color.	Product.	End point Temp. °C.	Sp. G. 60°F.	Deg. Be. 60°F.	By Vol. %	Cumulative %
White	Overpoint	148				
White	Gasoline—	175	.774	50.9	2.65	2.65
White	Naptha	200	.828	39.1	3.94	6.59
White		225	.849	34.8	6.21	12.80
Light amber	Kerosene	250	.845	35.6	22.65	35.45
Dark amber		275	.862	32.3	26.10	61.55
Total gasoline fraction					6.59	
Total kerosene fraction					54.96	

Distillation in vacuo—40 mm.

Light brown	Overpoint	174				61.55
Light brown	Fuel oil	200			0.22	61.77
Medium brown	Gas oil	225	.901	25.3	0.30	62.07
Dark brown	Lub. oil	250			0.15	62.22
Dark brown	Lub. oil	275			6.82	69.04
Dark brown	Lub. oil	300			11.34	80.38
Black	Residuum	+300	1.139		15.29	95.67
Total lubricating fraction					18.31	
Losses					4.33	100.00

Future Possibilities. Drilling in Vernon County seems to indicate that there is a considerable area in the northwestern part of the county which is underlain by an oil bearing sandstone—the Clear Creek member of the Cherokee formation. Oil or gas has been reported in wells in a remarkably large area as shown by Plate 13. As there has been no real test of the production of any of the wells it is difficult to say what the pos-

sible production may be but it is probable that the settled production of the wells will not be over two barrels a day. Practically none of the drilling has been guided by structure mapping and it may be that slightly larger wells will be found. At present development is held back by lack of refineries.

Recently there has been much attention paid to the possibilities of getting oil in formations below the Pennsylvanian. A number of wells have been drilled to depths up to 1900 feet but although one or two have reported showings of oil, there has been no production and all have been abandoned. As previously shown on page 101 there is no possibility of getting any commercial production of oil or gas below the Pennsylvanian in Vernon County.

ASPHALTIC SANDSTONE.

General. Sandstones containing bitumen and asphaltic material outcrop in a number of places in Vernon County and have been found in wells and drill holes. Most of the occurrences are in the Clear Creek sandstone member of the Cherokee but a few thin ledges are found higher in the formation and in the sandstones of the Labette shale of the Henrietta formation.

The thickness of the beds varies somewhat, but from reports and observations, it is safe to say that in those occurrences which are most likely to prove commercially valuable there is at least 10 feet of bituminous material, and in places as much as 30 feet, over a considerable area.

Character. The bituminous sandstone is brown to black on fresh surfaces and on exposed surfaces light brown to gray. It is rather friable where there is little bitumen but very tough when well cemented and consists of sub-rounded grains of quartz sand with a little mica. Apparently the cementing consists largely of the bitumen and when this is removed the rock crumbles easily.

The quantity of bitumen varies in different deposits and even in the same deposit but the average is probably less than 10 per cent. The composition shows that it is largely derived from crude petroleum, similar to that which is found in the same formations in wells near Richards, through the evaporation of lighter constituents near the outcrop of the sandstone. In some places the bitumen is still fairly liquid and flows from the rock into test pits and seeps out of cracks and crevices at the sur-

face. At other places evaporation has gone so far that there remains only a solid residue which does not flow even in the hottest weather. Analyses of specimens sent to this Bureau are as follows:

Oil, yield gal./ton	12	5¾	16
Oil, degrees Beaume	19.7	21.3	22.8
Total bitumen, per cent	5.50	3.79	8.56
% Asphaltene in bitumen	16.40	31.40	11.65
% Petrolene in bitumen	83.60	68.60	88.35

Analyses of samples taken by this Bureau are as follows:

ANALYSES OF ASPHALTIC SANDSTONES FROM VERNON COUNTY.

	Per cent.		
	1.	2.	3.
Soluble in carbon disulphide (total bitumen)	5.08	5.16	6.23
Soluble in petroleum ether of 88.80° Be. at 60°F. (petrolene)	4.00	3.81	5.59
Per cent of total bitumen	78.7	73.8	89.7
Balance by difference (asphaltene)	1.08	1.35	0.64
Per cent of total bitumen	21.3	26.2	10.3

Reaction of residue to dilute hydrochloric acid—Slight bubbling.

SCREEN ANALYSES AFTER IGNITION OF ASPHALTIC SANDSTONES FROM VERNON COUNTY.

Openings.		1.		2.		3.	
Mesh.	Inches.	% on screen.	Cumulative %	% on screen.	Cumulative %	% on screen.	Cumulative %
28	.0232	Trace	.....	Trace			
35	.0164	4.1	4.1	3.0	3.0	Trace	
48	.0116	6.8	10.9	5.0	8.0	6.8	6.8
65	.0082	19.1	30.0	11.5	19.5	16.3	23.1
100	.0058	41.5	71.5	38.0	57.5	45.3	68.4
150	.0041	17.3	88.8	24.0	81.5	24.5	92.9
200	.0029	5.4	94.2	9.0	90.5	3.8	96.7
−200	.....	5.8	100.0	9.5	100.0	3.3	100.0

1. Missouri Asphalt Rock Corporation. W. ½ lot 9 NW. ¼ sec. 3, T. 34 N., R. 33 W. Representative sample from stock pile, selected by the plant superintendent.

2. National Asphalt Refining Company. NE. ¼ SE. ¼ sec. 24, T. 35 N., R. 33 W. Representative sample from stock pile.

3. SE. ¼ SW. ¼ sec. 24, T. 34 N., R. 30 W. Old stock pile.

The loss on ignition is not a safe test for the amount of bitumen present, as water and carbon dioxide from calcite cementing would be driven off at the same time. The samples reported above were tested with acid and all gave a slight reaction showing that there is some lime present. In practice the ignition loss is used since the water and limestone is present in small quantities and a proper allowance can be made for them.

Most of the so-called asphalt of these sandstones is not a true asphalt but a heavy crude oil resulting from the evaporation of the lighter constituents and contains only a small proportion of asphalt as shown by the above tables. The gravity of the oil ranges from 19° B. to 23° B., and there is from 31 to 10 per cent asphaltene and from 69 to 90 per cent petrolene in the bituminous material.

The following results of examinations of Oklahoma asphaltic sandstones are taken from Snider.[1]

	Per cent.			
Bitumen soluble in CS^2	6.77	7.45	7.80	9.97
Specific gravity 25°C/25°C	0.991	1.019	1.017	1.032
Loss at 163°C (325°F) 5 hours	6.13	4.69	3.48	4.11
Bitumen insoluble in 86° Be. paraffin naptha	11.15	21.90	22.44	22.44
Fixed carbon	6.95	11.52	10.36	10.22

The first column is of a sandstone of which the bituminous content is so light and soft as to be used only as a flux or softening agent for the harder pitches.

In the same publication, Snider also gives results of analyses of rock asphalt pavement as put down in various cities in Oklahoma, some of which are mixtures of different rocks. They are as follows:

	Range in per cent.	Average of seven, per cent.
Total bitumen	7.85–10.10	9.18
Asphaltene content of bitumen	21.19–29.39	24.27
Petrolene content of bitumen	78.81–70.61	75.73

[1]Snider, L. C., Rock asphalts of Oklahoma and their use in paving: Okla. Geol. Surv., Circular No. 5, 1913.

Ten analyses of artificial sheet asphalt paving gave an average of 11.0 per cent total bitumen and 25.0 and 75.0 per cent of asphaltene and petrolene respectively. The rock asphalt pavements were reported as standing up better under wear and softening less in summer.

Some of the Vernon County asphalt or heavy oil is quite variable in asphaltene content. That from near Swart and Deerfield appears to be nearer the composition of the asphaltic sandstones which are being used in other parts of the country. The total bitumen content is low, 7 per cent to 7½ per cent being standard in the Kentucky industry, although it is claimed by some that 5½ per cent or even 5 per cent bitumen is enough. Practical road tests are necessary in the case of any deposit to determine its possibilities. The sandstone in the two deposits mentioned above is from a higher horizon than that at Bellamy which may account for the difference in composition.

