THE OCCURRENCE *of*

OIL AND GAS

IN MISSOURI

By M. E. WILSON

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MISSOURI BUREAU OF GEOLOGY AND MINES
H. A. BUEHLER, *Director and State Geologist*
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STRUCTURE MAP OF NORTHWEST PORTION OF VERNON COUNTY

(Contours on base of Pawnee Limestone)

Scale: 2 Inches = 1 Mile
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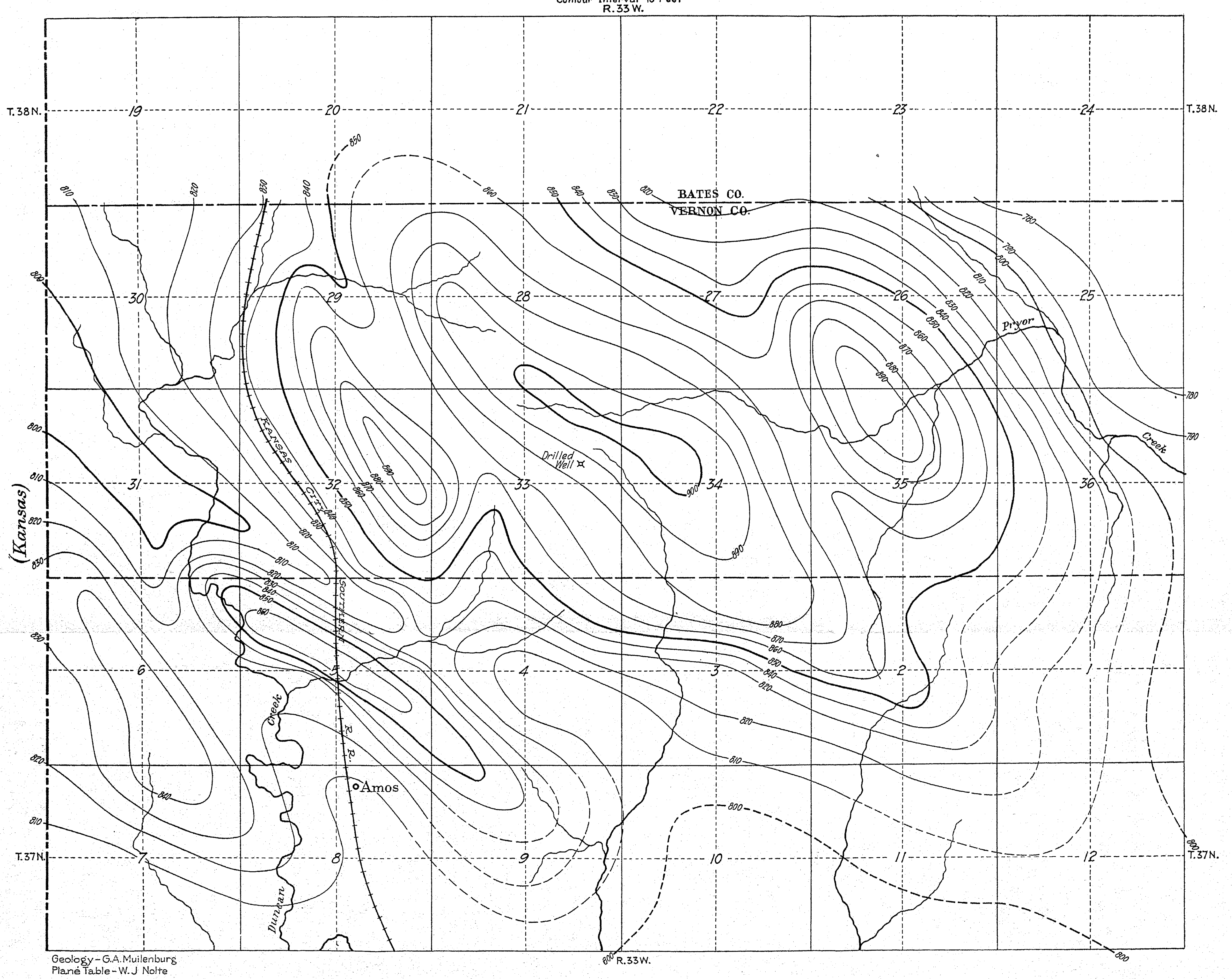

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STRUCTURE MAP OF WEST BOONE TOWNSHIP, BATES COUNTY

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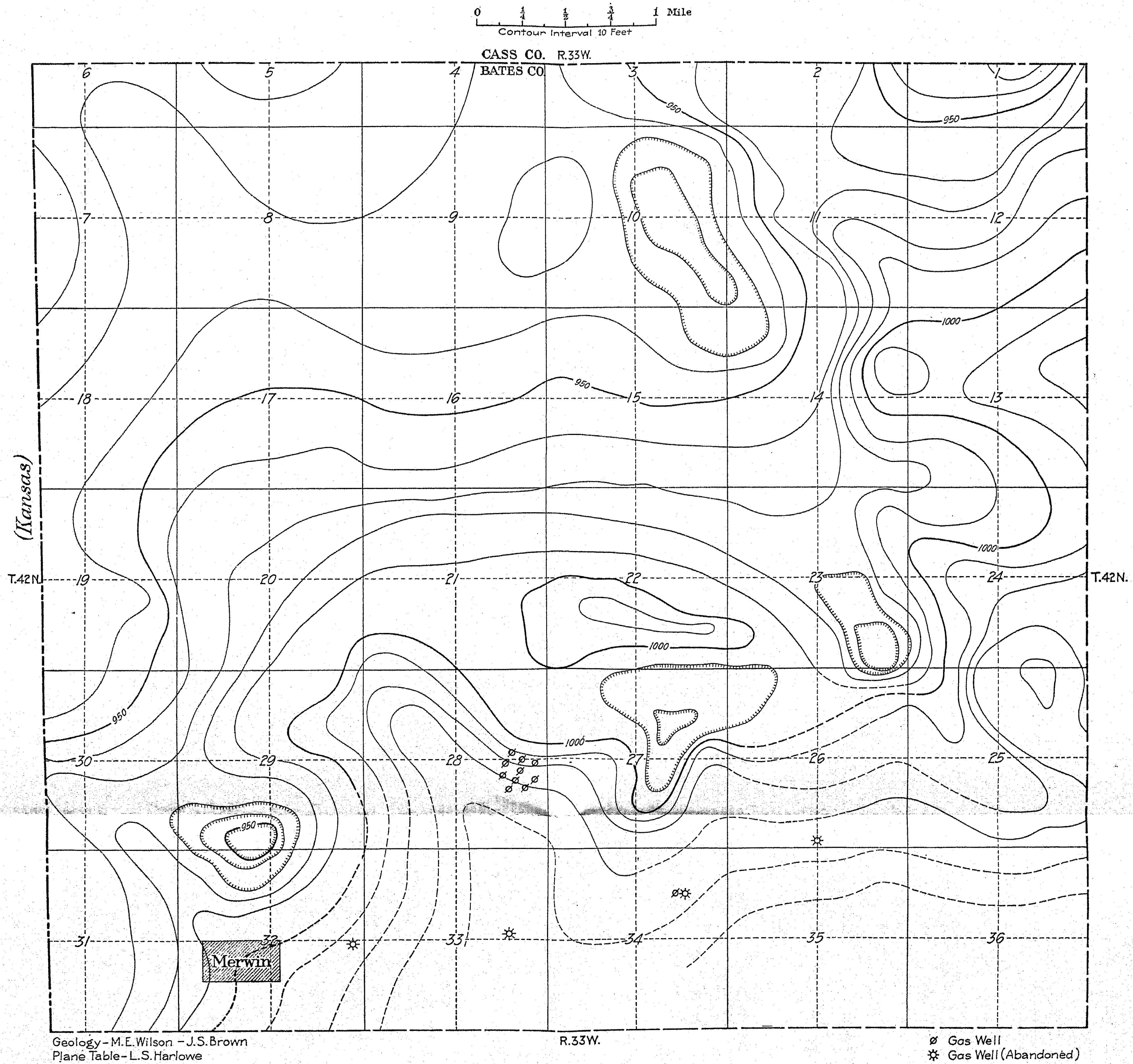

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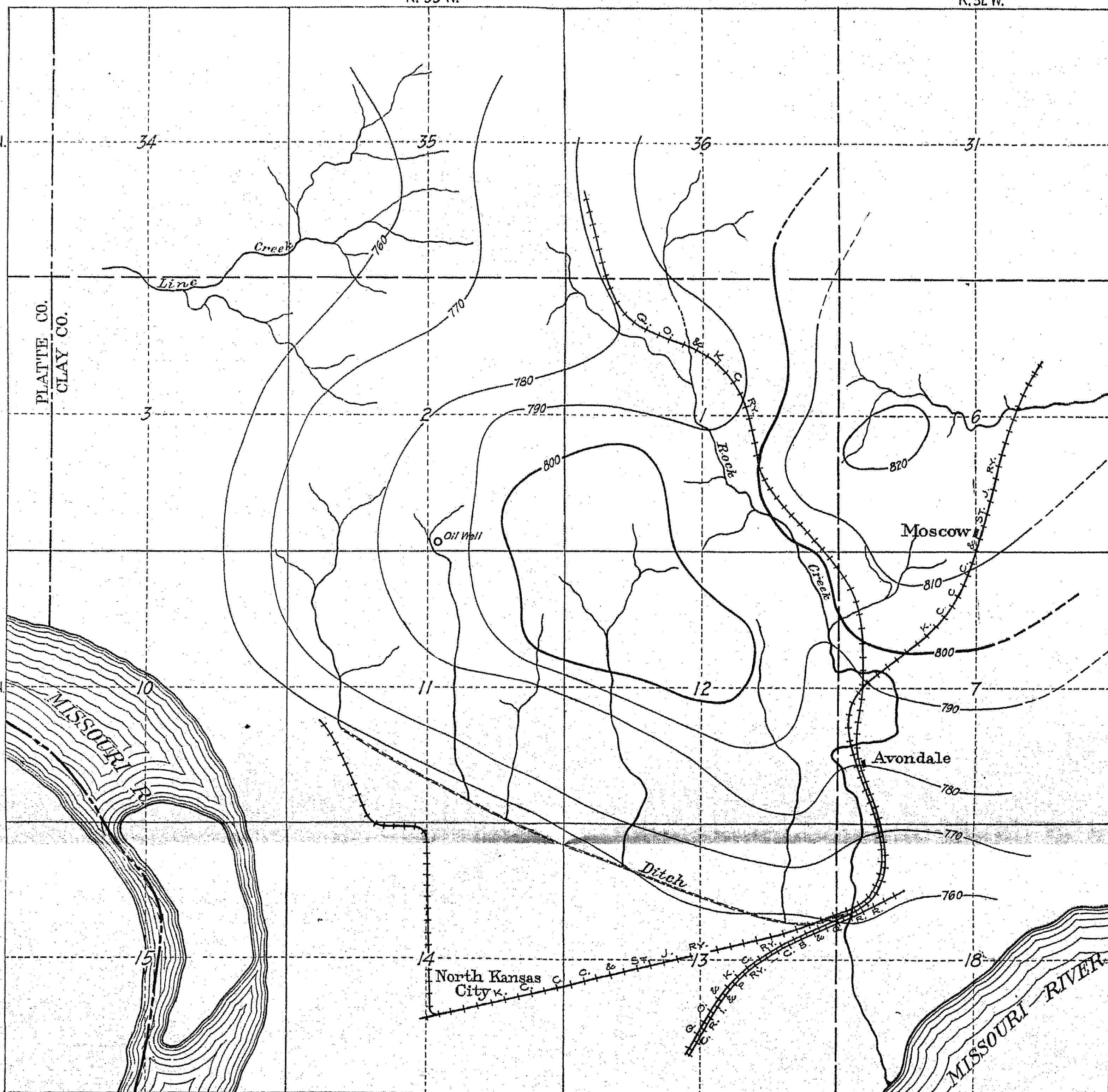

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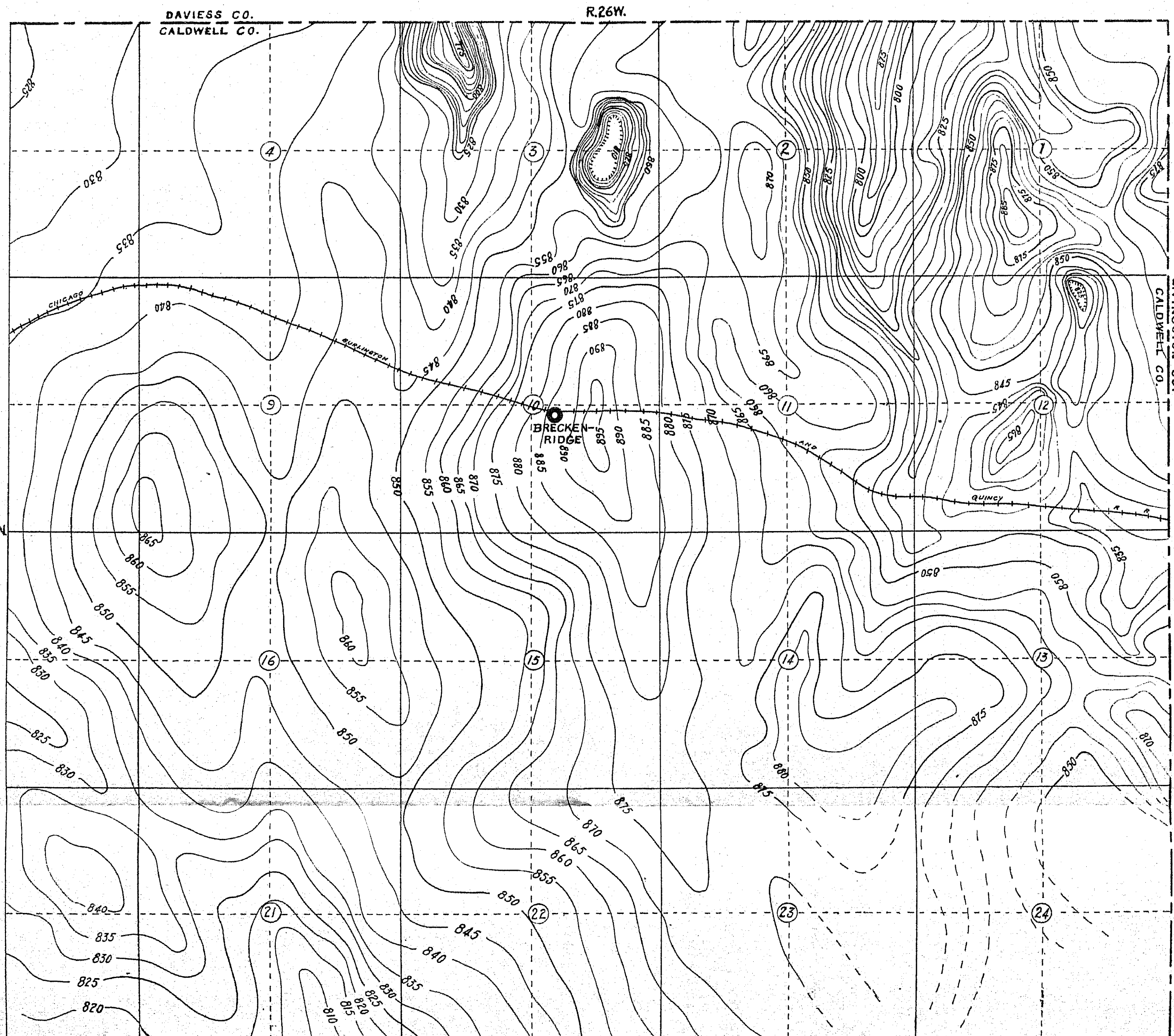
STRUCTURE MAP OF THE BRECKENRIDGE AREA, CALDWELL CO.

(Contours on top of Bethany Falls Limestone)

Scale: 2 Inches = 1 Mile

Contour Interval 10 Feet



Geology – C. W. Studt
Plane Table – C. O. Reinoehl

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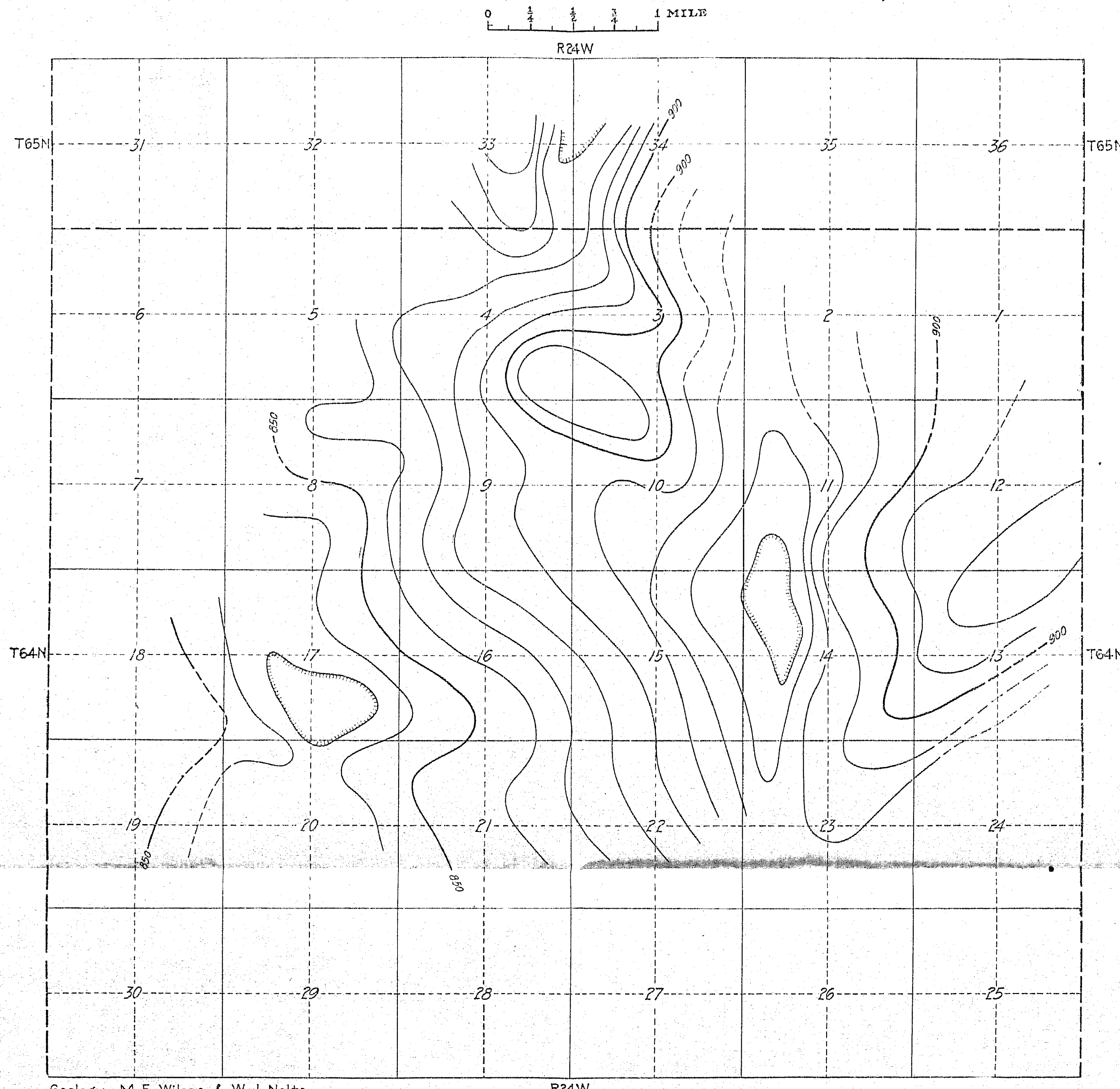
STRUCTURE MAP OF PRINCETON AREA MERCER COUNTY

(Contours on top of Bethany Falls Limestone)



Geology – M. E. Wilson & W. J. Nolte
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Missouri Bureau of Geology and Mines,
Rolla, Mo., Oct. 1, 1922.

To the President, Governor Arthur M. Hyde, and the Members of the Board of Managers of the Bureau of Geology and Mines:

Gentlemen: I have the honor to transmit herewith a report by Mr. M. E. Wilson on The Occurrence of Oil and Gas in Missouri.

The possibility of finding commercial quantities of oil or gas in Missouri has been the subject of more or less interest for over half a century, and this interest has increased with the remarkable developments in the adjoining states both to the west and to the east. In recent years this Bureau has received a greater number of requests concerning the occurrence of oil and gas than for any other mineral resource, in spite of the fact that the State is not an important producer of either fuel.

Large sums of money have been and are being spent in test wells, one or more of which have been sunk in over half the counties of the State.

As large areas of the State are underlain by geological formations that are not favorable for the production of oil and gas the geology has been discussed in considerable detail; especially is this true of those counties in which showings have been found.

There are several obvious and justifiable reasons why general interest has been maintained in the oil and gas possibilities of the State. An important production is obtained in the eastern tiers of counties in Kansas from pools located a relatively short distance west of the Missouri line. The general strike of the rocks in this region is from the southwest to the northeast into Missouri, and the trend of the producing territory has followed this strike. The Pennsylvanian rocks underlie approximately 25,000 square miles of the western and northwestern parts of the State and are a direct northeast extension of the same formations so richly productive in eastern Kansas. They are, in most respects, very similar, both lithologically and structurally, to the Pennsylvanian formations in Kansas, though nowhere do they reach the maximum thickness found in that State.

In many western Missouri counties in the Pennsylvanian area extensive outcrops of asphaltic sandstone occur, and these, together with a large number of shallow gas wells and a smaller number of wells from which some oil has been recovered, have created and maintained much interest in this region.

In the past much drilling has been done in areas where there is practically no possibility of striking either fuel. Drilling is now being carried on in various parts of the State and no doubt many holes will be sunk in the future, and it is hoped that the present report will prove a valuable guide in prospecting and may be the means of directing development in a systematic way to those areas considered favorable, and discourage test wells in those parts of the State in which there is no hope of final success.

Only the general features and possibilities can be outlined in a report of this character. The lack of producing pools places practically all drilling in the nature of "wild-catting," and before any campaign of development is undertaken a reliable geologist should be employed to advise regarding the favorable or unfavorable geological features of the particular area under consideration.

Respectfully submitted,

H. A. BUEHLER,
Director and State Geologist.

CHAPTER I.

THE ORIGIN AND ACCUMULATION OF OIL AND GAS.

There has been so much excellent literature published on the history, origin, composition and accumulations of oil and gas that it is not the intention herein to discuss these or kindred subjects at any length. The various reports on these subjects can easily be obtained by those desiring them. As Missouri is not an important producer of either oil or gas, it is primarily the intention in this report to discuss only the geologic and geographic occurrences of these fuels known at the present time in the State. However, there are certain general features relative to the occurrence of oil and gas which have an all-important bearing on some of the deductions relative to deposits in Missouri, and these features are briefly outlined in this chapter. For exhaustive discussions the reader is referred to the various text books on the subject or to the reports published by the Geological Surveys of such large oil and gas producing states as Kansas or Oklahoma.

It is needless to emphasize the present importance of oil and gas or the many industries entirely dependent upon a large and constant supply of these fuels. Not more than half a century ago petroleum was a relatively unimportant commodity which played little or no part in the industrial life of the nation and there was probably no conception of its future prominence. Although known and utilized to some extent by the earliest civilized peoples of which we have any knowledge, their uses of petroleum were naturally simple. Biblical accounts furnish evidence that some quantities, probably small, were used in religious services. Industrial uses were as a cement for bricks and tiles in building, in lining cisterns and granaries and in making the hulls of vessels water tight. The Egyptians also are said to have used it extensively in embalming and to it is accredited largely the remarkable preservation of the old Egyptian mummies. The Persians are known to have used some quantities in a crude way for heating and cooking.

At the present time petroleum is being produced on every continent and still new deposits are being sought the world over. In spite of the fact that the United States leads all other countries in the production of both petroleum and natural gas, our supply is not sufficient to satisfy the demands of the nation. It is well known that the largest oil fields become exhausted in time and with the present rate of consumption anxiety is expressed on all sides for our future supply of these fuels.

ORIGIN OF PETROLEUM.

A number of theories for the origin of petroleum have been advanced but all are not agreed as to which should be accepted as correct. Theories fall under two classes, one of which postulates the origin of petroleum from inorganic sources, and the other from organic sources. Today a very great preponderance of those who have studied the subject favor the organic theories and it is probably true that the inorganic theories have proportionately fewer adherents now than formerly. The rather general acceptance of the organic theory has been brought about largely by enlightenment on the geologic occurrence of petroleum, though a more thorough study of the chemistry of oils in recent times has also brought supporters to the inorganic theory. The substance of the two theories may be briefly outlined as follows:

Inorganic theories:—The inorganic theories for the origin of oil have been advanced by chemists and the original theories at least were evolved without particular attention to geologic conditions under which oil is now known to occur in the rocks. The earliest theory is that of the French chemist Berthelot who suggested that petroleum might be produced by purely chemical action on uncombined alkali metals, which existed in the interior of the earth under high temperatures. Later, in 1877, the Russian chemist Mendeljieff proposed a theory which has been much considered and which postulated the formation of petroleum by the reaction of water on masses of metallic iron and also on metallic carbides, which he supposed to exist deep in the earth's interior at high temperatures.

Objections to these theories have been offered in that they are not supported by the geologic occurrence of petroleum. If petroleum was formed in the manner postulated by these theories it would be natural to suppose that oil and gas would occur more commonly in the older rocks than in the younger which is in direct opposition to the actual facts. It could also be concluded from them that oil should be found in the igneous rocks, and it is well known that practically no commercial deposits of petroleum have been found in igneous rocks. It might also be expected that, in regions of great disturbance and faulting where exceptional opportunities are afforded for the escape of oil from deep-seated sources, showings of petroleum would be abundant. This also is not the case, and these considerations have done much to rally supporters to the organic theories which have no such obstacles in the way of their general acceptance.

Organic theories.—There are many theories for the organic origin of oil, but most of them differ only in details and are fundamentally very similar. They are all based on a source of supply for the oil in the organisms which have been imbedded in the rocks. However, some hold that the oil is derived from vegetable life, others from animal life, while still others hold that it has been derived from both animal and vegetable remains in the rocks. The earliest theories were based on a source of supply from the remains of plants associated with the coal deposits. The abundance of plant life during certain geologic periods was well known and natural gas has been found in coal beds at many localities. However, the great deposits of petroleum are not directly associated with deposits of coal and the type of oil produced from the distillation of coal is chemically very different from petroleum. It is believed by some that asphaltic oils are mainly derived from animal remains, and the paraffin oils from plants. Coal has been produced from terrestrial vegetation which was certainly not sufficiently abundant throughout all of the geologic periods to have produced the wide geologic distribution of petroleum deposits. It seems, therefore, in postulating the source of petroleum from plant remains, that marine plants must be looked to with greater favor than terrestrial plants. Marine plant life also has been abundant, and it is believed that some of our great deposits of oil can be directly traced to these. It is also known that some sea plants give rise to petroleum through decomposition. There is, therefore, good reason to believe that a part at least of the petroleum deposits have been derived from the remains of marine plants.

There are a very large number of adherents to the theory that petroleum is derived through the slow decomposition of animal matter which has been imbedded in the rocks. Much weight is given to this theory by the fact that animal matter can be converted into oils similar to petroleum in the laboratory, that animal remains are very abundant in the rocks from which the oil is produced, and that the process of conversion of certain of the animal parts into mixtures of hydrocarbons is not difficult of explanation. In fact, there is not much doubt on the part of many students of the subject but that some of our great oil deposits were derived from the remains of animal organisms in the rocks.

There are objections to the theory of exclusive origin of oils from animal remains the same as to the theory of exclusive origin of oil from vegetable remains, which have given rise to compromise theories, suggesting that both have played their part in furnishing a source of supply for the petroleum. In fact, some think that oil has been derived from both sources and have gone so far as to contend that the oil having been derived from vegetable remains could be distinguished from that having been derived from animal remains by a difference in composition.

Regardless of the type of life from which the oil may have been derived or of the differences in the methods of converting the organic remains into oil by natural processes, the organic theories for the origin of oil conform best to the geologic occurrence; and the associations of petroleum may be considered to have marked preference for the organic over the inorganic theories.

ACCUMULATION.

MOVEMENT OF OIL IN ROCKS.

From an initial stage of sparse dissemination through the oil-forming rocks it is a long step to the collection of a commercial deposit of oil in the reservoir rocks. This step involves first of all the forcing of the oil out of the more compact shales in which it is assumed to have been formed, into the more porous rocks which constitute suitable reservoirs for the accumulations. Secondly, the oil must migrate through the porus strata to points of collection. The main factors affecting the movement of oil from its place of formation to the points of collection are probably gravitatation, capillary attraction, rock pressure, gas pressure, flowage of water and the difference in the specific gravity of oil and water. There are other causes of the movement of oil and, of course, many factors which enter to influence the movement, but under these headings the main principles of movement may be outlined.

Gravitation. Oil is naturally subject to the force of gravity the same as all other substances, and where more effective forces are not involved, it will respond to the pull of gravitation. Thus in rocks which are dry and sufficiently porous for the easy movement of a viscous fluid, oil will descend until some barrier to its movement is encountered. However, the rocks commonly contain more or less water and it is probably very exceptional to find decidedly porous rock which is dry. For these reasons gravitation has not exerted nearly so strong a direct influence on the movement of oil through rocks as have other causes, though it is more indirectly a most important factor. The rare occurrence of oil pools in synclines or basins in the rocks, which would be brought about directly by the force of gravity are far less common than occurrences beneath anticlines or upwarped arches where the accumulation has been brought about by forces tending to counteract the natural effect of gravity on oil.

Capillary attraction. Capillarity, which causes oil to rise in a lamp wick or ink to be absorbed in a blotter, affects all liquids and is a very important factor in the movement of oil in rocks. The effect of capillarity in causing the movement of oil is much greater than that of gravity, though it is effective only in the finer grained rocks, and ceases to be a factor of movement in very coarsely porous rocks. As a direct factor it is also of greatest importance in dry rocks. The capillary attraction of water is much greater than that of oil because of the greatly superior surface tension possessed by the former. When these two liquids are present in the same rocks this difference is an important factor in causing a selective movement of the oil and water in that the water is drawn into the finer-grained rocks with the consequent expulsion of the oil. It is believed that in this manner, a large part of the oil has been forced from the fine shales in which it has been formed into the more porous rocks through which it may move by other forces to the point of accumulation. Capillarity plays its most important role probably in effecting such a movement as this, as it is not considered to have equal importance with other forces in bringing about a far-reaching migration of oil.

Rock pressure. Rock pressure, the pressure at any point due to the weight of the overlying rocks, is also responsible in some degree for the movement of oil. Particularly such rocks as shales are subject to compacting by virtue of the great weight of the overlying beds, and normally their weight increases directly with depth. The effect of such pressure on the shales is to reduce or to close the pore space originally present, with the consequent expulsion of at least a part of any oil contained. In this manner oil may be driven from the shales in which it was formed into the pore space of more resistant rocks such as sandstone.

Difference in the specific gravity of water and oil. It is generally conceded that probably the most important agent in effecting a general movement of oil through the rocks, is water, and that the movement is caused chiefly by the difference in specific gravity of the two fluids. In rocks containing both oil and water, the oil being the lighter is naturally forced upward by the pressure of the water toward the surface. In this manner it may rise along inclined porous strata for long distances to some point where the pressure is relieved or where it is trapped. Capillarity and rock pressure as well as other causes may affect the local movements of oil, gravity under special conditions may cause oil to move through porous rocks for considerable distances, but the presence of water and oil in the same rocks and the difference in the specific gravity of the two probably take first rank in causing a general, broad migration of oil to points of accumulation.

Gas Pressure. The pressure resulting from the formation of gas may be responsible for more or less movement in the accumulation of oil.

Water Flowage. After entering the more porous rocks the flowage of water may be responsible for the transportation of both oil and gas, the fuels being carried along mechanically with the movement of the water.

FACTORS NECESSARY FOR ACCUMULATION OF COMMERCIAL POOLS.

In considering the possibilities for finding commercial deposits of oil or gas in any region there are certain fundamental geologic requirements which are of vital importance. These are:

(1) Source: A source from which the fuels may be derived.
(2) Reservoir or a stratum of rock which is capable of storing a commercial supply in its pore space or openings.
(3) Cap rock or an overlying bed of rock so impervious as not to permit the upward escape of the oil.
(4) Structure: Some structural or textural condition of the rocks which favors a local accumulation.

These obvious requirements have been outlined time and again and they form the key-points upon which the present scientific search for oil is based. In order that a commercial deposit of oil or gas be brought about, each one must play its part, for the lack of any one of these requirements would make the occurrence of such a deposit impossible. The careful application of these simple principles to the geology of Missouri or to that of any other region may explain many costly failures in localities where study easily points out the absence of one or of all of the prerequisits of an oil or gas field. It is, of course, not always possible to predict the presence or absence of each of these conditions and there are regions where initial prospecting must be carried on somewhat in the dark. However, in some areas it is entirely possible to state that some one or more of the requirements are definitely lacking and in many regions it is possible to state that all of the requirements are locally present.

Source:—(Carbonaceous shales or limestone). While the theories of the origin of oil from organic material may not be endorsed by all, they are at least supported by an overwhelming majority of the students of the subject and may probably be considered as almost established. Upon this assumption, rocks which may form an important source of supply of oil and gas are those in which large amounts of animal or vegetable remains have been imbedded. They are chiefly the sedimentary rocks deposited in basins of water during periods when animal or vegetable life was abundant, or are rocks included in systems which are as a whole highly fossiliferous. Generally speaking, the rocks which are known to have been deposited under conditions unfavorable to the existence of life or which are not now as a whole highly fossiliferous, are rocks which do not as a rule contain a source of supply for oil and gas. However, it is probably not enough to say that rocks deposited when life was abundant or which are very fossiliferous contain sources from which large quantities of oil or gas may be derived. These rocks, considered in the aggregate, must also contain beds in which the animal or plant remains could have been buried and protected against rapid decomposition, or preserved to such an extent that the processes of conversion of certain parts into oil could have been carried on. It is generally believed that the shales derived from the finer sediments composed of muds, clays or oozes are the most favorable strata for the proper protection of the organic remains, and it is thought by many that the common source of our oil lies in the carbonaceous shales. It is certain that the great oil deposits of the Mid-Continent field are found in systems of rocks composed very largely of shales and that highly carbonaceous shales are of common occurrence in them. Also by distilling some highly carbonaceous shales large quantities of oil are obtained, and by drilling wells in the black, carbonaceous Noel shale in Missouri very small quantities of oil and gas are found which have without doubt come from a natural distillation of the organic material in the shale. While it may not be true that carbonaceous shales contain the source of all our commercial oil deposits, to them can probably be attributed the source of most of the oil. Carbonaceous limestone may also be a source where it is present in sufficient thickness to be of importance.

On this basis, it would appear that a large section of the older rocks in Missouri is probably lacking in sources from which commercial quantities of oil could be derived. Those rocks extending from the Lower Ordovician down to the granite floor are not highly fossiliferous nor do they contain any carbonaceous shales or limestones. In fact, in this entire section, representing more than 2000 feet of rocks, only one fairly persistent and important shale is found and this is not a carbonaceous shale. The oldest shale carrying a large amount of bituminous material found in Missouri is the Noel shale of either Upper Devonian or Kinderhook age, and in no system except the Pennsylvanian are such shales abundant.

However, it may be carrying matters entirely too far to assume, in the light of our present knowledge, that great sections of rocks which are lacking in bituminous shales, or practically lacking in shales of any description, and which are not highly fossiliferous, are also lacking in sources for commercial deposits of oil. It is nevertheless the case that these great sections of rock in Missouri, so far as known are nonpetroliferous throughout, while the only rocks in which significant quantities of oil or gas have been found are those containing large amounts of shale, some of which are carbonaceous.

Reservoir:—(Porous sandstone or limestone). It is evident that no commercial deposits of oil or gas could exist without the presence of porous rock strata in which large quantities of these fuels can be stored. Such a stratum of rock may be composed of sand, sandstone, limestone or dolomite, and not uncommonly small quantites of both oil and gas are found in shale. The most common reservoirs are sands or sandstones, though some of the largest deposits of oil occur in limestones which have been locally dolomitized. The ability of any of these rocks to serve as reservoirs for storage depends simply upon their porosity. Sands and sandstones usually contain a large pore space which can be filled with oil, though some tightly cemented, compact sandstones would serve no better as an oil reservoir than the more impervious shales or clays. Some limestones are naturally porous enough to store large quantities of oil, but usually limestone reservoirs have acquired their storage space through fracturing or solution, or by chemical change which has converted the limestone into a porous dolomite. Whether the oil bearing stratum is sand, sandstone, limestone or dolomite, it is very commonly referred to as the oil "sand." In oil fields where the production comes from limestone the term "lime sand" is frequently heard.

The experienced well driller can usually tell by looking at a sample of sandstone brought out of a well whether its porosity is sufficient to make it a good oil container. Therefore, in regions where no oil is produced, or in dry wells, drillers often refer to certain sandstone horizons as oil sand, probably because in their opinion the sandstone is sufficiently porous to make a good oil reservoir. This is, however, often misleading to a layman, who, upon hearing the term or upon seeing it written in a log, considers it to mean that either oil was found in the sand or probably should have been found.

Beds of rock which would form good reservoirs for the storage of oil are found in practically all the systems of rock exposed in Missouri from the Cambrian up. In fact, the Lamotte sandstone, the earliest sedimentary deposit in the State, would form an excellent oil reservoir. However, the presence of such porous rocks has in itself no significance, unless supported by other conditions vital to the formation of an oil deposit. There is no particular argument in favor of drilling a well for the purpose of penetrating certain sandstones underlying an area unless there are good reasons for believing that from some source these sandstones could have secured a supply of oil and that at the particular locality of the drilling structural conditions are favorable for an accumulation of a part of this oil. The capacity of sandstones will depend upon the size of the openings between the sand grains. When free and open the sandstones will have large capacity, but where the openings have been largely closed through cementing, the production will be small.

Cap rock:—(Impervious shale or limestone), In order that an accumulation of oil or gas be brought about in a stratum of rock it is necessary that this stratum be overlain by an impervious bed which prohibits the upward escape of the oil or gas which would otherwise result. It is obvious that a source of oil and a bed of rock in which it could accumulate would be of little value in bringing about a commercial deposit unless the oil were retained in the reservoir rock and not allowed to become dispersed through a great thickness of rock, or even to escape at the surface. Commonly cap rocks overlying the oil "sand" are shales, clays or limestones. Any of these rocks may form a suitable capping, but the cap rock may be composed of any other type of rock which is sufficiently impervious. In some regions where the rocks have been greatly disturbed, fractured and faulted there are many channels through which the oil may escape, even though shales and limestones.

Some highly faulted regions are therefore not considered desirable regions in which to prospect for oil and gas, because of the many possibilities for their escape even though they were at one time present.

STRUCTURAL CONDITION FAVORABLE TO THE ACCUMULATION OF OIL.

Regardless of how oil may have originated, it is almost certain that initially it occurred very sparsely disseminated through the rocks. Therefore, in order that a commercial deposit be formed it is necessary that the oil be collected at some point by a movement through the rock. The point of accumulation is controlled by the structural conditions of the rocks and has been brought about in most cases by the folding of original ly flat lying beds. Two of the most important factors which cause the migration of oil in the rocks are gravity and underground water. In rocks which are dry, oil, like any other liquid, will move toward the lowest points to which the openings lead. However, where the rocks are saturated or partially saturated with water, as they commonly are, the oil being lighter than the water, will be forced to rise to the highest points to which the openings lead. Therefore rocks which have been folded into a series of downwarped and upwarped arches and which

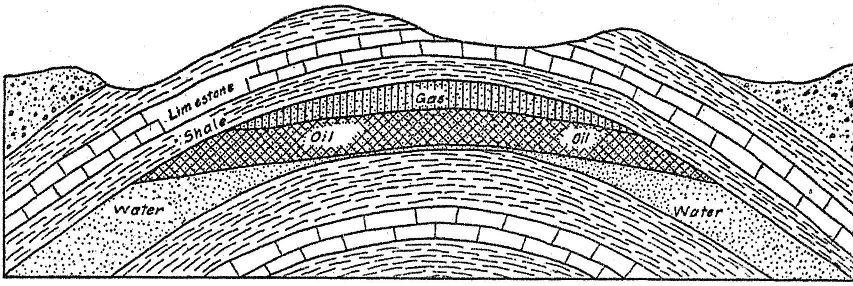

Fig.1

Anticline Showing Theoretical Position Of Gas, Oil, and Water

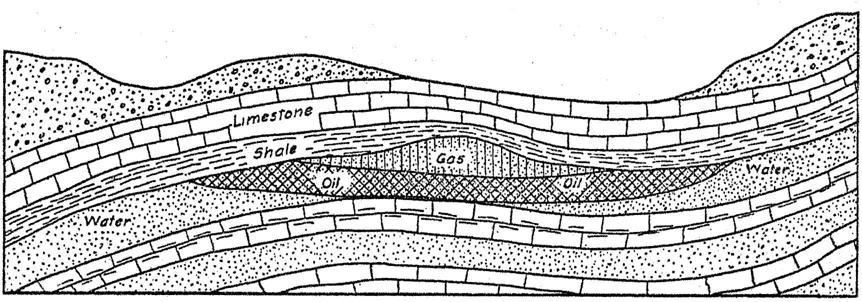

Fig.2

Terrace Showing Theoretical Position Of Gas, Oil, and Water.