In the case of those asphalts which are low in asphaltene content this might be remedied by adding Trinidad or other residual asphalts with a large content of asphaltene at the time of crushing and mixing or when heating previous to laying. A screen analysis of the sand in a deposit under consideration should be made to determine whether the proper proportion of different sizes is present to make a good binding sand and practical tests of the material should be made on roads subject to different types of heavy traffic.

The results of the screening in thetable on page 110 shows that the various sizes are in proportions to form a good aggregate. It would probably stand more of coarser fractions as the sand is very fine. Microscopic examination shows the grains to be mostly quartz in sub-angular fragments with considerable mica.

Location. In some localities these bituminous sandstones occur at or close to the surface. In places an area of at least a square mile could be made accessible by the removal of from two to twenty feet of overburden of soil, clay, and sandy shale. No attempt has been made to estimate the tonnage available in the different deposits since sufficient detailed prospecting has not been done to warrant it. Judging however from the outcrops and such wells and pits as have been sunk, all of the deposits mentioned below are of sufficient size for many years' production should an economic process be found for utilizing them. The quantity and character of the bituminous content probably varies both horizontally and vertically within short distances

and will be found to be in larger quantity but of lighter gravity back from the outcrop. Consequently deposits should be thoroughly prospected by drill holes and pits previous to development.

Allowing 14 cubic feet to the ton, an acre-foot of asphaltic sandstone will yield 3,100 tons and 40 acres ten feet thick would come to 1,240,000 tons.

Deposits Near Sheldon. About four miles east of Sheldon the asphaltic rock outcrops along the sides of bluffs and near the heads of ravines and has been found by wells and test pits to underlie a large but unknown area close to the surface. A well sunk in the SE. ¼ SW. ¼ sec. 27, T. 34 N., R. 30 W., encountered 21 feet of asphaltic sandstone at a depth of about 15 feet. In the southwest corner of the same section the stone outcrops near the heads of several ravines. Two test holes sunk in this section were reported to find 16 and 11 feet of the sandstone at depths of 22 and 21 feet respectively. Other wells nearby have reported up to 50 feet of the rock, some of it very rich. The deposit probably extends over parts of several sections varying in richness from place to place. Considerable of the area has less than five feet of overburden and by stripping 10 or 15 feet many millions of tons would be available.

About 4 miles northwest of Sheldon in sec. 15, T. 34 N., R. 31 W., a ledge of bituminous sandstone outcrops in the bottom of a valley. The ledge forms the bed over which the water flows during wet seasons and outcrops for a distance of about 100 yards. On the south side of the valley, about 10 feet above the creek bed, another ledge outcrops. The interval between the two beds is covered but wells show that it also consists of the same kind of material. It is said that other wells in this same locality penetrated about 20 feet of bituminous sandstone. From well records it is evident that the sandstone underlies an area of at least a square mile, at depths varying from 5 to 30 feet.

At the exposure above-mentioned, two well-defined joints about 10 feet apart, cut through the sandstone. The strike is N. 35° W. Along these joints the bituminous material oozes out of the rock in hot weather and forms little pools on the surface. Small fractures leading away from the main joints are filled with the tarry substance. As the rock in the outcropping ledge does not seem to be saturated, it is possible that much of it comes up from a lower bed.

This deposit is less than a mile from the main road between Milo and Sheldon, and if it can be successfully used for road building, can easily be made accessible.

Deposit Southeast of Bellamy. In section 24, T. 34 N., R. 30 W., asphaltic sandstone outcrops in a small valley near the center of the section and test pits and wells show a bed of the sandstone about 30 feet thick underlying several sections. In the pits a heavy black oil seeps out of the rock onto the water which partly fills the pits. On the surface of the rock small seepages evaporate leaving a heavy tarry residue. The rock thrown out of the pits is black and well saturated with oil. There seems to be little cementing material except for the bitumen.

Four test holes sunk in section 24 penetrated 30, 30, 26 and 30 feet, of asphaltic sandstone at depths of 5, 13, 9 and 11 feet respectively, and in the NE. ¼ SW. ¼ of the same section 27½ feet of the sandstone was found at a depth of 12 feet. There is apparently a large area underlain by 11 to 30 feet of the rock at depths ranging up to 25 feet. The overburden is soil and clay which could be removed easily.

Two samples of the rock tested for bituminous content have shown 7.5 and 8.2 per cent bitumen and a third (J. M. Lindgren, Univ. of Ill., analyst) gave 5.4 per cent of oil of 25.3° Beaume gravity which on evaporation yielded 12.7 per cent bituminous residue. An analysis of a sample from the stock pile of a small plant started in the southwest quarter of the section is given on page 110. So far as could be learned there has been no commercial production from this plant.

Deposits Near Deerfield. The National Asphalt Refining Company, a local concern, has started an experimental plant two miles south of Deerfield in the NE. ¼ SE. ¼ sec. 24, T. 35 N., R. 33 W. Asphaltic sandstone outcrops at the top of the bluff bordering the creek and the pit shows eight feet of sandstone more or less saturated with bituminous material. In places there are patches that are very low grade, the sandstone apparently being "tight" and not allowing the infiltration of the bituminous material. The rock in the pit is said to range from four to nine per cent bituminous matter. The rock is exposed for about 400 feet northerly along the creek and a drill hole 200 feet from the outcrop showed about 6 feet of the asphaltic sandstone at about 8 feet depth. No. 20 of the general section (*Conostichus broadheadi* zone) outcrops at the bridge one-half

mile south and may be traced north, being immediately below the sandstone which is probably a bed near the top of this member. The analysis of a sample is given on page 110.

The plant was in the experimental stage at the time of visiting in 1924. The process used includes crushing, screening, driving off the more volatile constituents in a continuous horizontal retort and addition of heavy asphalt. The company was about to make a shipment to Jefferson City for trial on the city streets.

Just north of Deerfield in the NE. ¼ SW. ¼ sec. 1, T. 35 N., R. 33 W. and to the east, six feet of asphaltic sandstone outcrops along Marmaton River and the same has been reported in a well in Deerfield at 18 to 20 feet depth. The rock contains about 5 per cent bituminous matter.

Similar sandstone carrying about 7 per cent bitumen is reported in dug wells in the SE. ¼ SW. ¼ sec. 3, and NE. ¼ NW. ¼ sec. 10, T. 35 N., R. 32 W.

The rock was found at about twelve feet depth and penetrated 5 to 6 feet without going through it.

Deposit West of Moundville. The Missouri Asphalt Rock Corporation has started operations in the W. ½ lot 9 NW. ¼ sec. 3, T. 34 N., R. 33 W. An area of about 200 acres has been prospected by pits and churn drill holes and asphaltic rock found at depths of from 4 to 12 feet and from 10 to over 17 feet in thickness. A pit has been opened and considerable rock is on the stock pile. The company plans to erect a treating plant on the Kansas City Southern Railway two miles to the west. Analyses of the rock are given on page 110.

STONE.

Vernon County being largely underlain by shales and soft sandstones, there is not a great deal of stone available for commercial use. The limestones, with the exception of the Mississippian, are usually too thin and shattered to furnish a large supply of building stone, and the sandstones are generally too soft or friable for permanent use in buildings. However, in many places the Clear Creek sandstone is quite hard and has been used. The old highway bridge in the SW. ¼ sec. 5, T. 36 N., R. 32 W., a mile east of Deerfield, over Drywood Creek, rests on piers of the Clear Creek sandstone which are apparently in as good condition as when built in the early seventies. The

sandstone has been used in the piers of many other bridges in the county in areas underlain by the lower beds of the formation which are usually harder than the upper beds.

The sandstone has also been used in foundations, for flagging, curbing, and in buildings. In some cases the stone was not properly selected and foundations have had to be replaced but where care has been taken to use only the harder beds the results have been satisfactory.

The Gilfillian Quarry in the NW. ¼ NW. ¼ sec. 31, T. 35 N., R. 31 W., shows what is apparently excellent stone. The bottom of the pit is now filled with water and the quarry has not been worked for many years. The pit shows a six-foot channelled face to the water's edge. The rock outcrops down the ravine to the northeast for a thickness of at least 30 feet and on the surface appears to be good stone. There is a tendency for the sandstone to case-harden by migration of the iron content to the surface through leaching, so that the interior can not always be predicted from the condition of the outcrop. The quarry opening is 55 feet by 140 feet. The depth is reported to be 60 feet. Much of the stone was shipped to Kansas City and used in large buildings. It showed a tendency to disintegrate by weathering and practically all of it had to be replaced. The stone apparently stands up well as long as it is kept wet but is unsuitable for building purposes. Across the road to the west there are many rough blocks of considerable size lying beside the old road-bed of a spur track from the Missouri Pacific Railroad. These were probably taken out as squared stone which has since spalled in weathering.

The Mississippian limestone where exposed is a good building stone. The ledge on the south bank of the Osage, west of Schell City, has been used in the past for lime burning at the old Belvoir lime kiln and might be used for both lime and building stone. The same limestone at its outcrops in the southeastern part of the county is also available for these industries. The limestone is quite cherty here, as elsewhere, and must be sorted before burning. All of the limestones in the county are of good quality for agricultural purposes.

The Henrietta limestones in the northwestern part of the county are used somewhat for small buildings but they are too much jointed and thin bedded to yield large dimensional stone.

The lack of suitable quarry sites in the vicinity of railroad transportation and the use of mine tailings obtained at a low

price from the Joplin mining district have prevented the development of a crushed stone industry.

UNDERGROUND WATERS.

Underground water supplies in Vernon County come from two horizons. Shallow wells get small supplies from near the surface by seepage into dug wells, and porous formations, yielding sufficient water for domestic purposes and small stock farms are found by drilled wells within about 100 feet of the surface. This water is often soft, but may contain considerable iron, alum, or gypsum as noted later in this report. Deep wells find supplies of sulpho-saline water in increasing quantities from the Mississippian limestone down to the Roubidoux sandstone horizon at 800 to 1,000 feet from the surface where large amounts of water are available. Flowing wells up to 140 gallons per minute are found in the valleys and much larger quantities could doubtless be pumped. The mineral content of this water apparently increases from the eastern to the western part of the county.

Shallow Wells. Dug wells are numerous in many parts of this county, as water can be obtained by digging down 15 or 20 feet in the dirt or soft Cherokee sandstone and shale which is the country rock over the greater part of the area. These dug wells often fail in dry seasons, however, and usually are then replaced by drilled wells. Ordinary drilled wells furnishing a supply merely large enough for household purposes, are from 35 to 150 feet in depth. The majority of the wells reported are less than 100 feet deep, and very few of them reach a depth of 150 feet without striking water though a number go below this in an attempt to get a stronger supply.

About two-thirds of the private house wells reported can be pumped dry, and in many of the others the water can be lowered part way, perhaps to the vein. Only a few were reported in which the water could not be lowered. In most of the wells the water rises 15 to 30 feet above the vein, although in some of the deeper ones it rises much farther.

Mr. Oscar Jones of Milo, a driller, reports that several wells 4 to 6 miles southwest of Nevada yield an "alum" water, while nearby wells on the same land sometimes do not strike this horizon, but find fresh water a little deeper. This water undoubtedly comes from the Clear Creek sandstone. A sample

taken from the well of O. D. Jones in the NW. ¼ SW. ¼ sec. 31, T. 35 N., R. 30 W., had a strong puckering taste and analyzed as follows:

ANALYSIS OF WATER FROM WELL OF O. D. JONES, NEAR MILO.

	Parts per million.
Silica (SiO^2)	53.0
Iron (Fe)	0.49
Aluminum (Al)	61.6
Calcium (Ca)	395.7
Magnesium (Mg)	147.4
Alkalies (Na & K)	356.5
Carbonate (CO^3)	None
Bicarbonate (HCO^3)	4.2
Sulphate (SO^4)	1950.0
Chlorine (Cl)	178.4
Nitrate (NO^3)	110.1
Total	3257.1
Volatile dissolved solids	449.0
Non-volatile dissolved solids	2777.0
Total dissolved solids	3226.0
Hardness (Soap)	2035.0

Sample collected November 25, 1925.

The well is used for stock only. As shown by the analysis the water contains essentially sulphates of calcium, magnesium, and the alkalies with considerable chlorides and nitrates the latter of which is probably derived from surface barnyard water seeping into the well through the wall. There is also an unusual amount of aluminum which combined with the sulphate gives the alum taste. The alum is probably derived from oxidation of pyrite in the overlying shales and solution of aluminum from the clay by the resulting sulphuric acid. Although the water was clear when collected, a red sediment, probably largely iron, was noted later but not analyzed.

Deep Wells. A number of holes deeper than the ordinary wells have been drilled in different parts of the county, either for water or in prospecting for oil and gas. Several large streams of water are almost invariably encountered in these holes, so that there is probably no place in the county at which a well

A. Flowing well at Pence Gun Club, northwest of Nevada.

B. Artesian well, Radio Springs Park, Nevada.

800 to 1,100 feet deep would not find a large amount of water, although probably somewhat sulpho-saline in character.

At the plant supplying water to the City of Nevada the driller reported that the 937-foot well struck a vein of water at 810 feet that washed the cuttings away from 810 to 820 and again at 860 the cuttings were washed away for the following five feet. A log and description of the well are given on page 125.

At the Nevada Crystal Ice and Cold Storage Company's well, on North Cedar Street, drilled at 850 feet elevation, the first water was reported at 575 feet and cuttings were lost there. At 665 to 695 "strong water openings" and lost cuttings were reported. The well is 700 feet deep.

Flowing Wells. There are a number of wells in Vernon County situated on land low enough so that the head is sufficient to cause them to flow. A few which flowed at first have since stopped flowing but indications are that this is due to caving in the well or plugging of the strainer and not to lowering of the head. Most of the flowing wells get the water from the Roubidoux sandstone at from 530 to 600 feet below the base of the Pennsylvanian. In some cases it seems probable that flowing water is encountered before reaching the Roubidoux, but the water is believed to come from that aquifer, penetrating crevices in the overlying dolomite to the point at which it is encountered. In at least one well—at the Pence Gun Club—(Pl. 10, A), flowing water was found in the Mississippian. It seems probable that wells drilled to the Roubidoux sandstone, if started on land not over 750 feet above sea level, will yield flowing water. In some places wells are flowing or water stands in the well at an elevation of 800 feet or slightly higher.

One of the oldest flowing wells in Vernon County is the Moore well, 800 feet deep, drilled in 1887, at what is now Radio Springs Park (Pl. 11, B). It was originally estimated to flow 240,000 gallons per day (0.37 sec.-ft., 165 gal. per min.). Some years ago it stopped flowing and later "blew itself in" again. The stoppage was probably due to caving. In 1914 another well 644 feet deep was drilled producing a smaller amount of flowing water than the first. A test pumped 30,000 gallons in two days (.023 sec.-ft., 10.4 gal. per min.) without lowering the water. The driller reported a strong vein of water at 630 to 640 that washed away the cuttings. There is 500 feet of 6½-inch casing in the well and the water stands seven feet from the top. Elevation 810 feet. The flow of the larger well is said to have been

reduced when the second came in. Neither well flows at present due either to caving or to lowering of the head by the heavy pumping at the city water supply plant a mile north. The analysis is discussed on page 121.

ANALYSIS[1] OF WATER FROM RADIO SPRINGS PARK, NEVADA, WELL NO. 1.

	Parts per million.
Silica (SiO^2)	14.0
Calcium (Ca)	80.02
Magnesium (Mg)	32.57
Sodium (Na)	306.9
Bicarbonate (HCO^3)	341.8
Sulphate (SO^4)	52.8
Chlorine (Cl)	473.7
Total	1301.79
Fixed residue	1127.8

No organic matter, potassium, or bromine. Trace of lithium.

The Pence Gun Club of Nevada drilled a 691-foot well in 1922 near the center of sec. 8, T. 36 N., R. 31 W., which produces a heavy flow of water impregnated with hydrogen sulphide, the gas escaping in fine bubbles at the outlet of the 6½ -inch casing. The elevation is about 740 feet. The driller, C. H. Staats, of Carl Junction, Mo., reports that the well started to flow at 270 feet, increasing somewhat at 470, 500 and 580 feet, and at 680 feet a strong flow came in. The character of the water at 270 feet was not noted. An analysis of the water is given and discussed on page 121. Rough estimates of the flow in the ditch and from the discharge curve from the horizontal pipe give a flow of a little over 160,000 gallons per day (0.25 sec.-ft.; 110 gal. per min.).