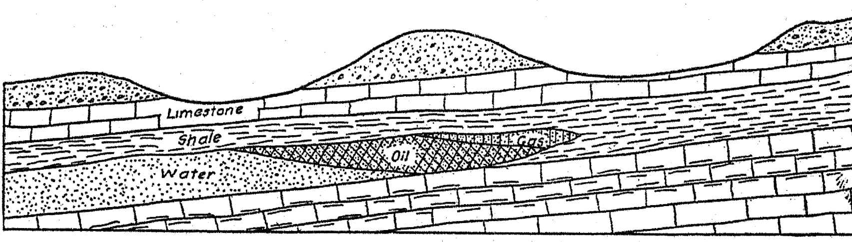

Fig.3

Lensing Sand Showing Theoretical Position Of Gas, Oil, and Water

Diagram illustrating the influence of structure on the accumulation of petroleum.

contain oil offer two possibilities for the accumulation of oil. If no water is present the oil will naturally accumulate by force of gravity in the bottom of the downwarped troughs or synclines. If the rocks contain water the oil will rise and accumulate above the water level under the upwarped arches or anticlines. As in most regions where oil is found the rocks are water containers, the oil is commonly found to have accumulated beneath the arches or in the higher parts of the porous beds where it has been trapped and forced to come to rest.

Were the folding of the strata always simple, causing a series of alternating synclines and anticlines, and the beds of rock uniform in character and not disturbed by faulting, the location of oil accumulation would be a fairly easy matter. Their location would depend generally upon whether the rocks were dry or saturated with water and the determining of the position of the synclines and anticlines. However, folding is of a very complex nature in many areas; the beds of rock change their character from one locality to another, and faulting may enter to complicate the conditions even further. The subject of geologic structure as affecting oil accumulation is therefore very complex and not easily understood without considerable study.

There are several simple types of structure which will be briefly mentioned as being most likely to affect the accumulation of any commercial deposits of oil found in Missouri. These are the anticlines, synclines, domes, structural terraces and monoclines containing lensing sandstones.

Anticlines:—The anticline is a very common type of upwarped fold. It may be described as an elongate fold in which the strata dip downward on both sides from an axis or from the crest of the fold. The fold dies away on either end and is usually roughly elliptical in outline, though its shape may be very irregular. The anticline may stand alone as a single fold or it may be flanked on both sides by downwarped folds called synclines. It may cover square miles or only acres, and may be very low or high in its vertical deformation. Such anticlines as have been found in Missouri are commonly very low and usually only to be outlined by careful observation.

Synclines:—The syncline, or depressed elongate fold, is probably of very little importance in Missouri. Though in regions of folding synclines are naturally common, the rocks are nearly everywhere saturated or partially saturated with water and accumulation of oil in the synclines would be expected only under very exceptional circumstances.

Domes:—Certain upwarped folds which have a more or less circular outline and on which the strata dip downward on all sides from a central point are commonly called domes. Usually domes are more prominent structural features than anticlines, though in some instances only arbitrary boundaries may be drawn between a structure which might be called an anticline and one which might be called a dome.

Monoclines containing lensing sandstone:—Where the rocks dip in one general direction the dip is referred to as a monoclinal dip or a monocline. Such a dip may be gentle or relatively steep, and it may extend over a very large area. However, such a dip alone, if uniform, will not affect the accumulation of oil. Some special condition of the reservoir rocks is essential to the accumulation of oil beneath the monoclinal dip; for instance a sandstone pinching out between impervious shale toward the upper edge of the dip, or grading laterally into the shale, or becoming tightly cemented to form a barrier to the passage of oil beneath the monocline. Many pools of oil have been formed under just these circumstances, but such pools can be located only by drilling as there are no surface indications in the way of structure from which the presence of the pools may be located.

Structural terraces:—The steepness of the dip on a monocline may vary, being very gentle in places, steep in other places and locally the rocks may flatten out. A place where the rocks flatten out on the dip, or where they become relatively flat would be called a terrace. Accumulations of oil are often affected by the flattening out of the rocks in this manner, many oil pools having been found beneath terraces.

CHAPTER II.

EXPLORATION FOR AND PRODUCTION OF OIL AND GAS IN MISSOURI.

EXPLORATION FOR OIL AND GAS IN MISSOURI.

The early exploration for oil and gas in Missouri was not closely followed. Practically all of the projects met with so little success that the results were not made public, and most of them were soon forgotten. The history of the exploration is, therefore, only valuable for its significance and bearing on the situation at the present time.

The first wells drilled in the state for oil or gas of which any record has been obtained, were sunk in Kansas City, Jackson County, in the late 60's following the Civil war. These wells, probably a few in number, were all shallow and resulted only in the finding of relatively light flows of gas and possibly showings of oil. In one of the wells, drilled sometime prior to 1872, at the site of the old Union Station, it is reported that small quantities of oil were obtained at shallow depths. Since the date when the first wells were drilled, Kansas City and the contiguous territory has been the seat of a great many projects launched at various times up to the present in the attempt to find larger quantities of oil and gas.

From 1870 to 1880 wells were drilled in Barton, Bates, Jackson, Ray, and Lafayette Counties, and it is probable that test wells were also sunk in Cass, Clay, and Carroll Counties, but no records have been preserved of such. The incentive for drilling in the early 70's seems to have been in nearly all cases except the Jackson County tests, the presence of outcrops of asphaltic sandstone and the associated "tar springs." Apparently led on by the belief that these sandstones and "tar springs" represented local accumulations of large quantities of oil, companies were organized, and several shallow tests wells were sunk north of Liberal, Barton County. One well, 500 feet deep, was drilled near Adrian, Bates County, a well 800 feet deep was drilled near Orrick, Ray County, and a well 800 feet deep was sunk near Higginsville, Lafayette County. None of these wells encountered significant showings of oil or gas below the asphaltic sandstones which led to the drilling.

With the beginning of the 80's, interest in finding oil and gas seems to have grown more widespread. Further prospecting was carried on in nearly all of the counties, previously mentioned, and wells were also sunk in Vernon, Clinton, Clay, Holt, Pettis, and McDonald Counties in western Missouri. In the central and eastern parts of the state tests were made in Chariton, Macon, Marion, Randolph, and St. Charles Counties. Several oil booms marked this decade of exploration, the first and most important of which seems to have followed the discovery of a small quantity of oil near Rich Hill, Bates County, in 1883. The oil found was at a very shallow depth, but when the initial well was tested it is reported that 5 barrels of oil were drawn. Great excitement followed this discovery, the price of land around Rich Hill increased remarkably and machinery was imported from Pennsylvania for an extensive drilling campaign. A large number of shallow wells were drilled in this locality in the summer of 1883 and in the following year or two, and several wells reached depths of 800 to 1200 feet. However, the sum total of the drilling seems to have been several light gas wells and several wells in which small quantities of oil were found.

Lesser flurries of excitement followed the discovery of a small quantity of oil near Richmond, Ray County, in 1886, and of gas at Independence, Jackson County, in 1887. In Kansas City a number of gas wells were drilled during the 80's but these were not sunk as a result of any particular boom. Even as early as this there was nothing new in the drilling of a small gas well in Kansas City. Interest in the locality had grown, however, and in 1886 a company was organized to sink a deep test well. This well, located near Raytown, a few miles southeast of the city, reached a depth of 2401 feet and the last 53 feet of drilling entered the granite floor. The well was not successful in finding any important oil or gas horizons. Deep wells in Clinton, Holt, Pettis, and McDonald Counties were also completed without any significant showings of oil or gas, but two shallow wells drilled near Richards, Vernon County, were successful in finding small amounts of gas. The flow was not sufficiently strong in one of the wells to be utilized, but in the other, located shortly northeast of the town, a stronger flow was secured. However, the well was never placed in use. In Clay County, a drill hole sunk in prospecting for coal at Randolph Station, encountered showings of oil and gas, but the quantity of neither was sufficient to be used. The wells drilled in the central and eastern parts of the state near Brunswick, Chariton County; Macon, Macon County; Palmyra, Marion County; Huntsville, Randolph County; and St. Charles, St. Charles County, were all dry.

The exploration during the 80's consisted all told of the drilling of 40 to 60 wells, all but a few of which were located in the west central counties from Vernon north to Clinton. Showings of oil or gas were found only in Vernon, Bates, Jackson, Clay, and Ray Counties.

The period from 1890 to 1900 marked very little if any advance over the previous 10 years, so far as new or important discoveries were concerned. In fact, a minimum of prospecting took place during this time and interest generally seemed to have waned. There were, no doubt, a few new gas wells drilled in Jackson and Bates Counties and in the latter county a flurry of excitement followed the discovery of a small quantity of oil near Adrian. The result of this was the drilling of several very shallow wells and one deep well, none of which found commercial quantities of oil.

However, following 1900, interest again revived, and in 1902-06 the Belton gas wells in northwest Cass County and the Mastin Ranch oil wells in southwest Jackson County were drilled. The latter group of five wells, although yielding only a small production and now abandoned, was the most important group of wells drilled in Missouri up to that date. In 1901 a group of shallow wells was also drilled in northwest Vernon County, near Stotesbury, from which small quantities of oil were obtained, and in the same year a group of 10 wells was sunk near Merwin, Bates County, in which oil was found but not in commercial quantities. In 1904 gas was discovered at Holt, Clay County, and a group of shallow wells was drilled which supplied the town. Later, in 1908, the Martin City, Jackson County, gas wells were drilled, and a shallow well was sunk on the Evans farm near North Kansas City, Clay County, from which a small amount of oil is still intermittently obtained. Aside from the wells mentioned a considerable number of gas wells, most of which gave light flows were added to the list in Jackson, Cass, and Bates Counties. It was also during the year 1903, that gas was discovered in eastern Missouri at St. Louis.

During this time also many deep test wells were sunk, notable among which were wells, described later, in Bates, Vernon, Caldwell, Holt, Nodaway, Harrison, and many other counties. These wells, ranging from 1100 to 2500 feet in depth, were unfortunately all failures. Drilling deep wells below the Pennsylvanian in southern Missouri is futile because of the absence of any source of carbonaceous shales or limestone in the formations below.

Since 1910 many new gas wells have been drilled from Vernon north to Jackson County but very few discoveries have been made aside from this area. The few discoveries made consist of a group of gas wells near Parkville, Platte County, drilled in 1912-14; a light gas well near Lathrop, Clinton County, drilled in 1911; three small gas wells in Barton County, near Minden, drilled in 1915; and several very light gas wells at Anderson and Noel, McDonald County, drilled in 1910-14. A group of oil wells has been drilled in southwest Jackson County, between Dallas and New Santa Fe. During the past few years over one hundred shallow wells have been drilled near Richards, Vernon County. A small refinery is being built and shipments are now being reported. Interest in exploration has been manifested in nearly all parts of the state, and during the past three years a number of test wells have been sunk.

"SURFACE INDICATIONS" OF OIL AND GAS.

Much of the prospecting for oil and gas in Missouri has been done by individuals or companies entirely inexperienced in oil operation, and competent advisors have very infrequently been consulted. An investigation concerning the reasons for locating and drilling many of the wells has been made and readily leads to the conclusion that what may be arbitrarily called "surface indications" of some type have most frequently been the cause. In fact, these "surface indications" have not only led to the sinking of many test wells by the inexperienced but they have also brought experienced "wild catters" from the various oil fields of the country to drill in many localities. Regardless of the value of these so-called indications of oil or gas it is so evident that they have and still do play such an important part in prospecting for oil as to merit some discussion. The several kinds of "indications" most commonly referred to are brieflly mentioned under the following headings:

(1) Similarity of topographic features to those of some oil-producing region.

(2) Similarity of types of surface rocks to those of some oil-producing region.

(3) Natural elevations thought to be anticlines, domes, or geologic structural features favorable for oil accumulation.

(4) Occurrence of outcrops of sandstones or limestones saturated with oil or asphalt.

(5) Tar springs and gas escapes.

(6) Scums on ponds, streams, or springs, having the appearance of oil.

Similarity of topographic features to those of some oil producing region:—Attention has very commonly been called to the fact that the surface features of some area were just the same as those of some oil producing locality in Kansas, Oklahoma, Texas, or even California. The exuberance with which this similarity seems to be so generally referred to can leave no doubt that in many cases it has been largely responsible for the excitement and hopefulness in the oil producing possibilities of the area. It must be admitted that parts of western Missouri have surface features similar to those of some oil producing regions in Kansas, parts of the dissected Ozark dome bear great surface resemblance to portions of the Osage in Oklahoma, and the lowlands of southeast Missouri look much like some oil producing areas in Louisiana and Texas. Still, the geologic conditions which are all important may not be at all comparable in the areas compared. For instance, some localities on the Ozark dome, which look like some localities in Osage County, Oklahoma, are entirely different geologically. In the former, old Ordovician or Cambrian rocks which antedate the oldest important oil or gas bearing formations, may lie at the surface, while in the latter the surface rocks are probably the younger Pennsylvanian beds. The deepest wells in the Osage have not been deep enough to reach the rocks which lie at the surface in some parts of the Ozark dome, where topographic comparisions have been made.

Thus, topographic similarity alone between an untested and a producing oil region has little or no significance, and its value was set forth some years ago in the following manner by Orton[1].

"It is obvious that all such guidance as this is entirely destitute of value, and, as a matter of fact, it is only the least intelligent location that is now made in this way. When the prospector has nothing more than this to offer in behalf of his location, it is obvious that he has no valid ground whatever for it. ****** It can bet set down with all assurance, therefore, that the superficial resemblances of untested territory to territory that has been proved productive, have no significance or value whatever. It is not worth while

[1] Orton, Edward. Occurrence of Petroleum, Natural Gas, and Asphalt Rock in Western Kentucky: Geol. survey of Kentucky, 1891, pp. 94-95.

to try to find ravines like those of Western Pennsylvania, nor drift-covered plains like those of Findlay, in or upon which to locate wells. The closest of such resemblances would not have the smallest possible significance."

Similarity of types of surface rocks to those of some oil producing region:—Besides topographic comparison, very frequently attention is called to the similarity of the kinds of surface rock found in parts of Missouri to those of oil producing regions in adjacent states. The statement that the same kind of limestone, shale, or sandstone appears at the surface in some western Missouri counties as appear in many Kansas counties in the oil fields and therefore the same rocks should occur below these to similar depths is not uncommonly advanced as a strong argument for the one area being as favorable as the other. In some areas under certain circumstances this might indeed be true, if the limestones, shales, or sandstones of the areas compared can be correlated. However, this is not always, probably not even commonly, the case, for experience has shown that these comparisons are generally based on casual observations by laymen who have no real understanding of geologic relations. For example, the limestone and shale exposures in one western Missouri county on the flanks of the Ozark dome were locally reported to be identically the same as the limestones and shales observed in Butler County, Kansas. Thus it was concluded that the underlying rocks in both counties should be about the same and the assumption formed the grounds for much local oil excitement. The facts are that the limestones and shales in the Missouri county were of Lower Pennsylvanian age while those to which they were compared in Butler County, Kansas, were Permian in age. In the Missouri localities a well sunk to a depth of 400 or 500 feet would reach the base of the Pennsylvanian rocks, while in the Kansas locality wells are sunk to depths of 200 or 300 feet or more before the top of the Upper Pennsylvanian beds is reached.

Because of the common similarity of appearance between the many different shales, limestones, and sandstones which constitute the Pennsylvanian system of rocks, it is an easy matter to make comparisons of beds occupying entirely different positions with respect to one another. For this reason such comparison should not be relied upon, for even though they be by chance correct they may have no special significance.

Natural elevations thought to be anticlines, domes, or geologic structural features favorable for oil accumulation:—In many instances elevations resulting from processes of natural erosion have been interpreted as geologic structural features constituting favorable places to prospect. A number of these so-called structures have been visited at the request of those desiring to drill on them for oil. In form they have been found to vary from the normal water divide between streams to such prominent elevations as Crowley's Ridge in the southeast lowland area, or the high mounds, which are so common in a number of the western counties south of Missouri river. So far as could be told, all of the elevations visited were purely erosional features not to be associated with local folding of the rocks. They offer no guidance whatever for propecting and do not indicate that the rocks have been folded. Weathering and underdrainage frequently removes softer beds, leaving the overlying harder stratum in a tilted condition often mistaken for structural dip.

It is a common belief that any such structure as could be produced by the arching of the rock strata should manifest itself by elevation at the surface, corresponding somewhat to the size and shape of the fold. It should be remembered, however, that most of the anticlines and domes of the Mid-Continent oil fields are very low folds, marked by gentle dips, and they are not usually revealed by surface prominence. Also the crest of an anticline may actually lie in a valley and structures may have no discernible topographic expression whatever. Experience has clearly shown that the anticlines or domes so far found in Missouri can be mapped only by the most careful geologic work.

Occurrence of outcrops of sandstones or limestones saturated with oil or asphalt:—In many parts of western Missouri sandstones and limestones outcrop which are locally more or less saturated with a heavy black oil, commonly called asphalt or tar. Naturally, these outcrops have always created much interest and have been the cause of oil excitements resulting in the drilling of a number of test wells. Such surface indications of oil as these must necessarily be considered as entirely different and of far greater possible importance than any of those previously mentioned. History records some remarkable discoveries based upon very similar surface indications in other regions and the fact that early explorers for oil in Missouri usually drilled their wells in the vicinity of these exposures finds easy and justifiable explanation. If such indications have successfully led to the discovery of important oil pools in some regions the question naturally arises, what may be their significance in western Missouri, do they signify the possible presence of commercial pools of oil in the strata beneath, or has the oil slowly migrated up the dip of the beds in which the local saturations occur, for considerable distances to the outcrop zone.

It seems evident that a number of wells have been drilled upon the supposition that the oil in the surface rocks probably arose from some more or less deeply buried source below the exposures and hence that the locality constituted an especially favorable place to drill. It is probably upon this assumption that wells 500 to 1600 feet deep have been sunk in proximity to the asphaltic rock exposures near Sheldon, Vernon County; West Line, Cass County; Adrian, Bates County; Higginsville, Lafayette County; Orrick, Ray County; and Braymer, Caldwell County.

The results of this drilling have been virtually the same. After penetrating the exposed asphaltic rock most of the wells encountered no further trace of oil, although at Higginsville similarly saturated sandstones were found shortly below the outcropping saturated beds. It would seem there had been sufficient actual drilling at and near these exposures to prove that the source of the oil which saturated the surface rocks is not to be looked for at some great depth beneath, but at some distance from the saturated outcrop in the direction of the rock dip. For instance, in counties in western Missouri bordering the Kansas line, the dip of the rock strata is to the west or northwest, and beds of rock which outcrop in the eastern townships dip downward beneath higher beds in the western townships. In some of these same counties sandstones saturated with heavy oil outcrop in the eastern townships while in the western townships wells drilled 100 or 200 feet deep encounter oil sands at virtually the same geologic horizon. Still farther west these same beds are carried by the continued dip to still greater depth, and there is no doubt but that sands at practically the same geologic horizons yield large amounts of oil in some of the Kansas fields. In other words the asphaltic sandstones of western Missouri are the outcropping edges of beds in the oil bearing formations which dip to the west or northwest, becoming more and more deeply buried in the direction of dip.

The source of the oil contained is probably the associated shales from which it has entered the sandstone and migrated up the dip of the beds to their outcropping edges. While there probably has been some little vertical movement of the oil from lower beds to those overlying, this movement has not been great. Therefore, the significance of the outcropping asphaltic rock is that at some place to the west or northwest down the dip of the strata the same beds or similar beds in the same formation may possibly be found to contain commercial quantities of oil. They do not necessarily imply deep pools of oil beneath the outcrops as it is almost certain that the source of the oil is not in rocks much, if any, older, than the formation to which the outcropping beds belong.

Tar springs and gas escapes:—In many localities in western Missouri "tar springs" occur and attention is frequently called to places where natural gas is said to escape. The "tar springs" are, of course, directly associated with the outcrops of asphaltic sandstone or limestone and consist simply of small seepages of oil during warm weather from the bedding planes, crevices, or openings, in the saturated rock. Wells sunk into the asphaltic sandstone often partially fill with oil or contain an oil scum on the water. The "tar spring" has the same significance as the asphaltic rock outcrops and any escapages of gas which may occur would probably have a similar significance. Relative to the general importance of the so-called oil or gas springs in any region, the following remarks by Orton[a] seem most appropriate.

"That surface indications (referring to oil or gas springs) may have very great value and significance in this direction, therefore, goes without saying. Do they always have such significance and value? Do all escapes of gas and oil stand for reservoirs underneath? This is an assumption that is often and most positively made, in connection with surface indications; but it is most baseless, mischievous and misleading. The truth is, that by far the greater number of such surface shows of gas and oil, probably 99 out of every 100, stand for no large accumulations whatever."

Scums on ponds, streams, and springs, having the appearance of oil:—Perhaps no mistake is so commonly made in interpreting surface indications of oil as that of mistaking the ordinary iron oxide scum which floats on stagnant or still water in ponds, springs, or streams, for an oil scum. The finding of these so-called oil scums has resulted in much excitement. The survey has been called upon to make numerous investigations of localities where surface oil seeps were reported to find the reports based entirely upon mistaken identity of scums of iron oxide for oil.

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[a]Orton, Edward. Occurrence of petroleum, natural gas and asphalt rock in Western Kentucky. Kentucky Geol. Survey, 1891.

It must be admitted that the iron oxide scum is deceptive, and in appearance does look like a scum of oil. It floats as a film on top of the water and has the iridescent rainbow colors. However, the iron film has no cohesiveness and when stirred with a stick readily breaks up in irregular pieces which have no tendency to reunite. This test probably forms the easiest method of distinguishing the material from oil which is viscous, tends to cling together and consequently does not break up like the iron scum.

There are of course, various other but much less commonly reported "surface indications" of oil.

PRODUCTION OF PETROLEUM AND NATURAL GAS IN MISSOURI.

PETROLEUM.

The amount of crude oil which has actually been marketed from Missouri wells is so small as hardly to merit discussion. Although the sale of petroleum has been reported intermittently since 1883, the total production cannot exceed a few thousand barrels, coming from about 15 wells in Jackson, Cass, Bates, Clay, and Vernon Counties. Unverified reports on the annual oil production of the State during a number of years past has shown a maximum value of about $6000, though more commonly only a few hundred dollars and often less than one hundred. From 1889-1899 the mineral statistics gathered by the U. S. Geological Survey, credited Missouri with a production of only 86 barrels a year. Since 1900, the output increased notably during two or three different years, but on the whole did not change greatly and for 1917-1918 no production at all was reported. Shipments are now being made from the shallow field in western Vernon County and this area will no doubt record the most important production up to the present time. The production is mentioned by counties in the following paragraphs.

Jackson County:—The oil produced in Jackson County has been chiefly obtained, according to report, from a group of five wells known as the Mastin group, situated in the southwest part of the county a short distance north of Belton, and from several wells in or near Kansas City. The five wells of the Mastin group, now abandoned, yielded, according to report, about ten barrels a day and approximately 300 barrels a month were shipped during the short period of their operation in about 1902. However, these wells were pumped for only a few months and since their abandonment, nearly 15 years ago, practically no sales of petroleum have been reported from southwest Jackson County. Several wells more recently drilled along the Missouri-Kansas line between Dallas and New Santa Fe have found oil and have been equipped for pumping.

In 1911, Mr. J. L. Woods Merrill reported the sale of oil from several wells in Kansas City, drilled in Big Blue River and Brush Creek valleys, to the value of $5,995, stating the average price per barrel at about one dollar. In the following year, the same producer reports no production, but in 1913, 1914, and 1916 he reports 600, 800 and 2000 barrels, respectively, produced from the same wells as in 1911. Since 1916, no production has been reported from these wells, and the statistics for the previous years could not be verified by this Bureau. The statistics collected by the United States Geological Survey in co-operation with this Bureau form the only available source of information on this production at present and it is believed that the figures may be in error. It is known that a small amount of oil has been sold locally from wells in Kansas City intermittently for many years, but aside from the production reported by Mr. Merril, the quantity has been of no importance.

Vernon County:—Small quantities of oil have been sold from one well in northwest Vernon County, near the town of Stotesbury. The well, drilled in 1901, is shallow, equipped only with a hand pump, and the oil is sold locally in small amounts to farmers. The total production is not known but must be very small.

Clay County:—Oil has been sold from but one well in Clay County. This well, drilled in 1908 and located near North Kansas City, was said to have been capable initially of producing between two and three barrels of oil per day. It is equipped with a small gasoline engine for pumping.

Bates County.—The sale of oil has been reported from only one well in Bates County. This well, near Merwin, in the northwest corner of the county, was drilled in 1886 and for a number of years following, from 8 to 278 barrels of oil per year were sold locally.

Cass County.—The oil produced and sold in Cass County has practically all come from two wells near Belton in the northwest corner of the county. From one well, operated by A. D.

Goodbar, about 100 barrels of oil per year was obtained for possibly two years by skimming the oil from the water, both of which flowed from the well. The other well, on the Rozier property, was pumped for a short time, yielding a very small daily production. All the oil was sold locally for lubricating purposes, and it is doubtful whether both wells produced more than 400 barrels. This, with the possible exception of a few barrels of oil from a very small well near Garden City, represents the total production of the county.

As to the total amount of oil produced in Missouri, few statistics are available, and only very rough estimates can be given. Aside from Jackson County, the production of Bates, Cass, Vernon and Clay will certainly not greatly exceed 1500 to 2000 barrels all told, and these figures are probably very liberal. Distributing this over a period of 33 years since the first production was recorded from Bates County, the average annual production is seen to be of relatively little importance. From Jackson County, including the reported sales of Mr. Woods Merrill and roughly estimating the sales from the Mastin wells, there would appear to be a total production of 11,000 or 12.000 barrels. This is no doubt a very liberal estimate and it is based chiefly on data and reports for which it is now impossible to obtain verification.

NATURAL GAS.

The amount of natural gas produced in Missouri during the past thirty years is of somewhat more importance than the petroleum. During the ten years from 1907 to 1917, this production was derived annually from 50 to 80 wells scattered in Clinton, Platte, Clay, Jackson, Cass, Bates, Vernon, Barton and McDonald counties. All of these wells are relatively shallow, most of them are small producers and over 90% may be called private wells used to supply the domestic needs of one or two residences. In the case of private wells, statistics relative to production and values are rarely kept with any degree of accuracy, and in many instances not kept at all. In the absence of records, many well owners fail to report their production and in consequence the figures represent only an estimate. The data collected annually by the United States Geological Survey, in co-operation with this Bureau, are as complete as can be obtained.

In 1889 the value of the gas produced, according to the statistics of the United States Geological Survey, was $35,687. This is the greatest value recorded for the last 30 years, and if correct it can only be accounted for by the use of gas from wells in and around Kansas City. During the following year, 1890, the production declined to one-third of this value, and from 1891 to 1896 varied from only $1500 to $4500 a year. In the following four years from 1897 to 1900 it ran from only $145 to $547. Up to the year 1900 by far the greatest amount of gas produced came from the wells in Jackson County in and around Kansas City. The falling off in production to a minimum for the years 1897 to 1900 is, therefore, due to the giving out or abandonment of the Kansas City wells previously drilled.

From 1902, the date when the first Belton, Cass County, wells were drilled, up to the present time the value of the gas production has varied from a minimum of $3077 to a maximum of $22,592 annually. The estimated volume of gas sold for the year of maximum production, 1908, was 152,280,000 cubic feet. During this period decided fluctuations in production were caused by the drilling at widely separated intervals of the Belton, Rich Hill, and Parkville gas wells. Each of these groups of wells for short periods supplied a comparatively large amount of gas, but through rapid failure were finally wholly or in part abandoned.

PRODUCTION OF NATURAL GAS IN MISSOURI FROM 1902 TO 1918.

Year.	Number of wells reporting production.	Value of production.	Year.	Number of wells reporting production.	Value of production.
1902	14	$2,154	1912	62	$11,595
1903	22	7,070	1913	60	6,795
1904	40	6,285	1914	61	5,319
1905	42	7,390	1915	47	5,077
1906	42	7,210	1916	53	17,584
1907	..	1,710	1917	47	8,230
1908	45	22,592	1918	40	5,548
1909	42	10,025	1919	26	3,000*
1910	49	12,611	1920	19	2,600*
1911	50	10,496			

*Estimated.

The following is a resume of the gas production by counties:

Barton County.—A small amount of gas is obtained in Barton County from three shallow wells on the Stephenson farm, 3 miles south of Minden. The gas is used to supply only one residence, although the three wells are reported to have a capacity of 250,000 cu. ft. a day.

Vernon County:—Vernon County in 1919 contained one producing gas well, located on the farm of J. M. Thurley, near Stotesbury. The well, which has a gas pressure of about 45 lbs., supplies heat and light for the farm residence only.

Bates County.—In 1917, production was reported from 30 gas wells in Bates County, from which was derived an estimated quantity of 6,343,000 cu. ft. of gas valued at $1823.00. The production from all but two of the wells was used for light and heat in residences. Two wells supplied a small amount of gas for industrial use.

Cass County.—Production statistics were received from only 6 gas wells in Cass County in 1917, but there were at least 5 additional wells in use, making a total of 11 producing wells. The estimated volume of gas produced from the 6 wells reporting was 900,000 cu. ft., valued at $270. The total production for the county was probably about 1,500,000 cu. ft. with a value of about $500. Only 6 consumers were reported to be using gas from the group of wells which once supplied Belton, and the other wells supply the needs of only one or two residences each.

Jackson County.—In 1917 there were reported 11 gas wells in Jackson County which produced 3,048,000 cu. ft. of gas valued at $937.00. The Martin City group of wells, the most important individual group in the county, was not in use during the greater part of the year, and consequently yielded only about one-eighth of their normal production. Also there was for this year no reported production from wells in Kansas City previously operated by Mr. J. L. Woods Merrill, and which yielded a considerable amount of gas. The 1917 production for Jackson County was therefore much reduced over the previous year when a production of 29,436,000 cu. ft., valued at $7,334, was reported from 20 wells. Most of the gas is used for domestic purposes, though a small amount is used in manufacturing. Martin City was supplied from the wells drilled near the town for a part of the year, but this group has now been abandoned.

Platte County.—The Parkville gas wells, which supplied the town of Parkville in 1917, yield the total gas production of Platte County. In 1917 these wells, five in number, produced 20,800,000 cu. ft. of gas, valued at $5,200. Since this year, however, the wells have gradually failed, causing three to be abandoned in 1918, and the abandonment of the project of supplying Parkville with gas seems necessary.

Clinton County.—One well drilled on a farm four miles east of Lathrop produced gas in 1917. The well supplied a single residence with heating and lighting gas, hence the production was relatively small. Very small quantities of gas have been found in several other wells in this vicinity, but the amounts have not been sufficient to be used.

Clay County.—No gas has been produced in Clay County since the abandonment of a group of five wells which supplied the town of Holt in 1912.

McDonald County.—No gas production has been reported from McDonald County in recent years and so far as known none of the several small wells which have been drilled are now in use.

St. Louis County.—The few gas wells drilled in the City of St. Louis have all been abandoned and the county has no production.

CHAPTER III.

GENERAL GEOLOGY AND STRATIGRAPHY.

INTRODUCTION.

The dominant structural feature of Missouri Geology is the Ozark dome, a large upwarped area, covering most of southern Missouri and extending into Arkansas and Oklahoma. Its surface rises above the surrounding region in nearly all directions by slopes so gentle as to be imperceptible to the eye and measurable only in long distances. The dome is the result of uplift during several periods of crustal elevation which took place slowly at widely separated intervals. Between these periods of elevation, long intervals of intensive erosion were taking place upon the area; its surface was thus being lowered and at times it was covered in part or in whole by invasions of the ancient seas. The history of the Ozark dome, therefore, covers both periods of elevation and degradation, the former being sufficient in either number or degree to overcome the latter and to produce the old highland whose granite peaks and ancient limestone or sandstone hills rise above and antedate the rocks of the surrounding plains.

Without some knowledge of this history, the geology of Missouri cannot be understood. It directly or indirectly controls or influences the distribution, thickness, position, and in a large measure the composition of the rocks exposed or reached by the drill over the greater part of the state. Its influence on these factors, therefore, extends far beyond the area commonly designated as the Ozark region, and generally speaking, only those rocks underlying the northernmost counties of the state are beyond the limits of its control. So in looking for an explanation of the general features of Missouri geology the commanding position of the Ozark dome and the relation of the origin of the various rocks underlying the State to the history of this dome cannot be overestimated.

Classes of rocks in Missouri.—The rocks found in Missouri fall on the basis of origin chiefly into two classes, igneous and sedimentary. A third class, the metamorphic, is so sparingly represented as to be relatively unimportant. The igneous rocks, formed by the cooling and solidification of molten masses, comprise the granites, porphyries, and diabase found only in the Ozark region.

The areas of igneous outcrop are relatively small and restricted chiefly to counties in the southeast part of the state. but such rocks have been reached by the drill as far north as Missouri River and as far west as the Kansas line.

The sedimentary rocks consist of a great assemblage of limestones, shales, sands, clays, and marls, which underlie nearly all of Missouri. These rocks are commonly made up of successive layers or beds, and hence are termed stratified rocks. Only in the sediments are important quantities of oil and gas likely to be contained.

Metamorphic rocks consist of either igneous or sedimentary rocks which have been completely altered by heat or pressure from their original condition. No important representatives of this class of rocks outcrop in Missouri.

CLASSIFICATION OF ROCKS IN MISSOURI.

Throughout the world, the sedimentary rocks are classified in the order of their respective ages. This classification is based on two factors: the time element, as revealed by the organic remains, and the physical conditions of deposition of the rocks themselves. These factors allow the rocks to be divided, according to their natural sequence, into systems, which in turn are divided into series, the series into groups, or into formations, and the formations into members. A system of rocks is therefore made up of two or more series, each usually comprising two or more formations, each of which may be composed of several members.

According to this classification the rocks of Missouri may be divided as illustrated in the following table, the oldest being placed at the bottom of the table and the youngest at the top.

GEOLOGIC SECTION IN MISSOURI.

Era.	System.	Series or group.	Formation.	Character of sediments
Cenozoic	Quaternary	Recent		Residual materials and alluvium.
		Pleistocene		Glacial drift, loess, and alluvium.
	Tertiary	Pliocene (?)	Lafayette	Gravel, sand, clay.
		Eocene	Jackson (?) Claiborne (?) Wilcox	Clays, sands, and marls.
Mesozoic	Cretaceous		Rocks not exposed in Missouri.	
Paleozoic	Pennsylvanian	Missouri	Wabaunsee Shawnee Douglas Lansing Kansas City For the members of these formations see page 62.	Shale, limestone, and sandstone.
		Des Moines	Pleasanton Henrietta Cherokee	Shale, sandstone, and limestone.
	Mississippian	Chester	Okaw Paint Creek Yankeetown Renault Auxvasse Carterville	Sandstone, limestone.
		Meramec	Ste. Genevieve St. Louis Salem	Limestone.

	Osage	Warsaw Keokuk Burlington } Boone Fern Glen	Limestone, chert, shale.
	Kinderhook	For formations of this group see p. 54.	Shale, limestone, sandstone.
Devonian	Upper	Craghead Creek Callaway	Shale, limestone.
	Middle	St. Laurent Beauvais Grand Tower-Cooper	Limestone.
	Lower	Little Saline Clear Creek Bailey	Chert, limestone.
Silurian	Oswegan	Sexton Edgewood Girardeau (Bainbridge?)	Limestone.
Ordovician	Cincinnatian	Thebes-Maquoketa Fernvale	Shale, sandstone, limestone.
	Mohawkian	Kimmswick Decorah Plattin	Limestone, shale.
		Joachim St. Peter Everton	Dolomite, sandstone.
Canadian or Early Ordovician		Powell Cotter Jefferson City Roubidoux	Dolomite, chert, sandstone.

GEOLOGIC SECTION IN MISSOURI—Continued.

Era.	System.	Series or group.	Formation.	Character of sediments.
Paleozoic, (Cont'd)	Late Cambrian or Ozarkian		Gasconade Proctor Eminence Potosi	Dolomite, chert.
	Cambrian	Upper	Doe Run Derby Davis Bonne Terre Lamotte	Dolomite, shale, sandstone.
Archeozoic	Pre-Cambrian	....	....	Granites, porphyries, quartzites.

DISTRIBUTION OF ROCKS ACCORDING TO AGE.

The oldest rocks exposed in Missouri are those found on the Ozark dome. Of these, the granite and porphyry peaks of the St. Francois Mountains, rising in St. Francois, Madison, and Iron counties to elevations as high as 1800 feet, are the most ancient and represent the oldest known system. Closely surrounding these are the oldest sedimentary rocks in the State—the Cambrian, composed chiefly of dolomite and sandstone. With distance from the peaks, these dip beneath younger Ordovician dolomites, magnesian limestones, and sandstones, which are still geologically old. At varying distances from the flanks, these Ordovician beds, which cover great areas of the dome, disappear beneath still younger rocks and with distance become deeply buried, and are reached only by the drill.

It is definitely known that younger sediments of the same age as those forming the plains surrounding the Ozark dome, once covered the older rocks now exposed in the dome itself. At different periods in the history of this highland it was sufficiently reduced by erosion to allow the ancient seas invading the continent to cover it wholly or in part. At other periods the seas were not sufficiently deep to inundate the area, and it remained a great land mass, rising out of the encircling waters. Therefore, a great thickness of sediments occurs beneath the plains surrounding the Ozark dome, only a part of which was ever deposited on the dome itself. The younger of these, the Mississippian and Pennsylvanian, have since been almost entirely removed by the intensive erosion which is characteristic of an elevated region, laying bare Ordovician and Cambrian rocks which are older than any rocks known to have produced commercial quantities of oil or gas.

The distribution of the younger sediments encircling and overlapping the Ozark dome is naturally irregular. Some were deposited in seas covering the entire area and their absence on the highland is due entirely to removal by erosion. Others were deposited in seas whose old shore lines rested on the flanks of the dome at different elevations. The present position of these rocks depends both on the extent of the seas in which they are deposited and on subsequent removal by erosion. This whole history of deposition and erosion has produced a complex geologic situation in and bordering the Ozark dome. Younger sediments, in places, far overlap the older. Certain beds of rocks which should occur in the normal succession of deposits are entirely absent in one place, sparingly present in another, and well represented at still another locality. Rocks of a given age at one locality consist of sandstone, at another of shale, and at another of limestone.

Because of these conditions, the rocks to be penetrated by deep drilling cannot be so closely predicted, as in a region of more regular deposition. Considerable study has of course brought to light many of the irregularities. For instance, it is known that on the northwest of the dome in such counties as Johnson, Vernon, and Barton, the Devonian, Silurian, Upper and Middle Ordovician, constituting the normal succession, are entirely absent, and the drill usually passes directly from Mississippian into Lower Ordovician. Those beds which are practically absent on the west occur in exceptional thickness on the east flank, while some beds which do occur on the west side are absent on the east. Such complexities must always be considered in attempting to correlate well records in the area surrounding the Ozark dome.

Other regions, it is true, offer similar stratigraphic problems; nevertheless, with distance from the Ozark dome, the succession of sediments becomes more complete. In northwest Missouri wells have penetrated in natural succession, Pennsylvanian, Mississippian, Devonian, and Silurian beds. In the northeast counties Pennsylvanian, Mississippian, Devonian, Silurian, Ordovician, and Cambrian strata are known to follow in natural sequence. In general, therefore, the situation becomes less complex with remoteness from the area bordering the Ozarks, though the details may offer equal difficulties.

PRE-CAMBRIAN SYSTEMS.

Distribution:—The oldest rocks in the state, those of igneous origin, occur in the southeastern part, and make up the St. Francois Mountains. They occupy a surface area of about 1200 square miles, chiefly in St. Francois, Washington, Iron, Reynolds, Wayne, and Madison counties, with outliers in Shannon, Carter, Ste. Genevieve, Bollinger, and Crawford. Although underlying all of Missouri these rocks are not known to outcrop in any other part of the state. North of Missouri River no known drill holes have yet been sunk deep enough to reach their surface. South of the river they have been reached at several points a long distance from the nearest surface exposure. The highest elevation recorded for an igneous rock peak in the St. Francois Mountains is 1800 feet above sea level. Southeast of this peak, about 70 miles, in a well near Dexter, Stoddard County, an elevation of 1700 feet below sea level was reached without encountering the granite surface. Northeast of the peak, about 75 miles, in the Insane Asylum well, St. Louis, igneous rocks were reached at an elevation of 3000 feet below sea level. In a drill hole near Sullivan, Franklin County, a depth of 1200 feet was required to reach the granite, and near Rolla, 1700 feet. In the western part of the state, the igneous rock surface has been encountered at or near Carthage, Lamar, Nevada, Monett, Osceola, and Raytown, Jackson County, and found to be at elevations of approximately 795, 870, 938, 560, 875, and 1,423 feet below sea level, respectively. At Forest City, in Holt County, a hole 2500 feet deep stopped before even reaching the Ordovician sediments, and it is probable that the greatest depth to the granite surface, in any part of Missouri, lies in the northwest corner of the state. As a result of long periods of erosion before the overlying sediments were deposited, the surface of the granite floor is so irregular that its depth may vary by several hundred feet in wells only a few miles apart.