The Stutz Gun Club has a small flowing well in the east center of sec. 27, T. 36 N., R. 32 W., at their club house. The well is 873 feet deep, starting at about 745 feet elevation and was drilled in August, 1918. The water is sulpho-saline.

The Ridgeway well, SE. ¼ NW. ¼ sec. 32, T. 36 N., R. 32 W., drilled for oil in 1919-20, flows five or six inches over the

[1]Recalculated to ionic form from an analysis by Schweitzer: Report on mineral waters. Mo. Geol. Survey, First ser., Vol. III, 1892, p. 122.

top of the 10-inch casing. The elevation is 760 feet. The depth of the water horizon is not known, but the close correspondence of the analysis, as given on page 122, to that of other well waters indicates that the water comes from the Roubidoux horizon. The water is heavily charged with hydrogen sulphide, the gas escaping at the mouth of the well. The flow is estimated at not far from 200,000 gallons per day (0.3 sec.-ft.; 140 gal. per min.).

The Litton well in the NE. ¼ NE. ¼ sec. 20, T. 37 N., R. 30 W., reported by Shepard[1] as 400 feet deep with a good flow of water strongly impregnated with hydrogen sulphide, has since ceased to flow, probably due to caving, as another well, drilled later at the same elevation, about 500 feet to the southeast and 500 feet deep has a small flow of sulpho-saline water. The elevation is about 765 feet.

On the farm of Mr. George Galvin in SW. ¼ NW. ¼ sec. 26, T. 36 N., R. 29 W., is a flowing well located on bottom land of Clear Creek. This well is about 660 feet deep (elevation of collar 760 feet), has a flow estimated at 57,600 gallons per day, (40 gallons per minute), and the water tastes and smells strongly of hydrogen sulphide and deposits a white scum around the outlet. It is a sulpho-saline water, the analysis of which is given on page 122.

All of the wells which get their main water supplies from the Roubidoux horizon show a very close relationship in the mineral content of the water. This is particularly true of the Galvin, Pence, and Ridgeway wells, the samples of which were collected at the same time and analyzed together. Not only is the character of these waters similar but they show a progressive increase in total salinity and constituents toward the west, i. e., down the dip of the formations and away from the outcrop. The waters are sulpho-saline in character with a large amount of bicarbonates and low silica. The water fresh from the wells has a decided sulpho-saline taste but on aerating and standing becomes potable especially when iced and local inhabitants who are used to it prefer it to purer waters of other regions which taste flat and insipid by contrast. Analyses of these waters follows. For analyses of other similar waters see pages 120 and 125.

ANALYSES OF FLOWING DEEP WELL WATERS, VERNON COUNTY.

	Parts per million.		
	1.	2.	3.
Silica (SiO^2)	7.8	8.6	6.4
Iron (Fe)	0.41	0.45	0.50
Aluminum (Al)	0.5	2.2	1.0
Calcium (Ca)	92.4	84.8	47.9
Magnesium (Mg)	40.5	38.1	22.3
Alkalies (Na & K)	388.1	349.9	127.6
Carbonate (CO^3)	None	1.5	None
Bicarbonate (HCO^3)	275.8	277.0	216.9
Sulphate (SO^4)	71.8	67.5	25.5
Chlorine (Cl)	691.5	627.2	212.5
Nitrate (NO^3)	None	None	None
Totals	1568.81	1457.25	660.6
Volatile dissolved solids	348	350	159
Non-volatile dissolved solids	1072	971	391
Total dissolved solids	1420	1321	550
Volatile suspended matter	0.2	0.4	None
Non-volatile suspended matter	None	None	None
Total suspended matter	0.2	0.4	None
Hardness (Soap)	434.8	400.0	254.8

1. Ridgeway well, SE. ¼ NW. ¼ sec. 32, T. 36 N., R. 32 W.
2. Pence Gun Club, sec. 8, T. 36 N., R. 31 W.
3. George Galvin, SW. ¼ NW. ¼ sec. 26, T. 36 N., R. 29 W.

Dr. Shepard[1] reports the following additional flowing wells:

In the southwest corner of sec. 30, T. 36, R. 33, is a well owned by E. S. Weyand. It is 650 feet deep, starts in Cherokee shale at an elevation of 765 feet A. T., and has a weak flow of water which has a strong odor of hydrogen sulphide and deposits a thin white film around the outlet. The water is said to rise in a pipe 15 feet above the surface.

Six miles east of Sheldon on the farm of L. C. Moore in sec. 30, T. 34, R. 29, on the western slope of a northeast-southwest anticlinal fold,[2] a well was bored through 17 feet of shale

[1]Shepard, E. M., Underground Waters of Mo.: Water-supply Paper, U. S. Geol. Surv., No. 195, 1907, p. 125.

[1]Shepard, E. M., *Idem*, p. 123.

[2]*Idem*, p. 124.

and sandstone producing flowing water. The well originally discharged from a pipe about four feet above the ground. It has since ceased to flow, probably from caving, although possibly from lowering of the head due to development of a seepage across the road to the south, as described under "springs."

Springs. No springs of notable size are found in the county. Prof. Schweitzer reports several small springs at Fairhaven in the SW. ¼ of sec. 18, T. 37, R. 29, the largest one having a flow of about 100 gallons per hour and the following analysis:

ANALYSIS[1] OF MAIN SPRING WATER, FAIRHAVEN SPRINGS.

	Parts per million.
Silica (SiO^2)	29.0
Iron (Fe)	9.79
Calcium (Ca)	60.77
Magnesium (Mg)	39.57
Alkalies (Na & K)	49.2
Bicarbonate (HCO^3)	202.5
Sulphate (SO^4)	246.2
Chlorine (Cl)	0.3
Total	637.33
Fixed residue	538.3
Specific gravity	1.0008

No organic matter, no potassium, traces of lithium, and manganese.

When visited in 1922 at the end of a very dry season the flow was only 40-50 gallons per hour. The spring apparently comes from the base of heavy sandstones (Clear Creek?) at an elevation of 805 feet.

The springs are all rather similar in character. Two wells yield water more strongly impregnated with mineral matter than the spring water. A hotel was built here and a small park laid out, with the intention of making a sanitarium and summer resort, but the hotel is now closed and the place practically abandoned.

A small sulphur spring flowing from the base of the Clear Creek sandstone in the NW. corner of the NE. ¼ sec. 29, T. 36 N., R. 31 W., was noted by both Broadhead and Norwood,[2]

[1]Recalculated to ionic form from Schweitzer, P., Report on mineral waters, Mo. Geol. Surv., 1st ser., Vol. III, 1892, p. 174.

[2]Geol. Surv. of Mo., Report of field work, 1873-1874, 1874, p. 139.

who reported it flowing at the rate of two gallons per minute. When visited in October, 1922, after a long dry summer and fall, and again in 1924, the spring was not flowing. A clay tile 30 inches high has been mounted over the spring and the water stood 12 inches below the ground level, with a thin scum of iron oxide on its surface. The elevation of the spring is about 750 feet.

Beauchamp Spring, center of sec. 1, T. 36 N., R. 29 W., flows from shales 20 feet below the base of the Clear Creek sandstone in a small valley, about 10 feet above the branch at an elevation of 745 feet. The water rises three feet in a tile and flows one and one-half to two gallons per minute. It is a sulphur water, although not strongly so.

Along both sides of a small stream flowing easterly through the south half of sec. 8, T. 37 N., R. 29 W., about 15 feet above water level there is a strong seepage of water from the shales even in dry weather. The elevation is about 830 feet. A similar seepage amounting almost to a spring is present from shales in the road between secs. 30 and 31, T. 34 N., R. 29 W., east of the creek and is probably closely associated with the Moore well nearby, which formerly flowed. A small pit has been dug in the field just south of the road and the water allowed to drain through a pipe to the road gutter. The water contains both sulphur and iron.

City and Village Supplies.