Character of rocks—The pre-Cambrian rocks of Missouri are composed chiefly of granite and porphyry with unimportant amounts of breccia, tuff, and diabase.

In the exposed areas porphyry constitutes about three-fourths of the rock of the system, and the granite one-fourth. The granite consists principally of quartz and feldspar with small quantities of rutile, zircon, and black mica, and is usually pink to red in color, though less commonly grayish. It is extremely hard drilling and the cuttings appear usually as a fine angular gray to reddish sand, speckled with small particles of black, shiny mica. Recent drilling at Pomona, in Howell County, shows a gray granite, at a depth of 2500 feet.

The porphyry consists of small crystals of feldspar and quartz embedded in a fine-grained ground mass containing numerous small grains of iron oxide. In color it is usually some shade of red or brown, much of it being quite dark. It varies greatly in texture and is also hard drilling.

Oil and gas possibilities—The igneous rocks are not oil or gas bearing and no possibility of success will attend drilling in these formations.

PALEOZOIC DIVISION.

After the formation of the granite and porphyry, the igneous surface was carved by erosion into a very uneven floor, upon which the earliest Cambrian conglomerates and sandstones were laid down. These were followed by a succession of formations consisting of dolomite, limestone, sandstone, and shale.

In the past all of the sediments beneath the St. Peter sandstone were referred to the Cambrian, but more recent and detailed study seems to warrant subdivision of this series. Certain formations at the base of this section are definitely Cambrian. Formations lying just below the St. Peter sandstone are definitely Lower Ordovician, but between these units lies a considerable thickness of sediments, the classification of which has not yet been fully decided. Ulrich has suggested that these rocks be referred to a new system called the Ozarkian, and while this term has not been officially adopted, it will be used here, for lack of any other satisfactory name.

CAMBRIAN SYSTEM.

The lower and middle Cambrian are not represented in Missouri, and the upper Cambrian is exposed chiefly in the vicinity of the St. Francois Mountains, where it consists of about 900 feet of dolomite, shale, and sandstone, conglomeratic at the base.

In parts of the State distant from the Cambrian out-crops, a few deep wells give a general clue to the character of the Cambrian, which is marked by a thinning of the sediments, especially of the basal sandstone.

The Cambrian rocks of Missouri include the Lamotte sandstone, the Bonneterre dolomite, the Davis shale, and the Derby-Doe Run dolomites.

SUBDIVISIONS OF THE CAMBRIAN SYSTEM IN MISSOURI.

System	Series.	Formation.	Thickness and character of beds.
Cambrian...	Upper Cambrian...	Doe Run, Derby, Davis } Elvins......	50′ to 120′, chiefly dolomite and shaley dolomite. 40′, average, chiefly dolomite. 150′ to 195′, chiefly shale with beds of limestone and conglomerate.
		Unconformity.	
		Bonne Terre..........	200′ to 480′, chiefly dolomite.
		Lamotte..............	50′ to 400′, chiefly sandstone resting unconformably on the igneous rock floor.
		Unconformity.	
	Middle Cambrian..	Absent in Missouri.....	....
	Lower Cambrian...	Absent in Missouri.....	....

Lamotte Sandstone. This, the oldest Cambrian formation known in the State, rests on the very unevenly eroded igneous rock floor, this situation resulting in great variations in the thickness of the sandstone. It outcrops chiefly in northeast St. Francois and western Ste. Genevieve and Madison Counties.

The greatest thickness recorded is 400 feet in a well at Pacific, the next greatest being 355 feet in a well at Farmington, the average is much less, being about 250 feet in Ste. Genevieve County and 150 feet near Flat River. The Lamotte, so far as known, has not been penetrated north of Missouri river, except possibly in the St. Peter well, St. Charles County. In the western part of the State, deep wells show the following thicknesses, Monette 110 feet, Carthage 167 feet, Lamar 195 feet and Raytown 98 feet. A recent well at Pomona in Howell County shows about 180 feet of typical Lamotte Sandstone. Between this and the granite at 2500 feet, lies about 135 feet of pink quartzitic sandstone of quite different character, possibly Lamotte, and possibly Pre-Cambrian. The formation probaby underlies most of the State.

It is usually well-bedded, coarse to fine-grained, yellow, gray, or brown in color, and very friable to lightly cemented. The sand grains are moderately well-rounded, to sub-angular. Shale and conglomerate lenses occur, and transitional greenish dolomite beds are common near the top.

Bonneterre Formation. The only outcrops (about 200 square miles) of this dolomite are in the St. Francois Mountain region, from which it dips out in all directions, most steeply to the east, reaching a depth of 2500 feet below sea level at St. Louis; a few feet above sea level at Salem, in Dent County; and 500 feet below sea level at Carthage.

The formation averages about 350 to 450 feet thick in St. Francois County. Its thickness in wells is hard to determine, but it probably maintains at least 200 feet over large areas. It is a massive to thinly bedded, non-cherty, gray to brown dolomite, varying from fine to coarsely crystalline, and carries few fossils. Oolitic beds are common. Drill cuttings of the formation are difficult to distinguish, but are characterized best by gray to brown color, lack of chert, oolitic beds, and position above the Lamotte and below the Davis.

Davis Formation. The Davis shale, which overlies the Bonneterre, is exposed chiefly in Ste. Genevieve, St. Francois, Jefferson, Washington, and Iron counties. Drill records show it persisting as far north as St. Charles County, at a depth of over 2500 feet and as far west as Salem, in Dent County, and Newburg, in Phelps County. It has not been identified beyond these points. South of the St. Francois Mountains there is scant record of the Davis.

In outcrops it varies between 150 and 194 feet in thickness, though 225 feet were penetrated in a well at Pacific. The formation is a complex of shale, dolomite, and conglomerate. The shale is usually greenish to black and distinctly laminated, the dolomites are thin-bedded, and the conglomerates consist of pebbles of limestone in a shale or lime matrix. The pebbles are frequently closely crowded and on edge, as many as 15 beds of this "edgewise" conglomerate occurring in the lower 100 feet of the formation.

Derby Formation. The Derby, which consist of about 40 feet of gray to brown, fine-grained, crystalline dolomite, in which soft porous beds alternate with hard brittle layers, overlies the Davis conformably. Its outcrop area is limited to southeast Missouri. Owing to its lack of distinctive characteristics, it is not easily recognized in cuttings, and its general distribution beneath younger beds is but poorly known.

Doe Run Formation. The Doe Run, the outcrop of which is also limited to southeast Missouri, overlies the Derby conformably. It has probably been identified in deep wells as far north as St. Louis, and as far west as Salem, Dent County. Beyond this it has not been recognized.

The Doe Run consist of 50 to 60 feet or more of alternating beds of argillaceous dolomite, dense finely-crystalline dolomite, and soft finely porous dolomite. "Cotton rock" texture, small quartz druses, and a yellow or buff color are characteristic.

The Cambrian formations are not favorable for the occurrence of either oil or gas and drilling in them will only result in failure.

LATE CAMBRIAN OR OZARKIAN.

The Ozarkian normally includes about 1000 feet of sediments, chiefly dolomites, which rest with slight unconformity upon the earlier rocks. Surrounding the Cambrian area in southeast Missouri, these rocks are found exposed as far north as Franklin and Gasconade Counties, as far south as Butler County, and as far west as Dallas County, outcropping prominently in nearly all of the deeper stream valleys which radiate from the crest of the Ozark dome.

There is an exceptional preponderance of dolomite, there being but one well-defined sandstone, and practically no shale. At some horizons chert (flint) beds predominate, though thick sections of non-cherty dolomite occur.

SUBDIVISIONS OF THE OZARKIAN IN MISSOURI.

System.	Formations.	Thickness and character of beds.
Late Cambrian or Ozarkian......	Gasconade............ Unconformity.	100′ to 300′, chiefly dolomite with chert. A thin sandstone; the Gunter at the base of the formation.
	Proctor .... Unconformity.	60′, chiefly dolomite which contains very little or no chert.
	Eminence............. Unconformity.	200′, very cherty dolomite.
	Potosi................ Unconformity.	250′ to 300′, siliceous cherty and drusy dolomite.

Potosi Dolomite. The Potosi consists of 250 to 300 feet of gray to buff, very cherty dolomite, particularly characterized by remarkably abundant quartz druses, and by thick beds and irregular honey-combed masses of chert; it being the oldest formation in the State in which chert is abundant. The dolomite varies from finely to coarsely crystalline, is very soluble and cavernous, and yields a deep reddish soil that is highly characteristic. There is a slight unconformity at its base.

The formation has a wide outcrop about the St. Francois Mountains, from Crawford County on the north to Wayne on the South. It is probably identifiable in wells as far west as Dent County, and east to St. Louis, where it was reached at 2800 feet.

Eminence Formation. The Eminence varies from a few feet to about 200 feet in thickness, owing to unconformities at base and top. It is a very cherty dolomite, typically exposed in Shannon, Carter, Reynolds, and parts of Jefferson, Franklin, Washington and Ste. Genevieve Counties, and doubtfully present in Camden and Morgan, but thus far not identified in other parts of the State.

Proctor Formation. The Proctor, locally absent, reaches a maximum thickness in outcrop, of about 60 feet in the type locality in Miller, Morgan, and Camden counties, being thinner in Carter, Shannon, and Washington. Elsewhere it does not appear to have been recognized.

Lying between cherty formations, it is characterized by being non-cherty, hard, bluish gray, pinkish, yellowish, or greenish dolomite; usually dark gray in well cuttings. It is medium to coarse grained, porous, and cavernous.

Gasconade Formation. The Gunter sandstone, the basal member of the Gasconade, varies from practically nothing to 36 feet. It consists of white to brown or reddish, fine to coarse grained, friable sandstone, with fairly well-rounded grains. Its type area is in Camden, Morgan, Miller, Dallas, and Benton Counties, particularly along the Osage and Niangua Rivers. Owing to unconformity at its base it is patchy and locally absent but deep drilling has shown its presence throughout the southern part of the state and as far north as Boone and Randolph Counties.

The dolomite member of the Gasconade overlaps from Gunter onto Proctor, Eminence and even Potosi. Bordering the St. Francois Mountain area, it caps the divides, dipping away under the higher rocks, but is exposed in most of the deeper valleys of the Ozark dome, such as Gasconade, Osage, White, Current, and Meramec Rivers, in most of the counties from Dallas and Benton on the West to Ste. Genevieve and Bollinger on the east, and from Franklin, and Miller on the north to Ripley and Ozark on the south. It has been reached by the drill as far as west Carthage and Nevada, and as far north as Baring, Knox County.

Varying from 230 to 300 feet in thickness, the Gasconade is massive gray to white, very crystalline, cherty dolomite, outcropping in rough crags and cliffs, and marked by caverns, sink holes, large springs, and cherty soils. A variety of cherts occur, bedded white types, oolitic at places; lamellar cryptozoan varieties; coarsely cellular cherts; and a variety, probably organic, resembling intertwined rope. In drill cuttings the Gasconade is granular, or sugary, and is sometimes mistaken for sandstone.

The Ozarkian beds are practically without oil or gas possibilities in Missouri.

CANADIAN (OR EARLY ORDOVICIAN)

The rocks of the Ordovician system differ materially from the Ozarkian below in being of extremely complex composition, and include pure limestones, shales, sandstones, magnesian limestones, and dolomites, one or two of the formations being very complex. Deposition was not continuous throughout the period and one very marked unconformity occurs. The early Ordivician has therefore been separated and called Canadian and this division has been followed in the present report.

The full thickness of these rocks, if the maximum of each formation existed in a single section, would be more than 2000 feet. This condition is approximated, but not reached, in deep wells in eastern Cape Girardeau and Perry counties. Elsewhere in the State the higher formations, especially, are absent or fall far short of their maximum development.

SUBDIVISIONS OF THE ORDOVICIAN AND CANADIAN SYSTEMS IN MISSOURI.

System.	Series.	Formation.	Member.	Thickness and character of beds.
	Cincinnatian	Thebes-Maquoketa		Shale and sandstone, in places thin flaggings of limestone.
		Fernvale unconformity		0′ to 4′ limestone.
		Kimmswick		40′ to 100′ crystalline limestone.
Ordovician	Mohawkian	Decorah		0′ to 30′ shale with thin seams of lime stone.

SUBDIVISIONS OF THE ORDOVICIAN AND CANADIAN SYSTEMS—Continued.

System.	Series.	Formation.	Member.	Thickness and character of beds.
		Plattin unconformity.		160′ to 690′ fine-grained limestone.
		Joachim		0′ to 365′, chiefly dolomite.
		St. Peter		35′ to 175′ white quartz sandstone.
		Everton unconformity.		0′ to 100′ white quartz sandstone and sandy cross-bedded dolomite.
Canadian.		Powell		100′ to 1000′, chiefly dolomite with chert and thin seams of sandstone, and beds of "cotton rock."
		Cotter		
		Jefferson City		
		Roubidoux unconformity.	Bolin Creek sandstone	60′ to 250′ sandstone, dolomite, chert, and "cotton rock."

CANADIAN.

Roubidoux Formation.—The Roubidoux occupies the greatest surface area of any formation in the Ozark region. East of St. Clair, Dade and Barry Counties it outcrops in nearly every county to Mississippi River; occupying the stream valleys about the margins of this area, but capping the divides widely in Crawford, Dent, Shannon, Reynolds, Carter, Wayne, Butler and northern Ripley Counties. The formation is believed to underlie practically all the remainder of the State being penetrated by the drill as far north as Knox County, as far northwest as Livingston County, as far west as Pittsburg, Kansas, and as far southwest as Miami, Oklahoma. In the northwest part of the State it lies below the deepest drilling.

The Roubidoux everywhere carries some sandstone, in some sections being dominantly sandy, in others dominantly limestone. The similarity of the limestone beds to formations both above and below, as well as the presence of similar sandstones at higher horizons, makes it difficult and often impossible to estimate the thickness from drill cuttings. Prof. Shepard reports as much as 300 feet in deep wells at Springfield. Measurements on the outcrop vary between 70 and 160 feet, possibly running to 200, but the average is nearer 100 feet.

The Roubidoux is the most variable formation of the Canadian series, nearby sections differing widely. In general, sandstones are dominant, though locally they make up less than one-fourth of the total thickness. Dolomite is abundant, varying from the coarse granular type of the underlying Gasconade to the fine argillaceous "cotton rock" of the overlying Jefferson City. Chert beds are common, locally reaching 40 feet in Miller County. Much of the chert is porous, some is cellular, and some oolitic, the beds commonly being brecciated.

The sandstone members, varying from a few feet to 50 feet in thickness, are well-bedded, notably cross-bedded, ripple-marked, and sun-cracked. The grains, which vary from coarse to fine, were originally rather well-rounded, though secondary quartz-enlargement gives an appearance of angularity in many samples. The rock varies from friable to quartzitic, and though gray to white on fresh surfaces, weathers red or brown, giving iron-stained soils.

The Roubidoux is one of the most important water-bearing horizons in Missouri.

Jefferson City Formation.—Above the Roubidoux, with apparent conformity, is the Jefferson City formation, followed in order by the Cotter and Powell. In older reports, these were all grouped under the one name Jefferson City; and owing to the difficulty of distinguishing these three, the term Jefferson City is herein used in its older unrestricted sense, to include all the beds above the Roubidoux and below the St. Peter.

As thus defined, the Jefferson City is exceeded in area of surface exposure in the Ozarks only by the Roubidoux. From Bollinger to Ripley Counties it is absent on the southeast flank; it forms a narrow belt on the east; and caps the divides more widely on the north, west, and south flanks. It is the oldest formation exposed north of Missouri River, and probably underlies the entire State north and west of its outcrop. Its maximum thickness is attained on the south flank; the drill penetrates 500 feet in Jasper County and 600 feet in Newton; on the east flank 500 feet is exposed; and to the north and northwest the average is 250 to 400 feet.

Although more uniform than the Roubidoux, the Jefferson City represents considerable diversity of shallow water deposition. Dolomite makes up a large part of the formation, varying from rather crystalline, mottled, rough-weathering pitted dolomite to fine-grained, argillaceous, gray to buff earthy "cotton rock." Chert nodules and beds of oolitic chert are common. Thin lenticular, rather fine-grained, well-cemented, slabby, gray to buff sandstones are present at several horizons, rarely reaching over 5 or 10 feet in thickness, though a persistent sandstone in the Cotter division occurs in Bollinger County, and has been traced across the southern and southwestern counties, where it reaches a thickness of at least 20 feet.

ORDOVICIAN

LOWER

St. Peter Sandstone.—The St. Peter rests unconformably on the unevenly eroded Jefferson City. Recent work has separated a dolomite and sandstone in the lower St. Peter of Ste. Genevieve and adjacent counties, as the Everton formation, but the term St. Peter is here used in the older sense to include these beds.

South of Missouri River, the St. Peter outcrop is probably confined to a narrow belt beginning in southern Cape Girardeau County, and extending north and northwest to Crystal City, Pacific and Klondike, thence west to Callaway County, where it passes beneath younger beds, and shows only as isolated patches, disappearing completely in a short distance. From Brewer, in Perry County, north to Missouri River, the St. Peter and overlying Joachim form a well-defined escarpment, facing the Ozark region. The formation is brought up by faulting in Lincoln County. Over the crest of the Ozarks many patches of sandstone once referred to the St. Peter are now considered to be Pennsylvanian. North of Missouri River, the St. Peter underlies all the area west to Moberly and Kirksville, but west of this evidence is uncertain, the records of the deep wells at Chillicothe and Marceline being very incomplete.

Owing to its unconformable base, the thickness varies suddenly and irregularly, from 10 to possibly 175 feet being reported, the average, including the Everton, lying between 75 and 125 feet. It is a massive, very slightly cross-bedded, friable white sandstone, sometimes iron-stained on the surface, composed of medium to coarse well-rounded and etched quartz grains of remarkable purity. From Jefferson County south a dolomite wedge separates the basal sandstone from that above, the dolomite and lower sandstone constituting the Everton. Thin shale seams occur at the contact with the Joachim above, and locally with the Jefferson City below.

The St. Peter is an important water-bearing horizon, best distinguished in cuttings by its remarkable purity and well-rounded and frosted grains.

Joachim Formation.—Above the St. Peter, the Joachim consists chiefly of thin to thick-bedded, non-fossiliferous, fine-grained to non-crystalline gray to buff dolomite, somewhat resembling Jefferson City "cotton rock." The formation carries little chert, but is sandy at the base. The Joachim caps the St. Peter escarpment from Callaway to Cape Girardeau County. Small outcrops occur in Lincoln County.

In outcrop along the escarpment it varies from 5 feet to 150 feet in short distances, owing to unconformity at the top, but thickens remarkably down the dip eastward, being about 50 feet on the outcrop at Pacific, and 120 feet in the Shorr-Kolkschneider Brewing Company's well in St. Louis. At Jackson 275 feet of Joachim was encountered in the Jackson Produce Company's well, and 365 feet in the State Normal School well at Cape Girardeau, while west of Cape Girardeau at Dutchtown, on the outcrop, it is again much thinner.

MOHAWKIAN SERIES.

Plattin Formation. The Plattin, partial equivalent of the Lowville and Black River, lies unconformably on the Joachim, and is a typically fine-grained gray to bluish pure limestone, carrying some chert, and locally argillaceous at the base. It is heavily-bedded and weathers with smooth rounded surfaces, commonly etched by solution into a coarse honey-comb structure that is extremely characteristic.

It occurs on the upland behind the St. Peter-Joachim escarpment, from Cape Girardeau to Callaway Counties, and is brought up by faulting in Lincoln County. It is not known either in outcrop or by drilling from the south or west flanks of the Ozarks. In Perry County the areas of Joachim and Plattin are marked by numerous sink holes and small caves.

Like the Joachim, the Plattin thickens eastward, down the dip, about 100 feet being exposed at Pacific, and 240 feet penetrated by the drill in St. Louis. At St. Marys the Schaff Milling Company well penetrated 325 feet of Plattin, at Jackson drilling shows 275 feet, and at Cape Girardeau about 690 feet. Underlying northeast Missouri, it is shown by drilling to vary from a few feet up to 175 feet.

Decorah Shale. In Jefferson and Ste. Genevieve Counties a very fossiliferous blue or green shale, with limestone beds, the whole not over 30 feet thick, and commonly considered the top of the Plattin, is the probable equivalent of the Decorah of the Iowa section.

Kimmswick Limestone. The Kimmswick, or "Receptaculite" limestone, resting above the Decorah or Plattin, consists typically of 70 to 100 feet of coarsely-crystalline very pure non-cherty limestone, white, gray, or pinkish in color, characterized by open water-enlarged joints, by honey-comb structure due to easy solubility, and by the abundance of the "sun-flower coral," Receptaculites.

This formation borders the Plattin on the east, in a very narrow belt from Cape Girardeau County to Callaway County, dipping eastward below younger beds. It is also exposed along the disturbed belt in Lincoln, Pike, and Ralls Counties. It is entirely absent from the south and west flanks of the Ozarks, and has not been encountered in any of the deep wells of the northwestern or north central part of the State, but underlies the northeastern part.

CINCINNATIAN SERIES.

Fernvale Limestone. A limestone from a few inches to 3 or 4 feet thick, carrying typical Richmond fossils, unconformably overlies the Kimmswick, which it closely resembles, and with which it is here included. It is known from Jefferson to Cape Girardeau Counties.

Thebes-Maquoketa Formation. The Thebes-Maquoketa, at one time incorrectly correlated with the Hudson River of the East, is the equivalent of the Maquoketa of Iowa. In Cape Girardeau County, the Thebes is an impure shaly sandstone. Further north in Ste. Genevieve County the lower 20 feet is impure sandstone, overlain by 30 or 40 feet of shale. At the Schorr-Kolkschneider Brewing Company's well in St. Louis, it consists of 120 feet of gray to blue shale. In Pike County it is made up of 100 feet of blue clay-shale, with thin limestone layers, the typical Maquoketa phase. In Pike and Ralls, a higher shale of similar appearance is separated from the Maquoketa by an inconspicuous limestone. These two together extending from the base of the Chouteau to the top of the Kimmswick, probably constitute the "Big Shale" of drillers, which at Kahoka is reported to be 265 feet thick. With present data, it is impracticable to separate them, though they might be discriminated, with carefully preserved drill cuttings. The Thebes-Maquoketa, the most restricted Ordovician formation in the State, is limited, so far as known, to the counties bordering Mississippi River north from Cape Girardeau, and to the second tier of counties, north from Shelby.

SILURIAN SYSTEM.

During this period, much of Missouri was probably land, and Silurian rocks, very sparingly represented, outcrop chiefly on the east in Cape Girardeau, Perry, Ste. Genevieve, Lincoln, Pike, and Ralls Counties. The entire section is limestone, bounded above and below by unconformities. The full thickness of about 200 feet is not present in any one section, about 80 feet being known in Pike County, and perhaps 120 feet in Ste. Genevieve. The present classification is tabulated below.

SUBDIVISIONS OF SILURIAN SYSTEM.

System.	Series.	Formation.		Member.
Silurian...	Cayugan or Upper Silurian..	Not represented in Missouri.		
	Niagaran or Middle Silurian.	Not represented in Missouri in outcrop.		
	Oswegan or Lower Silurian...	Alexandrian	Sexton limestone Edgewood limestone	Bowling Green, limestone, Noix oolite. Cyrene limestone.
			Girardeau limestone (Bainbridge)	

OSWEGAN OR LOWER SILURIAN SERIES.

Girardeau Formation.—The type locality of the Girardeau limestone is about two miles north of Cape Girardeau, where it outcrops over a limited area. The formation consists of about 40 feet of very compact, thin-bedded, bluish-gray fossiliferous limestone marked by numerous vertical joints. Very hard, thin layers of extremely fine grained siliceous limestone are separated locally by thin shaly partings.

At Bainbridge, only three or four miles northeast of the type locality for the Girardeau limestone, Ulrich has identified the Bainbridge limestone, which he considers younger than the Girardeau. Weller finds Silurian beds in Ste. Genevieve County, aggregating a thickness of 120 feet, "which are the exact equivalent of those at Bainbridge*." From descriptions it seems probable that these beds are in part at least referable to the Girardeau limestone.

Edgewood Formation.—The Edgewood limestone rests with unconformity on the Girardeau, on the Illinois side of the river, and Ulrich correlates a limestone found on the Missouri side, a few miles north of Cape Girardeau, with one member of this formation. However, the best development of the Edgewood in the Missouri seems to be in Pike, Lincoln, and Ralls counties. The lowest member, the Cyrene, comprises 6 to 11 feet of fossiliferous, light gray to brown limestone. Above this lies the Noix, a white to brown mass of siliceous oolites in a matrix of limestone reaching 8 feet thick, near Louisiana, but very local in extent. The Bowling Green, the upper member, is an impure, brown dolomitic limestone, varying from a few feet to 35 feet in thickness, well exposed near Bowling Green. In northeast Missouri, the Girardeau limestone is apparently absent, and the Edgewood is terminated above and below by unconformity. Moreover the three members are subject to variation, so that the formation may be only a few feet thick or from 50 to 60 feet.

Sexton Creek Formation.—The highest Silurian observed in northeast Missouri, the Sexton Creek limestone, probable equivalent of the Brassfield of eastern states, overlies the Bowling Green with unconformity, on the hills in southern Pike County, near Kissinger and Clarksville, where the greatest thickness found is about 25 feet.

Silurian rocks have a more restricted area of exposure than those of any other Paleozoic system in the State. South of Missouri River these rocks, either exposed or buried, are confined to a few counties on the eastern flanks of the Ozark dome. Many deep wells on the west flanks from Jasper County north to Jackson reveal no trace of Silurian deposits. North of Missouri River these beds have a more extended distribution in the eastern

*Weller, Stuart, Unpublished Mss. on the geology of Ste. Genevieve County, Mo. Bur Geol. and Mines.

counties, though they appear to be absent over most of the central and western areas. At Forest City, Holt County, however, Ulrich† correlates beds of fossiliferous dolomite reached at a depth of 2400 feet with Silurian beds of the Niagaran series. Just north of the Missouri line, at Bedford, Iowa, Norton‡ also classes as Silurian 575 feet of limestone, dolomite and shale reached at a depth of 1825 feet. Thus it would appear the Silurian was well represented under northwest Missouri, though the beds must thin out rapidly to the south and southeast.

DEVONIAN SYSTEM.

Devonian strata, while somewhat better developed and more widespread in Missouri than Silurian, are also of restricted occurrence. A large part of the state was land surface through much of Devonian time, during which the seas advanced and receded repeatedly, the advances coming from the south, east, and north. The order in which the various Devonian beds were laid down and the relationship of the beds in one area to those in another, therefore, have been confusing problems to solve. The following classification is tentative:

SUBDIVISIONS OF THE DEVONIAN SYSTEM IN MISSOURI.

System.	Series.	Formation
Devonian.	Upper Devonian.	Unconformity.
		Craghead Creek shale.
		Callaway limestone. unconformity.
	Middle Devonian.	St. Laurent limestone.
		Beauvais sandstone.
		Grand Tower limestone and Cooper limestone.
	Lower Devonian.	Little Saline limestone.
		Clear Creek chert.
		Bailey limestone. unconformity.

†Ulrich, E. O., The revision of the Paleozoic systems; Bull. Geol. Soc. America, Vol. 22, 1911.

‡Norton, W. H., Underground water resources of Iowa; Water supply paper U. S., Geol. Survey No. 293, 1912, p. 965.

The greatest development occurs in southeast Missouri in Ste. Genevieve, Perry, and Cape Girardeau Counties, where 650 feet or more of Lower and Middle Devonian beds are found, chiefly limestone, with one chert and one sandstone. Beds of Upper Devonian age, found in Boone, Callaway, Montgomery, and Warren Counties, composed of limestone and shale, total only 50 to 75 feet in thickness and constitute the next important development of sediments of this period. Limestones of Middle Devonian age also outcrop in these same counties and to the southwest in Moniteau, Cooper, Pettis, and Benton, and to the northeast in Lincoln, Pike, and Marion Counties, but the maximum thickness is not more than 25 or 30 feet.

LOWER DEVONIAN SERIES.

Bailey Limestone.—The Bailey, found only in southeast Missouri, consists of 100 feet or more of gray, yellow, or bluish-gray, fine-grained to crystalline limestone, partly dolomitic, the upper beds somewhat shaly. Chert, chiefly in the form of small concretions, occurs throughout. Bailey fossils, though not abundant, constitute a characteristic Helderbergian fauna.

Clear Creek Chert.—These beds, composed of more than 50 per cent chert, interlayered with limestone, carry a fauna reported to be of Oriskanian age, or younger than that of the Bailey limestone, upon which they rest conformably.

The Clear Creek, limited to southeast Missouri, and best developed in Perry and Cape Girardeau Counties, reaches 200 feet, but the formation weathers readily, and good outcrops are uncommon. Its exposures are characterized by a rough, hilly topography, the slopes covered with chert fragments, mixed with various colored clays. In places, as at Wittenburg, Perry County, the chert beds have weathered to a soft white to yellow tripoli, quarried for railroad ballast.

Little Saline Limestone.—Weller* describes 100 feet of heavily-bedded, fossiliferous, white to pinkish crystalline limestone, apparently younger than the Clear Creek and lying just below the Grand Tower. Outcrop is limited to a small area in Ste. Genevieve County, where it is the topmost Lower Devonian.

*Weller, Stuart, The Geology of Ste. Genevieve County, unpublished manuscript, Mo. Bur. of Geology and Mines.

MIDDLE DEVONIAN SERIES.

Grand Tower Limestone.—Middle Devonian seas were much more extensive in Missouri than Lower Devonian. The sediments, therefore, are found more widespread, the Lower Devonian apparently being restricted to three or four southeast Missouri counties.

The first beds of the Middle Devonian, the Grand Tower, are thick limestones, in part shaly and locally containing lenses of sandstone. In Ste. Genevieve County they rest on the Little Saline limestone, but in Callaway County they overlie unconformably the Ordovician. These beds are exposed in Ste. Genevieve*, Perry, and Cape Girardeau Counties in southeast Missouri, where they reach a maximum of 250 feet, and an average of perhaps 100 feet; and in Callaway, Montgomery, Warren, Lincoln and Pike Counties in the northeast part of the state, where they rarely exceed 15 feet.†

The Grand Tower is composed chiefly of limestone which varies from a fine-grained hard, brittle rock of gray to blue color, to a white, coarsely crystalline rock of marble-like texture. Some beds are very fossiliferous, crinoid stems being especially abundant. A small amount of chert is present in the lower beds of southeast Missouri.

Cooper Limestone.—About 30 feet of fine-grained, compact, white to light gray, sparingly fossiliferous limestone, known as the Cooper marble, occurs in Cooper, Boone, Moniteau, Pettis, and Benton Counties. Possibly it was deposited contemporaneously with the Grand Tower limestone, but in seas which, according to Branson, entered Missouri from the north, and were separated by a narrow land barrier from the Grand Tower seas.

Beauvais Sandstone and St. Laurent Limestone.—Resting on the Grand Tower limestone in a very small area in Ste. Genevieve County is about 50 feet of Beauvais sandstone, identified by Weller‡ as Middle Devonian. It is similar in appearance to the St. Peter, from which it is derived.

Overlying the Beauvais is about 100 feet of the St. Laurent, dominantly limestone, but with some highly arenaceous layers

*Weller, Stuart, The Geology of Ste. Genevieve County, unpublished manuscript Mo. Bur. of Geology and Mines.

†Branson, E. B., The Geology of Missouri, Eng. Ex. Station, Univ. of Mo. Vol. 19, No. 15, 1918, p. 61.

‡Weller, Stuart, Unpublished manuscript, Mo. Bur. Geology and Mines.

and some thin seams of pure sandstone, the highest Middle Devonian in this area.†

UPPER DEVONIAN SERIES.

Callaway Limestone.—In the upper Devonian seas, which covered a large part of northern Missouri, were laid down unconformably on Middle Devonian or older beds, formations which outcrop in Boone, Callaway, Montgomery, and Warren Counties. The basal beds named by Keyes‡ the Callaway formation consist° of forty to fifty feet of thin-bedded, dark gray limestone, followed by nine feet of shaly concretionary limestone, containing pyrite. The formation is very fossiliferous, attains its maximum thickness in southern Calloway and Montgomery Counties, and pinches out to the east and west in Warren and Boone Counties.

Craghead Creek Shale.—The highest Devonian beds exposed in Missouri*, the Craghead Creek, consist chiefly of sandy shales, dark blue to drab, with thin calcareous partings in the lower part, and light yellow to gray above, and attain a thickness of about 25 feet in Callaway County, but thin rapidly to the east, pinching out in Montgomery. They are not known to occur west of Callaway.

Comparatively little is known concerning the areas underlain by Devonian beneath younger formations. Lower Devonian beds seem to be restricted entirely to the southeast counties, and will probably not be encountered, even in drilling, elsewhere in the State. Aside from the small southeast Missouri area no Middle Devonian beds are known to occur, either in outcrop or from drill records, south of a line running east and west through northern Benton County, on the northwest flank of the Ozark dome. In fact, most deep wells drilled north of Benton and west of Cooper County, where Middle Devonian rocks outcrop, have reached older beds without encountering any recognizable Devonian deposits, indicating the patchy occurrence of these rocks in this area. The Noel (Chattanooga) shale in Greene and McDonald Counties, at one time correlated with the Devonian, is now considered Mississippian. No upper Devonian beds are known south of Missouri River.

†Weller, Stuart, Unpublished manuscript, Mo. Bur. Geology and Mines.

‡Keyes, C. R., Paleontology of Missouri; Mo. Geol. Survey, Vol. IV, 1894, p. 43.

°Branson, E. B., Geology of Missouri; Eng. Exp. Station, Univ. of Mo., Vol. XIX, No. 15, 1918, p. 61.

*Gregor, D. K., Am. Jour. Sci., Vol. XXVII, 1909, p. 375.

North of the river, Middle and Upper Devonian beds underlie a large area, though locally thin, patchy, or absent. The general thickness probably increases somewhat in a northerly direction. At Columbia, Moberly and Mexico, not more than 50 feet of sediments which can be doubtfully correlated with the Devonian have been passed through in deep drillings, while at Baring, Knox County, Norton* correlated 217 feet of fossiliferous limestone with the Devonian. At Bedford, Iowa, a few miles north of Worth County, Missouri, the same author finds 150 feet of sediments which he calls Devonian and at Forest City, Holt County, Missouri, Ulrich† places 300 feet of fossiliferous, magnesian limestone in the Middle and Upper Devonian groups.

MISSISSIPPIAN SYSTEM.

The name Mississippian has been applied to a system of rocks next younger than the Devonian which outcrop extensively in the Mississippi Valley. For a portion of these rocks composed of thick, cherty limestone, the term "Mississippi lime" has come into common usage among oil men.

Distribution.—Mississippian rocks occupy extensive surface areas in northeast and southwest Missouri, connected by a narrow, irregular belt crossing the central part of the State, bordering the north and northwest flanks of the Ozark dome A ragged strip also follows Mississippi River from St. Louis to Perry County. Small patches are scattered widely over the Ozark dome, indicating that this highland was at times almost or entirely covered by the Mississippian sea, the deposits being largely removed by later erosion.

To the west and north Mississippian rocks are everywhere present beneath the higher Pennsylvanian beds. They lie deepest where the overlying beds attain their maximum thickness in the northwest counties. At Tarkio they have been penetrated at 1650 feet; at St. Joseph, at 1200 feet; and at Kansas City, at 750 feet; becoming shallower southeastward, to the outcrop.

The total outcrop area of the Mississippian rocks in Missouri is about 8000 square miles.

General composition.—The Mississippian rocks of Missouri

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*Norton, W. H., Underground water resources of Iowa; Water-supply Paper No. 293, U. S. Geol. Survey, 1916, p. 515.

†Ulrich, E. O., cited by Hinds and Greene in: The stratigraphy of the Pennsylvanian series in Missouri, Vol. 13, 2nd ser., 1914, pp. 235-238.

are composed chiefly of limestone, most of which contains a large amount of chert (flint). Shales, present in subordinate amount, are most common in the basal part of the section. The Aux-Vasses sandstone occurs in the Chester.

Thickness.—In St. Louis County where the higher beds are well represented, a deep well penetrated maximum of 763 feet of these rocks. In northeast Missouri the entire thickness ranges from 250 to 450 feet and in southwest Missouri from 250 to 375 feet. Wells in Henry and Johnson Counties reveal less than 200 feet, and the maximum thickness reported in deep wells in northwest Missouri is about 450 feet. Outside the St. Louis area the thickness is rarely in excess of 450 feet, and is generally much less.

Sub-divisions.—The rocks of the Mississippian system in Missouri are subdivided into four groups, as shown in the following table.

CLASSIFICATION OF THE MISSISSIPPIAN SYSTEM.

System.	Group.	Formation.		
		S. E. Mo.	S. W. Mo.	N. E. Mo.
	Chester.........	Okaw. Paint Creek Yankeytown. Renault. Aux Vases.	Carterville.	
Mississippian.	Meramec.......	Ste. Genevieve limestone. St. Louis limestone. Salem limestone. Warsaw shale and limestone.		
	Osage..........	Keokuk limestone Burlington limestone Fern Glen.	Boone.	
	Kinderhook......	Sulphur Springs.	Chouteau. Hannibal. Louisiana. Phelps sandstone. Sac limestone. King limestone. Eureka shale.	Chouteau. Hannibal. Louisana. Saverton. Grassy Creek.

KINDERHOOK GROUP.

The Kinderhook group of rocks, consisting of shales, limestones, and sandstones, varies in composition and thickness in the different areas.

The thickness of the Kinderhook group is variable. In the northeast corner of the State, some 225 feet of shale, the big shale of drillers, has been referred to this group. More generally, however, the thickness is less than 100 feet, commonly less than 50 feet, and in places all of the beds are absent.

Sub-divisions of the Kinderhook Group.—Having been studied at different times these formations have been named differently in the various parts of the State.

In northeast Missouri the initial Kinderhook deposit consists of from one to forty-five feet of black, bituminous, fissil shale, known as Grassy Creek shale. It outcrops chiefly in Pike County. Overlying the Grassy Creek occurs a light blue somewhat sandy shale called the Saverton. It is exposed in Marion, Ralls and Pike counties and attains a maximum thickness of about 100 feet in Ralls County. The Louisiana limestone which overlies the Saverton shale has a maximum thickness of 70 feet. It is fine grained to compact in texture, and is hard and brittle. Above the Louisiana occurs the Hannibal shale which also has a maximum thickness of about 100 feet. It consists of an impure, sandy shale which is filled with tubular markings the result of worm borings, from which characteristic it was formerly called the "Vermicular Sandstone." The topmost member of the Kinderhook, called the Chouteau limestone, is from 20 to 55 feet thick. It consists of fine grained, argillaceous limestone of blue to drab color.

In southwest Missouri, according to Shepard*, the following succession is present. Originally the lower part of the series was referred to the Devonian. The Eureka or Noel, the initial deposit, is a black fissil shale, having a maximum thickness of about 50 feet. The King, a thin gray limestone overlies the shale. It is in turn overlain by the Sac limestone which has a thickness averaging about eight feet. The Phelps sandstone, averaging four feet in thickness, overlies the Sac. Above this sandstone occurs the Louisiana limestone, Hannibal shales and Chouteau limestone in succession similar to northeast Missouri.

In central Missouri the Phelps sandstone and Chouteau limestone form the Kinderhook succession.

The only Kinderhook formation in southeast Missouri is the Sulphur Springs. At its base it carries a thin unnamed shale. Above this is the Glen Park limestone correlated by Weller with the upper part of the Louisiana limestone. The

*Shephard, E. M., Geolcgy of Greene County; Mo. Geol. Survey, Vol. XII, 1st ser., p. 67

Bushberg sandstone is the upper member consisting of about 14 feet of brown fine-grained sand.

OSAGE GROUP.

Osage seas were more widespread than those of Kinderhook time covering most of Missouri, so that Osage deposits are more uniform and widespread, overlapping onto older beds. They consist everywhere chiefly of thick cherty, crystalline limestone which contrasts sharply with the complex of shales, sandstones, and argillaceous limestones of the underlying Kinderhook. The Osage formations make up the most characteristic Mississippian deposits, to which the name "Mississippi lime" is most generally applied. The thickness of the group measures from 200 to 300 feet.

Fern Glen Formation.—This formation, the oldest of the Osage group, outcrops in southeast Missouri, and consists of shaly, cherty limestone easily identified by its characteristic red color. It varies from a few feet to about forty feet in thickness.

Burlington Limestone.—The Burlington limestone, because of its thickness, extent, wide surface exposures, and economic possibilities, is the most important Mississippian formation in Missouri. Commonly classed with the overlying formation as the Burlington-Keokuk, the two comprise the Boone limestone of the southwest Joplin district, as published by U. S. Survey.

The Burlington, known as the "Encrinital limestone" from the abundance of crinoids, is essentially a very cherty, highly fossiliferous, crystalline limestone, having a thickness of 100 to 200 feet or more. Chert constitutes a large part and locally almost one-half, and is present chiefly in beds, varying in thickness from mere seams to as high as 40 feet, the maximum being reached in the Grand Falls chert member. Numerous concretions or nodules are also present. The chert is commonly white to yellow or light to dark blue in color and is not known to occur in oolitic form, a distinguishing feature between this and the chert of the older formations. Residual chert is conspicuously strewn over the areas in which this formation is the country rock.

This limestone, where typically developed, is very coarsely crystalline, very pure and very soluble, especially the light gray to cream-colored beds which characterize the formation. Some beds, however, are impure and shaly and in southwest Missouri certain beds are dolomitized in places.

The Burlington is commonly medium to heavy bedded, well jointed, and, because of its solubility, highly permeable, making it a valuable water producer. On fresh fractures the limestone sparkles from the crystal surfaces and has the appearance of marble, and is easily distinguished, being well known to drillers of northeast and southwest Missouri.

In the latter region the lower portion of the formation consists of from 50 to 100 feet of argillaceous cherty limestone known as the lower Burlington, above which occurs from 0 up to 40 feet of solid chert known as the Grand Falls chert.

Keokuk Limestone.—The Keokuk is very similar to the underlying Burlington, the two constituting the Burlington-Keokuk, or Boone of southwest Missouri. They are nearly co-extensive, the Burlington being slightly more widespread. The Keokuk, ranging from an average of about 20 feet to a maximum of about 60, is a very cherty crystalline, fossiliferous limestone.

MERAMEC GROUP.

The Meramec group, chiefly limestone, attains its greatest development along Mississippi River from Ste. Genevieve County north into St. Louis and St. Charles counties, and from Marion County north to the State line. Though not exposed to the west these rocks are well developed below the Pennsylvanian in northwest Missouri. They are not, however, as widespread or important as the Osage group, which they overlie. The Meramec group is composed of the Warsaw, Salem, St. Louis and Ste. Genevieve limestone formations.

Warsaw Formation.—The Warsaw directly overlies the Keokuk and in St. Louis County consists of about 75 feet of beds, chiefly shale, yellowish near the top and bluish below with subordinate limestone, darker, more dense and finer grained than the Keokuk. It contains an abundance of fossils, particularly the spiral bryozoan, Archimedes. In southeast Missouri the Warsaw is nearly pure limestone with little or no shale. In northeast Missouri the formation is composed of shaley limestone, interlayered with shale, through which are scattered innumerable geodes, cavities lined with crystals of quartz and calcite.

In southwest Missouri the Warsaw is chiefly limestone and chert, the chert comprising about 50 per cent of the formation and occurring in very thick layers, locally weathered to tripoli.

At its base is the Short Creek oolite, one to eight feet thick, defining excellently the lower limits of the Warsaw.

In the deep drill hole at Forest City, Holt County, 40 feet of Warsaw beds were penetrated.

Salem Limestone.—The Salem, overlying the Warsaw, is typically a heavy-bedded, cross-bedded, granular or oolitic limestone, very fossiliferous but carrying little or not chert. It has been considered the equivalent in age of the famous Bedford stone of Indiana. In northeast Missouri the Salem is more shaley than in the St. Louis area, while in Ste. Genevieve County it is a pure partly oolitic limestone, over 100 feet thick. It is very largely restricted to the eastern part of the state.

St. Louis Limestone.—The St. Louis limestone is confined chiefly to the eastern river border counties, from Perry County to the Iowa State line, swinging west through Knox and Scotland counties. In the deep Forest City boring 40 feet of beds credited to this formation were reached at a depth of 1621 feet.

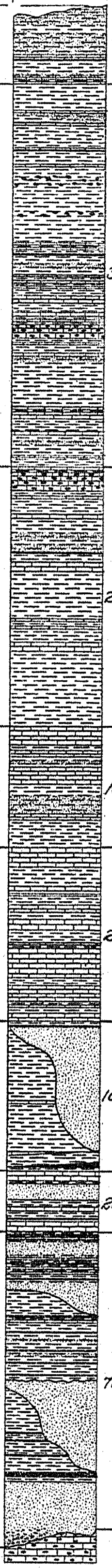
The maximum thickness, 325 feet, occurs at the type locality in St. Louis County, where it consists chiefly of fine grained dense, cherty limestone, containing subordinate layers of shale. Many of the beds have the close, dense texture of lithographic limestone, a character useful in identifying the formation.

In northeast Missouri the composition is much more complex than at St. Louis, the formation containing more shale and thick zones of brecciated material.

Ste. Genevieve Limestone.—The Ste. Genevieve is represented in Missouri by a single limestone, restricted, so far as known, to Ste. Genevieve County, though it is known to extend eastward with increasing thickness into Illinois and Kentucky. At its type locality near the town of Ste. Genevieve, where it is extensively quarried, it is a pure white to light gray partly oolitic and cross-bedded limestone, about 100 feet thick.

CHESTER GROUP.

The uppermost group of Mississippian rocks, known as the Chester, occupies an extremely small area in Perry and Ste. Genevieve counties, of a thickness of 200 to 300 feet of limestone, sandstone, and shale. In southwest Missouri small isolated patches of Chester also occur in Jasper County, chiefly filling old sink holes.

Series	Group	Formation	Section	Thickness (feet)	Character of Rock
Pennsylvanian	Missouri	Wabaunsee		100+	Shale and sandstone with thin persistent beds of limestone
		Shawnee		350-475	Shale and sandstone with many persistent beds of limestone and two thin coal beds
		Douglas		200-300	Shale and sandstone with thin limestones; one—the Oread at the top—persistent. Two or more thin coal beds in places
		Lansing		100-140	Shale and sandstone with thin limestones—two in the upper half of the formation being persistent
		Kansas City		200-225	Limestone and shale with a few thin and lenticular beds of sandstone
	Des Moines	Pleasanton		100-225	Shale and sandstone with one or two non-persistent limestones and a few coal beds
		Henrietta		26-110	Limestone, shale and sandstone with one or two thin coal beds
		Cherokee		75-710	Shale and sandstone with a few thin limestones in the upper 100 feet and a number of coal beds. The upper part contains thick limestones locally

Generalized columnar section of the Pennsylvanian in Missouri.

Chester in Southeast Missouri.—The initial Chester deposit consists of a fine-grained, yellow sandstone 40 to possibly 60 feet thick, called the Aux Vases.

Overlying the Aux Vases sandstone in a very small area in Ste. Genevieve County is the Renault* formation, composed of 80 feet of limestone, sandstone and shale. Above the Renault, the Yankeytown is a thin, siliceous, mostly cherty formation limited in its distribution to a small area in Ste. Genevieve and Perry counties. Above this, the Paint Creek is a deep red, non-laminated shale, known only in Perry County. The Okaw, which caps the group is a pure limestone, oolitic in part.

To the east in Illinois the Chester group thickens rapidly and underlies a large part of that state.

Chester in Southwest Missouri.—The Chester of southwest Missouri, known as the Carterville, consists of isolated patches of a heterogeneous mixture of shaley conglomeratic limestones, calcareous, clayey, and sandy shales, shaley sandstone, massive hard sandstone, and even quartzites. It occurs in local patches, filling sink holes.

PENNSYLVANIAN SYSTEM†.

Distribution.—The Pennsylvanian rocks or "Coal Measures" cover an area of approximately 25000 square miles in Missouri, chiefly in the northern and western part of the State, the eastern and southern limits being extremely irregular as shown on the State geologic map. The Pennsylvania seas at times submerged a large part of the Ozark region, and the Pennsylvanian strata undoubtedly once covered a much larger area in Missouri than they do at present, as shown by small patches high on the Ozark dome. The removal of the Pennsylvanian from this region is the result of long periods of erosion, the sediments being first stripped from the high central part. As the process continued the inner margin gradually and irregularly receded down the flanks. The eastern border of the Pennsylvanian north of the Missouri River, however, is principally the result of normal erosion along Mississippi River on an area of broadly folded, and in places faulted, rocks. The Pennsylvanian rocks, therefore, now surround the Ozark dome on the west, northwest, and north,

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*Weller, Stuart, Unpublished manuscript: The Geology of Ste. Genevieve County.

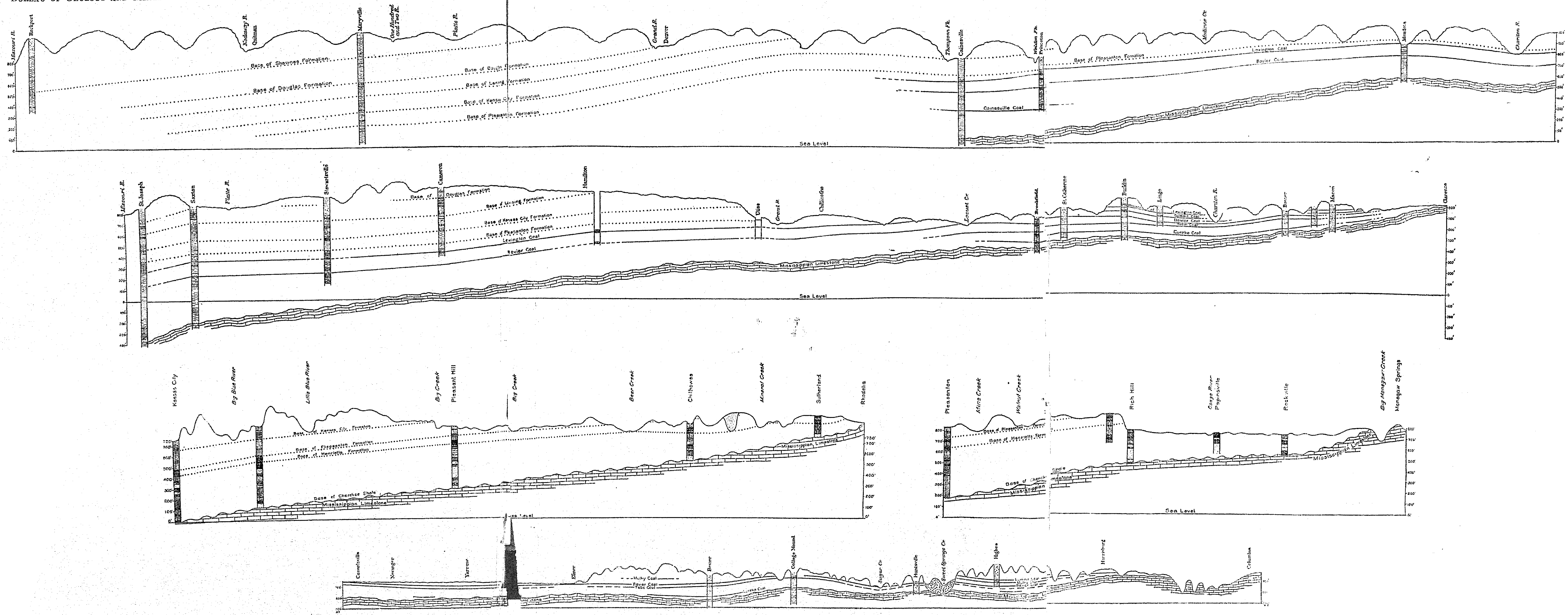
†A very detailed discussion of the Pennsylvanian rocks is published in Volume 13, 2nd ser. of the reports of this Bureau, entitled, the stratigraphy of the Pennsylvanian series in Missouri, by Henry Hinds and F. C. Greene.

dipping away from the uplift and exposing successively younger formations with distance from the crest.

General composition.—The Pennsylvanian rocks of Missouri are composed dominantly of shale with lesser but still important amounts of sandstone and a still smaller proportion of limestone occurring in relatively thin beds. The shales are variable, chiefly hard, yellow to blue, laminated beds, or soft blue to gray clay shales. Black fissile shales are especially abundant in the lower formations and white to gray fire clays are commonly found at the base. The shales are not uncommonly sandy, and grade laterally into beds of fine-grained micaceous gray to brown sandstone, varying from a few feet to 100 feet or more in thickness. Sandstones are more abundant in the lower and limestones in the higher formations. The limestones are thin but many of them are persistent, the maximum thickness of any individual bed being about 50 feet, while most of them average less than 25 feet.

Thickness. — All told, the Pennsylvanian includes about 1900 feet of sediments — shale, sandstone, limestone, clay, and coal. At no one point, however, are all of these beds present, and the greatest depth penetrated by a well to reach their base is about 1700 feet. This thickness is shown in plate 3, the depths representing actual well records. The exact depth to the base of the Pennsylvanian in any particular locality depends upon (1) the number of formations present, (2) the variable thickness of these formations (3) the extent to which the top formation has been eroded, (4) the uneven Mississippian floor upon which they rest, and (5) the amount of unconsolidated materials overlying them. There is thus difficulty in making a close estimate on the depth the drill will have to penetrate to reach the base of the Pennsylvanian in a given locality, unless nearby well records are available. The Cherokee shale alone varies from less than 300 feet to more than 700 feet in thickness, and in the northern part of the state the mantle of glacial drift varies from only a few feet to as much as 300 feet.

Toward the southern and eastern borders of the Pennsylvanian area, only the lower formations are present, but to the northwest, west, and southwest into Kansas and Oklahoma, higher formations come in increasing the total thickness. To the north and northwest into Iowa and Nebraska the thickness decreases. The westward increase is well illustrated by taking the records of a set of borings from east to west; for example,



Cross sections of northwestern part of Missouri.

at Eldorado Springs, Missouri, the base of the Cherokee was reached at a depth of 63 feet; at Nevada, Missouri, at 163 feet; at Ft. Scott, Kansas, at 472 feet; at Moran, Kansas, at 930 feet; and at Iola, Kansas, at 1040 feet. Deep wells still farther west reached the base of these deposits at still greater depths, as much or more than 2500 feet being required in western Greenwood County, Kansas, to completely penetrate the Pennsylvanian formations.

Stratigraphic relations.—The Pennsylvanian commonly rests with unconformity upon the Mississippian, overlapping onto the Ordovician, on the Ozark crest. In eastern, northern, and northwestern Missouri, the drill in reaching the base of the Pennsylvanian enters the Meramec group of the Mississippian. In north-central and western Missouri the older Osage group directly underlies the Pennsylvanian. Any of the limestones of the Meramec or Osage group are easily distinguished from the limestone members of the Pennsylvanian by their much greater thickness and by their position below the thick Cherokee shale, which contains only very thin limestone layers. The Boone limestone 200 to 325 feet thick, carries a much larger amount of chert than any of the Pennsylvanian limestones, and is coarsely crystalline in contrast to the dense, fine-grained testure of any of the Pennsylvanian limestones with which there is a possiblity of confusion. The color of the Boone is commonly light gray to cream while that of the thin Pennsylvanian limestones above is commonly dark gray to blue. The St. Louis limestone is fine-grained, light gray to gray in color, and carries some chert. Its average thickness at St. Louis is 325 feet, but in northern Missouri wells seldom encounter more than 100 to 150 feet of it, which however, is sufficient to distinguish it from any Pennsylvanian limestone.

Nomenclature and subdivisions.—The Pennsylvanian system of rocks is composed of two series of formations, the Lower, or Des Moines, and the upper, or Missouri. These series correspond to the Lower and Upper "Coal Measures," terms in common usage in Kansas. The line of division is drawn at the top of the Pleasanton shale. The Des Moines, or "Lower Coal Measures" is composed of three formations, the Cherokee, Henrietta, and Pleasanton; and the Missouri, or "Upper Coal Measures" includes five formations, the Kansas City, Lansing, Douglas, Shawnee, and Wabaunsee. Most of the formations are again subdivided into members, as for instance the Henrietta formation is composed of the Ft. Scott limestone, the Labette shale, and the Pawnee limestone. Each member of a formation constitutes a unit, though not necessarily a homogeneous one. In some shale members persistent beds of limestone occur to which names have been given. For instance the Raytown and Cement City limestone beds lie in the Chanute shale member of the Kansas City formation.

SUBDIVISIONS OF THE PENNSYLVANIAN SYSTEM IN MISSOURI.

Group	Formation.	Member.	Bed.
Missouri	Wabaunsee formation	Undifferentiated	
		Tarkio limestone	
	Shawnee formation	Scranton shale	
		Howard limestone	
		Severy shale	
		Topeka limestone	
		Calhoun shale	
		Deer Creek limestone	
		Tecumseh shale	
		Lecompton limestone	
		Kanwaka shale	
	Douglas formation	Oread limestone	
		Lawrence shale	Amazonia limestone (toward top).
		Iatan limestone	
		Weston shale	
	Lansing formation	Stanton limestone	
		Vilas shale	
		Plattsburg limestone	
		Lane shale	Farley limestone (in middle).
	Kansas City formation.	Iola limestone	
		Chanute shale	Raytown limestone (toward top). Cement City limestone (near base).
		Drum limestone	
		Cherryvale shale	
		Winterset limestone	
		Galesburg shale	
		Bethany Falls limestone	
		Ladore shale	
		Hertha limestone	
Des Moines	Pleasanton formation	Undifferentiated	
	Henrietta formation	Pawnee limestone	
		Labette shale	
		Fort Scott limestone	
	Cherokee shale	Undifferentiated	

DES MOINES GROUP.

The Des Moines or Lower Pennsylvanian, is composed predominantly of shales and sandstones occupying a stratigraphic position between the base of the Hertha limestone and the top of the Mississippian. Of the three formations comprising it, only the middle one, the Henrietta, contains important limestone members, though both the lower formation, the Cherokee, and the upper, the Pleasanton, contain a few thin limestone beds of doubtful persistence. Shale and sandstone average 75% of its thickness, and limestone, clay and coal the remaining 25%. Actual measurements of the full thickness show it to vary between 669 and 895 feet, the maximum being in Holt County. The area of outcrop includes about 16,000 square miles, bounded on the east and south by the Mississippian and on the northwest by the Missouri or Upper Pennsylvanian, under which rocks the Des Moines strata dip. The Des Moines has produced most of the oil and gas found in Missouri, and also in Kansas, and much of that in Oklahoma, and probably outranks the overlying Missouri in respect to future possibilities for production.

Cherokee shale.—The Cherokee, the basal formation of the Pennsylvanian, includes all beds between the base of the overlying Ft. Scott or "Oswego" limestone and the Mississippian limestones below. Where its full thickness is present it varies, in Missouri, from less than 100 feet in Audrain County to over 700 feet in Holt County. Thicknesses of less than 300 feet, however, are confined chiefly to the counties along the eastern margin of the Pennsylvanian outcrops, where portions have been removed by later erosion. The following figures represent the average thickness in the counties of western and northern Missouri: Barton and Vernon 300 feet; Cass 390 feet; Jackson 340 feet; Platte 555 feet; Holt 712 feet; Gentry 700 feet; Harrison 653 feet; Livingston 450 feet; Carroll 340 feet; Lafayette 320 feet; and Henry about 230 feet. The great thickness in Holt, Buchanan and surrounding counties is due to the presence of lower and older beds than occur elsewhere in the Missouri Cherokee.

The formation consists chiefly of shale but contains a considerable quantity of sandstone, thickest and most abundant in the lower part, but also in considerable amount interstratified with the upper shales. Coal beds and very thin limestones serve as the only general markers to the stratigraphy of the formation, the sandstones and shales as a rule being too irregular and variable to serve in this capacity, though locally, as in Vernon County, certain of them form prominent and persistent markers.

The sandstones of the Cherokee vary from thin seams to beds over 60 feet thick, composed chiefly of fine to medium, angular quartz grains, gray to brown in color and commonly micaceous. They vary greatly in hardness, though generally they are not tightly cemented and are relatively soft. They are lenticular, thickening and thinning rapidly and irregularly, and laterally grading into shale. It is quite impossible to correlate one individual bed with another many miles away, though locally a bed may be well-defined over a considerable area, either in outcrop or in wells. In southwest Missouri the Graydon sandstone is a persistent member which is correlated over a large area.

Wells penetrating the full thickness of the Cherokee have never failed to encounter one or more beds of sandstone, varying from a small percentage to over one-third of the total. This variation seems to be relatively greater in the west central counties than in those of the northwest part of the State.

Henrietta Formation.—The Henrietta rests on the Cherokee and outcrops in an extremely irregular, narrow band from the west edge of Vernon County northeast to the Iowa line north of Putnam and Schuyler Counties. In the southwest counties the outcrop forms an escarpment, very prominent in Vernon and Bates Counties rising above the Cherokee plain; and a strip of hilly country extends back from this to the higher Pleasanton plain.

The maximum thickness of the Henrietta is about 110 feet in Vernon and Bates Counties, decreasing northward to 50 or 60 feet in Jackson County and 40 or 50 feet in Putnam. The thickness, however, is rather variable, becoming probably about 70 feet in Holt, but decreasing in Clinton and Daviess to not over 30 feet. The formation is divided into three members, a lower limestone called the Ft. Scott, an upper limestone called the Pawnee, and a shale separating these two, called the Labette. The Labette shale constitutes at least half of the entire formation, and consists of shale, sandstone and one or two thin limestones.

The Ft. Scott or "Oswego Lime" Member is the first limestone of great area extent and important thickness above the base of the Pennsylvanian. It consists, where typically developed, of two limestones separated by a shale. The total thickness varies from 8 to 53 feet with an average of about 21 feet. In many places the thickness of the separating shale exceeds that of both limestones, in other places the shale is reduced to a mere film. Both limestones show a considerable variation and in places the lower one is apparently absent. A thin coal seam is present locally in the shale.

The Labette shale member forms the principal part of the Labette in most areas, with thin limestones, "slate" and coal seams commonly present, but locally sandstone is predominant. The thickness is extremely variable, ranging from a few feet to as much as 65 feet.

The Pawnee limestone member is composed of a solid ledge 3 to 35 feet thick. Underlying a great thickness of shale and sandstone which is comparatively free from limestone, this member is usually easy to identify. Both the Ft. Scott and the Pawnee limestones contain quantities of the fossil coral, *Chaetetes milleporaceous* which looks like a honeycomb composed of ex-extremely minute cells.

TYPICAL SECTIONS OF HENRIETTA. DRILLING NEAR SPRAGUE, BATES COUNTY.

	Ft.	In.
Clay (base of Pleasanton formation)	4	8
Limestone (Pawnee)	18	6
Shale, slaty (top of Labette)	1	8
Shale, blue	2	4
Limestone	7	6
Shale, slaty (horizon of Butler coal)	5	6
Clay	3	
Sandstone	26	4
Coal		4
Clay (base of Labette)	4	10
Limestone (upper limestone of Fort Scott member)	21	
Shale, slaty	3	
Clay	5	2
Limestone (lower limestone of Fort Scott member)	10	4

Pleasanton Shale.—The Pleasanton is the uppermost of the three formations of the Des Moines. Its outcrop extends from western Bates County northeast to Chariton River in Livingston County in an irregular strip 5 to 20 miles wide. From Chariton River north through Putnam County the area of exposure widens to 50 miles. The outcrop is limited on the east by the Henrietta escarpment and on the west by a similar escarpment formed by higher limestones. The maximum thickness of the

Pleasanton occurs in Bates County where it is in excess of 200 feet. The thickness varies considerably even within small areas.

The greater part of the Pleasanton is shale, but sandstone is abundant and in places preponderates. Locally the shale at certain horizons has a distinctive red color. Over most of the area of occurrence limestone is practically absent or is represented by one or two thin seams, but in Bates County and in the northwest counties, several thin limestones are present. Two fairly persistent coal beds occur, one near the top and one near the base of the formation. The Pleasanton in Missouri has not been divided into members because of the irregularity of the composing sediments. The Altamount and Coffeyville limestones which afford a basis for such a division in Kansas are apparently not persistent in Missouri, though the Altamount is undoubtedly present in places.

PLEASANTON FORMATION IN JOHNSON, CASS, AND JACKSON COUNTIES.

Stratum.	Thickness.	Depth.
	Feet.	*Feet.*
Shale, bituminous	1½	1½
Shale, argillaceous, or porous sandstone	13½	15
Limestone, sandy	1	16
Sandstone, calcareous; 3 inches of coal at base	1½	17½
Shale, sandy	35½	53
Coal, a few inches	—	—
Shale, clayey	15	68
Sandstone, buff	4	72
Sandstone and shale	45–55	117
Limestone	2	119
Shale, marly, and limestone nodules	7	126
Shale, olive and purple	10	136
Shale, sandy, and shaly sandstone	22	158
Coal (Holden)	1	159
Shale	6	165
Limestone	2	167
Shale	9	176

MISSOURI GROUP.

The Missouri or Upper Pennsylvanian covers the Des Moines west of the Pleasanton shale outcrop and occupies an area of about 8,000 square miles. The eastern limit of occurrence extends from near Amsterdam, Bates County, northeast to the Iowa line in northeastern Mercer County. Small outliers occur east of the main body (see geologic map). The series includes about 1000 feet of sediment in Missouri, this thickness occurring in Atchison County where all the formations are present. Westward in Kansas the thickness is greater, while to the east and south it decreases as the higher formations are removed by erosion.

The Missouri differs from the Des Moines in having more persistent strata, more limestone, less sandstone and much less coal. The limestones are segregated chiefly in certain horizons between which occur thick shales as free from limestone as the Cherokee or the Pleasanton formation of the Des Moines. A very important segregation of limestone lies at the base of the group. Limestone forms about 25 per cent of the total, sandstone about 6 per cent.

FORMATIONS AND MEMBERS OF MISSOURI GROUP.

Formation.	Member.
Wabaunsee formation	Undifferentiated shale and limestone. Tarkio limestone.
Shawnee formation	Scranton shale. Howard limestone. Severy shale. Topeka limestone. Calhoun shale. Deer Creek limestone. Tecumseh shale. Lecompton limestone. Kanwaka shale.
Douglas formation	Oread limestone. Lawrence shale with Amazonia limestone bed. Iatan limestone. Weston shale.
Lansing formation	Stanton limestone. Vilas shale. Plattsburg limestone. Lane shale with Farley limestone bed.
Kansas City formation	Iola limestone. Chanute shale with Raytown limestone bed and Cement City limestone bed. Drum limestone. Cherryvale shale. Winterset limestone. Galesburg shale. Bethany Falls limestone. Ladore shale. Hertha limestone.

Kansas City Formation.—The Kansas City formation lies at the base of the Missouri and has a thickness of 200 to 225 feet.

It outcrops from northwest Bates County northeast to the Iowa line in Harrison and Mercer Counties. The eastern edge of the outcrop is marked over much of the distance by a sharp escarpment rising above the Pleasanton plain.

The Kansas City formation consists of nine members, five limestones and four shales. In Jackson County one half of the total thickness is limestone; farther north the limestone decreases to less than half the total. Very little sandstone is present though at three horizons in the Chanute shale member thin beds occur locally. The following tabulation indicates the names and arrangement of the members comprising the formation:

SUBDIVISIONS OF KANSAS CITY FORMATION.

Kansas City formation	Iola limestone.	
	Chanute shale	Upper shale. Raytown limestone. Middle shale. Cement City limestone. Lower shale.
	Drum limestone.	
	Cherryvale shale.	
	Winterset limestone.	
	Galesburg shale.	
	Bethany Falls limestone.	
	Ladore shale.	
	Hertha limestone.	

GENERALIZED SECTION OF THE KANSAS CITY FORMATION AT KANSAS CITY.

Stratum.	Thickness.
	Feet.
Iola limestone member:	
Limestone, gray to buff; thinly-bedded; increasing in thickness from top to bottom; non-cherty; "Crusher ledge"	25–30
Chanute shale member:	
Shale, blue to olive; ocher concretions; fine grained; slightly arenaceous	21–25
Limestone (Raytown bed), variegated, gray; large fossils; "Calico ledge"	5–8
Clay	(parting)
Limestone, blue	1–1½
Shale, bituminous and blue	2
Limestone	1–1½
Shale, blue	1–1½
Limestone, blue, shaly	1–1½
Shale, blue, buff and red	8–13
Limestone (Cement City bed), drab; fine-grained; "Building ledge," lower half-foot "fish-tooth ledge"	9–10
Shale, blue and olive	4
Shale, yellow, nodular, ochery	3–4
Drum limestone member:	
Limestone, irregularly bedded	2–3
Limestone, oolitic, gray; very fossilferous; "Oolitic ledge"	11–13
Shale, blue	1
Limestone, gray, seams buff, solid, fossilferous, "Bull ledge"	6–7

GENERALIZED SECTION OF THE KANSAS CITY FORMATION—Continued.

Stratum.	Thickness.
	Feet.
Cherryvale shale member:	
Shale, dark	13–15
Limestone, shelly	1
Shale, drab	1
Limestone	1
Shale	2
Limestone	1
Shale, buff	1
Shale, blue	3
Coal	—
Winterset limestone member:	
Limestone, dark blue; black chert in upper 4 ft., "Chert ledge"	12–16
Shale, blue, slaty	4–5
Limestone, drab; fine-grained	3–8
Shale	½
Limestone	2
Shale	1
Limestone, blue to drab	3–5
Shale, blue	½
Limestone	1
Galesburg shale member:	
Shale, yellow, ochery	1
Shale, blue	2
Shale, bituminous	1
Shale, argillaceous	2
Bethany Falls limestone member:	
Limestone, nodular, shelly	2–4
Limestone, oolitic	1
Limestone, grayish; upper 6 ft. mottled, lower crystalline; fine-grained	18–21
Ladore shale member:	
Shale, blue	2–3
Shale, bituminous	1–2
Limestone, dull	1
Shale	½
Limestone	¼
Shale, blue	2–3
Hertha limestone member:	
Limestone	6

The basal Hertha, 4 to 18 feet thick, is composed of resistant, heavy-bedded, gray, ferruginous, crystalline limestone. On exposure it commonly has a brown to chocolate color locally giving rise to the name "chocolate rock."

The Ladore shale separates the Hertha from the overlying Bethany Falls limestone and is 4 to 30 feet thick. The average thickness more closely approaches the minimum. The member consists of shale, "slaty" shale, shaly limestone and thin limestone seams. In places considerable sandstone is present.

The Bethany Falls, one of the most prominent members of the Kansas City, is 15 to 24 feet thick, light to dark gray in color and fine-grained. An upper bed 3 or 4 feet thick, is composed of limestone nodules, lower beds, 12 to 21 feet thick, are rather dense gray limestone, the upper portion of which is mottled light to dark gray in color. Due to this characteristic the Bethany Falls is locally known as the "spotted rock."

The Galesburg, separating the Bethany Falls from the overlying Winterset limestone, is 5 to 10 feet thick, composed of blue shale at the top and base with a seam of "slaty" shale in the middle.

The Winterset, 25 to 40 feet thick, consists chiefly of blue, thin-bedded limestone separated in the upper part especially by means of shale. It is everywhere very cherty, the chert in the upper portion ranging from blue to almost black in color, and being fossiliferous. Locally certain beds closely resemble the Bethany Falls "spotted rock."

The Cherryvale, 13 to 25 feet thick, separating the Winterset from the overlying Drum limestone, is a blue or buff shale with thin, lenticular limestones.

The Drum limestone, ranging from 3 feet or less to 18 feet, is absent in places south of Jackson County. Typically it occurs in two parts, an upper oolitic ledge and a lower massive ledge, and locally it contains considerable chert.

The Chanute varies from 30 to 70 feet or more in thickness and is composed of 3 shales separated by 2 beds of limestone. The limestone between the lower and middle shale, called the Cement City, is 5 to 10 feet thick; that between the middle and upper shale, called the Raytown, is from 5 to 10 feet thick. Both are very persistent. Certain horizons in the middle and upper shale grade locally into sandstone and the same may be true of the lower shale.

The Iola, the top member of the Kansas City, is the thickest limestone in the entire Pennsylvanian series in Missouri. In Cass County it reaches a little more than 50 feet, in Jackson County, about 40 feet. To the north it thins considerably. This member is a light gray, somewhat crystalline, thinly-bedded limestone with a few shaly partings.

Lansing Formation.—The Lansing formation rests on the Kansas City. Except for the northwest corner of Jackson County, it occurs only north of Missouri River, outcropping north through Clay and Ray Counties to the Iowa line in Harrison, County. In Platte County the formation has a thickness of 140 feet but in localities to the east and north is less than 100 feet thick. The lower half is chiefly shale and sandstone, the upper half chiefly limestone. It is composed of four members: the Lane shale, the Plattsburg limestone, the Vilas shale and the Stanton limestone.

The lowest member of the Lansing is the Lane shale, 50 to 80 feet thick. The upper part is composed of sandstone and sandy shale, the lower part chiefly of shale, separated by the Farley limestone lens, which ranges from a thin calcareous shale to a limestone 10 feet thick.

The very persistent Plattsburg limestone, above the Lane shale, varies from a few feet to a maximum of about 20 feet. It is chiefly a blue, argillaceous limestone weathering to a buff color. The member may usually be distinguished by the very dark blue to black chert in the upper part, and by a persistent pelecypod horizon near the base.

Separating the Plattsburg limestone from the overlying Stanton limestone is the Vilas shale, 3 to 20 feet thick. It varies from a clayey or sandy shale to a black "slaty" shale, locally containing a thin seam of coal.

The Stanton, the highest member of the Lansing, is composed of three limestones separated by two shales. The upper and lower limestones are thin. The middle one is about 15 feet thick and is known as the "main ledge." This "ledge" is a gray, thin-bedded limestone with a buff layer at the top about 2 feet thick. The "lower ledge" is blue in color, while the "upper ledge," where thick, contains a layer of sandstone and green shale. The "main ledge" is most commonly observed in outcrops. The total thickness depends upon the shales, which vary considerably. In places 20 feet of shale separates the upper limestone from the "main ledge." Thus a maximum thickness of about 45 feet may be reached, the average being between 20 and 30 feet.

GENERALIZED SECTION OF LANSING FORMATION IN PLATTE COUNTY.

	Thickness (Average).	
	Ft.	*In.*
Stanton limestone member:		
Limestone, gray, sandy, in thin beds	2	6
Shale, gray, red and green; sandy in localities	7	4
Limestone, upper part buff, argillaceous, nodular, not bedded; lower part (main part) gray, thin-bedded, jointed, fossiliferous	14	6
Shale, black and slaty in middle, blue-gray or greenish at top and bottom.	4	6
Limestone, dark gray or blue, dense, in 2 to 5 thin beds	2	8

GENERALIZED SECTION OF LANSING FORMATION—Continued.

	Thickness (Average).	
	Ft.	*In.*
Vilas shale member:		
Shale, gray and greenish; sandy where maximum thickness is present....	14	8
Plattsburg limestone member:		
Limestone, blue to gray, in thin to thick beds, different beds oolitic, crystalline, argillaceous and cherty..............................	17	7
Lane shale member:		
Shale and sandstone, calcareous at top..............................	20	6
Limestone, with interbedded shale and sandstone, a variable group of beds.	10	9
Shale, argillaceous and sandy..	33	
Average thickness..	138	

Douglas Formation.—The Douglas overlies the Lansing and has a wide outcrop from Platte County northeast to the Iowa line, in eastern Worth and western Harrison Counties. It varies from 200 to 300 feet in thickness and is composed essentially of shale and sanstone with the thick important Oread limestone member at the top. Below the Oread, the formation bears a close resemblance to the Cherokee and Pleasanton of the Des Moines. The strata are irregular because of the lenticular nature of the limestones and the presence in certain localities of channel-like sandstones at the base. Four members compose the Douglas consisting of alternating limestones and shales.

The Weston, the basal member of the formation, is 60 to 100 feet thick and is composed chiefly of soft argillaceous shale. It commonly forms the lower part of an escarpment capped by the overlying Iatan limestone.

The Iatan, above the Weston, has a thickness of 2 to 22 feet and is a dark to light gray mottled limestone with large red splotches in places on the weathered surface. Locally it is absent, either having never been deposited or having been removed by erosion before the deposition of the overlying shale.

The Lawrence separates the Iatan from the Oread limestone above and consists of 130 to 200 feet of shale and sandstone with a persistent limestone bed, the Amazonia, 16 feet thick, 25 to 100 feet from the top. The beds above the Amazonia are prevailingly sandy, those below are more commonly argillaceous. In places much of the member is replaced by a sandstone, apparently a channel deposit, well exposed in southern Platte and southwest Clay Counties, and encountered in wells to the northwest.

The highest member of the Douglas is the Oread, composed of four beds of limestone separated by thin beds of shale. The lower limestone is 3 to 8 feet thick and blue or gray in color. Above it lies 10 to 20 feet of blue to drab, sandy shale or red clay, succeeded by a dense dark gray, even-bedded limestone about 2 feet thick. Above is a shale about 5 feet thick which is usually in part black and "slaty." The next limestone varies from 17 to 35 feet in thickness, is thin-bedded, cherty, and has wavy, shaly partings. Above this limestone, and separated from it by clay shale as much as 14 feet thick in places, is the so-called "Waverly flagging," consisting of 3 feet or more of gray somewhat oolitic limestone.

The Oread is an important and very persistent member and can be followed southwest into Oklahoma. It forms a characteristic escarpment, giving rise to very conspicuous outcrops.

TYPICAL SECTION OF DOUGLAS FORMATION, NEAR SOUTH ST. JOSEPH.

Stratum.	Thickness.	
	Ft.	*In.*
Loess and drift	—	—
Limestone, wavy-bedded; thin layers; buff shaly partings (lower part of upper limestone of Oread member)	7	
Covered	19	
Shale, drab	5	
Limestone, dark brown; shaly to massive (lower limestone of Oread member)	7	
Sandstone and sandy shale; covered slope at bottom (top of Lawrence)	43	
Limestone, gray; even-bedded; weathers to buff (No. 137, Amazonia bed)	7	
Shale, blue, argillaceous; with brown ferruginous concretions	52	
Shale; very calcareous; fossiliferous; forms a resistant band where outcropping	2	6
Shale, red and green; argillaceous (base of Lawrence)	15	
Limestone, gray and compact (Iatan)	1	9
Shale parting (Iatan)		3
Limestone, gray and compact (Iatan)	2	
Shale, blue, argillaceous; to bottom of pit (top of Weston)	25	
Shale in drill hole	50	

Shawnee Formation.—The Shawnee, which rests on the Douglas, is the thickest formation of the Missouri series, varying from 475 feet to a minimum of about 350 feet at the Iowa line. Its outcrop extends from northwest Platte County north to Iowa, covering part of Buchanan, Atchison and Holt, and most of Andrew and Nodaway, and extending eastward into Worth and Gentry Counties. Although shale is dominant, beds of limestone occur throughout. The thicker shales are prevailingly sandy and micaceous; the thinner ones associated with the limestones are argillaceous or calcareous. There are several layers of black, "slaty" shale and thin coal seams in the formation. It consists of nine members briefly mentioned in the order of their occurrence from the bottom to the top of the formation.

The Kanwaka shale, at the base of the formation, consists of 30 to 50 feet of shale and sandstone.

The Lecompton consists of thin alternating limestones and shales, in all, 20 to 30 feet thick. In drillings, the limestone at this horizon is often reported as "chalk rock." Its fossil content has also given it the name of "sea-urchin" limestone.

The Tecumesh, 60 feet thick along Missouri River, is chiefly shale but contains some sandstone in places.

The Deer Creek consists of three limestones with intervening shales. The member is 30 to 35 feet thick, the three limestones comprising about 2/3 of the thickness.

The Calhoun is made up of 20 to 25 feet of shale, sandy shale, and sandstone with several thin limestone lenses.

The Topeka consists of about 25 feet of blue to buff limestone withinterbedded shale. On exposure the outcrop becomes a deep buff color.

The Severy, 30 feet thick, is a sandy shale, bituminous in the upper part and containing the Nodaway or Quitman coal bed.

The Howard limestone, the cap rock of the Nodaway coal, consists of two beds of limestone each about 2 feet thick, separated by 2 to 8 feet of shale.

Above the Howard limestone lies about 200 feet of clay, sandy shale, and sandstone with a number of thin buff-weathering limestones in the upper half. This is the Scranton shale member, comprising the highest beds of the Shawnee formation.

TYPICAL SECTION OF THE SHAWNEE FORMATION, NORTHWEST MISSOURI.

	Thickness.	
	Ft.	*In.*
Shale (top of Scranton)	25	
Lime	2	
Shale, red	5	
Shale, blue	15	
Shale, red	5	
Shale, blue	22	
Limestone (Elmo cap rock)	5	
Shale, blue	32	
Shale, red	6	
Sandstone	2	
Shale, blue (base of Scranton)	73	

TYPICAL SECTION OF THE SHAWNEE FORMATION—Continued.