Nevada. (Pop. 7139) obtains its municipal water supply from three drilled wells located on a hill in the western part of the town at an elevation of about 900 feet. These wells are 850, 1,001, and 937 feet in depth. Water is pumped from the wells to a concrete reservoir of 1,000,000 gallons capacity, from which it is pumped to the system. Air lift is used to pump water from the two older wells, but an electrically driven Pomona deep-well pump was installed in the last well. Ordinarily only two wells are pumped; the third being used only in an emergency. About 450,000 gallons per day are pumped. The water is hard and is treated before being used in the boilers.

The following is the driller's log of the 937-foot well drilled in 1913:

LOG OF CITY WATER-WORKS WELL, NEVADA.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil and clay	14	14
Sandstone	91	105
Soapstone and black slate	53	158
Sandstone and shale	5	163
Brown limestone	27	190
White and gray sandy limestone	95	285
Soapstone and brown sandy limestone	35	320
White sandstone	6	326
Blue shale, brown sandy limestone	24	350
Blue and white flint	105	455
Brown, sandy limestone, yellow flint	35	490
Dark blue gassy flint, selvage and white spar, soapstone	40	530
White and blue flint, gray limestone	55	585
White limestone and white flint	180	765
White sandstone	9	774
Gray fine-grained limestone	50	824
White sandstone	22	846
Gray limestone	54	900
Water at 810′ and 860′.		
White flint, bluish limestone	37	937

18″ hole to 14′
13″ hole to 352′ — 10″ casing to 352′ — Water stands 96′ from surface and is lowered about 25′ by pumping.
10″ hole to 500′
8 ¼″ hole to 937′

The following is the average of two analyses recalculated to ionic form, made for the company by M. H. Thornberry, Research Metallurgist, Missouri School of Mines and Metallurgy, October 30, 1920:

AVERAGE OF TWO ANALYSES OF WATER FROM CITY WATER-WORKS WELL, NEVADA.

	Parts per million.
Iron (Fe)	1.82
Aluminum (Al)	2.53
Calcium (Ca)	88.2
Magnesium (Mg)	36.3
Sodium (Na)	338.1
Potassium (K)	95.4
Bicarbonate (HCO^3)	138.8
Sulphate (SO^4)	83.76
Chlorine (Cl)	552.6
Total	1337.51
Total dissolved solids	1452.95

The other towns of the county depend almost entirely upon private wells and cisterns for their water supply. These are generally shallow, and many of them are dug wells.

Sheldon (Pop. 544). Most of the house wells are drilled wells 40 to 50 feet deep. Two public wells here are 60 and 90 feet deep, respectively, and are fitted with hand pumps.

Schell City (Pop. 596) gets much of its water from dug wells, which often fail in dry seasons. Where a large supply is needed, as for the mill at Schell City or for watering stock, wells have been drilled, and these generally strike a good vein of water at about 150 feet below the surface.

Walker (Pop. 309) has chiefly dug wells. The public well here is a dug well 20 feet deep, equipped with a hand pump.

About half of the wells at *Moundville* (Pop. 240) are dug wells. The public well here is also a dug well, and is equipped with a hand pump. As these dug wells often fail in dry seasons, they are gradually being replaced by drilled wells 40 to 60 feet deep.

Near *Richards* (Pop. 359) drilled wells are a little deeper, usually 80 to 150 feet deep.

At *Deerfield* (Pop. 238) most of the house wells are dug wells. The public well here is a 97-foot drilled well with a hand pump. Other drilled wells are from 60 to 75 feet deep.

Most of the wells at *Harwood* (Pop. 215) are also dug wells 15 to 20 feet deep. Three public wells here are all dug wells about 20 feet deep equipped with hand pumps.

Stotesbury (Pop. 141) gets its water from dug wells 30 to 35 feet deep. These wells are in the unconsolidated surface materials as the country rock here is a hard limestone. In most parts of the county bed rock is soft sandstone or shale, and wells are often dug in it. The public well at Stotesbury is a dug well about 30 feet deep equipped with a hand pump.

Milo (Pop. 134) has a drilled public well. Drilled wells near here are usually 60 to 70 feet deep.

CLAYS AND SHALES.

Vernon County is underlain by deposits of weathered shales and shales and clays occupying the interval between the various coal beds, particularly in the Cherokee formation. While raw materials are being worked at only three localities at present, laboratory tests of outcrop and drill samples collected during

the course of the investigation show accessible deposits of considerable extent which should furnish, with the coal beds of the county, the basis for a more extensive heavy clay products industry.

Burning Tests. The burning tests were made in a down draft laboratory kiln, gas-fired to 825° C., and oil-fired above that temperature. The test pieces were oxidized for five hours at 900° C., and then drawn at the temperatures indicated. The fired properties were determined by the methods suggested by the Committee on Standards, American Ceramic Society.[1]

Cherokee Formation.

Norman Tile Co. The Dederick shales in the lower part of the Cherokee formation are used at the plant of the Norman Tile Company, at the north edge of Nevada on the Missouri Pacific Railroad.

Hollow building and drain tile are manufactured. The plant is equipped with a ten-foot dry pan, one stiff-mud machine with a capacity of 8,000 5-inch by 12-inch tile per day, three round, down draft, coal-fired kilns, and one oil-fired continuous drying kiln, also equipped to utilize waste heat.

The following section measured in the clay pit shows the character of the raw materials:

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	1	1
Clay, yellow (weathered residual)	6	7
Shale, yellow, soft	6	13
Shale, blue, hard	6	19

The blue shale, which adds stiffness to the mixture, extends 10 feet below the floor of the pit. Analyses of the yellow and blue shales are as follows:

[1]Jour. Amer. Cer. Soc., year book, (Reprint) pp. 1-62, 1921-1922.

CHEMICAL ANALYSES OF DEDERICK SHALES FROM PIT OF THE NORMAN TILE CO., NEVADA, MO.

Analysis No.	226	227
SiO^2	61.77	63.83
Al^2O^3	15.46	14.37
Fe^2O^3	7.32	6.71
MgO	2.48	2.53
CaO	1.23	1.27
Na^2O	1.37	1.16
K^2O	3.50	3.41
°H^2O +	4.65	4.50
H^2O—	1.33	.67
TiO^2	.67	.82
P^2O^3	.12	.07
SO^2	.18	.14
S	None	.51
MnO	.14	.13
Total	100.22	100.12

°Includes organic matter and CO^2.

REMARKS:

Analysis No. 226—Six feet buff shale not weathered, W. F. Norman Tile Co., Nevada, Mo.

227—Hard blue shale, W. F. Norman Tile Co., Nevada, Mo.

Pohl Brick Co. Dederick shales are also utilized at this plant, which is located in the southwest part of Nevada on the Missouri-Kansas-Texas Railroad. The plant is equipped with a soft-mud machine and three rectangular kilns, two with a capacity of 300,000 each, and one with a capacity of 247,000 bricks. The burned brick are hard and dense and have a pleasing dark red color. Ninety per cent of the output is sold as face brick.

The clay pit is located two miles west of the plant on the flood plains of Little Drywood Creek, the raw material being hauled to the plant over the railroad. A section measured in the pit shows the following succession:

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	1	1
Clay, iron-stained	1 ½	2 ½
Shale, weathered	1 ½ to 4	4 to 6 ½

Three parts clay and one of weathered shale are used in mixture, the properties of which are given below.

PROPERTIES OF UNBURNED BRICK, POHL BRICK CO., NEVADA, MO.

Plastic and Dry Properties.

Color wet	Greenish-gray.
General plasticity	Good.
Per cent shrinkage water	7.2
Per cent pore water	16.5
Per cent water of plasticity	23.7
Dry transverse strength	No sample.
Dry condition	Dries satisfactorily.
Dry volume shrinkage Per cent of dry volume	13.2
Calculated linear shrinkage Per cent dry length	4.6

Fired Properties.