	Thickness.	
	Ft.	*In.*
Limestone, brown, shaly; at base is a 4-inch grayish-blue layer of carbonate of lime and iron (top of Howard)	1	
Shale	4	
Limestone, ash-blue; silicious and pyritiferous (base of Howard)	1	6
Sandstone (top of Severy)		10–16
Shale, bituminous; absent in places, maximum	2	6
Clay, sandy		2
Coal (Nodaway)		4
Shale, light blue, clayey	2	
Shale, sandy		2
Shaly slope; shale at bottom	25	
Limestone; shaly and nodular (top of Topeka)		3
Shale, with brown, concretionary nodules of limestone	1	6
Limestone, rough, concretionary		10
Shale		10
Limestone, blue, even-bedded		10
Shale, blue	2	
Limestone, blue	1	1
Shale	10	
Limestone, ash-blue, weathers brown	1	6
Shale, yellow, gray streaks	2	10
Limestone, brown (base of Topeka)	1	6
Shale, yellow; bands of bituminous shale in the lower part (top of Calhoun)	7	
Sandstone	2	6
Limestone, grayish-blue	1	6
Shale		5
Limestone, gray; abounds in many fine univalves		6 ½
Shale, blue	3	6
Limestone, deep-blue, even layer		4
Shale, blue; at the base of this and resting on No. 186 is a calcareous stratum (base of Calhoun)	8	
Limestone, gray and buff (upper limestone of Deer Creek member)	15–20	
Shale, blue, argillaceous, and black, bituminous	5	
Limestone, gray, compact; full of calcite streaks; weathers buff (in two layers—upper 4 inches, lower 1 foot 8 inches); (middle limestone of Deer Creek member)	2	
Shale, drab	11	
Limestone, buff; two layers with shale partings (lower limestone of Deer Creek member)	4	
Shale, blue; argillaceous and arenaceous; micaceous (top ot Tecumseh)	52	
Limestone "conglomerate" corrugated; resembles the Iatan and Amazonia	2	
Shale, blue and buff (base of Tecumseh)	8	10
Limestone, gray; buff shaly partings; thin- and wavy-bedded (top of Lecompton)	5	6
Shale, blue, argillaceous	2	
Shale, black, bituminous	2	
Shale, argillaceous		4
Limestone, dark; full of Fusulina	1	
Shale, buff; calcareous at top ("chalk"); argillaceous at bottom	9	8
Shale, buff and white; calcareous	4	
Limestone, buff; in three layers with shale partings; contains many spines of Echinocrinus (base of Lecompton)	5	6
Shale, gray or blue; argillaceous or arenaceous; in places, sandstone (top of Kanwaka)	25	
Limestone, gray; even-bedded; in two layers	2	6
Shale, drab, argillaceous (base of Kanwaka)	16–20	
Limestone (top of Douglas formation)	—	—

Wabaunsee Formation.—The highest Pennsylvanian beds in the State are represented by the lower 100 feet of the Wabaunsee formation, which is much thicker in Kansas, owing to the presence of higher members. In Missouri the Wabaunsee is practically confined to Atchison County, where it consists largely of shale, sandy shale, and sandstone, with three or more persistent limestones and one irregular coal seam.

The Tarkio limestone, the bottom of the Wabaunsee, is 10 to 14 feet thick and consists of a basal bed about 4 feet thick overlain by thin layers of limestone separated by equally thin layers of shale.

Above the Tarkio lies about 20 feet of shale and sandstone overlain by the Nyman coal seam. A thin cap rock of limestone covers the coal. The remainder of the formation consists of sandy shale and sanstone containing one or two thin layers of limestone.

SECTION SOUTHEAST OF LANGDON.

Stratum.		Thickness.	
		Ft.	*In.*
Limestone		1	6
Shale, black			9
Limestone			17–19
Shale			6
Coal (Nyman)			8
Clay			2
Covered		18	
Limestone, dark blue	(Tarkio)	1	6
Clay, red, non-laminated	(Tarkio)	1	6
Limestone, brown, massive	(Tarkio)	3	6
Shale, blue (top of Scranton)		4	8
Slope covered with shale at bottom		22	

GENERAL STRUCTURE FEATURES OF PENNSYLVANIAN ROCKS.

Regional Dip.—The most prominent structural feature of the Missouri Pennsylvanian is the regional northwest dip away from the Ozark Dome. The general direction is approximately N. 57° W. In western Missouri, south of the River, the strata dip gently to the northwest; in northwest Missouri the dip is more westerly; in the north central part of the State the strata lie almost flat; while in the extreme northern counties the dip swings around to the southwest.

The regional dip is usually so slight that the rocks appear to the eye to lie flat, and the importance of this dip becomes evident only when large areas are considered. Actual measurements on certain beds of limestone and coal have shown the north and west components to average only 2.7 feet to 7.7 feet per mile. The total northwest dip of the surface strata will, however, average somewhat higher over considerable areas, though very rarely will it exceed 7 to 16 feet to the mile. To the west in Kansas, it increases to an average of 20 to 25 feet to the mile, and in northern Oklahoma, to 30 feet. Dips as high as 30 feet to the mile are rather easily noted in relatively small areas. Extended observations have shown, however, that where the regional northwest or west dip in Missouri reaches as high as 20 to 30 feet to the mile, local folding is usually responsible and the presence of a low terrace or possibly of an anticline or dome may be looked for.

Folding.—Folds in the Pennsylvanian area are commonly as gentle as the regional dips. Areas of marked deformation occur, but are very limited in size, and more commonly are gentle undulations detected only by the most careful geologic work over considerable areas. Well-developed anticlines or domes that are readily visible are practically lacking in the entire area. It is true that in a number of counties, including Vernon, Cass, Gentry, Caldwell, Livingston, Grundy and especially Linn, very pronounced folding is revealed by sharp dips accompanied in places by faulting, but such folding is very local and exceptional in all cases known. In the field work carried on by the Survey, it was found that the nature of the folding in the various parts of the Pennsylvanian area could be determined only by the most careful and detailed observations.

Hinds and Greene*, after an exhaustive study of the area, state,

> "The local structure seems to fall into three classes, which, however, are not separated by hard and fast lines. The first class of structure comprises the low undulations common in the western interior coal field and is best shown in coal mines with extensive workings or along creek beds.
>
> "The second class is the most striking and includes the small areas, usually two or three to a county, in which the rocks dip rather steeply and are faulted in a few places.
>
> "The last, and perhaps the most important class from an economic standpoint, includes the folds whose axes trend northwest and southeast. This class of folding like the regional dip, however, is so gentle that it can be detected only where geologic work covers a comparatively large area."

Considering the last class first because of its general importance, reference to Plate 4, will reveal the occurrences of a

*Hinds and Greene, "The stratigraphy of the Pennsylvanian series in Missouri"; Missouri Bureau of Geology and Mines, Vol. XIII, 1915, pp. 204, 205.

series of narrow, elongate anticlines extending in a westerly or northwesterly direction. These long anticlinal folds occur roughly paralleling one another from Vernon County northward to the State line. The folds are all low considering their size, and in most cases their axes are difficult to trace and have therefore been plotted in a general way only. The presence of this series of anticlines was determined from a general study of the entire Pennsylvania area, including surface observations, a large amount of data on the coal beds, and numerous well records. At best, however, the axes of the anticlines could be located only approximately, subject to change upon further study. While several of the anticlines have a deformation of from 50 to 100 feet, they are wide, with low dips, and therefore do not appear as sharp easily observed folds.

The larger anticlines have been named from points through which they pass, and are from south to north; the Shell City-Rich Hill; the Ladue-Freeman; the Centerview-Kansas City; the Richmond-St. Joseph; the Salisbury-Quitman; the Trenton; the College Mound-Bucklin; and the Kirksville-Mendota. The folding seems to be sharper, and the deformation greater south than north of Missouri River. The folding tends to die out in north central Missouri.

While these structures are not prominent and are very low, still they may have some influence on oil and gas accumulation. On these low anticlines may occur local domes, constituting especially favorable places to test. Much work will be necessary to reveal their real importance.

The first class of folding mentioned, including minor local undulations producing low anticlines, synclines, domes, and terraces, is represented at many localities in the Pennsylvanian area, as shown in the several structure maps accompanying this report. These areas are believed to be sufficiently typical to indicate the types of structure further mapping may be expected to reveal. There is, however, no doubt that some of the low local dips found in the Pennsylvanian, especially in the coal beds, have not been produced by folding, but are simply depositional. From a single outcrop, or in an area where outcrops are scarce, it is not always possible to tell whether a dip is the result of folding or is simply depositional, but where the outcrops are sufficiently good to permit study the distinction can be made. Along the creeks, it is surprising to note the extremely slight changes in the elevation of the exposed beds, and it is not at all common to find districts where there are undulations of sufficient extent to be significant.

A vast amount of work will be necessary to determine the nature of the structure classed under minor undulations, if oil prospecting in the Pennsylvania area is to be intelligently guided. The structures are commonly so low that marked dips are not in evidence. Good outcrops are scarce, the best available for mapping consisting of several thin limestone members separated by shales of marked variation in thickness. To obtain reliable structure maps, the problem is therefore usually one of careful and detailed mapping, for there are not many districts that lend themselves satisfactorily to reconnoissance work.

The last type of structure, including small areas of marked folding and faulting, is rather remarkable, occurring in a region characterized by extremely gentle folding and general lack of disturbance. Still, scattered over the Pennsylvanian region, according to Hinds and Greene "usually two or three to a county," are small areas, from a few acres to over a square mile, where the rocks are faulted in places, and dip at high angles in many directions. Such areas are known to occur scattered from Vernon County north to Gentry and east to Linn, and the surface rocks involved vary in age from the Cherokee shale to the Douglas formation. Concerning their origin, Hinds and Greene conclude,

> "These disturbances may be explained in two ways. Some may be due to solution of the underlying Mississippian, causing a collapse of the Pennsylvanian strata; others are probably due to the intersection of larger folds, where exceptional strains have resulted in steep dips or faults."

The writer's observations indicates that cross-folding more satisfactorily accounts for the disturbances than the solution of the underlying Mississippian limestones. However, no definite conclusion has been reached concerning their actual origin and they constitute a problem which deserves much study.

The detailed structural features necessary for intelligent prospecting in the Pennsylvanian rocks in Missouri are not always easily determined. The lower formations, which are most widely exposed, are composed chiefly of shale or of sandstone and contain few persistent beds which might serve as markers for mapping. The higher formations contain more limestone members but these occur chiefly north of Missouri River in an area heavily covered with glacial drift. Detailed structural mapping over a very large part of the Pennsylvanian area in Missouri is, therefore, difficult, and in many localities impossible. For this reason, and because the folds are commonly very low and determinable usually by detailed work alone, it is considered worth while to mention briefly the possibility of doing detailed mapping on the various formations.

Cherokee formation.—The Cherokee outcrop offers very little opportunity for detailed mapping. Lacking resistent beds, its topography is principally a flat to rolling plain with a scarcity of outcrops except along large streams. Locally, as in northwest Vernon County, thin limestones occur and outcrop sparingly, but over most of the area correlations are impossible. The coal beds offer the only satisfactory markers of any persistence in the formation. These do not commonly outcrop, but in many localities can be identified in the logs of drill holes and wells. In some areas the Cherokee offers no chance at all for structural mapping and at best the work is difficult and more or less unsatisfactory.

Henrietta formation.—The Ft. Scott and Pawnee limestones of the Henrietta constitute excellent markers for mapping. Being resistent they frequently form escarpments and ridges, and the Henrietta outcrop area is one of rough topography. Except in the northern part of the State, where the drift is thick, the Henrietta outcrop offers excellent opportunity for mapping, but unfortunately occupies only a narrow, ribbon-like strip of territory between the Cherokee and Pleasanton formation.

Pleasanton formation.—The Pleasanton formation probably offers less opportunity for mapping than the Cherokee. Locally thin limestone seams and certain shale beds are rather easily followed, but over most of its extensive area of outcrop, the shales and sandstones of which the formation is almost entirely composed, are totally devoid of markers. Its topography is typically flat to gently rolling, with very few outcrops and these of little value for structural mapping.

Kansas City formation.—The Kansas City outcrop is the most satisfactory mapping territory in the Pennsylvanian. In Mercer, Harrison and parts of Daviess Counties the drift buries the outcrops on the divides, but the limestones appear prominently along the principal streams. Elsewhere the several limestone members outcrop conspicuously in ledges and well-marked escarpments. One or more of these members can nearly always be easily followed for long distances and the various beds are readily correlated from place to place.

Lansing formation.—The Plattsburg and Stanton limestones of the Lansing outcrop conspicuously in parts of Platte, Clay and Clinton Counties and form good markers. Farther north they are generally concealed by the drift, and become split into a number of thin beds very similar to those present in the separating shale members. The correlation of the various beds is made difficult by the absence of good outcrops, the exposures being restricted to very narrow zones along the larger streams. As a whole, structural mapping is carried on with greater difficulty in the Lansing than in the Kansas City formation.

Douglas, Shawnee and Wabaunsee formations.—All three of these formations lie in an area partly covered with drift. Out crops occur abundantly in a narrow zone bordering the Missouri bluffs and extend a short distance back up the tributary streams. Over the wide divides, however, outcrops are extremely rare. The area as a whole is, therefore, unfavorable for good, detailed structural mapping.

CRETACEOUS SYSTEM.

No rocks of Cretaceous age are exposed in Missouri. Deep wells, however, in the southern part of the Southeast Lowland have in two or three instances penetrated unconsolidated sands believed to be Cretaceous. These beds described under the name Ripley sand, are discussed later, in the paragraphs on the Southeast Lowlands.

TERTIARY SYSTEM.

Exposed along Crowleys Ridge in the Southeast Lowlands are beds of loose sands, gravels and clays of Tertiary age. The oldest of these belong to the Wilcox formation, described in early reports on this area as the Lagrange formation. Only the upper beds are exposed in Missouri, and their total thickness is not known. Above the Wilcox formation lie the Lafayette gravels, possible Tertiary. These beds are discussed in the paragraphs on the Southeast Lowlands. Patches of chert gravels, possibly Lafayette, have been found in the vicintity of St. Louis and elsewhere in the State.

QUATERNARY SYSTEM.

PLEISTOCENE DEPOSITS.

The Pleistocene unconsolidated deposits overlie the bed rock and consist of drift, loess and alluvium.

Drift.—Scattered over nearly all the upland of northern Missouri as far south as Missouri River and across into northern Jackson, Lafayette, Saline, Cooper and St. Louis Counties, lies a mantle of drift varying from a few feet to over 300 feet in thickness. In a few parts of northwest and northeast Missouri, even the deepest streams have not cut below this mantle, but over most of this area bed rock is exposed along the deeper valleys. The drift is believed to represent two ice invasions though it is not considered necessary to differentiate their deposits here.

In composition the drift consists chiefly of clays, sandy clays and sands. Boulders of various sizes and types are scattered through the clays without arrangement. Logs of wood are occasionally encountered by the drill in local gravel beds at depth. The thickness of the drift varies from 100 to 300 feet along the Iowa state line, thinning to the south. Exceptional thickness is shown where pre-glacial valleys have been filled by the drift.

Loess.—Loess is a fine yellow to buff-colored clay found in greatest development in proximity to Missouri and Mississippi Rivers, and capping Crowley's Ridge in the Southeast Lowlands. This clay is, however, widely distributed over the northern part of the State as a very thin mantle. The thickness is extremely variable, ranging from only a bare covering in the northern counties to as much as 200 feet along Missouri River.

Alluvium.—Alluvial sands, clays and gravels of Pleistocene age underlie many of the low ridges, such as Sikeston and Sandy Ridge, in the Southeast Lowland area. This alluvium it has not been considered necessary to differentiate from the recent alluvial covering of this district, and they are discussed together.

RECENT DEPOSITS.

The recent deposits include alluvium and residuum. The alluvium, composed of clay, sandy clay, sand and gravel in alternating layers of various arrangement, fills the valleys of most of the important streams to a considerable depth. Along the Missouri and Mississippi Rivers a maximum thickness of 150 feet has been encountered. Underlying the Southeast Lowland area the alluvium has a thickness in places of over 200 feet.

The residuum is the result of weathering of the bed rocks, and is the predominant mantle over the Missouri upland south of the Missouri River. Its composition depends upon the type of rock from which it was derived; that overlying the Pennsylvanian shales and sandstones differing from that overlying the cherty dolomites of the Ordovician. Over the Ozark dome the residuum, often called "geest," consists of a heterogeneous mixture of clay, chert and sand, ordinarily but a few feet thick. However, on the southeastern slopes of the dome it is exceptionally well developed, and 100 to 250 feet must be passed through locally to reach the bed rock.

AGE OF ROCKS IN WHICH OIL AND GAS HAVE BEEN FOUND IN MISSOURI.

Recent		Pockets of marsh gas in alluvium.
Pleistocene		Small pockets of gas in Sullivan and other north Missouri counties, in drift.
Tertiary		None; marsh gas in Southeast Lowlands.
Cretaceous		None.
Pennsylvanian	Upper Pennsylvanian	Asphaltic limestone (Bethany Falls) in Cass, Jackson, and Caldwell counties; no oil or gas.
	Lower Pennsylvanian	Gas wells and light oil wells from Barton County, north to Clinton County in western Missouri. These rocks yield principal gas found in state. Asphaltic sandstones of west Missouri. Oil seeps in Graydon sandstone.
Mississippian	Chester Group	None.
	Meramec Group	None.
	Osage Group	Small pockets of asphaltic, heavy, oil in southwest Missouri in Boone limestone.
	Kinderhook Group	Gas in McDonald County from Noel shale; also showings of oil. Gas in St. Louis County in very small amounts.
Devonian		Oil reported in Putnam County is probably of Devonian age.
Silurian		None.
Ordovician	Upper Ordovician	None.
	Middle Ordovician	Gas and showings of oil in St. Louis County from Plattin ("Trenton") limestone. Very small quantity of gas in Lewis County probably in these rocks.
	Lower Ordovician	None.
Ozarkian		None.
Cambrian		None.
Pre-Cambrian		None.

CHAPTER IV.

OIL AND GAS IN ROCKS OLDER THAN THE PENNSYLVANIAN.

IGNEOUS AND PRE-CAMBRIAN ROCKS.

No appreciable amount of oil or gas has ever been found anywhere in the igneous or in the pre-Cambrian rocks, and it would be difficult to account for any source for these fuels in important quantities. Hence, where such rocks outcrop or after they are reached by the drill there is no chance of obtaining oil or gas in commercial quantities. In the portions of Iron, Madison, Wayne, Shannon, Reynolds, St. Francois, Washington and adjacent counties where the granites and porphyries outcrop, or where these rocks are only thinly covered by broken or faulted sediments, there is no possibility of encountering oil or gas. Elsewhere in the state, drilling should be discontinued as soon as the granite or porphyry is encountered.

CAMBRIAN ROCKS.

The Cambrian rocks are distinctly older than any of the oil or gas producing formations in the fields of Illinois, Kansas or Oklahoma, and have never been noted to be petroliferous in Missouri. In the history of oil and gas production the Cambrian rocks have played an almost negligible part up to the present time and are not considered as favorable formations in which to prospect for these fuels.

These rocks where exposed, in and around the St. Francois mountain region, have been well studied. The only sandstone present lies at the base of the section and rests directly on old igneous rocks. This sandstone, the Lamotte, while thick, carries only a very few fossils and from its stratigraphic relations it would be difficult to account for any source from which it could receive important quantities of oil. The overlying Cambrian formations are composed chiefly of dolomites with a lesser amount of shale, and, where buried beneath younger sediments, are chiefly "tight," compact rocks, offering poor storage space for oil.

On no account can drilling for petroleum in the Cambrian rocks of Missouri be advised, and all the evidence available indicates the improbability of finding oil or gas in these strata.

OZARKIAN (LATE CAMBRIAN).

The Ozarkian rocks are also older than any of the important oil and gas bearing formations in the country, and so far as known no trace of either fuel can be credited to them either in Missouri or in any of the adjoining states.

In Missouri the Ozarkian formations consist almost entirely of more or less compact dolomites, fine-grained to crystalline with only one thin, non-persistent sandstone, the Gunter. Nowhere along their outcrops on the Ozark highland, or in the surrounding region where they have been penetrated by the drill, have these rocks shown any indications of being petroliferous. There is, therefore, no basis whatever for advising oil or gas prospecting in them in Missouri, and all available evidence would seem to indicate that there is practically no possibility of their containing commercial quantities of either fuel.

As these rocks are practically non-petroliferous, a very large part of the Ozark region in Missouri offers very little hope of yielding commercial quantities of oil or gas. These rocks outcrop extensively from Ste. Genevieve County on the east to Dallas on the west, and from Gasconade and Moniteau on the north to Oregon and Ozark Counties on the south. Where they are not exposed in this great area, either they are removed by erosion or they are covered by a thin veneer of younger rocks, which, for the most part, can be looked upon with scarcely more favor as possible sources of oil and gas.

ORDOVICIAN ROCKS.

The oldest formations in North America productive of large commercial quantities of oil and gas belong to the Middle Ordovician series which includes the Trenton limestone. In the various oil fields of this Continent, rocks of nearly all geologic systems younger than the Ordovician are listed among the important oil-bearing horizons, but at only a few unimportant localities have rocks older than Middle Ordovician been cited as productive. Similarly in Missouri, the oldest formation in which any appreciable traces of oil and gas have been found is the Plattin limestone. The Plattin, probable equivalent of the Black River, and the overlying Kimmswick, partial equivalent of the Trenton, are the Missouri representatives of the Middle Ordovician.

Lower Ordovician.—Below the Plattin limestone lie over 500 to 1000 feet of Lower Ordovician or Canadian beds, ranging from the Joachim dolomite down to the Roubidoux sandstone. The Roubidoux and Jefferson City formations, which constitute the two basal members of the group, are extensively exposed over the Ozark highland and certainly underlie the greater part of the State. The St. Peter sandstone and Joachim limestone, the two upper formations, are less widely exposed, but are well developed in eastern Missouri. These rocks, from the Joachim down to the Ozarkian, are all older than the well known productive horizons of the Ordovician. In Howard and Estill counties, Kentucky, however, gas flows and a showing of oil has been reported from the "Calciferous limestone" of lower Ordovician age.* It is also reported that the Burgen sandstone, the probable equivalent of the St. Peter in Oklahoma, has produced a little oil. In Missouri the entire series has been closely studied and the rocks have been drilled through at many widely separated points throughout the State without finding the remotest evidence of oil or gas.

Both the St. Peter and Roubidoux sandstones are known as valuable water-bearers, though throughout most of the area of their distribution, except the Ozark Dome, they yield saline water or brines. The Roubidoux supplies the deep well water in the Joplin district and Springfield, as well as the artesian mineral waters at Nevada and Clinton, and is known to yield salt water at Higginsville, Moberly, Chillicothe, Macon, Hannibal, and many other points. The St. Peter yields fresh water at Moberly but is the source of the sulpho-saline artesian waters at LaGrange and Canton. Because these sandstones have been so extensively drilled for their waters, they have been widely studied over much of the state and certainly neither can be considered with any favor as a likely bearer of commercial quantities of oil or gas.

In short, from a study of the Lower Ordovician and older formations in Missouri, based on outcrop observations and many borings which have in part or in whole penetrated them, and from the well-known scarcity of petroliferous deposits in these rocks, no encouragement for prospecting in them can be given. Hence where they outcrop it seems clearly inadvisable to begin drilling for oil, and drilling should be discontinued when the St. Peter sandstone, an easily identified horizon, has been penetrated.

*Kentucky Geol. Survey, Bulletin No. 1; Oil and gas, pp. 44 and 55, 1905.

By consulting the State geologic map accompanying this report the Cambrian, Ozarkian, and Lower Ordovician formations can be seen to cover a large part of the southern portion of the State, especially throughout the Ozark region proper. Because of the unfavorable geological conditions the area is not considered favorable to the production of oil or gas in commercial quantities.

The lack of a possible source of oil is shown by deep tests that have been drilled throughout the Ozark region. The records (See page 270) indicate the absence of any carbonaceous shale or limestone that might serve as the original source.

Middle and Upper Ordovician.—The only locality in Missouri where either oil or gas has been obtained from Ordovician rocks is in St. Louis County. Here, in the City of St. Louis, a number of wells 600 to 930 feet deep have found gas and some very small quantities of oil, chiefly between the depths of 550 and 750 feet. Minor occurrences of both oil and gas are reported at still higher levels. The source of the principal finds is the Plattin ("Trenton") limestone, according to Fenneman,* who also concludes that the minor occurrences at higher levels have probably escaped upwards from this source. Only a few of the gas wells, of which there were probably a dozen, have been investigated, but it is concluded that the principal source of supply was the same in all the wells and that the accumulation has taken place under small folds or anticlines in the area. St. Louis lies in a rather marked syncline of large size in which small anticlines having a north-northwest trend and cutting the regional dip transversely are known to occur. The axis of one of the anticlines observed in the west bluff of the Mississippi passes through the workhouse quarry west of north past Compton Hill reservoir and dies out in the vicinity of Grand Avenue viaduct. It has a maximum vertical deformation of fully 200 feet and beneath it the Plattin limestone is reached at a shallower depth than to the east or west. Several of the wells showing oil and gas are located on this fold. Other wells not located on this fold, it is suggested, are probably situated on similar folds whose limits have not yet been determined.

The following information concerning several of the wells is quoted from Fenneman.†

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*Fenneman, N. M., Geology and Mineral Resources of the St. Louis Quadrangle; U. S. Geol. Survey, Bulletin 438, p. 58, 1911.

†N. M. Fenneman, op. cit., pp. 59-61, 1911.

"The best known of these wells are near the center of St. Louis, on the north end of the pitching anticline. At the Welle-Boettler Bakery, on the corner of Vandeventer avenue and Forest Park boulevard, three wells entered the Plattin limestone. One of these found little indication of either gas or oil, but tapped a very heavy brine in the Plattin. Another found a similar brine and likewise a quantity of gas, which was used under bake ovens for about six months in 1904. It was equivalent at the start to 7 or 8 bushels of coke daily. The closed pressure is said to have reached 240 pounds per square inch, but the circumstances under which this observation was taken are not known. The pressure gradually weakened, until at the end of one year but little gas continued to escape. This well when pumped yielded about a barrel a day of heavy black, ill-smelling oil. It is known that both gas and oil came from levels below 565 feet, and probably below 600 feet.

"The strata passed are known in part from the following record of a well drilled in November, 1904. This well is one of three, no two of which are more than 200 feet apart."

RECORD OF WELL ON NORTHWEST CORNER OF VANDEVENTER AVENUE AND FOREST PARK BOULEVARD, ST. LOUIS, MO.*

	Thickness, Feet.	Depth, Feet.
Filled ground	20	20
Soft gray clay	20	40
Sand and gravel	20	60
Hard gray limestone, shaly, a little water	20	80
Soft brown limestone	20	100
Hard brown limestone	20	120
Soft gray limestone; water at 140-160 and 185-210 feet	120	240
Soft gray shale	20	260
Hard gray limestone	5	265
Soft gray limestone and shale	15	280
Gray limestone; showing of oil at 280-290 and 305-325 feet	180	460
Very hard gray limestone and chert	10	470
Hard gray limestone	15	485
Soft gray shale	5	490
Hard gray limestone	20	510
Soft, dark red shale; showing of oil	20	530
Hard gray limestone	35	565
Hard gray limestone and shale, caving badly	35	600
Soft black shale; a little oil	20	620
Soft brown limestone, "Trenton"; a little oil	30	650

*Obtained by E. O. Ulrich from the driller, E. D. Meloy, and published in Bulletin U. S. Geol. Survey, No. 264, p. 89, 1905.

"The well yields a small amount of gas.

"In drilling one of the other two wells (not the productive gas well) samples were carefully kept and labeled to indicate the depth. The description of these agrees with the log given above.

SAMPLES FROM WELL AT WELLE-BOETTLER BAKERY, ST. LOUIS, MO.

	Depth in feet.		Depth in feet.
Fine gravel	55	Gray limestone	545
Brown limestone	70	Brown limestone	560
Gray limestone	90	Gray limestone	580
Gray limestone	170	Gray shale	600
Gray limestone	220	Dark, nearly black, calcareous shale	610
Gray limestone	225	Limestone	624, 640
Gray limestone	240	Same (may be mixed with shale)	662
Gray limestone	285	Blue noncalcareous shale	685
Limestone and chert	322	Dark brown non calcareous shale	735
Limestone and chert	380	Gray limestone	805-850-900
Limestone and chert	420	Brownish-gray limestone	934
Limestone and chert	485		
Limestone with brown shale (Fern Glen)	525		
Brown shale or limestone (Fern Glen)	528		

"From the above log and samples it is known that the base of the red shale of the Fern Glen is at 530 feet. This is underlain first by 35 feet of hard gray limestone and then by 35 feet of limestone and shale said to contain small quantities of oil. Still lower is 20 feet of black shale which undoubtedly contained some oil. The correlation of these beds beneath the Fern Glen is uncertain, but there is little reason to doubt that the stratum beneath these, a soft brown limestone between 620 and 662 feet, is K mmswick limestone.*

"Less than half a mile south by east from the above-described wells, at Tamm's glue factory, is a well which for a short time yielded a considerable amount of gas. Samples taken during the drilling indicate that this gas came from essentially the same horizon as that at the bakery. The base of the red shale of the Fern Glen is here at a depth of 505 feet. As the surface of the ground is 10 to 15 feet lower than at the Welle-Boettler wells, this indicates a northerly dip of the strata of not more than 10 or 15 feet within that distance. Allowance must be made for liability to error in reporting depths; for the dip as determined by other horizons is considerably greater. The section of Tamm's well below the Fern Glen is as follows:

PARTIAL SECTION OF WELL AT TAMM'S GLUE FACTORY, ST. LOUIS, MO.

	Feet.
Red shale (Fern Glen)	495–505
Gray limestone with gas	505–530
Brown shale	530–540
Soft brown limestone (probably Kimmswick); contains gas	540–575
Buff limestone, probably yielding gas	575–610
Blue shale	610–680
Brown shale	680–710
Gas below brown shale, rock not known	710–

*E. O. Ulrich (Bull. U. S. Geol. Survey No. 264, 1905, p. 90) provisionally classes the 70 feet of limestone beneath the Fern Glen as Kinderhook and the 20 feet of black shale as the Ohio shale (Devonian).

"Drops of oil similar to that found in the Welle-Boettler well were frequently observed. Like several of the wells above mentioned, this well was shot with dynamite.

"At the quarry of the Fruin-Bambrick Construction Company, one-third of a mile southeast of Tamm's well, similar pockets of gas were encountered at slightly higher levels and in similar rocks. The section is almost identical with that of the Tamm well.

"At various other places in St. Louis 'showings' of oil have been observed in deep wells. A well drilled in 1905 at the Union Brewery, Gravois and Michigan avenues, St. Louis, encountered a very small amount of oil, but its depth is variously stated. It will be observed that this location is south by east of those mentioned above, not far from the axis of the anticline. A similar showing is said to have been found in a well drilled fifteen or twenty years ago at the Grone Brewery, Twentieth street and Clark avenue."

The gas wells found in the St. Louis area were all short-lived and the gas is evidently localized and controlled by the small anticlines. Many other deep wells in St. Louis and St. Louis County, some sunk in search of oil and gas, have been drilled through the Ordovician rocks without results, but most of these have been sunk without reference to structural conditions. Regarding the prospects of future development in this area Fenneman states further:

"So far as oil and gas have been found in this region, their occurrence is exactly where it should be expected from a study of the structure, namely, on the crest of a gentle anticline. It is not improbable that there are similar anticlines not now known. Other similar pockets of gas and oil may therefore be found in the future. So long as they remain undiscovered there is no positive evidence that larger ones may exist than those already found. Any search for them should be preceded by a careful exploration of local folds. This is emphasized by the remarkable agreement of the distribution so far as known with the anticlinal theory.

"Difficulties in applying this theory to the St. Louis region arise: (1) from the loess cover and the fewness of the outcrops; (2) from three unconformities of erosion and, to an unknown extent, of angle. The first of these unconformities is between the Kimmswick limestone, which contains the supposed deposits, and the overlying upper Ordovician shale believed to be of Maquoketa age. The second is between the Ordovician system and the Carboniferous. Discrepancy of angle corresponding to those unconformities has not been shown in this area, and it is probably not great if it exists at all. It is to be remembered, however, that the localization of gas and oil is determined by relatively small folds. The third unconformity is between the Mississippian and the Pennsylvanian series. Although a distinct unconformity of angle at this horizon is not shown within the area considered, it is known to exist at places somewhat nearer the Ozarks, and may yet be found in this area. To judge from the wells whose logs were obtained, there is a strong supposition that in the small anticline in St. Louis which has given showings of gas and oil the Kimmswick limestone is essentially parallel to the beds at the surface (St. Louis limestone)."

With the discovery of the small gas wells and showings of oil in the Middle Ordovician rocks in St. Louis County, the question naturally arises as to what may be expected from these and the Upper Ordovician rocks in other parts of Missouri. South of Missouri River the question is apparently easily answered as the Middle and Upper Ordovician beds are entirely absent except in the St. Louis County area and southeast in a narrow belt along Mississippi River as far as Cape Girardeau County. Wells should, therefore, not be sunk in counties to the west with the idea of reaching the "Trenton limestone." North of the River these rocks are only known to occur in and east of the tier of counties in which Randolph and Macon are situated or in northeast Missouri. In this section of the State they have been completely penetrated in every county, with the exception of Schuyler, without yielding any appreciable quantities of oil or gas.

The following is a partial list of the deep wells which have penetrated these rocks in northeast and east-central Missouri. Where possible, the depth to the St. Peter sandstone is noted, inasmuch as this sandstone lies below the Middle Ordovician beds, and once reached, indicates that the horizon of the "Trenton" limestone has been passed, and that deeper drilling for oil or gas is practically useless.

PARTIAL LIST OF DEEP WELLS IN NORTHEAST MISSOURI

County.	Location, approximate.	Depth of well.	Depth to Ordovician.	Depth to St. Peter sandstone.	Driller.	Date.	Remarks.
St. Charles	St. Peters	2700	437	798	R. D. Silver	1910	Test well.
	St. Charles	1475	Unknown.	Unknown.	Shible Brewing Co.	......	For water.
	West of St. Charles	....	....	....	....	......	Test well.
Warren	Warrenton	815	200	368	City of Warrenton	1912	For water.
Montgomery	Montgomery City	800	....	480	Montgomery City	1898	For water.
	Montgomery City	1250	....	....	....	......	....
	Wellsville	857	340	495	C., B. & Q. R. R.	......	For water.
	Bellflower	1500	300 +	485	T. W. Schowengerdt	1912	Test well.
Callaway	Fulton	6 wells 700 to 1142	Upper and Middle Ordovician absent. Lower Ordovician at 250. ±.				....
	N. E. of Cedar City	1300	Well started in Lower Ordovician.				Test well.
	Cedar City	....	Well started in Lower Ordovician.				Test well.
Audrain	Mexico	1100	....	450	Mexico Water and Light Co.	1896	For water.
	Mexico	1173	420	450	Mexico Power Co.	1914	For water.
	Vandalia	684	....	652	City of Vandalia	1910	For water.

Lincoln	New Chantilly	650	300 ±	595	W. Overall	1913	For water.
	Moscow Mills	740	425	661	Prairie Oil and Gas Co.	......	For water.
	Ordovician rocks at surface in part of Lincoln County.						....
Pike	Louisiana	1275	....	500 to 600 ft.	....	1887	....
	Clarksville	833	270	750	E. L. Roberts	1900	For water.
	Ashburn	665	....	510	....	......	....
Clark	Kahoka	1200	682	1060	Missouri Condensed Milk Co.	1908	For water.
	Revere	890	....	Not reached.	R. C. McKee	......	For water.
	Wayland	725	....	Not reached.	A. J. Johnson	......	For water.
Lewis	LaGrange	850	375 ±	800	W. H. Thomas	1888	For water.
	Canton	730	560	Not reached.	Canton Oil & Gas Co.	1914	Test well.
	Canton	928	530 ±	895	Canton Oil & Gas Co.	1915	Test well.
	Monticello	1052	....	930	E. S. Smith	1914	For water.
	N. W. of Canton 5½ mi.	....	600 ±	....	T. M. Long	1915	For water.
	N. of Canton, 6½ mi.	941	....	Near bottom	Kaskaddin	1915	For water.
Marion	Palmyra	1770	370 ±	600	....	1898	Test well.
	Hannibal	1435	350 ±	601	Vernett well	1894	For water.
	Nelsonville	875	510 ±	650	C. H. Mohr	......	For water.
	Woodland	510	350 ±	505	C. Way	......	For water.

PARTIAL LIST OF DEEP WELLS IN NORTHEAST MISSOURI—Continued.

County.	Location, approximate.	Depth of well.	Depth to Ordovician.	Depth to St. Peter sandstone.	Driller.	Date.	Remarks.
Scotland	Memphis	1200	850 ±	Not reached.	City of Memphis	1914	For water.
	Gorin	1238	875 ±	1100	Midland Oil & Gas Co.	1907	Test well.
Knox	N. W. of Hurdland	1308	600 ±	955	Midland Oil & Gas Co.	1905	Test well.
	N. W. of Baring	1450	550 ±	900	Midland Oil & Gas Co.	1908	Test well.
	Kenwood	856	....	Not reached.	Midland Oil & Gas Co.	1909	Test well.
	Baring	2125	....	944	Santa Fe R. R.	1912	For water.
	Edina	800 ±	....	Not reached.	City of Edina	......	For water.
Ralls	6 mi. east of Perry	490	230 ±	478	T. E. Allison	1913	For water.
	New London	Ordovician at surface.					
	Ilasco	545	358	....	Atlas Portland Cement Co.	......	For water.
	Monroe City	2150	400 ±	650	City	1910	For water.
Shelby	Bethel	620	400 ±	612	Mars. Bros.	......	For water.
	Bethel	613	450	Not reached.	J. H. Moore	......	For water.
	Clarence	810	....	825	Clarence Oil & Gas Co.	1910	Test well.

Probably the most interesting set of wells sunk with the idea of testing the "Trenton" limestone in northeast Missouri is the group drilled by the Midland Oil and Gas Company, in Knox and Scotland Counties. This company sank four wells in 1907-09, near Gorin, Baring, Hurdland, and Kenwood, all except one reaching or passing below the St. Peter sandstone. None of the wells were successful in finding important quantities of either fuel, if, indeed, even showings were encountered, and the wells all ended in salt water horizons at depths of 856 to 1450 feet. The following record is more or less typical of the rocks penetrated by the group.

DRILLER'S RECORD OF GORIN FLOWING WELL. MIDLAND OIL & GAS COMPANY, GORIN, SCOTLAND COUNTY.

	Thickness feet.	Depth. feet.
Soil, black	12	12
Sand and gravel	20	32
Gravel, dark (water)	20	52
Clay, blue	18	70
Sand, white	10	80
"Black Jack"	65	145
Sand (water)	15	160
Limestone, yellowish, hard	20	180
Sandstone	36	216
Limestone, hard	10	226
Shale, blue	10	236
Limestone, hard	13	249
Sandstone (water)	35	284
Shale, soft, pyrite	29	313
Sandstone, light color	3	316
Shale	5	321
Limestone, hard, blue	79	400
Limestone, flinty	50	450
Sandstone	7	457
Limestone, flinty	56	513
Shale	15	528
Limestone	25	553
Shale, "Big shale"	220	773
Limestone	35	808
Shale	70	878
Limestone	39	917
Limestone, fossils	105	1022
Sandstone, water-bearing	7	1029
Limestone, fossils	71	1100
Sandstone, white, sugary (St. Peter)	73	1173
Shale	5	1178
Sandstone	18	1196
Limestone (dolomite)	42	1238

In 1915 two test wells were sunk by the Canton Oil and Gas Company, near Canton, Lewis County, both of which entered the Middle Ordovician strata, and one of which reached the St.

Peter sandstone. Neither well encountered showings of oil or gas in the "Trenton" limestone and both resulted in striking artesian flows of salt water. The record of the deeper well follows:

RECORD OF THE CANTON OIL AND GAS COMPANY WELL NO. 2, S. W. ¼, N. W. ¼, SEC. 14, T. 62 N., R. 6 W.

	Thickness	Depth.
	Feet.	*Feet.*
Loess, clay and shale	40	40
MISSISSIPPIAN SYSTEM:		
Burlington-Keokuk formation:		
Limestone, blue to gray, crystalline, white and blue chert	100	140
Limestone, fine-grained, grayish-blue	80	220
Limestone, medium-grained, grayish-blue, white chert	60	280
Hannibal formation:		
Shale, gray, uniform	50	330
Shale, sand, greenish	40	370
Louisiana formation:		
Limestone, grayish-brown, hard, fine-grained	50	420
DEVONIAN SYSTEM (?)		
Shale, bluish gray	40	460
Shale, clayey, dark gray	20 +	480 +
ORDOVICIAN SYSTEM:		
No record	65 +	545 +
Limestone, light to dark gray, fine-grained, much calcite and pyrite, more crystalline toward base	175 +	720
Limestone, light gray, very hard, fine-grained	30	750
Limestone, magnesian, fine-grained, brown, hard	60 +	820 +
No record	80—	880 +
Limestone, very free effervescence, almost non-magnesian	15 +	895
Sandstone, white, coarse-grained, St. Peter	33 +	928 +

A number of other test wells exploiting the "Trenton" limestone, similar to those drilled in Scotland, Lewis, and Knox Counties, have been drilled in the counties to the south with results no more encouraging. In fact, aside from the St. Louis area, few if any significant showings of oil or gas have been found in wells penetrating the Upper or Middle Ordovician in Missouri. A very small flow of gas has been reported from a well near Mayfield, Lewis County, possibly from these rocks though the horizon from which it came is not certain. The flow was so small and short-lived as to indicate that only a local pocket had been found. From the data available there seems to be very little to encourage prospecting in the Upper and Middle Ordovician rocks in northeast Missouri, though from the St. Louis discoveries, these rocks may be considered as possible producers. Under equally favorable structural conditions there is no reason to believe that gas wells similar to those in St. Louis might not be found in northeast Missouri, and under more favorable conditions, possibly still larger supplies of either oil or gas may be encountered. No test well in the area should be considered complete until these rocks have been penetrated and the St. Peter sandstone reached.

Following are several well records showing the character of the strata penetrated down to or below the St. Peter sandstone in various parts of northeast Missouri:

RECORD OF MISSOURI CONDENSED MILK FACTORY WELL, KAHOKA, CLARK COUNTY.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil and yellow clay	15	15
Clay, yellow, drab and blue	135	150
Sand and gravel	11	161
MISSISSIPPIAN SYSTEM:		
St. Louis Limestone:		
Limestone, gray	9	170
Sandstone, soft (water)	9	179
Limestone, very fine, gray	51	230
Warsaw shale and limestone:		
"Soapstone"	60	290
Burlington-Keokuk formation:		
Limestone	110	400
Fire clay	6	406
Limestone, with chert	66	472
Kinderhook formation:		
"Soapstone," blue	30	502
Sandstone, bluish	9	511
DEVONIAN SYSTEM: (Possibly some Kinderhook at top.)		
Shale, blue-gray	126	637
"Soapstone," ash color	20	657
Shale, brown	25	682
ORDOVICIAN SYSTEM: (Upper and Middle.)		
"Cincinnati" shale:	85	767
"Trenton" and Joachim formations:		
Limestone	293	1060
St. Peter sandstone:		
Sandstone	131	1191
ORDOVICIAN SYSTEM: (Lower or Canadian)		
Jefferson City dolomite:		
Limestone (dolomite)	12	1203

RECORD OF THE J. W. SCHOWENGERDT WELL, BELLFLOWER, MONTGOMERY COUNTY.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil and clay	70	70
Gravel and "shell rock"	36	106
MISSISSIPPIAN SYSTEM:		
Flint rock	38	144
Limestone	96	240
Sandstone, white	22	262

RECORD OF THE J. W. SCHOWENGERDT WELL—Continued.

	Thickness.	Depth.
	Feet.	*Feet.*
ORDOVICIAN SYSTEM:		
Limestone (includes Kimmswick)	223	485
Sandstone (St. Peter)	110	595
ORDOVICIAN (LOWER) AND OZARKIAN SYSTEMS:		
Limestone, gray	165	760
Sandstone, white, very hard	18	778
Limestone, whitish	37	815
Sandstone, white	23	838
Limestone, brown	20	858
Sandstone, white	62	920
Limestone, white	30	950
Sandstone and limestone	50	1000
Limestone, white	50	1050
Sandstone, white	80	1130
Limestone, blue, very hard	26	1156
Sandstone and limestone	44	1200
Limestone, white crystalline	75	1275
Flint rock	32	1307
Limestone, whitish	193	1500

RECORD OF R. D. SILVER WELL, ST. PETERS, ST. CHARLES COUNTY.

	Thickness.	Depth.
	Feet.	*Feet.*
Alluvium	25	25
MISSISSIPPIAN SYSTEM:		
St. Louis limestone:		
Limestone, fine-grained, gray chert	115	140
Burlington-Keokuk limestone:		
Limestone, gray to white, coarsely crystalline chert	140	280
Burlington-Chouteau limestone:		
Limestone, gray, finely crystalline chert	119	399
Hannibal shale:		
Shale, gray to brown, sandy	38	437
ORDOVICIAN SYSTEM:		
Kimmswick limestone:		
Limestone, gray to white, coarsely crystalline, cherty	105	542
Kimmswick-Plattin limestone:		
Limestone, dark gray, fossiliferous, fine-grained, cherty	49	591
Plattin limestone:		
Limestone, gray to drab, very fine-grained	151	742
Joachim dolomite:		
Dolomite, brown to gray	56	798
St. Peter sandstone:		
Sandstone, white, rounded grains	202	1000
Jefferson City formation:		
Magnesian limestone, gray to buff, fine-grained, shale, sandstone and chert	334	1334
Roubidoux formation:		
Sandstone, white, coarse to fine; dolomite, buff, crystalline, some chert	116	1450
OZARKIAN SYSTEM:		
Gasconade formation (including Gunter sandstone):		
Dolomite, gray, white, crystalline; white chert	570	2020
Sandstone, white, fine-grained	130	2150
Potosi formation:		
Dolomite, brown, finely crystalline, chert	257	2407

RECORD OF R. D. SILVER WELL—Continued.

	Thickness.	Depth.
	Feet.	*Feet.*
CAMBRIAN SYSTEM:		
Davis formation:		
Sandy shale	41	2448
Magnesian limestone, dark gray, finely crystalline	4	2452
Shale, blue, sandy	4	2456
Bonne Terre formation:		
Dolomite, brown and black carboniferous shale	181 +	2637 +
LaMotte (?) sandstone at	....	2700

RECORD OF MEXICO POWER COMPANY'S WELL, MEXICO, AUDRAIN COUNTY.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil and clay	45	45
PENNSYLVANIAN SYSTEM (Des Moines series):		
Limestone, drab, fine-grained	5	50
Shale, dark, bituminous	10	60
Limestone, drab, fine-grained	8	68
Coal	1	69
Shale, gray, clayey	51	120
Limestone, drab	12	132
Shale, blue	10	142
MISSISSIPPIAN SYSTEM:		
Burlington limestone:		
Chert, white to blue	8	150
Chert, white; limestone, gray, crystalline	5	155
Chert, white; dark, sandy, shale	17	172
Limestone, brownish-gray, crystalline	70	242
Chouteau limestone:		
Calcareous shale	15	257
Limestone, gray, finely crystalline, compact	103	360
Hannibal shale:		
Shale, light gray	5	365
Sandstone, fine; shale, and a little limestone	18	383
DEVONIAN SYSTEM:		
Limestone, light gray, crystalline, sandy	37	420
ORDOVICIAN SYSTEM:		
Joachim limestone:		
Magnesian limestone, gray, finely crystalline	30	450
St. Peter sandstone:		
Sandstone, white	168	618
ORDOVICIAN (Lower) and OZARKIAN SYSTEMS:		
Jefferson City formation:		
Shale, gray, clayey; pyrite	10	628
Dolomite, "cotton rock"	82	710
Sandstone, fine; green shale; cherty	20	730
"Cotton rock," oolitic chert	90	820
Dolomite, fine-grained, gray	70	890
"Cotton rock"	10	900
Dolomite, gray, finely crystalline; cherty	40	940
Roubidoux sandstone:		
No sample; water	24	964
Dolomite, finely crystalline, cherty	16	980
No sample	10	990
Dolomite, light gray	25	1015
Cuttings washed away	15	1030

RECORD OF MEXICO POWER COMPANY'S WELL—Continued.

	Thickness.	Depth.
	Feet.	*Feet.*
Dolomite, crystalline, quartz grains and white chert	50	1080
No cuttings	20	1100
Gasconade formation:		
Dolomite, white, small amount of sand	25	1125
Dolomite, gray to white	48	1173

RECORD OF PRAIRIE OIL AND GAS COMPANY WELL, MOSCOW MILLS, LINCOLN COUNTY.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil and clay	8	8
Hardpan, yellow	4	12
Soapstone, blue	40	52
Mixed gravel, water	3	55
MISSISSIPPIAN SYSTEM:		
Sandstone, white, hard	25	80
Limestone, brown, hard, cherty	260	340
MISSISSIPPIAN-DEVONIAN SYSTEMS:		
Soapstone, blue, soft	10	350
Limestone, brown, very hard	72	422
Shale, brown, soft	3	425
ORDOVICIAN SYSTEM:		
Limestone, brown to white	95	520
Sandstone, yellow, hard	15	535
Limestone, brown, hard	126	661
St. Peter sandstone	79	740

RECORD OF ROBERTS WELL, CLARKSVILLE, PIKE COUNTY.

	Thickness.	Depth.
	Feet.	*Feet.*
Clay, residual	75	75
MISSISSIPPIAN:		
Burlington-Chouteau limestone:		
Limestone, crystalline, gray, cherty	25	100
Hannibal shale:		
Shale, bluish-gray	100	200
Louisiana limestone:		
Limestone, fine-grained, light to dark gray	40	240
DEVONIAN SYSTEM:		
Hamilton shale:		
Shale, dark blue	10	250
SILURIAN SYSTEM:		
Limestone, brown to white, fine-grained	20	270
ORDOVICIAN SYSTEM:		
Maquoketa shale:		
Shale, gray to bluish-gray, calcareous	75	345
Limestone, argillaceous, sandy, dove-colored, hard	95	440
Kimmswick limestone:		
Limestone, crystalline, gray, cherty	160	600

RECORD OF ROBERTS WELL—Continued.

	Thickness.	Depth.
	Feet.	*Feet.*
Plattin limestone:		
Limestone, fine-grained, drab	100	700
Joachim limestone:		
Dolomitic limestone, gray	50	750
St. Peter sandstone:		
Sandstone, white, well-rounded quartz grains	83	833 +

RECORD OF C. H. MOHR WELL, NELSONVILLE, MARION COUNTY.

	Thickness.	Depth.
	Feet.	*Feet.*
Clay	45	45
Blue shale	150	195
Limestone	60	255
Gray shale	35	290
Limestone	220	510
Red sandstone, oil and gas (?)	15	525
Limestone	125	650
White sandstone, mineral water (St. Peter)	10	660
Hard rock (?)	2	662
Sand and limestone	213	875

RECORD OF T. E. ALLISON WELL, PERRY, RALLS COUNTY.

	Thickness.	Depth.
	Feet.	*Feet.*
Dirt	2	2
Flint rock and boulders	20	22
Limestone	12	34
"Soapstone" shale	126	160
Limestone, white	10	170
Shale, red, "Soapy"	50	220
"Soapstone' shale	210	430
Limestone, gray to brown	48	478
Sandstone, white, coarse (St. Peter)	12	490

RECORD OF ST. LOUIS INSANE ASYLUM WELL, ST. LOUIS.

	Thickness.	Depth.
	Feet.	*Feet.*
Clay	40	40
PENNSYLVANIAN SYSTEM: (80 feet)		
Tumbled masses of limestone	4	44
Red clay	5	49
Limestone	8	57
Red clay	4	61
Coal	5	66
Fire clay	2	68
Limestone, light colored, bottom of dry well	3	71
Clay, blue and drab; slightly calcareous	9	80
Limestone, cherty	6	86
Shales, dark bluish-gray	21	107
Limestone, cherty	4	111
Coal	1	112
Clay, light blue	8	120
MISSISSIPPIAN SYSTEM: (670 feet)		
Limestone, hard, cherty, upper part fine grained, lower part coarse	139	259
Shales, blue	3	262
Limestone, drab and gray, generally hard and cherty	176	438
Limestone and shale, alternating	98	536
Limestone, hard, blue, cherty	167	703
Sandstone, very fine-grained	6	709
Limestone, light gray to drab, cherty	81	790
Chouteau limestone: (93 feet)		
Limestone, red	10	800
Limestone, light gray to drab, cherty	83	883
ORDOVICIAN SYSTEM:		
Clay, shale, light gray or blue	139	1022
Limestone, blue and drab	194	1216
Limestone, light blue, cherty; salt water at 1220	9	1225
Limestone, light to dark	79	1304
Joachim limestone (148 feet):		
Limestone, light drab to dark gray, cherty	148	1452
St. Peter sandstone (133 feet):		
Sandstone, mostly pure white, clear rounded grains	133	1585
Jefferson City limestone (517 feet):		
Limestone, buff and drab, cherty	517	2102
Roubidoux sandstone (82 feet):		
Sandstone, hard, pure, with some limestone beds with chert	82	2184
OZARKIAN SYSTEM:		
Gasconade limestone (659 feet):		
Limestone and chert, drab, buff, cherty; sand abundant	659	2843
Gunter sandstone (37 feet):		
Sandstone	37	2880
Undifferentiated:		
OZARKIAN AND CAMBRIAN SYSTEMS:		
Limestone, mostly free from chert and sand	142	3022
Sandstone, dirty to blue and reddish-gray	98	3120
Shale, dark, magnesian	13	3133
Limestone, yellowish-drab to gray, with little sand	371	3504
Mostly hard, thin-bedded sandstone	41	3545
Sand and limestone	13	3558
PRE-CAMBRIAN SYSTEM:		
Sandstone, brown, near upper part; the lower mostly granite	285½	3843½

SILURIAN ROCKS.

No oil or gas has yet been found in Missouri which can be definitely credited to the Silurian rocks. The very limited distribution of these beds in the State apparently restricts the possibilities of their productiveness to the northeast and perhaps the extreme northwest counties. South of Missouri River they may be practically eliminated, for there they occur only in Cape Girardeau, Perry and Ste. Genevieve Counties, where they form the surface rocks or are covered by younger beds only locally. In northeast Missouri, however, the Silurian beds have received much attention because of their productiveness at nearby localities in Illinois.

The Pittsfield gas, across the river from Pike County, Missouri, in Pike County, Illinois, is obtained through shallow wells reaching down into "yellowish brown more or less vesicular magnesian limestone" of Silurian age which probably represents a portion of the Edgewood limestone of the Sexton formation.

Wells in eastern Pike County, Missouri, show records very similar to those around Pittsfield, and it is believed that the same Silurian beds are present, in part at least, in this county and probably in the adjoining counties to the north and south. The Pittsfield gas wells occur on a rather well-defined anticline.

In Hancock, McDonough and Schuyler counties, Illinois, near the town of Plymouth, oil is obtained in the Colmar field from a patchy sandstone reached at depths ranging from 400 to 500 feet, called the Hoing sand. This sandstone where present rests with unconformity on the Thebes (Ordovician) formation, and is considered to be of Silurian age. It occurs in lenses having a maximum thickness of about 25 feet, but is entirely pinched out between the various patches. An examination of available well records in northeast Missouri does not reveal the presence of any sandstone which can be correlated with the Hoing sand However, very few detailed records are available for study in this area and there is really no definite proof one way or the other regarding the presence or absence of this sandstone. There is no apparent reason why it should not occur in the northeast counties under conditions similar to those just east in Illinois, and under similarly favorable structural conditions it might yield commercial quantities of oil. Recently the discovery of oil (quantity unknown) has been reported in southeast Putnam County in a sandstone which may prove to lie at the horizon of the Hoing sand. From a very generalized and incomplete record of the well, the oil-bearing sand can be definitely placed below the Mississippian beds, but more evidence will be required to determine whether it is of Devonian or Silurian age. It seems most probable that it is Devonian.

At the present time there is very little that can be said about oil and gas possibilities in the Silurian rocks in northeast Missouri. Since neither in outcrop nor in wells, are they known to have shown evidence of being petroliferous (with the possible exception of Putnam County) the only encouragement to prospect them comes from the Illinois occurrences.

DEVONIAN ROCKS.

No oil or gas have been found in the Devonian beds in Missouri. The black fissile Noel (Chattanooga or Grassy Creek) shale of uncertain age is here considered to be Mississippian rather than Devonian.

The restricted distribution and nature of occurrence of the Devonian rocks south of Missouri River would certainly almost eliminate them as possible oil or gas producers in this part of the state. They occupy very limited areas in Cape Girardeau, Perry, and Ste. Genevieve Counties, and elsewhere are known to occur only as thin local patches. North of the river their distribution is more or less uncertain though they are known to underlie a considerable part of this portion of the State. They have been penetrated at many points in northeast counties without giving any evidence whatever of being petroliferous.

MISSISSIPPIAN ROCKS.

The Mississippian rocks are oil producers in many localities including some of the fields in Illinois, Oklahoma, and Kansas. In Missouri small quantities of gas and showings of oil have been found in the Kinderhook group in McDonald and St. Louis Counties, and asphalt occurs in the Boone limestones at a number of points in southwest Missouri. The following brief discussion describes these occurrences:

McDONALD COUNTY.

McDonald County is underlain by the Mississippian rocks except in the deeper valleys of the southern part where the older Lower Ordovician formations are exposed. The Mississippian has a maximum thickness of about 300 feet in the county, but over most of the area much less than 300 feet is required to reach the basal black, bituminous, fissile shale, or "slate" herein called the Noel. It is 25 to 40 feet thick, underlies the entire county except where removed in the valleys of the southern part, and extends north into Newton County, east into Barry, and south and west beyond the borders of the State. Locally it may be underlain by a thin bed of sandstone, though commonly it is found to rest directly upon the Lower Ordovician dolomites. Previously this shale has been described as the Chattanooga and classified as Devonian, but more recent study indicates that it probably belongs in the lower Mississippian and constitutes a part of the Kinderhook group. Excellent exposures occur in Elk River Valley near Noel, in Indian Valley as far north as Lanagan, and along Sugar Creek east of Pineville.

Wells at or near both Noel and Anderson have found small quantities of gas and traces of oil in the Noel shale. Some of these wells yield a few thousand cubic feet of gas per day and the gas has been utilized for heating and lighting the residences of the owners. The depths at which gas is encountered depends upon the topographic elevation at the well and varies from less than 50 to 250 feet. Fresh water is found both above and below the shale though that found below commonly contains sulphuretted hydrogen gas. Nothing more than traces of oil have yet been found in this formation.

There is no doubt that the gas and oil have their origin in the shale itself, hence the occurrences do not warrant the prospecting of the rocks below the oil and gas horizon. The shale rests unconformably on Lower Ordovician beds, in which no traces of oil or gas have even been found in the State and in which prospecting is not advised.

The finding of gas in McDonald County caused some excitement a number of years ago resulting in the sinking of two deep test wells. Both were failures, finding no indications of oil or gas below the Noel shale, though at Noel it is stated that enough oil was found in the shale to obtain a sample. The average log of wells drilled through the shale is shown in the following record:

RECORD OF WELL DRILLED BY McDONALD LAND COMPANY.
N. E. ¼, S. W. ¼, SEC. 29, T. 22 N., R. 32 W.

	Thickness.	Depth.
MISSISSIPPIAN SYSTEM:	*Feet.*	*Feet.*
Boone formation:		
Surface flint and dark gravelly clay	10	10
Limestone hard, white, thin layers of flint	20	30
Limestone and spotted flint	5	35
Flint, blue and brown, white spots of limestone	14	49
Limestone and spotted flint	4	53
Limestone and spotted flint, cuttings smell strongly of oil	12	65
Limestone, dark and blue flint; odor of oil noticeable 200 feet from drill	8	73
Limestone, dark and blue flint in alternating layers; white limestone in spots; some oil	15	88
Limestone, white	7	95
Limestone, white; trace of pyrite	25	120
Limestone, white and blue, selvage; oil odor, FeS_2 in selvage	5	125
Noel shale:		
Black gummy mud, filled with organic matter; also FeS_2, with some oil	17	142
Shale and black mud; some FeS_2; more oil	13	155
Slate, shale and FeS_2	17	172
ORDOVICIAN SYSTEM (LOWER):		
Limestone, white	11	183
Limestone, white; white and blue flint	4	187
Limestone, white	13	200
Water a few feet from surface. Depth	....	200

The persistence of the Noel shale beneath the County suggests the possibilities of finding gas and small quantities of oil at widely scattered points, where structural conditions are favorable. The occurrence will in all cases be shallow, probably nowhere exceeding 300 feet in depth, and it is also probable that the amount of gas found will be relatively small and similar to those at Noel and Anderson.

RECORD OF DEEP WELL AT NOEL, McDONALD COUNTY.

	Thickness.	Depth.
MISSISSIPPIAN SYSTEM:	*Feet.*	*Feet.*
Limestone with layers of chert	95	95
Non-cherty gray limestone	36	181
Soft brown shale, slightly carbonaceous (Noel)	59	190
ORDOVICIAN SYSTEM AND OLDER ROCKS:		
Limestone, gray, cherty	25	215
Gray and white limestone, with chert and fragments of black slate	115	330
Soft, shaly, gray magnesian limestone	30	360
Limestone, hard	55	415
Limestone, gray	50	465
Limestone, compact, gray	201	666
Fine-grained gray limestone with hard black shale	99	765
Limestone, light gray, compact, cherty	115	880

The possibilities of finding oil or gas in the Noel shale in adjoining counties would seem to be similar to those in McDonald if the shale is present in sufficient thickness and where structural conditions are favorable. However, this formation does not extend farther north in Newton County than Seneca, Neosho, and Granby, and it thins notably toward these points. At Neosho it is not more than five feet thick. To the east, in Barry County, the shale also thins rapidly and is known to underlie only the southwest townships. The area of possible production from the Noel shale is, therefore, very limited in southwest Missouri, and there seems no reason to expect larger gas wells than those already found at Noel and Anderson.

In the bed of a small stream on the Taylor farm (NW. ¼ sec. 11, T. 49 N., R. 1 E.) in Lincoln County, along the Cap au Gres fault, between Troy and Foley, a shale outcrop is found which is known locally as oil shale because it burns, giving off an odor of petroleum. This shale, previously described with the Devonian beds by Potter,* is probably Kinderhook.

ST. LOUIS COUNTY.

A number of wells drilled in the city of St. Louis have found small quantities of natural gas and a little oil. These wells are distributed from Carondelet on the south to several miles north of Normandy Heights, though several of the best known are near the center of the city. Fenneman† states with reference to the oil and gas in the wells that

> "***most of such occurrences are in the Plattin ('Trenton') limestone (of Ordovician age) though still smaller quantities are encountered at higher levels, having probably escaped upward from the Plattin limestone."

The records of these wells available for study are very poor and difficult to correlate. There is no doubt, however, that some of the minor oil showings and probably some of the gas occurrences indicated in the records are higher than the Plattin limestone and apparently in the shales of the Fern Glen formation or in the Kinderhook. Since the chief occurrences are believed to be in the Plattin, these wells are described under the heading "Oil and Gas Occurrences in the Ordovician."

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*Potter, W. B., The Geology of Lincoln County; Geol. Survey of Missouri, pp. 243-244, 1872.

†Fenneman, N. M., The Geology of the St. Louis Quadrangle; U. S. Geol. Survey Bull. 438, p. 58, 1911.

GENERAL POSSIBILITIES IN THE MISSISSIPPIAN.

In the groups of Mississippian rocks above the Kinderhook, including the Osage, Meramec, and Chester, the only oil or gas which has been found in Missouri is the heavy asphaltic oil or "tar" in the Boone formation of the southwest counties. In Cedar, Dade, Barton, Jasper, Barry, and probably other counties in this section of the State, the Boone is locally bituminous, the bitumen occurring in the form of a heavy black oil similar to that in some of the higher asphaltic sandstones of the Pennsylvanian. The asphalt in Jasper County is not uncommonly found in the mines at a considerable depth below the surface. At many of the localities where the Boone (Burlington-Keokuk) limestone is bituminous, overlying beds of asphaltic sandstone of Pennsylvanian age are also present. A study of these localities indicates clearly that the source of the bitumen is the sandstone of the Pennsylvanian from which the material has simply seeped downward into the underlying Boone limestone. In fact, most of the occurrences of bitumen in the Boone are not far removed from localities where the Pennsylvanian sandstones are asphaltic and they all occur in an area where Pennsylvanian beds have but recently been removed by erosion. Since in many places the bitumen in the Boone can be traced directly to the overlying Pennsylvanian beds and since the nature of occurrence and character of the bitumen is nearly everywhere the same it is believed that the source of the material in all cases is the overlying Pennsylvanian rocks.

The Osage and Meramec groups of Mississippian rocks, composed chiefly of thick limestone beds, are not considered favorable for the production of oil or gas in commercial quantities in the State.

From Chester beds, much oil is obtained in Illinois, where these rocks underlie a great area with considerable thickness. Much of the oil credited to the Mississippian in Oklahoma and probably in Kansas, is also supposed to come from the Chester group, though some possibly comes from breaks near the top of the limestones of the Osage. The Chester group is so sparingly represented in Missouri as to be almost negligible and therefore cannot be considered as a factor in possible production. The general absence of the Chester is a very important feature relative to oil and gas in the Mississippian of the State.

SUMMARY BY COUNTIES, OF AREAS EXPOSING ROCKS CHIEFLY OLDER THAN PENNSYLVANIAN.

Except for the Plattin-Kimmswick, of Middle Ordovician age, and the Kinderhook group of the Mississippian, which have yielded only very negligible amounts of oil and gas, these fuels have not been found in Missouri, in rocks older than the Pennsylvanian. In most of the older beds prospecting is considered either definitely useless, or at best very uncertain.

The following counties are underlain chiefly by Mississippian and older beds, the Pennsylvanian, if present at all, occurring only as thin patches, usually capping the upland areas. Although wells have been drilled in many of the counties, the tests have been wholly without success, and it is not believed that exploration for oil or gas in any of these counties is justifiable.

Montgomery and Warren:—With the exception of occasional outliers of the Cherokee formation of the Pennsylvanian, these counties are underlain chiefly by the Mississippian, Devonian and Ordovician formations down to and including the Jefferson City dolomite.

Franklin and Jefferson Counties:—Bordering the northeast Ozark region, these counties are underlain chiefly by the Roubidoux, Jefferson City, St. Peter, Joachim, Plattin and Kimmswick formations.

Ste. Genevieve County: Outcropping successively from the Mississippi to the western boundary of the County, there are exposed representative formations of the entire series from the Mississippian down to and including the underlying granite. The County has a greater number of formations exposed than any other in the State.

Iron, Madison and St. Francois Counties:—The area occupied by these counties is underlain by the oldest sedimentary formations in the State where these border the granite and porphyry knobs which form the St. Francois Mountains. The Lamotte sandstone, Bonneterre dolomite, Davis shale, Derby-Doe Run dolomite and Potosi dolomite constitute the chief sedimentary formations.

Washington County:—The area is underlain largely by sedimentary formations extending from the Roubidoux sandstone to the Lamotte sandstone. In the southeast part of the County granite and porphyry outcrop, forming prominent hills between which the sedimentary series is found.

Shannon, Carter and Reynolds Counties:—Deeply cut by the drainage of Current and Black Rivers, outcrops of the underlying formations are frequent. The ridges are underlain by the Roubidoux sandstone with the Gasconade and older formations exposed in the valleys. Granite and porphyry outcrop over considerable areas, especially in Shannon County.

Ripley, Butler, and Wayne Counties:—The southern portions of these counties extend into the lowland area of Missouri and are underlain by several hundred feet of unconsolidated Tertiary deposits. In the upland portions of each county, the Roubidoux sandstone outcrops on the ridges while the main streams have cut into the Gasconade and lower formations. In the northern part of Wayne County, much of the area is underlain by granite and porphyry, the sedimentary formations being exposed only in the stream valleys.

Bollinger County:—The Jefferson City dolomite underlies the eastern portion of the County with Roubidoux sandstone and the underlying Gasconade especially prominent to the west.

Cape Girardeau and Perry Counties:—Lower Silurian and Ordovician outcrop successively from the Mississippi Rivver westward in both counties. In the northeast portion of Perry County a small area in underlain by the Devonian and Mississippian systems, and the Ozarkian is exposed in the extreme western part.

Phelps, Crawford, and Dent Counties: These counties are underlain chiefly by the Jefferson City dolomite along the uplands and by the Roubidoux sandstone and Gasconade dolomite in the areas bordering the major streams. Small patches of the Pennsylvanian rest on the older formations.

Texas County: This County is underlain chiefly by the Jefferson City and Roubidoux formations with some Gasconade dolomite appearing along the deeper streams.

Oregon and Howell Counties: The Gasconade formation outcrops along Eleven Point River, bordered on either side by an area of Roubidoux sandstone, which is also exposed along Spring River and in the valleys of the north half of Howell County. The remainder of the area is underlain by the Jefferson City formation.

Osage, Gasconade, and Maries Counties: The upland of these counties is underlain by the Jefferson City formation with Roubidoux sandstone bordering the principal streams, the valleys and river bluffs being composed of the underlying Gasconade. Pennsylvanian is found overlying the Jefferson City on much of the upland area.

Camden, Dallas, Laclede and Pulaski Counties: The Jefferson City and Roubidoux formations underlie the larger part of these counties with the Gasconde dolomite outcropping chiefly along the stream valleys. Occasional outliers of the Mississippian occur overlying the older formations. Marked deformation associated with a pegmatite dike near Decaturville, Camden County, exposes formations older than the Gasconade in a restricted area.

Moniteau, Miller, Morgan, and Cole Counties: These counties are underlain chiefly by the Jefferson City dolomite, the Roubidoux sandstone and the Gasconade formation, the lower members of the series outcropping chiefly along the larger rivers. Outliers of both the Mississippian and the Pennsylvanian are scattered throughout the area, although usually of restricted areal extent.

Cooper County: The Mississippian series underlies the greater part of the County with Ordovician formations outcropping along the southern edge, while the upland near Boonville is underlain by the Cherokee formation of the Pennsylvanian.

Polk and Hickory Counties: The uplands constituting the western part of these counties are underlain by Mississippian formations. The remainder of the area is chiefly Ordovician dolomites. Scattered outliers of the Pennsylvanian rest on the older series.

Lawrence and Dade Counties: With the exception of outliers of Pennsylvanian sandstone and shale which occur in restricted areas, both counties are underlain by the Mississippian.

Greene and Christian Counties: The upland area of both counties is underlain by Mississippian limestones with Ordovician formations exposed along the deeper stream channels.

Barry and Stone Counties: The Jefferson City dolomite forms the underlying formation along White River and its main tributaries. The uplands of both counties are underlain by the Mississippian formations, over which are occasional restricted patches of shale and sandstone of the Pennsylvanian.

Webster and Wright County: Webster County is underlain chiefly by Mississippian limestone on the uplands and by Jefferson City along the stream courses and throughout the northern half of the County. Wright County is underlain chiefly with the Jefferson City formation with Roubidoux sandstone along the Gasconade and its tributaries.

Stone and Taney Counties: The uplands of Stone and the western part of Taney County are underlain with Mississippian limestone. In the area bordering the principal streams and in the major portion of the eastern half of Taney County, the Jefferson City dolomite is the chief surface formation.

Douglas and Ozark Counties: These counties are underlain chiefly by the Jefferson City formation, outliers of Mississippian limestone occurring along the ridges. The Roubidoux formation borders the larger streams and the Gasconade occurs along the river valleys in northern Ozark and southern Douglas County.

Newton and Jasper Counties: With the exception of small outliers of the Pennsylvanian these counties are underlain by the Mississippian limestone. Many water wells have drilled to the Roubidoux sandstone in both counties. These have not encountered either oil or gas.

CHAPTER V.

OIL AND GAS IN THE PENNSYLVANIAN ROCKS.

The Pennsylvanian rocks of Missouri, seem, at the present time, to be the most likely containers of important oil and gas reservoirs in the State. It is thought the possibilities probably lie chiefly in the lower Pennsylvanian strata. This conclusion is readily drawn from analogy to the Kansas-Oklahoma fields, from the evidence of the known oil and gas occurrences in the State, and from the general lithologic composition of these rocks. It is, however, not the intention to convey the impression that in these strata alone lie the oil and gas possibilities of the State. Small quantities of gas have been found in shales of the Mississippian series, a little oil doubtfully in the Devonian, some gas and a little oil in the "Trenton" of eastern Missouri and very small quantities of oil have been reported in the Tertiary sands of the Southeast Lowlands. The significance of these finds, discussed elsewhere, has been made fairly well-known both by geologic study and by extensive drilling.

The Pennsylvanian rocks, however, cover a very large part of Missouri and consist of the same formations with the same characteristics, which a short distance to the southwest of the State yield large quantities of oil and gas. Furthermore, in more than a dozen counties, wells have encountered gas sands in the Lower Pennsylvanian formations, wells yielding varying amounts of gas ranging as high as 1,000,000 cu. ft. per day. In at least 7 counties oil has been found in wells, some of which have yielded for a time at least 1 to 3 barrels per day, and in as many or more counties Pennsylvanian sandstones or limestones saturated with bitumen outcrop at the surface. Over an area of many thousand square miles, these rocks occur with a thickness of from 500 feet or less to 1700 feet, and it is definitely known that they embrace local structural features favorable to the accumulation of oil and gas. The Pennsylvanian, therefore, is considered to be more important than any other system, relative to the oil and gas possibilities of Missouri, and has thus been made the principal issue of discussion in this report.

The Lower Pennsylvanian or Des Moines series has been the source of nearly all of the oil and gas yet obtained from the Pennsylvanian in Missouri. In Clinton County, north of Missouri River, very small quantities of gas have been reported from horizons which are apparently in the Kansas City formation of the Upper Pennsylvanian. In Cass, Caldwell, and Jackson counties the Bethany Falls limestone member of the same formation locally contains asphalt, or heavy, thick, oil. Aside from these observed and reported occurrences no other important evidences of oil or gas in the upper Pennsylvanian have yet been found. In the Lower Pennsylvanian both oil and gas have been found in relatively small quantities in the Cherokee, Henrietta, and Pleasanton formations.

The Cherokee is by far the most important formation both with respect to the amounts of oil and gas found in it, and the widespread location of the finds. It also exhibits abundant evidence, in the exposed asphaltic sandstones, found in Barton, Vernon, Cedar, Hickory, Bates, and other counties. that many of its sandstones are possible oil containers. In Vernon, Bates, Cass, Jackson, Platte, and other counties these same sandstones, at about the same horizons, where buried beneath higher beds, are supplying shallow wells, 150 to 600 feet deep, with gas in volumes ranging from a few thousand cubic feet to possibly a million cubic feet per day. In Vernon, Bates, Cass, Jackson, Platte, Clay, Johnson, and Ray Counties small quantities of oil have been found. It is believed that in the Cherokee lies the greatest possibility for finding commercial pools of oil and gas of any of the Pennsylvanian formations.

The Henrietta formation is much thinner than the Cherokee and contains only local lenses of sandstone in the Labette shale. Gas has been obtained from such lenses in Jackson and Cass Counties and probably in some of the wells in Bates County. In other localities small amounts of gas and showings of oil have been reported from the Labette shale member, either from sandstones or from bituminous shale.

The Pleasanton shale contains a large amount of sandstone from which gas has been obtained as far north as Clay and Clinton Counties, and south of the River in Jackson, Cass, and Bates Counties. At Kansas City shallow wells sunk to the base of the Pleasanton have found sands yielding a small amount of oil, and in Vernon, Bates, Ray, Carroll, Clinton and other counties asphaltic sandstones of Pleasanton age outcrop.

In the Kansas City formation of the Upper Pennsylvanian, some showings of gas appear to have been found near Lathrop, Clinton County. The gas probably occurs in one of the lower shale members. In Cass, Jackson, and Caldwell counties the upper beds of the Bethany Falls limestone member are also asphaltic; quite extensively so in west-central Cass County. This is the highest stratigraphic occurrence of bitumen or gas in the Pennsylvanian rocks in the State, with the possible exception of the gas reported in Clinton County, concerning which the data are very meager.

The following is a brief discussion by counties of the known occurrences in the Pennsylvanian together with typical drill logs.

COUNTIES IN WHICH THE MOST IMPORTANT OCCURRENCES OF OIL AND GAS HAVE BEEN FOUND IN THE PENNSYLVANIAN ROCKS.

BARTON COUNTY.

The Cherokee shale underlies the greater portion of Barton County except along the eastern and southeastern portions where the Mississippi limestone is the surface formation. In the northwest corner of the county small remnants of the Henrietta occur as isolated mounds, above the Cherokee.

Structurally the dip of the formations is to the northwest. Gentle folding occurs in different localities but no detailed mapping has been done to show its extent.

The Pennsylvanian is relatively thin being at a maximum less than 400 feet in thickness.

There are no productive oil wells in the county, but small amounts of gas have been found in sandstones in the Cherokee shale at several points, and the gas is being utilized at one place. Three miles south of Minden, on the farm of J. J. Stephenson, (Sec. 19, T. 31N., R. 33W.) three wells, each about 220 feet deep, were drilled in 1915 for the purpose of obtaining water. A light gas pressure was encountered in all of the wells at a depth of about 200 feet, just above the Mississippian limestones, and sufficient gas was obtained for domestic use. The three wells yield about 250,000 cubic feet of gas per day and have been in continuous use for four years.

Asphaltic sandstone beds in the Cherokee shale outcrop at several points in the county, and have been penetrated by shallow wells at other points. The beds impregnated are extensive, though of irregular outline and thickness, and extend northward into Vernon County. Two miles north of Liberal asphaltic sandstone has been extensively quarried, the stone being used for flagging and curbing. The bituminous material is chiefly in the form of a very heavy, black oil, similar in character to that found and described in Vernon County. In places it seeps out slowly, in warm weather, between the bedding planes or along joint planes in the sandstone to form what are locally called "Tar Springs". In shallow wells, dug or bored in these sandstone beds, the water often becomes covered with an oil scum.

The following log shows the general character of the Cherokee and underlying formations:

RECORD OF THE ELLSWORTH-KLANER CONSTRUCTION COMPANY WELL MINDEN, BARTON COUNTY.

	Thickness.	Depth.
	Feet.	*Feet.*
Clay, yellow	10	10
PENNSYLVANIAN SYSTEM:		
Cherokee shale:		
Sandstone, yellow	18	28
Coal	3.5	31.5
Shale, light	33.5	65
Shale, dark	9	74
Lime shell	2	76
Coal	3	79
Shale, light	17	96
Sandstone, brown	12	108
Shale, dark	17	125
Shale, light	20	145
Sandstone, light	20	165
Shale, dark	27	192
Shale, black	18	210
Sandstone, light	5	215
Shale, black	19	234
MISSISSIPPIAN SYSTEM:		
Burlington-Keokuk limestones:		
Limestone, flint, dark	16	250
Limestone, flint, light	40	290
Limestone, brown	288	578
Kinderhook shale:		
Shale, blue	24	602
Limestone, dark	6	608
Shale, blue	4	612
ORDOVICIAN (Lower) SYSTEM:		
Jefferson City formation:		
Lime with little flint, brown	232	844
Limestone, light	4	848
Flint, extra hard	6	854
Roubidoux formation:		
White sandstone	13	867
Limestone, brown	5	872
Sandstone, brown, extra hard	18	890
No cuttings	5	895
Sandstone, white	5	900
No cuttings	5	905
Sandstone, white	7	912
Sandstone, white crystal, hard	10	922
No cuttings	5	927
Sandstone, white crystal	2	929

RECORD OF THE ELLSWORTH-KLANER CONSTRUCTION COMPANY WELL—Continued.

	Thickness.	Depth.
	Feet.	*Feet.*
OZARKIAN SYSTEM:		
Gasconade formation:		
Limestone, sandy, fine-grained	21	950
No cuttings	12	962
Limestone and flint	3	965

The first recorded tests for oil in Barton County were drilled about 1870, when several wells 75 to 130 feet deep were sunk about 9 miles northwest of Liberal. At a depth of some 50 feet asphaltic sandstone was encountered, and heavy, black oil in very small quantities entered the wells. No oil was recovered. Since then a number of deep wells have been sunk in different parts of the county, some in search of oil, and some for water. These wells are tabulated below:

DEEP DRILL HOLES IN BARTON COUNTY.

Owner.	Location.	Date.	Depth.	Base of Pennsylvanian.	Purpose.	Remarks.
E. A. Adams	Lamar	1887	1040	150	Water	
D. A. Beamer	Near Lamar	1911	1880	135	Oil	Finished in granite.
Lamar Pure Ice Co.	Lamar (south edge)		800		Water	
H. Bennett	Liberal	1907	1170	250	Oil	
Liberal Coal & Mining Co.	Southeast of Liberal	1915	821	200	Water	
Ellsworth-Klaner Construction Co.	Minden	1915	965	224	Water	
Western Coal & Mining Co.	Near Minden		860	224	Water	
Weir Coal Co.	Near Minden		860	224	Water	
Clement Coal Co.	Near Minden		900	224	Water	
Stephenson Coal Co.	Near Minden		907	224	Water	
K. C. Southern R. R.	Oskaloosa	1902	885	300	Water	
W. R. Crowther	Golden City	1905	1452	Started in Mississippian	Oil	No oil.

The record of the D. A. Beamer deep well at Lamar is appended for the geologic section underlying Barton County.

RECORD OF D. A. BEAMER WELL, LAMAR, MO.