Temperature, °C.	Color.	Calculated linear shrinkage, per cent dry length.	Volume shrinkage, per cent dry volume.	Per cent absorption.	Per cent apparent porosity.
950	Buff	0.6	1.8	21.5	36.6
990	Buff	0.5	1.4	20.4	35.2
1030	Buff	1.0	0.2	19.4	34.7
1070	Reddish-brown	1.3	3.9	17.6	31.8
1110	Reddish-brown	2.7	8.7	12.5	24.4
1130	Reddish-brown	3.7	10.6	10.3	20.8
1170	Reddish-brown	5.1	14.4	7.3	15.4
1210	Dark brown	6.0	16.9	4.1	9.0
1250	Greenish-gray	0.0	0.0	6.4	11.6
1290	Greenish-gray	0.2	6.4	11.7	19.6

Deformation temperature: 1310°–1330°C.
Best firing range: 950–1170°C.
Overburning temperature: 1250°C.
Hardness: Steel hard at 1110°C.
Structure: Open burning to 1070°C.: vitrifies at 1110°C.: vesicular at 1250°C.
Condition: No kiln white; completely oxidized: swelled at 1250°C.
Class of ware: Face brick, common brick, sewer pipe, hollow tile, flower pots.

Deerfield Tile Co. Weathered clay shales lying above the Clear Creek sandstone member of the Cherokee formation have been used in the manufacture of building, drain and glazed tile, and silo blocks by the Deerfield Tile Company, Deerfield. The plant, however, has not been in operation for several years.

The clay pit is about one mile west of the plant in the SW. ¼ NW. ¼, sec. 12, T. 35 N., R. 33 W., where a 5-foot face of slightly sandy iron-stained, plastic, gray clay is worked. The

floor of the working pit is very sandy gray clay. The material has recently been shipped to Pittsburg, Kansas, and used in the manufacture of flower pots.

The following properties were determined from composite face samples of the material.

CLAY FROM THE PIT OF THE DEERFIELD TILE COMPANY, DEERFIELD.

Plastic and Dry Properties.

Color wet	Light reddish-brown.
General plasticity	Excellent.
Per cent shrinkage water	17.1
Per cent pore water	15.2
Per cent water of plasticity	32.3
Dry transverse strength	171.6
Dry condition	Dries satisfactorily.
Dry volume shrinkage Per cent of dry volume	32.9
Calculated linear shrinkage Per cent dry length	12.4

Fired Properties.

Temperature, °C.	Color.	Calculated linear shrinkage, per cent dry length.	Volume shrinkage, per cent dry volume.	Per cent absorption.	Per cent apparent porosity.
950	Reddish-buff	1.0	2.7	17.2	31.9
990	Reddish-buff	2.4	6.8	15.3	29.4
1030	Reddish-buff	3.2	9.3	13.7	27.0
1070	Reddish-buff	4.8	13.6	10.3	21.6
1110	Light red	7.1	19.8	5.8	12.9
1130	Light red	7.1	19.8	5.4	12.1
1170	Mahogany	8.2	22.6	2.3	5.5
1210	Dark grayish-brown.	8.3	23.0	1.2	2.7
1250	Dark gray	4.6	13.1	4.5	9.4
1290	Geenish-gray	4.2	11.8	4.2	8.3

Deformation temperature: 1450°C.
Best firing range: 990°–1070°C.
Overburning temperature: 1070°C.
Hardness: Steel hard at 1070°C.
Structure: Vitrifies at 1110°C.: vesicular at 1250°C.
Condition: Completely oxidized, no kiln white: swelled at 1150°C.
Class of ware: Paving brick, sewer pipe, hollow block, common brick, drain tile.

Other Clays and Shales Sampled. Shales lying above the Clear Creek sandstone member were sampled just south of Horton, in the center of sec. 21, T. 37 N., R. 31 W., on the west side of the Missouri Pacific Railroad, where a hole was augured nine feet through yellowish to reddish brown, slightly sandy, plastic weathered shale. Nodules of limonite were common, and some light-colored chert was also found in the clay.

Detailed burning tests, however, show this clay to be unsatisfactory for use in the manufacture of clay products. The presence of lime in the clay is indicated by white spots and the dirty green color developed in the test pieces on firing.

The clay vitrified at 1130° C., and deformed at 1170° C.

The "Middle" or "Two-foot" coal mined in the Rich Hill-Panama district and in the Mounds near Walker is underlain by clay of considerable thickness. A test hole augured at the Mays coal pit in the NW. ¼ NE. ¼ sec. 17, T. 36 N., R. 30 E., showed 9 feet of blue-gray clay, the base not being reached. The upper 4½ feet contained some fine sand, which increased in amount with depth, the lower 4½ feet being quite sandy. The lower part of the clay had a distinct astringent taste.

The properties of the clay given below were determined from samples of the upper and lower portions of the underclay.

UPPER 4½ FEET OF "MIDDLE" OR "TWO-FOOT" UNDERCLAY.
Plastic and Dry Properties.

Color wet	Medium gray.
General plasticity	Good
Per cent shrinkage water	8.4
Per cent pore water	15.5
Per cent water of plasticity	23.9
Dry condition	Dries satisfactorily.
Dry volume shrinkage Per cent of dry volume	15.4
Calculated linear shrinkage Per cent dry length	5.4

Fired Properties.

Temperature, °C.	Color.	Calculated linear shrinkage, per cent dry length.	Volume shrinkage, per cent dry volume.	Per cent absorption.	Per cent apparent porosity.
950	Buff	0.4	1.1	18.3	32.8
990	Salmon	1.8	5.4	16.3	30.6
1030	Salmon-red	4.1	11.7	11.1	22.9
1070	Buff-red	4.9	13.9	8.5	18.1
1110	Brown	5.8	16.4	3.6	8.1
1130	*a*	*a*	*a*	*a*	*a*
1170	Brown	7.5	20.8	0.6	1.4
1210	Dark greenish-gray	0.8	2.5	4.7	8.8

*a*No test pieces drawn at 1130°.

Deformation temperature: 1370°C.
Overburning temperature: 1130°–1170°C.
Best firing range: Under 990°C.
Hardness: Steel hard at 1030°C.
Structure: Open burning to 950°C.: vitrifies at 990°C.: vesicular at 1210°C.
Class of ware: Possibly flower pots.

LOWER 4½ FEET, "MIDDLE" OR "TWO-FOOT" UNDERCLAY.

Plastic and Dry Properties.

Color wet	Medium gray.
General plasticity	Excellent.
Per cent shrinkage water	9.8
Per cent pore water	14.7
Per cent water of plasticity	24.5
Dry transverse strength	295.3
Dry condition	Dries satisfactorily.
Dry volume shrinkage Per cent of dry volume	19.6
Calculated linear shrinkage Per cent dry length	7.0

Fired Properties.

Temperature, °C.	Color.	Calculated linear shrinkage, per cent dry length.	Volume shrinkage, per cent dry volume.	Per cent absorption.	Per cent apparent porosity.
950	Light buff.....	1.4	4.2	15.8	29.6
990	Reddish-buff.....	3.3	9.6	13.4	26.2
1030	Reddish-buff.....	4.0	11.5	11.5	23.1
1070	Reddish-buff.....	5.2	14.8	9.3	19.6
1110	Brown.....	7.3	20.4	5.4	12.1
1130	Brown.....	7.9	21.9	2.8	6.4
1170	Reddish-brown.....	8.7	23.9	0.8	1.9
1210	Greenish-gray.....	4.8	13.6	4.9	10.1
1250	Dark green.....	1.5	4.5	8.2	15.2

Deformation temperature: 1250°C.
Best firing range: 950°C.–1030°C. (Short.)
Overburning temperature: 1170°C.
Hardness: Steel hard at 990°C.
Structure: Open burning to 990°C.: vitrifies at 1070°C.: vesicular at 1210°C.
Condition: Completely oxidized, kiln white: swelled at 1210°C.: developed small black blisters at 1250°C.
Class of ware: Could be mixed with upper part of seam for common brick and flower pots.

The "Middle" or "Two-foot" underclay is also present in the Bainter coal pit in the SW. ¼ SE. ¼ sec. 18, T. 34 N., R. 32 W., northwest of Bronaugh.

Face samples were taken in a ditch in the north part of the pit where 4 feet or more of clay is exposed. The clay is overlain by 15 inches of coal and could be recovered at low cost.

No kiln white was developed in the burned test pieces and the fired properties given below show the clay to be in general of better quality than the material exposed at the same horizon at the Mays pit.