	Thickness.	Depth.
PENNSYLVANIAN SYSTEM:	*Feet.*	*Feet.*
Cherokee shale:		
Shale and sandstone	135	135
MISSISSIPPIAN SYSTEM:		
Burlington-Keokuk limestones:		
Limestone, white to gray, cherty	165	300
Shale, bluish-gray; some limestone	5	305
Limestone, gray to dark gray, with white chert	75	380
Chert and limestone	30	410
Limestone, buff, with some chert	15	425
Chert, white to bluish-white	15	440
Limestone	50	490
Northview (Hannibal) shale	45	535
Compton (Louisiana) limestone:		
Limestone, fossiliferous, fine-grained, dark gray	10	545
ORDOVICIAN (Lower) SYSTEM:		
Jefferson City dolomite:		
Dolomite, fine-grained, gray, sandy	25	570
Dolomite; some sandstone and chert	95	665
Sandstone, fine-grained	5	670
Dolomite, fine-grained, oolitic chert	125	795
Sandstone, fine-grained	5	800
Dolomite, dark, fine-grained	15	815
Sandstone, fine-grained	5	820
Dolomite, crystalline	90	910
Roubidoux sandstone:		
Sandstone, white to red	25	935
Dolomite, buff; some sandstone	15	950
Sandstone, a little oolitic chert	5	955
OZARKIAN AND CAMBRIAN SYSTEMS:		
Gasconade dolomite:		
Dolomite, gray to buff	240	1195
Gunter sandstone:		
Sandstone, fine white	10	1205
Proctor to Bonneterre dolomites (inclusive):		
Dolomite, dark gray, crystalline	125	1330
Missing, water channel	25	1355
Dolomite	300	1655
LaMotte sandstone:		
Sandstone, white, coarse-grained	195	1850
PRE-CAMBRIAN SYSTEM:		
Granite, red, quartz, biotite and feldspar	50	1880

VERNON COUNTY.

The abundance of shallow occurrences of oil and gas and the presence of asphaltic sandstones and "Tar Springs" has long attracted interest to Vernon County.

The County is practically everywhere underlain by Lower Pennsylvanian, except along the eastern border where the Mississippian limestones outcrop in the valley of Horse and Cedar Creeks, and near the central part where one or two Mississippian inliers appear. The Cherokee shale underlies most of the area, but in the west and northwest townships, and elsewhere in local outliers, the Henrietta limestone, forming mounds, escarpments and high ridges, covers the Cherokee, and is in turn covered by the Pleasanton shale in the northwest corner of the County. The thickness of the Cherokee varies, according to the amount which has been removed by surface erosion. Where fully present under the Henrietta it is approximately 375 feet thick, but over most of the county wells reach its base at from less than 100 to a little over 200 feet. The Henrietta has a thickness of about 100 feet where fully present and probably as much as 100 feet of Pleasanton overlies it in parts of the northwest township. There is, therefore, a maximum thickness of between 500 and 600 feet of Pennsylvanian in the northwest part of the county.

The regional dip is to the northwest about 10 feet to the mile, allowing a fall of about 400 feet between the southeast and northwest corners. Local folding is, however known to occur, especially in the northwest and southwest portions of the County, where anticlinal structures have been observed. Dr. Shepard* mentions an anticline in the southeast portion of the county, east of Sheldon, the western slope of which crosses sec. 30, T.34 N. R. 29W., with a northeast-southwest trend, stating that this anticline is one of a series of similar folds. In the northwest part of the County marked folding (see accompanying structure map†) has produced several well-defined anticlines. No doubt, folding as yet unobserved occurs in other parts of the County, this probably being the cause of the small inlier of Mississippian limestone in sec. 20, T. 36N., R. 31W., about two miles north of Nevada. The structural conditions of the northwest part of the county are most favorable for oil and gas accumulation because it is only in this part of the County that the Pennsylvanian attains a sufficient thickness.

Between 100 and 200 shallow oil wells have been sunk in the western and northwestern parts of the county in the region about Richards and Stotesbury. These wells are reported to make from half a barrel to two barrels per day. The productive horizons are reached from about 100 to 300 feet in depth, the

*Shepard, E. M., Underground waters of Missouri; U. S. Geol. Survey, Water-Supply Paper No. 195, 1907, p. 124.

†Plate 6.

sand reaching a thickness of 30 feet. In some of the wells gas has been encountered. The oil is black and in general has a gravity not over 22° B.

Up to the present time but little oil has been produced, as no pipe line serves the district and but little pumping has been done. Some oil has been stored in tanks and at present a small refinery is being erected.

The general character of the Cherokee is shown by the following record:

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

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	9	9
PENNSYLVANIAN SYSTEM:		
Cherokee shale:		
Soapstone	20	29
Coal	3	32
Soapstone	13	45
Soapstone 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:		
Burlington-Keokuk limestone:		
Limestone, cherty	67	345

Asphaltic sandstone occurs in greatest abundance in the south part of the County, especially the southeast part around Bellamy, T. 34N., Rs. 29 and 30W. Outcrops occur, however, in all the southern tier of townships; in T. 35N., R. 32W.; and in the northwest part of the County. Test pits sunk in sections 24 and 27, T. 34N., R. 30W., where the rock has been investigated most, revealed 11 to 30 feet of asphaltic sandstone. A distillation of one sample yielded 8.2% asphaltic material. Two analyses of this material yielded an average of 10.22%

Asphaltine and 80% Petroline. The material is not true asphalt but a very heavy black oil at this locality. Wells dug in the asphaltic sandstone partially fill with water which is soon covered with bitumen seeping in. In warm weather the bitumen, at points where the asphaltic sandstone is exposed, oozes out along the bedding and joint planes, forming "Tar Springs." There is, undoubtedly, a very large supply of this asphaltic sandstone to be found at or very rear the surface in Vernon County.

Showings of oil and gas have led to the sinking of a number of deep wells in different parts of the County. These, together with those sunk for water, are listed below.

DEEP WELLS IN VERNON COUNTY.

Owner.	Location.	Date.	Depth.	Base of Pennsylvanian.	Purpose.	Remarks.
E. S. Wyand	Richards (4 mi. SW.)	1889	650		Oil & gas	Some gas encountered, flowing water well.
Missouri Oil and Development Company	Stotesbury (just south of)	1901	345	278	Oil & gas	Some oil found.
E. T. Sutton	Walker (4 mi. NW. of)		400			Flowing water well.
Vernon Oil and Mining Co.	Sheldon (7 mi. E. and 1½ mi. N. of)	1903	1175			
Vernon Oil and Mining Co.	Sheldon (4½ mi. W. of)	1903	1306	115		Asphaltic formation penetrated from 25 45 feet.
Nevada Gas, Oil and Asphaltic Company	Nevada (about 5 mi. NW. of)		1447	161		
Nevada Gas, Oil and Asphaltic Company	Nevada (just south of)		1800			Finished in granite rock.
U. S. Government	Nevada (3.5 mi. SE. of)	1909	940	185	Water	
Fort Scott & Nevada Light, Heat, Water & Power Co.	Nevada	1913	937	163	Water	
Nevada Water Company	Nevada		1001	170	Water	
Radio Park Co.	Nevada	1887	800		Water	
Nevada Oil and Gas Co.	Rinehart (1 mi. SE. of)	1921	2018	190	Oil	Not completed.

The following record is fairly illustrative of the geological section underlying Vernon County to a depth of 1000 feet. Below this, as explained, it differs essentially from any other deep well drilled in Vernon County or in western Missouri.

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

	Thickness.	Depth.
	Feet.	*Feet.*
PENNSYLVANIAN SYSTEM:		
Cherokee shale:		
No samples (reported chiefly shale and sandstone)	170	170
MISSISSIPPIAN SYSTEM:		
Burlington-Keokuk limestones:		
Limestone, light gray, cherty, crystalline	299	469
Northview shale:		
Shale, clayey, bluish gray	5	474
ORDOVICIAN SYSTEM:		
Jefferson City formation:		
Dolomitic limestone, bluish gray, fine-grained	15	489
Chert, light to dark blue with 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 sandstone: (exact limits undeterminable):		
Sandstone, subangular, white, coarse grains; a small amount of dolomite and chert in cuttings	20	770
Dolomite, bluish gray, fine-grained, with much chert	65	835
Gasconade formation:		
Dolomite, gray to white, cherty	177	1012
PRE-CAMBRIAN SYSTEM: (?)		
Quartzite, white to pink; dolomite, brownish gray	62	1074
Quartzite, clear to pink	45	1119
Quartzite sandstone in small fragments and splinters of quartz, colorless to pinkish; mica	133	1252
Metamorphosed shale (?) greenish gray to dark blue with specks of pyrite	67	1319
Quartzitic sandstone, chiefly in splinters, chips, and angular grains of clear to pinkish quartz; some mica and pyrite	168	1487
Quartzitic sandstone, gray to brown to colorless, in fine angular to splintery chips	224	1711
Metamorphosed shale (?), light gray to greenish, cloudy particles	21	1732
Quartzite	139	1871
Quartzite with dark inclusions like augite, a greenish mineral like serpentine	147	2018

The cuttings from about 1074 feet to the base of the well are very much alike in general composition, except those from 1252 to 1319 feet and those from 1711 to 1732 feet. Some large fragments of a very typical light gray to pink quartzite appear at various depths, but most of the cuttings are composed of fine fragments, splinters and chips of quartz which have the appearance of being derived from quartzite. There is apparently a considerable variation in the degree of hardness of the quartzitic material, at different horizons. It is in part unquestionably a typical quartzite, and in part, probably, an extremely hard quartzitic sandstone. Much mica is contained in the material.

Throughout the southwest part of the State an immense unconformity intervenes at the base of the Mississippian, the Devonian, Silurian, and Upper and Middle Ordovician beds being practically absent. The Rinehart well passes directly from the base of the Mississippian into the Lower Ordovician. Below the Northview shale the cuttings represent the Jefferson City formation of Lower Ordovician age, for at a depth of 560 feet, or about 86 feet below the Mississippian, the oolitic cherts of this formation appear in abundance. The base of the Jefferson City beds (276 feet thick) was reached at a depth of approximately 750 feet, and the Roubidoux sandstone was then entered. Below the Roubidoux, dolomite, in all probability representing the Gasconade formation of Ozarkian age, was penetrated to a depth of about 1012 feet where a hard quartzite or quartzitic sandstone was encountered, which, with some variation in character, persisted to the base of the well at a depth of about 2018 feet.

To a depth of approximately 1012 feet, as revealed by the well cuttings, the log of the Rinehart well is entirely normal, agreeing in general features with the logs of other wells drilled in southwest Missouri. Identically the same sequence of formations with but little change in character is found in many wells in Jasper, Barton, Henry, and St. Clair Counties, Missouri, and at Pittsburg and Ft. Scott, Kansas. However, below 1012 feet, or below the appearance of the quartzitic sandstone, the log changes completely in character from any of the many other deep-well records examined for this part of Missouri. In all of the other wells concerning which data are available, some 700 to 800 feet of dolomitic limestone has been penetrated below the Roubidoux sandstone. All wells of sufficient depth have penetrated the Lamotte, which as revealed by excellent well records has a thickness from Jasper County north to Jackson County of 98 to 195 feet. All wells drilled below it have entered the granite floor.

The Rinehart well, instead of penetrating the 700 to 800 feet of dolomite commonly found below the Roubidoux sandstone, less than 250 feet was found in this well. Replacing these missing beds are over 800 feet of chiefly pure quartzite or quartzitic sandstone, entirely different in character from any other rocks encountered in the deep wells of southwest Missouri.

From the lack of data, the analysis of this problem is difficult. It is improbable that this material represents a local thickening of the Lamotte sandstone or other sandstone formations below the Gasconade.

By virtue of the character of the quartzitic materials penetrated and the apparent geologic relations, the writer is inclined to classify that part of the Rinehart well recorded below the 1012-foot depth as pre-Cambrian. It is possible to correlate this portion of the record with the Sioux quartzite of Iowa, Minnesota and Dakota.

BATES COUNTY.

The Pennsylvanian rocks entirely underlie Bates County, dipping at a low angle to the northwest and becoming generally thicker by the addition of successively higher beds toward the northwest corner. In the southeast part where the Cherokee shale alone is present, the base of the Pennsylvanian or the top of the Mississippian limestones is reached at a depth of 310 feet or less, though where fully present the Cherokee is 375 feet thick. The overlying Henrietta is 90 to 110 feet thick, the Pleasanton about 200 feet, and the Kansas City, the youngest formation exposed in the County, about 200 feet. In various parts of the County the base of the Pennsylvanian has been reached by the drill as follows:—Rich Hill, 313 feet; Butler, 490 feet; Adrian, 534 feet; Sprague, 483 feet; Amsterdam, 582 feet; and Merwin, 623 feet; northwest corner of County, 730 feet.

The regional dip is to the northwest like that of the counties to the south, and at an equally low angle. Two rather well-developed anticlinal folds cross the County from southeast to northwest, parallel to the regional dip. The southernmost fold, beginning at the southeast corner of the County, roughly follows the course of the Osage river; the northernmost enters at the junction of St. Clair and Henry Counties with Bates, becoming somewhat less well-defined toward the northwest corner of the County.

The more detailed structural features have not been worked out except in the northwest township as shown on the accompanying map (Pl. 7). That local folding has taken place elsewhere is known, however, and its effects may be observed in the pronounced easterly dip in some of the mounds northeast of Butler, and in the sharp folds in the Rich Hill coal.

Both oil and gas have been produced to a small extent in Bates County and at the present time there are over 30 productive gas wells, the largest number in any county in the State. These are all of small capacity, most of them supplying only heat and light on the farms where they were drilled. Formerly a group near Sprague supplied gas for the city of Rich Hill, but these were abandoned in 1913. Oil has been found in a great many wells in very small amounts, and for a long period up to the year 1915 a small production of petroleum was reported intermittently from a well near Merwin.

Oil and gas wells in Bates County are practically restricted to the west half, and the greater number are in the northwest quarter from Adrian west to Merwin. There are a number of gas wells in Merwin and one or more in Adrian, Amsterdam, Amoret, Hume and Sprague. A large number of wells south and east of Sprague have been drilled with success and some half dozen of these are producing at the present time.

No important discoveries of gas have been reported from the eastern half of the County, though it is probable that light flows are to be obtained there at localities as yet undiscovered.

The gas wells vary in depth from 100 to 375 feet, the average depth of 30 wells being 245 feet. Most of the gas is obtained from sandstone beds in the Cherokee shale, though in the northwest townships some has been found in the Pleasanton sandstones and in the Labette shale member of the Henrietta formation. The gas horizons of the Cherokee shale are distributed almost throughout its entire vertical section.

The initial gas pressure in the wells varies from less than five pounds up to eighty-five pounds. In about one-half of the wells it has exceeded forty pounds, and in ten type wells it averaged 42.4 pounds. When allowed to flow freely the life of the average well is comparatively short, as illustrated by the group which once supplied Rich Hill. However, a number of wells used lightly on farms or for the supply of a single residence have been continuously in service for 13 to 21 years.

Probably the most important group of gas wells ever drilled in the County were those of the Bates County Gas Company, beginning about two miles southwest of Rich Hill and strung out to the west, just south of Sprague, for about five miles. In all, the Company is reported to have drilled thirty-eight wells, from 1908 to 1912, in about one-half of which gas was found. Nine of the wells were sufficiently strong to be used in supplying Rich Hill and it is reported that these wells furnished about 2,000,000 cubic feet of gas per day. The average depth of the wells ranged from 300 to 375 feet and the gas sand, encountered at 300 to 340 feet, in the Cherokee shale, is said to be 6 to 8 feet thick with water below the gas. The initial gas pressure was as high as 85 pounds in the strongest well but no estimate is available of the gas volume from the individual wells. By August, 1913, the supply had become so nearly exhausted that no further attempt has been made to supply Rich Hill. A number of the wells are still being used on the farms for lighting and heating where the demands upon them are not great.

The following is a list of the gas wells in Bates County which have reported production.

PARTIAL LIST OF GAS WELLS WHICH HAVE BEEN DRILLED IN BATES COUNTY.

Owner.	Location.	Depth of wells.	Gas at	Pressure.	Remarks.
J. T. Ackerman	Hume	266–318		70–75	
Bates County Gas Company	Rich Hill to Hume				Supplied Rich Hill till exhausted, August, 1913, 9 wells.
J. J. Brown	Adrian	185		40	
J. F. Bowers					
Cheppel & Scott	Merwin	285			Two wells.
W. W. Cheverton		270			
L. C. Comer	Amsterdam	210–220		30	
N. H. Conyers	Sprague	376		74	
W. D. Corbin	Kansas City	258–351		20–47	
Darby Fruit Farm	Amoret	500	204	53	Gas sand at 204 feet.
S. L Stewart	Drexel	325	320	60	Sold to J. T. Stewart.
J. W. Eastburn	Rich Hill	300–350		50	
J. M. Erwin	Merwin	302		40	
A. M. Frazer	Adrian	120			Two wells.
E. D. Frazier	Drexel	165			
T. E. Grider	Merwin	125–208		40	
C. R. Hodges		200		50	Wells sold to T. J. Erwin.
George Coon	Amsterdam	160–132		40	
A. J. Hoover	Adrian	245		40	
J. J. Houtz	Merwin	210		40	
J. J. Lacey	Merwin	212			Scully Owner.
J. R. Martin	Merwin	237		20	
P. J. Mornger		104			

PARTIAL LIST OF GAS WELLS WHICH HAVE BEEN DRILLED IN BATES COUNTY—Continued.

Owner.	Location.	Depth of wells.	Gas at	Pressure.	Remarks.
W. F. Parmney..............	....	195	....	40	Well sold.
W. F. Patchin..............	Merwin.........	198-200	....	25	....
C. E. Phillips..............	Amsterdam.....	205	....	60	....
Geo. F. Ruble..............	Amoret.........	....	....	....	....
P. A. Sargent..............	Amoret.........	80	....	....	....
E E. Shockley.............	Merwin........	270	....	41	....
S. L. Standish..............	Hume..........	280-165	....	....	Ruined by water.
T. L. Weirich..............	Rich Hill.......	273	....	28	....
E. S. DeForest.............	Merwin.........	273	....	28	....
E. H. Wyatt................	Adrian..........	105	....	20	....
R. C. Raney................	Merwin (NE. ¼, sec. 34, T. 42 N., R. 33 W...	....	....	....	....
Waynes & Beadles...........	Hume..........	500	....	....	....
E. Wigglesworth............	Merwin.........	254	....	....	....
A. S. Rosier................	Merwin.........	....	....	....	....
L. L. Erwin-McPherson......	Merwin.........	200	175	47	....

The presence of asphaltic sandstone outcrops and "Tar Springs" led to oil prospecting at an early date in Bates County. Prior to 1873 a test well 525 feet deep was sunk about four miles west of Adrian. A shallow well drilled east of Amoret found oil bearing sand at a depth of fifty-eight feet. In 1883 a number of wells were drilled near Rich Hill and Amoret, the deepest being 1200 feet.

A well drilled in West Boone Township near Merwin in 1896 encountered oil at 200 feet and yielded about one barrel per day. Additional wells near Adrian yielded some oil.

In 1901 a group of ten wells were sunk on the Henry Denhart property one and one-half miles northeast of Merwin. These varied in depth from 212 to 719 feet. Some oil was encountered in all of the wells in the E. ½ sec. 28, T. 42 N., R. 33 W., in the Pleasanton sandstone, at depths of 72 to 160 feet; in the Henrietta a little gas and traces of oil were found at 200 to 250 feet; and in the Cherokee the deeper wells found oil-bearing sandstones at depths of from 300 to 467 feet. None of the wells yielded a sufficient amount of oil to pump and the oil was very heavy, black, and viscous, similar to that found near Adrian. It is probable that the best showings were the shallow ones from the Pleasanton.

More recently other tests have been made in the County near Merwin and Foster and at other points but none of the wells have found sufficient quantities of oil to pay to pump, and most of that found has been the heavy, thick, black oil.

DIAMOND DRILLING TWO MILES SOUTHWEST OF RICH HILL.
(NW. ¼, SE. ¼, SEC. 13.)

	Thickness.		Depth.	
	Ft.	*In.*	*Ft.*	*In.*
Loose earth	12	..	12	..
PENNSYLVANIAN SYSTEM:				
Cherokee formation:				
Shale, blue	8	..	20	..
Shale, black, "slaty"	1	..	21	..
Shale, blue	6	6	27	6
Coal (Summit?)	1	1	28	7
Clay	..	8	29	3
Limestone	5	9	35	..
Shale, black, "slaty"	6	6	41	6
Shale, drab	9	6	51	..
Coal (Mulky?)	..	10	51	10
Clay	12	8	64	6
Shale, black, "slaty," soft	4	..	68	6
Coal	..	6	69	..
Clay	4	..	73	..
Shale, black, "slaty"	2	8	75	8
Coal (Upper Rich Hill)	..	7	76	3
Clay	6	7	82	10
Sandstone	14	..	96	10
Coal (Lower Rich Hill), "slaty"	3	11	100	9
Shale, blue	26	..	126	9
Shale, black, "slaty"	3	..	129	9
Coal	1	10	131	7
Clay	2	..	133	7
Shale, blue	2	2	135	9
Coal	..	2	135	11
Clay	3	10	139	9
Shale, sandy	25	..	164	9
Sandstone	5	..	169	9
Shale, sandy	8	..	177	9
Sandstone, gray and white	99	..	276	9
Coal	..	5	277	2
Shale, blue	5	1	282	3
Shale, black, "slaty"	3	..	285	3
Shale, blue, sandy at top, "slaty" below	23	5	308	8
Coal	..	10	309	6
Clay	4	4	313	10
MISSISSIPPIAN SYSTEM (Lower limit of coal):				
Limestone	66	2	380	..

RECORD OF H. DENHART, WELL NO. 2, MERWIN.
(SE. ¼, SEC. 28, T. 42 N., R. 33 W.)

	Thickness.	Depth.
	Feet.	*Feet.*
Soil and clay	28	28
PENNSYLVANIAN SYSTEM:		
Pleasanton shale:		
Brown sand (trace of oil)	35	63
White sandstone	10	73
Soapstone	16	89
Sandstone	28	117
Brown sandstone (trace of oil)	8	125
White sandstone	17	142
Soapstone	8	150
Gray limestone	5	155
Soapstone	7	162
Gray limestone	8	170
Coal (Mulberry)	3	173
Soapstone	2	175
Henrietta formation:		
Gray limestone (Pawnee)	17	192
Soapstone (Labette shale)	12	204
Limestone (Labette shale)	5	209
Black "slate" (Labette shale)	8	217
White sandstone (Labette shale)	4	221
Soapstone (Labette shale)	11	232
Dark limestone (Fort Scott)	23	255
Cherokee shale:		
Soapstone	21	276
White sandstone	22	298
Soapstone and "slate"	14	312
White sandstone	3	315
Brown limestone (trace of oil); dark shale	40	355
Coal	1	356
Shale	5	361
Black "slate"	11	372
Coal	1	373
Shale	30	403
Shale	9	412
Soapstone	14	426
Black "slate" (some gas)	12	438
Shale	19	457
White sandstone (trace of oil)	18	475
Brown sand	11	486
"Slate"	15	501
White sand	32	533
White sandstone and "slate"	37	570
"Slate"	35	605
"Slate" and sand	8	613
White sand	12	625
MISSISSIPPIAN SYSTEM:		
Burlington-Keokuk limestone:		
Limestone and flint	94	719

RECORD OF GAS WELL ON DARBY FRUIT FARM, NEAR AMORET.
(SW. ¼, SEC. 29, T. 40 N., R. 33 W.)

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	5	5
Pleasanton formation:		
Soapstone	10	15
Yellow lime	5	20
Soapstone, blue	12	32
Limestone	6	38
Soapstone	5	43
Limestone	4	47
Shale	10	57
Limestone	3	60
Soapstone	5	65
Henrietta formation:		
Pawnee limestone:		
Limestone	15	80
Labette shale:		
Black soapstone	13	93
Limestone	5	98
Black "slate"	5	103
Soapstone	5	108
Sandstone	5	113
Light shale	18	131
Fort Scott lime:		
Oswego lime	19	150
Black "slate"	4	154
Limestone	4	158
Cherokee shale:		
Shale	12	170
Sandstone	4	174
Shale	26	200
Sand (gas)	10	210
Shale	45	255
Limestone	3	258
Shale	6	264
Black "slate"	9	273
Brown shale	27	300
Light shale	26	326
Dark shale (gas)	17	343
Coal	3	346
Fire clay	5	351
Shale	12	363
Sand	6	369
Coal	2	371
Dark shale	9	380
Light shale	12	392
Dark shale	3	395
Broken sand	10	405
Shale	81	486
Water sand	14	500

The asphaltic sandstones which outcrop at widely separated points, so far as observed, consist principally of beds in the Pleasanton shale. These sandstones are exposed at several points in T. 42 N., R. 33 W., west of Adrian; in T. 40 N., R. 33 W., east of Amoret, and in T. 40 N., R. 31 W., northeast of Butler.

There are a number of other points in the County outside the townships mentioned where outcropping Pleasanton and Cherokee sandstone beds have been found to be bituminous, and locations have been noted east of Amoret and south of Butler where the Henrietta limestones were partially impregnated with oil. There is no doubt that the shallow "oil sands" of the Pleasanton and Cherokee found in the northwest part of the County are partially the equivalents of the outcropping asphaltic beds.

Following is a partial list of the deep wells in Bates County.

PARTIAL LIST OF DEEP WELLS IN BATES COUNTY.

Owner.	Location.	Date.	Depth.	Base of Pennsylvanian.	Remarks.
Darby Fruit Farm.........	Amoret...............	....	580	Not reached.	Gas at 200 and 320 feet in shale. Water well.
	Amsterdam...........	....	800	582	Water well; salt water at 715 feet.
Nichel Well..............	Amsterdam...........	....	505	449	Oil sand at 338 feet.
	Near Adrian..........	1890	1025	534	....
	Foster................	1916	1300+	....	....
City of Rich Hill..........	Rich Hill.............	....	1006	....	Water well.
Henry Denhart...........	Merwin (northeast of)..	1901	719	625	Showings of oil.
R. C. Brown..............	Near Sprague.........	....	912	....	....
Rich Hill Coal Company...	Rich Hill, NW. ¼, sec. 17, T. 38 N., R. 31 W.	1885	....	315 to 400	8 wells 400 to 1200 feet deep near Rich Hill.

CASS COUNTY.

The Pennsylvanian, represented by the Cherokee, Henrietta, Pleasanton and Kansas City formations, entirely underlies Cass County, and dips at a low angle to the northwest, becoming thicker in the direction of dip by the addition of successively higher beds. The Mississippi limestone has been encountered at depth ranging as follows: Creighton, 260 to 300 feet; Garden City, 475 feet; Pleasant Hill, 580 feet. At Belton drilling to a depth of 825 feet did not reach the Mississippian.

The most pronounced structural feature of the County consists of a well-defined anticlinal fold entering near the southeast corner and passing northwest in the direction of dip, into T. 45N., R. 33W. On the north of this fold a broad syncline is developed which includes the area northwest to the Jackson County line (see Pl. 4).

The only detailed structural features which have been worked out are shown on the map of the Belton area*, where

*Plate B.

several well-developed anticlines were found. Evidences of local folding have been noted in other parts of the county, however, especially about midway between Freeman and West Line, where the Bethany Falls limestone is found considerably above its normal level, dipping 15° southeast. The dips in this locality suggest the possibility of faulting similar to that found near Belton.

In the eastern part of the County only the most gentle dips have been observed and it is probable that the folding is very low.

Small quantities of both oil and gas have been found over practically the entire area, the showings being more widespread than in any other county. However, as in Bates, the west half of Cass County contains most of the wells, the principal group being situated in the northwest corner. The gas-bearing sands have been reached at depths of from 95 to 662 feet; principally, however, at depths of less than 300 feet. The average of 15 type gas wells is only 242 feet. The gas sands lie chiefly in the lower half of the Pleasanton and in the upper half of the Cherokee. Small quantities have been found in the Labette shale member of the Henrietta. The depth of the gas sands in either the Pleasanton or Cherokee naturally depends largely upon their location in the County, the deepest sands occurring in the west and northwest townships where the higher formations are present. Around Belton, the Cherokee gas sands are reached at depths of 400 to 662 feet and the Pleasanton sands at 250 to 300 feet. In the southeast part of the County near Eightmile the productive Cherokee sands are 150 to 230 feet in depth. Most of the gas wells in the western part of the county do not reach the Cherokee and are supplied from the Pleasanton sands. The initial pressure in a number of typical productive wells ranged from 10 to 85 pounds. Most of the wells are used only to supply the domestic needs on farms, but gas has been piped into Belton, Cleveland, and West Line from wells close to those towns, and a number of consumers are still being supplied. Water troubles have been the cause of the abondonment of a number of wells. In some the gas rises through the water and both are obtained from the same well. Such wells, however, are usually short-lived, though in exceptional cases a single residence has been supplied with gas in this manner for many years.

The most important gas wells yet drilled are those in the neighborhood of Belton. Here from a number of wells 300 to

425 feet deep, initial gas pressures of 60 to 85 pounds were obtained and in one well 662 feet deep a pressure of 185 pounds was encountered. To the south, about one mile east of Jaudon, a good flow of gas with a reported pressure of 110 pounds was obtained at a depth of about 400 feet from a sandstone in the Cherokee shale. Still farther south, at and near Cleveland, West Line, and Drexel, wells have been sunk and sufficient quantities have been obtained to supply adequately one or several residences.

In the central and eastern part of the county the most successful wells have been drilled around Peculiar, Harrisonville, and Garden City. Fron the Geo. Paustian well, 2½ miles southwest of Peculiar, enough gas for the heating and lighting a farm house was obtained at a depth of only 95 feet.

RECORD OF WELL ON WRIGHT FARM, NEAR PECULIAR, (NW. ¼, SEC. 3, T. 44N., R. 32W.)

	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
PENNSYLVANIAN SYSTEM:				
Pleasanton formation:				
Sandstone, reddish	7		7	
Shale and soapstone (showing of oil at 117)	110		117	
Shale, blue (at 146 feet a streak of oil sand)	29		146	
Shale	22		168	
Henrietta formation:				
Limestone, light gray	4		172	
Shale	5		177	
Limestone, gray	4		181	
Shale	4		185	
Limestone	13		198	
Shale and soapstone	14		212	
Limestone ("slate," gas and much water)	6		218	
Limestone	7		255	
Cherokee formation:				
Shale	15		270	
Limestone	5		275	
Shale	3		278	
Limestone	3		281	
Coal	1	6	282	6
Shale	87	6	370	
Limestone, white	10		380	
Shale, blue	14		394	
Coal	..	6	394	6
Shale, blue	1	6	396	
"Slate" and some coal	9		405	
Shale (a little sand and gas at 450)	45		450	
Shale	25		475	
Limestone	5		480	
Shale	110		590	
Sandstone, gray to white, angular grains	20		610	
Shale, light gray	5		615	
Limestone, fine-grained	5		620	
Shale, light gray	5		625	
Shale and limestone	5		630	
Shale, light gray with pyrite	15		645	
Limestone, gray, with much pyrite	5		650	
Sandstone, gray, very fine	5		655	

The gas in this well apparently comes from the Pleasanton formation. On the R. W. Coates farm, 3 miles southeast of Peculiar, gas encountered at a depth of 165 feet in a well drilled for water forces the water out at the surface. Other wells in this vicinity supply farm houses for heating and lighting. A well 382 feet deep drilled for water on the County Poor Farm at the north edge of Harrisonville, encountered a gas sand yielding a 22-pound pressure. Four and one-half miles west of Harrisonville on the Andrew Wright farm considerable gas was found at a depth of 480 feet in the Cherokee shale. On the Christian Hauder farm, 4 miles northwest of Garden City, in a well 420 feet deep, gas was encountered at 157 and 230 feet in sandstones, both of which are probably in the Cherokee shale. Sufficient pressure to light and heat a house is obtained, the gas rising through water in the well. Gas is quite commonly found in this vicinity in wells similar in character to the Hauder well. A little gas was encountered in a well on the north edge of Pleasant Hill, between 200 and 300 feet in depth and several wells drilled around Archie have encountered light flows.

The following is a partial list of the gas wells in Cass County.

PARTIAL LIST OF WELLS IN CASS COUNTY IN WHICH GAS HAS BEEN FOUND.

Owner.	Location.	Date.	Depth.	Gas Depth.	Pressure.	Remarks.
Geo. M. Scott and Geo. D. Goobar..	Belton, secs. 14, 26, T. 47N., R. 33W	1902	275–800	275–400	60–685	Group of about 15 wells used to supply Belton.
Christian Hauker...	NE. ¼ sec. 16, T. 44N., R. 30W	1913	426	150–230	....	Used in lighting and heating farmhouse.
Boner Stock Co.....	SW. ¼ sec. 8, T. 46 N., R. 30 W........	1914	300	Gas in last 100 feet of drilling...	....	Not enough for use.
County Poor Farm.	Harrisonville........................	1911	382	....	22	Not used.
R. W. Coates......	NW. ¼ sec. 26, T. 45N., R. 32W........	1912	350	165	....	Gas forces water out at surface, not used.
	Near Garden City......................	......	....	....	....	....
F. P. Rust.........	SW. ¼ sec. 9, T. 45N., R. 32W	1912	172	160	....	Small amount of gas found.
J. S. Jackson.......	SE. ¼ sec. 24, T. 44N., R. 32W.........	1911	140	95	....	Still showed gas pressure in 1914, not used.
A. A. Whitsett.....	Lot sec. 3, T. 44N., R. 32W	1913	330	....	....	Gas spouts water.
Andrew Wright....	NE. ¼ sec. 33, T. 44N., R. 32W	1914	655	480	....	Enough gas at 480 feet to keep water boiling in well.
J. C. Cutler........	West Line............................	......	22.5	....	25	Supplies one family.
W. L. Burney......	....	......	....	....	....	....
H. F. Britton......	Peculiar..............................	......	....	....	....	....
Geo. A. Lapland....	Peculiar..............................	......	600	....	120	Supplies one family.
J. A. Murphy......	Drexel................................	......	....	....	....	....
Geo. Panstair......	SE. ¼ sec. 18, T. 45N., R. 32W	1911	95	....	....	Supplies one family.

RECORD OF BELTON GAS COMPANY WELL NO. 3.
(SE. ¼ SEC. 14, T. 46N., R. 33W.)

Stratum.	Thickness.	Depth.
	Feet.	*Feet.*
Soil	5	5
Joint clay	7	12
PENNSYLVANIAN SYSTEM:		
Kansas City formation:		
White lime (Iola limestone)	10	22
Blue shale	5	27
Red shale	10	37
Blue lime	20	57
White slate	10	67
White lime	3	70
Blue slate	5	75
White sand	15	90
White slate	20	110
White lime	40	150
Black slate	5	155
White lime	15	170
Black slate	5	175
Water (175)	..	...
Blue lime	15	190
Pleasanton formation:		
White shale	92	282
Top of gas sand (282)	..	...
Gas sand	12	294
Gas sand	17	311
Black slate	4	315
White slate	30	345
White sand	10	355
White slate	10	365
White lime	8	373
Henrietta formation:		
White shale	7	380
Blue lime	15	395
White shale	5	400
Black slate	6	406
Blue lime	7	413
Black slate, water and gas	5	418
Gas sand	7	425
White slate	5	430
Sand and lime	10	440
Dark slate	3	443
White slate	7	450
Lime	5	455
Cherokee formation:		
White slate	20	475
Oil sand	15	490
Shale, white	15	505
Black shale	25	530
Gas sand	15	545
Black slate	10	555
Flint lime	5	560
White slate	40	600
Black slate	40	605
White slate	35	640
White slate	10	650
Dark slate	50	700
Gray oil sand, small showing	35	735
White slate	20	755
Oil sand	10	765
While shale	15	780
Sand and salt water (780)	..	...
Oil sand	25	805
Black slate	10	815
Sandy lime	5	820

RECORD OF SCOTT & MARSH WELL NO. 1, BELTON.
(NE. ¼ SEC. 14, T. 46N., R 33W.)

Stratum.	Thickness.	Depth.
	Feet.	*Feet.*
Soil	12	12
PENNSYLVANIAN SYSTEM:		
Kansas City formation:		
Lime (Iola limestone)	5	17
Gumbo	13	30
Red rock	10	40
Lime	17	57
Red rock	5	62
White sand	30	92
White slate	10	102
Lime	38	140
Pleasanton formation:		
White shale	5	145
Blue lime	40	185
White slate	40	225
Water sand	10	235
White slate	47	282
Gas sand	10	292

Oil has been produced in the northwest corner of the County, near Belton. The production here was very small and came from the Rosier and Dumbar wells, north and east of the town.

RECORD OF ROZIER WELL, (NE. ¼ SEC. 1, T. 46N., R. 33W.)

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	5	5
PENNSYLVANIAN SYSTEM:		
Kansas City formation:		
Clay, blue	15	20
Limestone	10	30
Shale, light	10	40
Shale, blue	40	80
Limestone, very hard (Bethany Falls and Winterset)	50	130
Shale, blue	2	132
Coal (black shale)	3	135
Limestone, white (Hertha)	20	155
Pleasanton formation:		
Shale, blue	45	200
Shale, light	68	268
Shale, blue	15	283
Shale, light	20	303
Rock, red	5	308
Limestone, very hard	10	318
Shale, blue	30	348
Henrietta and Cherokee:		
Limestone, very hard	9	357
Gas sand	10	367
Shale	5	372
Limestone, hard	10	382
Gas sand	8	390
Shale, light	12	402
Sand, water	10	412
Shale, dark	7	419
Shale, bituminous	5	424
Shale, light	15	439
Oil sand	20	459

RECORD OF OIL WELL OF GARDEN CITY OIL COMPANY.
(SEC. 15, T. 44N., R. 29W.)

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	8	8
PENNSYLVANIAN SYSTEM:		
Henrietta and Cherokee formations:		
Shale, gray	6	14
Limestone	15	29
Shale, black	14	43
Shale, gray	40	83
Limestone	2	85
Shale, gray	5	90
Shale, blue	7	97
Oil sand	25	122
Sandstone, broken	4	126
Shale, black	3	129

RECORD OF WELL ON R. F. CLAY FARM, NEAR PLEASANT HILL.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	3	3
PENNSYLVANIAN SYSTEM:		
Kansas City formation:		
Limestone	60	63
Shale, light	10	73
Limestone	5	78
Pleasanton formation:		
Shale, light	52	130
Shale, dark	60	190
Sand	20	210
Shale	5	215
Henrietta formation:		
Limestone	10	225
Shale, dark	5	230
Limestone	20	250
Shale	5	255
Limestone	10	265
Cherokee shale:		
Shale, light	40	305
Sandstone	10	315
Shale, dark	15	330
Sandstone	20	350
Shale, dark	10	360
Sandstone	40	400
Shale, dark	90	490
Shale, light	40	530
Shale, dark	10	540
Sandstone, reddish	20	560
Shale, dark	40	600
Sandstone, water	40	640
Shale	5	645
MISSISSIPPIAN SYSTEM:		
Limestone	5	650

In the eastern part of the County a considerable number of test wells have been sunk near Archie, Garden City, Creighton, Latour, East Lynne, Harrisonville, and Pleasant Hill, to depths ranging from 150 to 1200 feet, none of which have yet been successful, except for showings or very small quantities of oil. In the western part of the County a 776-foot well has been drilled at Main City and a 1485-foot well sunk at West Line. The record of the former well is given below.

RECORD OF DREXEL OIL COMPANY WELL,
(SW. ¼, SE. ¼, SEC. 29, T. 43N., R. 33W.)

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	11	11
PENNSYLVANIAN SYSTEM:		
Kansas City formation:		
Shale, clayey	8	19
Limestone, gray, fine-grained, cherty	16	35
Shale, clayey, blue	52	87
Limestone, gray, fine-grained	13	100
Pleasanton formation:		
Shale, gray, clayey	100	200
Sandstone	35	235
Shale, clayey, bluish gray	31	266
Henrietta formation:		
Limestone, gray, fine-grained	5	271
Shale, clayey, light gray	5	276
Limestone, gray, fine-grained	19	295
Shale, black, fissile, "slate"	24	319
Limestone, light gray, finely crystalline	2	321
Cherokee shale:		
Shale, light to dark	79	400
Sandstone, fine, micaceous	23	423
Sandstone, fine-grained, hard	3	426
Limestone, shale, cuttings mixed	44	470
Sandstone, shaly	10	480
Shale, gray	10	490
Coal seam, ground fine	1	491
Shale, light to dark gray	49	540
No sample, reported coal	8	548
Shale, dark gray, hard	34	582
Sandstone, fine angular grains	8	590
Shale, oil show at bottom	100	690
Sandstone, gray, fine, hard	10	700
Shale, light to dark	31	731
MISSISSIPPIAN SYSTEM:		
Limestone, crystalline	14	745
Shale, gray	26	771
Limestone	5	776

Asphaltic limestone outcrops in the western part of the County from near Freeman west to West Line. The asphaltic horizon is in the Bethany Falls limestone and comprises beds from 7 feet thick near Freeman, to 3 1/2 feet thick near West

Line, occurring at the top of the limestone member. The saturation of these beds appears to follow a fissure in the limestone, through which the oil has probably ascended from the underlying rocks. The bituminous content varies from 6 to 11 per cent and the rock has been quarried and used experimentally in paving. Asphaltic sandstones in the lower Pennsylvanian, similar to those found in the counties to the south, although present, have not been observed extensively in Cass County.