"MIDDLE" OR "TWO-FOOT" UNDERCLAY, BAINTER COAL PIT.
Plastic and Dry Properties.

Color wet	Medium gray.
General plasticity	Good.
Per cent shrinkage water	12.1
Per cent pore water	12.0
Per cent water of plasticity	24.1
Dry transverse strength	No sample.
Dry condition	Satisfactory.
Dry volume shrinkage Per cent of dry volume	23.9
Calculated linear shrinkage Per cent dry length	8.7

Fired Properties.

Temperature, °C.	Color.	Calculated linear shrinkage, per cent dry length.	Volume shrinkage, per cent dry volume.	Per cent absorption.	Per cent apparent porosity.
950	Light buff.....	0.0	0.0	14.6	27.6
990	Light buff.....	0.8	2.4	13.5	26.3
1030	Dirty cream.....	2.5	7.3	10.6	21.7
1070	Dirty cream.....	3.8	10.9	7.9	16.7
1110	Putty.....	5.1	14.6	5.5	12.1
1130	Putty.....	5.7	16.0	4.0	9.1
1170	Drab.....	7.0	19.5	0.9	2.0
1210	Light gray.....	5.8	16.3	1.0	2.4
1250	Light gray.....	2.2	6.4	4.9	9.8

Deformation temperature: 1490°–1530°C.
Best firing range: 950°–1110°C.
Overburning temperature: 1210°C.
Hardness: Steel hard at 990°C.
Structure: Open burning to 1030°C., vitrifies at 1070°C.
Condition: No kiln white, completely oxidized, dark core at 1250°C., swelled at 1210°C.
Class of ware: Face brick, common brick, hollow tile.

The interval between the "Two-foot" and the "One-foot" or "Moundville" coal is composed of shale, sandstone, and nodular limestone, and a persistent bed of blue-gray, sandy clay underlying the Moundville coal.

A composite sample of this underclay was collected from a 4½-foot drill hole at the coal pit on the Prewitt farm in the NE. ¼ NE. ¼ sec. 17, T. 36 N., R. 30 W.

The clay is light gray in color, very sandy, and has good plasticity. Considerable kiln white was developed in firing but could be eliminated by treatment.

MOUNDVILLE UNDERCLAY, PREWITT COAL PIT.

Plastic and Dry Properties

Color wet	Medium gray
General plasticity	Good
Per cent shrinkage water	10.1
Per cent pore water	9.3
Per cent water of plasticity	19.4
Dry transverse strength	328.8
Dry condition	Satisfactory.
Dry volume shrinkage Per cent of dry volume	21.1
Calculated linear shrinkage Per cent dry length	7.6

Fired Properties.

Temperature, °C.	Color.	Calculated linear shrinkage, per cent dry length.	Volume shrinkage, per cent dry volume.	Per cent absorption.	Per cent apparent porosity.
950	Dirty cream.....	0.1	0.4	12.5	25.0
990	Dirty cream.....	0.4	1.2	11.2	22.6
1030	Cream.....	0.4	1.2	10.6	21.7
1070	Cream.....	1.2	3.5	10.0	20.5
1110	Dirty yellow.....	2.3	6.7	7.4	15.9
1130	Dirty yellow.....	2.6	7.7	6.6	14.3
1170	Drab.....	3.4	9.8	5.1	11.2
1210	Light gray.....	1.7	4.9	5.8	11.9
1250	Light gray.....	3.4	9.1	10.6	19.4

Deformation temperature: 1390°–1410°C.
Best firing range: 1110°–1130°C.
Overburning temperature: 1170°C.
Structure: Open burning to 1070°C., dense to 1130°C., vitrifies at 1130°C., vesicular at 1210°C.
Hardness: Steel hard at 1030°C.
Condition: Test pieces not completely oxidized in 5 hours, much kiln white, blisters at 1210°C., swelled at 1210°C.
Class of ware: With treatment could be used for common brick.

The "Moundville" coal, the distribution of which is shown on the geologic map, is overlain by drab to blue-gray shale of varying thickness which weathers a light buff color, due to the oxidation of the included pyrite, and into heavy block-like slabs. Limestone concretions are common and the upper part of the shale is often sandy. As the coal is generally mined by stripping, the shale could be mined at low cost. The lower portion of the shale overlies the strip pit on the Prewitt farm in the NE. ¼ NE. ¼ sec. 17, T. 36 N., R. 30 W., where 7½ feet of characteristic material is exposed.

The shale is dense burning but vitrifies and becomes steel hard at 990° C., and swells and became vesicular at 1170° C. Complete deformation was obtained at 1330° C. Efflorescence or kiln white was developed in firing, and would have to be eliminated before utilization.

The roof of the Moundville coal is well exposed in the B-E-L Mining Company's pit in the SE. ¼ sec. 16, T. 34 N., R. 32 W., northwest of Bronaugh, where the following section was measured:

	Thickness.		Depth.
	Ft.	*In.*	*Feet.*
Soil and clay, brown	1–4		4
Limestone, nodular		6–8	4½
Shale, clay, light brown	2		6½
Shale, black blocky	5		11½
Shale, gray with limestone concretions	9	6	21

Samples of the shale immediately above the coal burned similarly to the material from the same horizon at the Prewitt coal pit.

The clay deforms at 1290° C., and shows much efflorescence. It begins to vitrify at 1030° C., and swells readily after this temperature.

The Moundville shale has a total thickness of 20 feet at the Lavery coal pit, lots 8 and 9, sec. 8, T. 34 N., R. 32 W. The upper part is light greenish-gray to buff, grading downward into bluish-gray shale. Burning tests show the shale to be similar to the material from the same horizon mentioned above. The sample had approximately the same deformation point as the other two samples described, a low vitrification point, spalled readily after vitrification and developed much kiln white.

Burning tests of the Moundville shale from the localities mentioned are as follows:

MOUNDVILLE SHALE, LAVERY COAL PIT, SOUTHWEST OF MOUNDVILLE.

Plastic and Dry Properties.

Color wet	Gray.
General plasticity	Fair.
Per cent shrinkage water	5.2
Per cent pore water	17.8
Per cent water of plasticity	23.0
Dry transverse strength	165.5
Dry condition	Satisfactory.
Dry volume shrinkage Per cent of dry volume	9.1
Calculated linear shrinkage Per cent dry length	3.1

Fired Properties.

Temperature, °C.	Color.	Calculated linear shrinkage, per cent dry length.	Volume shrinkage, per cent dry volume.	Per cent absorption.	Per cent apparent porosity.
950	Dark tan.....	0.6	1.6	20.6	35.8
990	Light salmon.....	1.8	5.3	18.3	33.3
1030	Salmon.....	3.5	10.1	15.2	29.0
1070	Salmon.....	5.7	16.1	11.3	23.1
1110	Reddish-brown.....	8.8	24.1	5.0	11.5
1130	Reddish-brown.....	9.2	25.0	4.0	9.2
1170	Dark brown.....	10.9	29.1	0.6	1.5
1210	Dark brown.....	5.1	14.5	5.6	11.2
1250	Dark olive-green....	1.3	3.8	3.7	6.5

Deformation temperature: 1330°–1350°C.
Best firing range: 950°–1110°C.
Overburning temperature: 1170°C.
Structure: Open burning to 990°C., vitrifies at 1030°C., vesicular at 1210°C.
Hardness: Steel hard at 1070°C.
Condition: Completely oxidized, kiln white, black blisters at 1130°C., swelled at 1210°C.
Class of ware: Paving brick, common brick, hollow block.

MOUNDVILLE SHALE, B-E-L MINING COMPANY COAL PIT.

Plastic and Dry Properties.

Color wet	Dark gray.
General plasticity	Fair.
Per cent shrinkage water	17.3
Per cent pore water	7.5
Per cent water of plasticity	24.8
Dry transverse strength	171.6
Dry condition	Satisfactory.
Dry volume shrinkage Per cent of dry volume	14.4
Calculated linear shrinkage Per cent dry length	5.1

Fired Properties.

Temperature, °C.	Color.	Calculated linear shrinkage, per cent dry length.	Volume shrinkage, per cent dry volume.	Per cent absorption.	Per cent apparent porosity.
950	Light salmon.....	2.1	6.2	16.5	31.1
990	Light salmon.....	5.0	14.1	12.0	24.7
1030	Light red.....	8.1	22.4	6.4	14.4
1070	Medium red.....	11.2	29.9	0.7	1.5
1110	Chocolate.....	10.3	27.8	0.5	1.2
1130	Chocolate.....	5.4	15.4	1.0	2.2
1170	Deep mahogany....	13.5	35.2	21.0	27.4

Deformation temperature: 1290°C.
Best firing range: 950°–1030°C.
Overburning temperature: 1170°C.
Hardness: Steel hard at 990°C.
Structure: Open burning to 990°C., vitrifies at 1030°C., vesicular at 1130°C.
Condition: Much kiln white, spalls easily when vitrified, swelled at 1130°C.
Class of ware: Possibly common brick.

MOUNDVILLE SHALE, PREWITT COAL PIT.

Plastic and Dry Properties.

Color wet	Dark gray.
General plasticity	Good.
Per cent shrinkage water	10.5
Per cent pore water	21.3
Per cent water of plasticity	31.8
Dry transverse strength	178.6
Dry condition	Satisfactory.
Dry volume shrinkage Per cent of dry volume	18.8
Calculated linear shrinkage Per cent dry length	6.7

Fired Properties.

Temperature, °C.	Color.	Calculated linear shrinkage, per cent dry length.	Volume shrinkage, per cent dry volume.	Per cent absorption.	Per cent apparent porosity.
950	Buff	1.6	4.6	22.4	38.2
990	Reddish-buff	4.6	13.2	17.3	28.2
1030	Reddish-buff	7.9	21.8	10.1	23.0
1070	Salmon-red	11.1	29.5	5.3	12.3
1110	Salmon-red	13.3	34.9	0.7	1.7
1130	Dark reddish-brown.	13.4	35.0	0.7	2.5
1170	Dark reddish-brown.	0.6	1.9	11.2	7.3

Deformation temperature: 1330°–1350°C.
Best firing range: None.
Overburning temperature: 1170°C.
Hardness: Steel hard at 990°C.
Structure: Dense at 950°C., vitrifies at 990°C., vesicular at 1170°C.
Condition: Completely oxidized, much kiln white. Swelled at 1170°C.
Class of ware: None, entirely too much kiln white.

The Fort Scott Mining Company is stripping the Fort Scott coal in the SW. ¼ sec. 33, T. 35 N., R. 33 W. The upper part of the overburden is 5 to 10 feet of yellowish-gray, very plastic, slightly gritty clay shale. The dry and fired properties shown below were obtained from samples of the material.

SHALE FROM PIT OF FORT SCOTT COAL MINING COMPANY.

Plastic and Dry Properties.

Color wet	Yellowish-brown.
General plasticity	Excellent.
Per cent shrinkage water	21.8
Per cent pore water	14.4
Per cent water of plasticity	36.2
Dry transverse strength	241.6
Dry condition	Satisfactory.
Dry volume shrinkage Per cent of dry volume	45.5
Calculated linear shrinkage Per cent dry length	18.3

Fired Properties.

Temperature, °C.	Color.	Calculated linear shrinkage, per cent dry length.	Volume shrinkage, per cent dry volume.	Per cent absorption.	Per cent apparent porosity.
950	Light red.....	3.7	10.4	10.4	21.3
990	Light red.....	6.3	17.5	5.5	12.5
1030	Medium red.....	8.3	22.8	1.5	3.8
1070	Mahogany.....	8.3	23.0	1.0	2.3
1110	Mahogany.....	7.7	21.3	0.9	2.1
1130	Dark mahogany....	7.3	20.3	0.6	1.5
1170	Dark mahogany....	4.5	12.8	3.2	8.4
1210	Dark mahogany....	2.1	6.1	4.5	9.0

Deformation temperature: 1390°–1410°C.
Best firing range: Under 950°C.
Overburning temperature: 1130°C.
Hardness: Steel hard at 950°C.
Structure: Dense to 950°C., vitrifies at 990°C., spalls easily.
Condition: Completely oxidized, blisters at 1130°C.
Class of ware: Common brick and flower pots. Has excessive drying shrinkage.

Separated from the above clay by two to four inches of coal in the same pit is 1½ feet of gray, finely gritty underclay. The clay has the highest deformation point of the materials tested, and has a long vitrification range.

The clay, however, would have to be treated to eliminate the excessive drying shrinkage, and because of the low vitrification point, and the excessive spalling would require careful burning. The dry and fired properties of the lower clay are given below.

CLAY BELOW THIN COAL, PIT OF THE FORT SCOTT MINING CO.

Plastic and Dry Properties.

Color wet.....	Greenish-gray.
General plasticity.....	Excellent.
Per cent shrinkage water.....	14.5
Per cent pore water.....	14.2
Per cent water of plasticity.....	28.7
Dry transverse strength.....	279.0
Dry condition.....	Satisfactory.
Dry volume shrinkage Per cent of dry volume.....	27.7
Calculated linear shrinkage Per cent dry length.....	10.2

Fired Properties.

Temperature, °C.	Color.	Calculated linear shrinkage, per cent dry length.	Volume shrinkage, per cent dry volume.	Per cent absorption.	Per cent apparent porosity.
950	Cream	1.5	4.3	15.2	28.4
990	Cream	3.3	9.5	14.7	28.2
1030	Buff	5.5	15.4	7.8	16.6
1070	Medium buff	7.1	19.7	3.8	8.4
1110	Medium buff	7.7	21.2	1.0	2.3
1130	Dark buff	8.1	22.4	0.5	1.3
1170	Light tan	8.3	22.8	0.6	1.4
1210	Putty	7.2	20.1	0.9	2.0
1250	Light gray	3.4	9.8	4.0	8.0
1290	Light gray	3.1	8.9	3.4	6.7

Deformation temperature: 1530°C.
Best firing range: None.
Overburning temperature: 1250°C.
Structure: Dense, vitrifies at 950°C.
Hardness: Steel hard at 990°C.
Condition: Completely oxidized, few dark blisters at 1170°C., swelled at 1250°C.
Class of ware: Could be blended with overlying shales for brick, hollow tile, flower pots.

HENRIETTA FORMATION.

The Labette shale member of the Henrietta formation outcrops in the northwest part of the county and is the only other shale member of importance. In places it attains a thickness of 11 feet. Six to eight feet of yellowish-brown, iron-stained sandy clay is exposed in a cut along the Kansas City Southern Railway in the SW. ¼ SE. ¼ NW. ¼ sec. 32, T. 38 N., R. 33 W.

The following data were obtained from face samples:

Plastic and Dry Properties.

Color wet	Light brown.
General plasticity	Excellent.
Per cent shrinkage water	17.9
Per cent pore water	11.6
Per cent water of plasticity	29.5
Dry transverse strength	193.9
Dry volume shrinkage Per cent of dry volume	36.7
Calculated linear shrinkage Per cent dry length	14.1

Fired Properties.

Temperature, °C.	Color.	Calculated linear shrinkage, per cent dry length.	Volume shrinkage, per cent dry volume.	Per cent absorption.	Per cent apparent porosity.
950	Reddish-buff.....	0.4	1.3	11.8	2.3
990	Reddish-buff.....	1.0	3.1	11.8	2.4
1030	Salmon-red.....	1.3	4.0	10.9	2.2
1070	Salmon-red.....	1.8	5.2	11.1	2.3
1110	Brown.....	1.8	5.2	10.5	2.2
1130	Brown.....	1.8	5.4	10.0	2.1
1170	Dark brown.....	1.7	5.0	9.9	2.1
1210	Deep red.....	1.7	5.0	9.4	1.9
1250	Dark greenish-brown	2.1	6.1	8.2	1.7

Deformation temperature: 1390°–1410°C.
Best firing range: 950°–1070°C.
Overburning temperature: 1210°C.
Hardness: Steel hard at 1070°C.
Structure: Dense, vitrifies at 1070°C.
Condition: Slight kiln white, completely oxidized, swelled at 1250°C.
Class of ware: Common brick, drain tile, flower pots. The clay would require treatment for drying shrinkage, and cracks developed in drying. The fire shrinkage is low and constant from 950°–1210°C.

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