PARTIAL LIST OF DEEP WELLS IN CASS COUNTY.

Owner.	Location.	Date.	Depth Feet.	Base of Pennsylvanian.	Remarks.
Harrisonville Gas & Water Co.	NE. ¼, sec. 12, T. 44 N., R. 51 W.	....	505	451	Showing of oil at 192 and 248.
Archie Oil & Gas Co.	SW. ¼ sec. 3, T. 42 N., R. 31 W.	....	1095	575	Gas at 220.
Mo. Pacific R. R.	Pleasant Hill.	....	605	580	Sunk for water.
Creighton Oil, Gas & Developing Co.	Sec. 25, T. 43 N., R. 29 W.	1910	575	260	No oil or gas.
Drexel Oil Co.	SE. ¼ sec. 29, T. 43 N., R. 32 W.	1917	776	730	Showings of oil at 670 feet.
Andrew Wright.	NE. ¼ sec. 3, T. 44 N., R. 32 W.	1914	655	Not reached.	Gas and oil, gas at 218 and 450 feet; oil at 117 and 146 feet.
Garden City.	Garden City.	1914	691	470	Water well.
Geo. M. Scott.	Belton.	....	1000	825	Gas found.
Frazier Bros.	Near Archie.	1917	1800	No data.	....
Garden City Oil Co.	Near Garden City.	1917	No data.	....	....
J. Weisser.	West Line.	1918	1485	717	....
Latour Oil Company.	Latour.	1919	1207	374	....
	East Lynne.	1918	600	....	....
J. P. Farmer.	Pleasant Hill.	1918	650	....	....

RECORD OF WEISSER WELL NO. 3, WEST LINE.

	Thickness.	Depth.
PENNSYLVANIAN SYSTEM:	*Feet.*	*Feet*
Kansas City formation:		
Limestone, asphaltic (Bethany Falls)	5	5
Limestone and shale	40	45
Pleasanton formation:		
Shale, gas at 228	205	250
Henrietta formation:		
Limestone (Pawnee)	8	258
Sandstone, showing of oil	5	263
"Slate," black	15	278
Sandstone, gas	10	288
"Slate," black and blue	55	343
Sandstone, mixed with "slate"	7	350

RECORD OF WEISSER WELL NO. 3, WEST LINE—Continued.

	Thickness.	Depth.
PENNSYLVANIAN SYSTEM—Continued.	*Feet.*	*Feet.*
Cherokee shale: (Doubtful contact.)		
Coal	..	...
Shale	38	388
Sandstone, white	33	421
Shale	37	458
Sandstone, dark	11	469
Shale	7	476
"Slate," black	15	491
Shale	2	493
Sandstone, white	22	515
Shale	15	530
Limestone (?)	28	558
Shale, black, with gas	5	563
Limestone (?)	16	579
Sandstone, white	22	601
"Slate," black	10	611
Shale, dark	16	627
Limestone, sandy	19	646
Shale, white	22	668
Shale, black, with gas	40	708
Limestone	2	710
Shale	7	717
MISSISSIPPIAN SYSTEM:		
Limestone and flint	90	807
Shale, white	5	812
Limestone	10	822
Shale, blue	2	824
Sandstone, yellow	45	869
Limestone, dark	50	919
Shale	2	921
Limestone, dark	50	971
ORDOVICIAN (LOWER) AND OLDER SYSTEMS:		
(Contact doubtful)		
*Sandstone, yellow	60	1031
Limestone, sandstone, shale and flint, in one-foot layers	8	1039
Sandstone, white	32	1071
Limestone, dark	48	1119
Sandstone	52	1171
Limestone	6	1177
Sandstone	58	1235
Limestone	32	1267
"Slate"	4	1271
Sandstone, yellow	50	1321
"Slate," black	2	1323
Sandstone	24	1347
Limestone, dark	60	1407
Sandstone	54	1461
"Slate," black	3 ½	1464 ½

*It is probable that most of the so-called sandstone penetrated in the last 500 feet of the well is really dolomite, which, in the form of drill cuttings, may very closely resemble sand.

JACKSON COUNTY.

Jackson County is entirely underlain by the Pennsylvanian, and contains the highest beds and greatest thickness of these rocks of any county south of Missouri River. All the formations from the Cherokee to the Lansing, inclusive, are exposed, but the Pleasanton and Kansas City are the most widespread and directly underlie over nine-tenths of the surface. The Winterset, Bethany Falls and Iola limestone members of the Kansas City formation are conspicuously exposed over much of the County, in bluffs along the streams. The geology of the County has been described in detail in Vol. 14, 2nd series of the reports of this Bureau. The regional dip is to the northwest 6 to 10 feet to the mile, and the underlying Mississippian limestone has been encountered at depths recorded as follows. Longview, 650 feet; Raytown, 735 feet; Kansas City (51st and Holmes Streets), 800 feet. The maximum depth to the base of the Pennsylvanian is probably a little over 900 feet.

Little is known about the detailed structural conditions of Jackson County. A structure map of the southwest township appears in this report, and one of Kansas City is contained in the report of this Bureau on the "Geology of Jackson County," but no other maps have been published. The northwest dip is so low that the rocks appear to the eye to be level. However, from Lone Jack to the northwest corner of the County the dip is 260 feet. The most important structural feature is the broad anticlinal fold entering the southeast corner of the County from Johnson County, and passing northwest through Kansas City. This fold is flanked on the north and south by broad synclinal depressions extending laterally to beyond the limits of the County. (See structure Pl. 4.) No doubt detailed work would reveal the presence of local structural features of importance in many parts of the area similar to those already found in the southwest portion. In several districts marked local dips with minor faulting have been observed.

RECORD OF STRATA IN CORE DRILLING NEAR RAYTOWN.*

Stratum.	Thickness.		Depth.	
PENNSYLVANIAN SYSTEM:	*Ft.*	*In.*	*Ft.*	*In.*
Kansas City formation:				
Chanute and Cherryvale shale:				
Shale, light, calcareous	32		32	
Limestone	2		34	
Shale, blue	17	6	51	6
Winterset limestone:				
Limestone	15	3	66	9
Galesburg shale:				
Shale, slaty	3	2	69	11
Bethany Falls limestone:				
Limestone	22	9	92	8
Ladore shale:				
Shale, slaty	4	7	97	3
Hertha limestone:				
Limestone	15		112	3
Pleasanton formation:				
Shale, some parts gritty	94	9	207	
Coal		2	207	2
Shale, some parts gritty	61	3	268	5
Henrietta formation:				
Limestone	8	7	277	
Shale, slaty	11		288	
Limestone	4		292	
Slate		10	292	10
Coal	1	6	294	4
Fire clay, hard	5	8	300	
Limestone	5		305	
Shale, slaty	14	2	319	2
Limestone	4	3	323	5
Cherokee shale:				
Slate	1	1	324	6
Coal (Lexington)	1	2	325	8
Slate (Lexington)		8	326	4
Coal (Lexington)		9	327	1
Limestone	12	9	339	10
Shale	12	2	352	
Limestone, hard ("Rhomboidal")	3	6	355	6
Slate, black	3		358	6
Coal (Summit)	1	3	359	9
Fire clay	2	7	362	4
Limestone	7	1	369	5
Shale	4		373	5
Limestone	4	3	377	8
Slate	3		380	8
Coal (Mulky)	1		381	8
Fire clay	5	8	387	4
Sandstone	11	10	399	2
Sandstone, streaks of slate or shale	32	3	431	5
Shale, slaty	15	4	446	9
Slate and shale	5	6	452	3
Coal (Bevier)	1	8	453	11
Shale and slate	49		502	11
Slate	6		508	11
Coal	1	4	510	3
Limestone	8		518	3
Slate and shale	6		524	3
Coal		10	525	1

*Ten miles southeast of Kansas City (sec. 7, T. 48 N., R. 32 W.). Drilled in 1886. Record furnished by S. J. Hatch.

RECORD OF STRATA IN CORE DRILLING NEAR RAYTOWN—Continued.

Stratum.	Thickness. Ft.	Thickness. In.	Depth. Ft.	Depth. In.
PENNSYLVANIAN SYSTEM—Continued:				
Cherokee shale—Continued.				
Limestone	18	6	543	7
Sandstone, showing of gas	16	2	559	9
Shale, sandy	23	2	582	11
Shale, sandy, micaceous	37	7	620	6
Shale, sandy, streaks of slate	33	2	653	8
Sandstone	15	7	669	3
Shale, sandy	24		693	3
Shale	15		708	3
Sandstone, coarse, salt water	43	9	752	
MISSISSIPPIAN SYSTEM:				
Burlington-Keokuk:				
Limestone, cherty	333		1085	
Kinderhook group (?):				
Limestone, dark, with shelly layers	100		1185	
Sand, dark-reddish	15		1200	
ORDOVICIAN SYSTEM:				
Joachim (?)*:				
Limestone, bluish, fine-grained, shelly in places	57		1257	
St. Peter:				
Sandstone, white at top, reddish at bottom	64		1321	
CAMBRO-ORDOVICIAN SYSTEM:				
Limestone, gray and brown	129		1450	
Limestone, shelly and clayey	10		1460	
Limestone, light, coarse, and porous	160		1620	
Limestone, shelly	20		1640	
Sandstone, white	16		1656	
Limestone, light, flinty, porous, water disappeared or was lost	74		1730	
Limestone, gray, clayey, and sandy	20		1750	
Limestone, gray, hard, fine-grained	70		1820	
Sandstone, gray, hard, fine-grained	15		1835	
Limestone, gritty, porous, crystalline, in places white and flinty	215		2050	
Sandstone, hard, coarse	50		2100	
CAMBRIAN SYSTEM:				
Limestone, with seams of gray and brown shale	40		2140	
Limestone, dark and light, fine-grained	110		2250	
Sandstone, hard, coarse	98		2348	
PRE-CAMBRIAN:				
Granite	53		2401	

*Correlation below 1,200 feet by E. O. Ulrich; U. S. Geol. Survey Water-Supply Paper 195, p. 86, 1907.

Both oil and gas have been produced in small quantities in Jackson County. A group of wells recently drilled near Dallas, and other wells now being sunk in this locality, have shown the greatest possibilities. Gas is being produced from wells at a number of localities and used for domestic purposes, and it has been used in the past, to a small extent, in manufacturing enterprises.

Nearly all of the wells in which oil and gas have been found are located in the western third of the County, the greatest number of them in or near Kansas City. So far as known, none of the wells in the eastern part have encountered significant quantities, though a little gas is reported to have been found at a depth of 474 feet in a well at Buckner. However, very few wells have been sunk in the eastern part of the County and the apparent restriction of the oil and gas to the western part may be due chiefly to the larger number of wells drilled there.

The oil and gas bearing horizons are chiefly in the lower part of the Pleasanton shale, in the Labette shale member of the Henrietta formation, and in the upper part of the Cherokee shale. Small amounts of gas have also been found in the lower part of the Cherokee. The various horizons are distributed throughout more than 400 feet of strata, entirely in the lower Pennsylvanian beds. The oil horizons have been found in the same beds but principally in the lower part of the Pleasanton formation and the upper part of the Cherokee. Neither oil nor gas has been found below the base of the Pennsylvanian in Jackson County.

In nearly all the wells the gas has been found in sandstones but in a few it is reported in black slaty shale ("slate"), and in a very few others in coal beds. It is known that the coal in the Brush Creek mine was very gaseous. Water, usually salt, has been found both above and below the gas horizon.

The depth to the oil and gas sands varies from only 75 feet to 552 feet, as recorded in 50 wells; depending upon the stratigraphic position of the sands, and upon the surface elevation and geologic horizon at which the wells were started. Most of them reached the oil and gas horizons between 220 and 450 feet.

The first wells in the County were drilled in Kansas City, soon after the close of the Civil War. The earliest drilling, of which there is a reliable record, was put down near the old Union Depot in or before 1872. The number of wells drilled and the proportion of them that produced gas are unknown, but a summary of available data indicates that 100 to 150 wells have been drilled and that probably 100 of these have been productive. However, a large number of unproductive wells may have been drilled but not recorded.

RECORD OF WELL OF DR. I. M. RIDGE.

(At Twentieth and Woodland streets, Kansas City.)

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	10	10
PENNSYLVANIAN SYSTEM:		
Kansas City formation:		
Limestone (Raytown)	5	15
Sandstone	20	35
Limestone, shaly (Cement City)	5	40
Limestone, solid (Cement City)	9	49
Sandstone	6	55
Limestone (Drum)	10	65
Sandstone	18	83
Limestone	2	85
Sandstone	7	92
Flint layers (Winterset)	12	104
Slate (Winterset)	2	106
Limestone (Winterset)	10	116
Shale, dark	7	123
Limestone (Bethany Falls)	24	147
Sandstone	5	152
Limestone (Hertha)	2	154
Pleasanton formation:		
Sandstone	10	164
Shale and limestone	3	167
Sandstone	84	251
Shale and limestone	8	259
Sandstone, gas at 282	35	294
Shale and limestone	20	314
Sandstone	14	328
Coal	1	329
Henrietta formation:		
Limestone	5	334
Sandstone	8	342
Limestone	3	345
Sandstone	5	350
Slate, black, gas, and salt water	3	353
Sandstone	5	358
Limestone and sandstone	28	386
Cherokee shale:*		
Sandstone	8	394
Limestone	4	398
Shale, coal, gas	4	402
Sandstone	6	408
Limestone	3	411
Sandstone	14	425
Limestone	1	426
Shale, bituminous, salt water	2	428
Limestone	8	436

*Contact approximately determined.

In those wells producing gas the initial rock pressure is usually reported between 50 and 100 pounds and flows of 500,000 cubic feet per day have been obtained. At Martin City a well drilled by Mr. Louis Knoche is reported to have had an initial pressure of 187 pounds and the flow measured 1,500,000 cubic feet. The pressure increases gradually and the wells usually last but a few years. For a number of years the Pier Brass Works, the Kansas City Bolt and Nut Company and the Withe Gas Engine Works utilized the gas obtained by drilling a number of wells at Sheffield, where the sand was encountered at a depth of 275 feet.

Near the State line between Dallas and New Santa Fe a number of wells have been drilled in the last few years which have produced some oil. The Mastin group near Belvidere Station consisting of five wells produced from one to three barrels per day and for a time shipped about 300 barrels per month. The period of production was relatively short.

The production in the vicinity of Dallas comes from a sand approximately 75 to 115 feet below the Ft. Scott limestone. The sand varies from 15 to 55 feet in thickness averaging approximately 33 feet. An initial production of 50 to 70 barrels is reported by Mr. C. W. Miller of the Dallas Oil & Gas Company.

Showings of oil have been encountered in at least a dozen wells in Kansas City. A number of these are located along the Big Blue from Sheffield south to Leeds. Several are in Brush Creek valley, while others are in the heart of the city.

Following logs indicate the character of the formations and the depth of the various sands in different parts of the County:

RECORD OF WELL OF WITTE GAS ENGINE WORKS.

(Sixteenth and Oakland streets, Kansas City.)

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	15	15
Sand	10	25
Gravel	8	33
Sand	30	63
PENNSYLVANIAN SYSTEM:		
Pleasanton formation:		
Limestone	1	64
Gravel	9	73
Limestone	2	75
Shale	10	85
Limestone	6	91
Shale, red	4	95
Limestone	12	107
Shale	20	127
Henrietta formation:		
Limestone	3	130
Shale	30	160
Sand, gas	10	170

RECORD OF WELL OF WITTE GAS ENGINE WORKS—Continued.

	Thickness.	Depth.
PENNSYLVANIAN SYSTEM—Continued.	*Feet.*	*Feet.*
Cherokee shale:		
Shale	4	174
Sand	6	180
Shale	12	192
Sand	4	196
Shale	13	209
Limestone	5	214
Shale	18	232
Sand, gas	15	247
Shale	20	267
Sand	8	275
Sand, oil	29	304

ANALYSIS OF GAS FROM WELLS OF KANSAS CITY BOLT AND NUT COMPANY.*

Constitutent.	Per cent.
Methane, marsh gas (CH_4)	92.90
Carbon dioxide (CO_2)	.83
Nitrogen (N)	5.43
Oxygen (O)	.20
Carbon monoxide (CO)	.10
Helium (He)	.04
Ethylene (C_2H_4)	.50
Total	100.00

*Analysis, Hamilton P. Cady and David F. McFarland. Published in Am. Chem. Soc. Jour., vol. 29, p. 1530, 1907.

RECORD OF WELL OF SCRUGGS & JOHNSON (MASTIN NO. 7).
(W. ½, NW. ¼ SEC. 36, T. 47 N., R. 33 W.)

	Thickness.	Depth.
	Feet.	*Feet.*
Soil and clay	10	10
PENNSYLVANIAN SYSTEM:		
Limestone	5	15
Rock, red	10	25
Shale, blue	10	35
Limestone	10	45
Shale, blue	46	91
Limestone	33	124
Shale, bituminous, water	5	129
Shale, dark	100	229
Limestone	76	305
Shale, light	50	355
Shale, bituminous, water	5	360
Limestone	2	362
Shale, green	11	373
Oil sand	6	379

RECORD OF WELL OF L. H. KNOCHE. (SE. ¼ SEC. 20, T. 47 N., R. 33 W.)

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	13	13
Gravel	5	18
PENNSYLVANIAN SYSTEM:		
Kansas City formation:		
Limestone, gray (Bethany Falls)	14	32
Shale	5	37
Limestone	1	38
Shale	5	43
Limestone (Hertha)	12	55
Pleasanton formation:		
Shale, light	40	95
Limestone, shelly	10	105
Shale, dark	40	145
Gas sand	5	150
Shale, light	15	165
Shale, dark	5	170
Shale, light	15	185
Shale, red	5	190
Shale, dark	32	222
Henrietta formation:		
Limestone	5	227
Shale	2	229
Limestone	5	234
Shale	4	238
Limestone	7	245
Limestone, hard	2	247
Limestone	3	250
Gas sand	7	257
Cherokee shale:		
Shale, dark	10	267
Limestone	5	272
Gas shale, hard, bituminous	4	276
Oil sand	5	281
Shale, white, sandy	32	313
Limestone	5	318
Shale, dark	20	338
Oil and gas sand	27	365
Shale, dark	23	388
Oil sand	14	402
Shale, dark	71	473
Shale, light	10	483
Shale, dark	12	495
Coal	7	502
Shale, dark	5	507
Shale, light	15	522
Gas sand	25	547

RECORD OF WELL NO. 6, DALLAS OIL AND GAS COMPANY; REINSCH FARM, JOHNSON COUNTY, KANSAS, ONE MILE SOUTH OF DALLAS.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	3	3
PENNSYLVANIAN SYSTEM:		
Kansas City formation:		
Shale, soft, red	7	10
Limestone, hard, white	6	16
Shale, soft, blue	7	23
Limestone, hard, white	5	28
Shale, soft, blue	35	63
Limestone, hard, white	2	65
Shale, soft, blue	7	72
Limestone, hard, white	31	103
Shale, dark, medium	6	109
Limestone, hard, white	21	130
Shale, soft, dark	4	134
Limestone, hard, white	2	136
Shale, soft, dark	1	137
Limestone, hard, white	1	138
Shale, light, soft	3	141
Limestone, hard, white	10	151
Pleasanton formation:		
Shale, soft, dark	4	155
Shale, soft, light	98	253
Sand, medium gray	13	266
Shale, soft	11	277
Rock, soft, red	4	281
Limestone, conglomerate	4	285
Rock, medium red	6	291
Shale, soft, light	24	315
Henrietta formation:		
Limestone, hard, white	6	321
Shale, sort, light	5	326
Limestone, hard, light	4	330
Shale, soft, light	3	333
Limestone, hard, light	11	344
Shale, soft, dark	17	361
Limestone, hard, gray	7	368
Cherokee shale:		
Shale, soft, black, salt water	7	375
Shale, soft, light	16	391
Sandstone, hard, light	26	417
Shale, medium light	30	447
Sandstone, medium light, gas sand	14	461
Sandstone, soft, light, oil sand	46	507
Shale, soft, blue	2	509

RECORD OF JERSEY-WYOMING OIL COMPANY WELL NO. 4; GILL FARM.

(NW. ¼, NE. ¼ SEC. 7, T. 47 N., R. 33 W.)

	Thickness.	Depth.
	Feet.	*Feet.*
Clay	12	12
PENNSYLVANIAN SYSTEM:		
Kansas City formation:		
Limestone (Iola)	10	22
Shale, blue	4	26
Limestone	16	42
Shale, blue	6	48
Shale, red	8	56
Limestone	10	66
Shale, blue	6	72
Limestone	8	80
Shale, blue	32	112
Limestone	6	118
Shale, blue	2	120
Limestone	34	154
Shale	2	156
Limestone	8	164
Shale, blue	2	166
Limestone	8	174
Shale, light	5	179
Limestone	20	199
Pleasanton formation:		
Shale, blue	150	349
Shale, red	6	355
Shale, blue	30	385
Shale, black	1	386
Henrietta formation:		
Limestone	6	392
Shale, blue	20	412
Limestone	2	414
Shale, dark	4	418
Limestone	3	421
"Slate," black, salt water	4	425
Shale, light	3	428
Limestone	4	432
Cherokee shale:		
Shale	44	476
Limestone	1	477
Shale, blue	18	495
Shale, light	22	517
Oil sand	30	547
Shale, blue	3	550

RECORD OF BADGER LUMBER COMPANY EMPLOYEE'S WELL, 15TH AND KENSINGTON STS., KANSAS CITY.

	Thickness.	Depth.
	Feet.	*Feet.*
Clay, yellow	37	37
PENNSYLVANIAN SYSTEM:		
Kansas City formation:		
Limestone	8	45
Soapstone	4	49
Limestone	8	57
Shale, hard	3 ½	60 ½
Limestone	8 ½	69
Shale	4	73
Limestone	2 ½	75 ½
Pleasanton formation:		
Soapstone	4	79 ½
Shale, hard	7	86 ½
Limestone, flinty	3 ½	90
Shale, soapy	6	96
Coal seam	..	...
Shale and soapstone	62	158
Limestone	3	161
Sandstone, showing oil near top, dry below	18	179
Soapstone	10	189
Limestone	2	191
Soapstone	10	201
Limestone "cap rock"	3	204
Sandstone, oil sand	16	220

PLATTE COUNTY.

Pennsylvanian rocks entirely underlie Platte County and have a greater thickness than in any of the counties south of Missouri River. The Cherokee, Henrietta and Pleasanton are covered by higher beds, the exposed formations ranging from the Kansas City, which outcrops along the deep valleys on the southern edge, to the Shawnee, which underlies the hills in the northwest corner of the County. The Lansing and Douglas formations directly underlie most of the surface. Near Hampton a deep test well for oil, starting in the lower Douglas, encountered the Mississippian limestones at a depth of 1060 feet. A deep well near Weston, starting in the upper Douglas, penetrated the Pennsylvanian strata to a depth of 1033 feet and finished near the base of the Cherokee shale, indicating 1100 or 1200 feet of the Pennsylvanian. Farther northwest where the Shawnee overlies the Douglas the total thickness probably somewhat exceeds 1200 feet. Toward the south part of the County these rocks become thinner, though a well 840 feet deep near Tiffany Springs did not reach their base. The minimum thickness, about 700 feet, occurs in the Missouri bottoms east of Parkville. A great part of the Platte County is very hilly and the depth to the base of the Pennsylvanian may vary from 200 to 300 feet from the valley to hilltop. The regional dip is slightly north of west, about 12 feet to the mile. The dip is modified by a series of anticlines and shallow synclines, whose axes pass northwest and southeast parallel to the dip. Ordinarily the dips are so gentle as to make the rocks appear level though in places of strong local folding they measure 20° or more.

The anticlines are mostly short, low, irregular and without southeast closure. One prominent anticline beginning just northeast of the Union Chappel School passes west to Settles Station and thence northwest to the Platte Valley School, dying out near the bluffs of Missouri River. Shorter anticlines lie just to the south of Platte City, to the north of Parkville, west of Ridgely and between Dearborn and Edgerton.

Interest in oil and gas in Platte County centers around the group of wells in sections 6, 8 and 17, T. 51N., R. 34W., located about five miles northwest of Parkville, which have until recently supplied that town with gas. The first well in this locality was sunk in 1910 by the Tiffany Springs Oil Company, in the SE. ¼ SE. ¼ sec. 8, T. 51N., R. 34W. At a depth of 535 feet, about 12 feet of hard sandstone was penetrated reported to yield 1,000,000 cubic feet per day. No further gas was found although the drilling was continued to a depth of 840 feet before the well was capped. The results obtained from this well encouraged further testing, and in 1912-1913 the Parkville Gas Company drilled two wells in the NE. ¼ sec. 17, one of which was successful. Two more wells were drilled in 1914, in the same section, one yielding 1,000,000 cubic feet per day at about 147½ pounds pressure, according to the report of the Company. Later, the Company drilled another good well in the same quarter section, and one in the SE. 1/4 sec. 9. In 1917, the entire group, therefore, consisted of 7 wells, 540 feet to 595 feet in depth, five of which were productive, the gas coming from a sand near the top of the Cherokee shale, at depths of 488 to 540 feet. The sand is extremely hard and fine grained, and is 9 to 20 feet in thickness. The rocks above carried very little water.

The Parkville gas wells are located near the northwest end of the anticline which passes north of the town and, from the structural conditions, there is apparently an opportunity to expand the field. However, the gas sand is very erratic, pinching out within very short distances and appearing to be entirely absent locally. Two of the earlier wells, and several sunk in 1918, failed to encounter the sand at all. This makes drilling extremely precarious, and has considerably discouraged development.

In 1918, the supply, after 4 to 6 years, had become so diminished as to be inadequate for the demands of the company, and the failure to bring in new wells is likely to cause the complete abandonment of the group.

RECORD OF WELL OWNED BY PARKVILLE GAS COMPANY,

(NW. ¼ SEC. 17, T. 51 N., R. 34 W.)

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	9	9
PENNSYLVANIAN SYSTEM:		
Lansing formation:		
Shale	21	30
Limestone (Plattsburg)	15	45
Shale, sandy	15	60
Shale	8	68
Limestone	5	73
Shale	52	125
Kansas City formation:		
Limestone	30	155
Shale	12	167
Limestone	8	175
Shale	10	185
Limestone	17	202
Shale	14	216
Limestone	4	220
Shale	3	223
Limestone	20	243
Shale	6	249
Limestone	3	251
Shale	2	253
Limestone	12	265
Shale	3	268
Limestone (Bethany Falls)	20	288
Shale	2	290
Limestone	15	305
Pleasanton formation:		
Shale	120	425
Red cave	9	434
Shale	23	457
Henrietta formation:		
Limestone	3	460
Shale	20	480
Limestone	8	488
Shale	2	490
Limestone	3	493
Shale	7	500
Limestone	6	506

RECORD OF WELL OWNED BY PARKVILLE GAS COMPANY—Continued.

	Thickness.	Depth.
PENNSYLVANIAN SYSTEM—Continued.	*Feet.*	*Feet.*
Cherokee shale:		
Shale	6	512
Sandstone and shale	12	524
Shale	36	560
Limestone	3	563
Shale	7	570
Limestone	3	373
Shale	2	575
Limestone	3	578
Shale	17	595

The group mentioned above are the only gas wells of commercial importance in the County, though a well drilled near the Park College water plant in Parkville encountered a small quantity of gas at a depth of 275 feet. Showings of gas have been reported at a few other localities.

RECORD OF PARK COLLEGE WELL, PARKVILLE, MISSOURI.

	Thickness.	Depth.
	Feet.	*Feet.*
Dirt	15	15
Gravel	2	17
PENNSYLVANIAN SYSTEM:		
Kansas City formation:		
Soapstone	5	22
Limestone	2	24
Soapstone	3	27
Limestone	0.5	27.5
Soapstone and limestone	2.5	30
Limestone and shale	28.5	58.5
Shale, light to dark, salt water	9	67.5
Limestone (Bethany Falls)	19	86.5
Shale	11	97.5
Limestone	8	105.5
Pleasanton formation:		
Shale, light, sandy	24	129.5
Shale, dark	75	204.5
Limestone, porous	4	208.5
Shale, dark to red	7	215.5
Shale, soft, sandy	32	247.5
Henrietta formation:		
Limestone	6	253.5
Shale	14	267.5
Oil sand, gas	4	271.5
Sandstone, gas	11	282.5
Shale, dark	8	290.5
Soapstone	16	306.5
Limestone	6.5	313.0

Thus far, no commercial quantities of oil have been found in the County though from a well 2 miles southeast of Tiffany Springs on the Higgins farm, in the same locality as the Parkville gas wells, several barrels of oil are said to have been bailed from a depth of 590 feet. This oil probably came from near the base of the Pleasanton formation, as the well was drilled at a surface elevation much higher than the gas wells.

Log of well on the Higgins farm (SE. 1/4, Sec. 8, T. 51 N., R. 34 W.) is given on p. 4, Folio 206, U. S. Geol. Survey.

The following is a tabulation of most of the wells drilled in this county.

PARTIAL LIST OF DEEP WELLS IN PLATTE COUNTY.

Owner	Location.	Date	Depth.	Remarks
Danciger Bros	Near Weston, NE. ¼ sec. 2, T. 53 N., R. 36 W	1915	1033	Finished in Cherokee shale; no oil or gas.
Danciger Bros	N. ½ sec 3, T. 52 N., R. 35 W	1915	955	Finished in Cherokee shale; no oil or gas.
Wm. Wilson	SE. ¼ sec. 1, T. 51 N., R. 34 W	....	480	....
Tiffany Springs Oil Company	SE. ¼ sec. 8, T. 51 N., R. 34 W	1910	840	Finished in Cherokee shale: obtained large flow of gas.
Tiffany Springs Oil Company	SE. ¼ sec. 8, T. 51 N., R. 34 W	1910	600	Several barrels of oil bailed from depth of 590 feet.
Parkville Gas Company, M. Fickle.	SW. ¼ sec. 9, T. 51 N., R. 34 W	1916	595	Large flow of gas, pressure 147, from 374-583 feet in Cherokee shale.
Parkville Gas Co	NW. ¼ sec. 17, T 51 N., R. 34 W.	1915	595	Dry well; no sand at gas horizon.
Parkville Gas Co	NW. ½ sec. 17, T. 51 N., R. 34 W.	1915	495	Gas sand at 488 feet.
Parkville Gas Co	NE. ½ sec. 17, T. 51 N., R. 34 W.	1915	505	Gas sand at 497 feet.
	Weston	1907	409	No oil or gas.
LaSalle Oil Co	Hampton	1919	2420	No oil or gas.
Home Riverside Coal Company	Leavenworth, Kansas	....	2116	No appreciable quantity of oil or gas.

RECORD OF WELL OF THE LASALLE OIL COMPANY, HARSTOCK FARM, NW. ¼ SW. ¼, SEC. 29, T. 52 N., R. 34 W.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	15	15
Sand	17	32
PENNSYLVANIAN SYSTEM:		
Shale, blue	3	35
Limestone, white	37	72
Shale, blue	3	75
Limestone	5	80
Shale	10	90
Limestone, hard	20	110

RECORD OF WELL OF THE LASALLE OIL COMPANY—Continued.

	Thickness.	Depth.
PENNSYLVANIAN SYSTEM—Continued.	*Feet.*	*Feet.*
Shale	30	140
Limestone	15	155
Shale, blue	4	159
Limestone	3	162
Shale	8	170
Limestone, white	15	185
Shale	15	200
Limestone	10	210
Shale, white	15	225
Limestone	10	235
"Slate"	9	244
Limestone	6	250
Shale, blue	20	270
Limestone	26	296
"Slate," white	4	300
Limestone	14	314
Shale, white	76	390
Limestone	5	395
Shale, blue	3	398
Limestone	2	400
Shale, blue	10	410
Limestone	10	420
Sandstone, dry	15	435
Shale, white	25	460
Limestone, white	10	470
Shale, white	10	480
Limestone	10	490
Sandstone, water	20	510
Shale	85	595
Limestone	5	600
Shale	5	605
Limestone	5	610
Shale	33	643
Limestone	2	645
Shale	85	730
Limestone	8	738
Shale	37	775
Limestone	15	790
Shale	40	830
Limestone	10	840
Shale, white	10	850
Limestone	15	865
"Slate," black	55	920
Sandstone, water	30	950
"Slate," black	5	955
Limestone, sandy	10	965
Shale, white	10	975
Sandstone	11	986
Shale, white	29	1015
Shale, blue	20	1035
Sandstone	10	1045
Shale, blue	15	1060
MISSISSIPPIAN SYSTEM:		
Limestone	210	1270
Sandstone	20	1290
Limestone, sandy	60	1350
Sandstone, water	25	1375
Limestone, hard	76	1451
Shale, white	29	1480

RECORD OF WELL OF THE LASALLE OIL COMPANY—Continued.

	Thickness.	Depth.
UNDIFFERENTIATED: SYSTEMS OLDER THAN MISSISSIPPIAN:	*Feet.*	*Feet.*
Limestone, white to brown	160	1640
Sandstone, white	20	1660
Limestone, white	10	1670
Sandstone, water	30	1700
Limestone, white	50	1750
Sandstone, white	15	1765
Limestone, white	19	1784
Sandstone, gray	43	1827
Shale, blue	5	1832
Limestone, hard	3	1835
Sandstone, water	20	1855
Limestone, gray	15	1870
Sandstone, white	35	1905
Limestone, sandy	45	1950
Sandstone, white	40	1990
Limestone, sandy	55	2045
Sandstone, white	55	2100
Limestone, hard	50	2150
Sandstone, water	10	2160
Limestone, hard	175	2335
Sandstone, white	35	2370
Limestone, sandy	50	2420

The driller's record of this well is not given in sufficient detail for correlation. The well started in the lower part of the Douglas formation and reached the Mississippian limestones at a depth of 1060 feet. The base of the well at 2420 feet probably rests on Cambrian or Ordovician.

CLINTON COUNTY.

The Pennsylvanian entirely underlies Clinton County. The lowest exposed formation, the Kansas City, outcrops at only two points, one in the northeast corner along Shoal Creek; the other at the south margin just north of Holt. Elsewhere the Lansing and Douglas formations directly underlie the surface. The thickness of the Pennsylvanian varies from 800 or 1000 feet in the southeast to nearly 1200 feet in the northwest. The only complete well section available is located in the northwest corner of the County (sec. 23, T. 57N., R. 32W.). This well, starting in the Douglas, reached the Mississippian limestone at a depth of approximately 1170 feet. A test well a few miles south of Plattsburg, reported to be about 1400 feet deep, must have penetrated well toward the base of the Mississippian, if not actually below, but no record could be obtained. At Cameron a well 600 feet deep reached the top of the Pleasanton shale at 405 feet and finished near the top of the Cherokee shale. A considerable thickness of glacial drift covers portions of the County.

The northwest regional dip in Clinton County is less than 10 feet to the mile, and the dominant structural feature is a broad, low, anticlinal arch, passing from the southeast to the northwest corner of the county (see Pl. 4). No detailed features of the structure are known except in the vicinity of Holt, Clay County, where a small area has been mapped*. The area shows a normal regional dip with considerable minor folding but no important anticlines.

No appreciable amount of oil has been reported in any of the wells drilled in Clinton County, but gas has been found at several localities. The only well now in use is on the farm of R. S. Stockton (SW. 1/4 sec. 22, T. 55N., R. 30W.), 4 1/2 miles east and a little north of Lathrop. It is 410 feet deep, gas having been encountered in sandstones at depths of 246 and 300 feet, probably in the Pleasanton.

RECORD OF COAL PROSPECT, LATHROP, MISSOURI.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	50	50
PENNSYLVANIAN SYSTEM:		
Limestone	11	61
Shale	4	65
Limestone	25	90
Shale	28	118
Limestone	1	119
Sand, shale	9	128
Limestone, hard	2	130
Sand, shale	25	155
Limestone, hard	1	156
Shale	20	176
Limestone	22	198
Shale	2	200
"Slate," black	2	202
Shale	16	218
Limestone	9	227
"Clod," yellow	1	228
"Kimble"	4	232
Shale, purple	8	240
Limestone	6	246
Shale	19	265
Limestone	8	273
Shale, lime layers	12	285
Shale, dark	16	301
Limestone	25.5	326.5
Shale, bituminous	2.5	329
Fire clay	1	330
Limestone	24	354
"Slate," black	2	356
Limestone, sandy	7	363
Limestone	13	376
Shale, sandy	5	381
Fire clay	1	382
Shale, sandy	70	452

* Pl.—

RECORD OF COAL PROSPECT, LATHROP, MISSOURI—Continued.

	Thickness.	Depth.
PENNSYLVANIAN SYSTEM—Continued.	*Feet.*	*Feet.*
Sandstone	7	459
Shale, mixed sand	8	467
Limestone, sandy	5.5	472.5
Limestone, hard	1.5	474
Shale, dark	10	484
Shale, sandy	9	493
Limestone	2	495
Shale, lime layers	21	516
Limestone, hard	8	524
Shale, sandy	14	538
Limestone, hard	2.5	540.5
"Clod"	2¼	542¾
Coal	1¼	544
Fire clay and "slate"	2½	546½
Sandstone	7½	554
Limestone, hard	3	557
Shale, dark blue	5	562
Limestone	4	566
Shale	6	572
Limestone	7	579
Shale, blue	4	583
Limestone and sandstone	2	585
Shale	4	589
Limestone	14	603

The initial pressure is reported to have been 60 pounds, and the gas has been used for lighting and heating the farmhouse for eight years. Gas was also found about 3 miles northwest of the Stockton well in sec. 8, T. 55N., R. 30W., at a depth of about 300 feet, and in NE. 1/4 sec. 17, T. 55N., R. 30W., at about the same depth, probably from the same horizon as in the Stockton well. Neither well has ever been utilized. Five miles northwest of Lathrop, on the Williams and Chenoweth farms in secs. 10 and 16, T. 55N., R. 31W., gas has been found in two wells 360 and 353 feet in depth. Pressure and flow were not determined in either case, as the gas was not used. In the Chenoweth well the gas was encountered at depths of 145, 250 and 313 feet, the first gas possibly coming from one of the lower shale members of the Kansas City formation. A small showing has also been found in a well at Hemple, in the northwest corner of the County, occurring at a depth of only 65 feet. The Holt gas wells lie just over the southern boundary of Clinton, in Clay County, and are discussed on a later page.

In 1887 a well was sunk in the NE. 1/4 sec.20, T. 57N., R. 22W., about 3 miles northeast of Hemple, to a depth of 791 feet, without success. A well 1269 feet deep was finished two miles east of the former well, also without success. The Mississippian limestones were reached at 1170 feet. A diamond drilling at Cameron and one at Lathrop both reached a depth of 600 feet without encountering either oil or gas. The most recent test, also unsuccessful, was sunk in 1917, by the Clay-Clinton Oil and Gas Company, near the Mt. Zion Church, about 3 miles south of Plattsburg. The depth is reported to have been about 1400 feet, which would place the base of the hole below the Pennsylvanian.

The record of the Stewartville Development Company well is appended for reference.

RECORD OF WELL OF STEWARTVILLE DEVELOPMENT COMPANY,

N. E. ¼ SEC. 23, T. 57 N., R. 32 W.

	Thickness.	Depth.
	Feet.	*Feet.*
No record	50	50
PENNSYLVANIAN SYSTEM:		
Limestone, gray, fine-grained	55	105
No record	75	180
Shale	120	300
Limestone, gray, finely crystalline	..	385
Shale, black, carbonaceous	15	400
No record	80	480
Shale, reddish	60	540
Limestone, gray, fine-grained, and blue shale	30	570
No record	30	600
Shale, blue to black	10	610
No record	..	...
Shale, sandy, micaceous	..	685
Limestone, gray, crystalline	15	700
No record	10	710
Shale	65	775
Shale, black, carbonaceous	5	780
No record	20	800
Shale, very sandy, micaceous	115	915
Sandstone, fine-grained, and shale	70	985
Sandstone, fine-grained	115	1100
Shale	20	1120
Shale, coarse sand, and chert	..	1165
MISSISSIPPIAN SYSTEM:		
Limestone, gray, crystalline	15	1180
Limestone and chert	89	1269

CALDWELL COUNTY.

The Pennsylvanian entirely underlies Caldwell County. The Pleasanton shale, the lowest outcropping formation, occurs in the valley of Shoal Creek, from Kingston east, and along the valley of Muddy Creek in the southern part of the County. The

Kansas City and Douglas formations underlie all of the upland area. The minimum thickness is in the eastern part of the County, the maximum in the western. Near Braymer, a well starting near the base of the Kansas City formation reached the Mississippian at a depth of 673 feet, while depths of 800 to 1000 feet would no doubt be required in the western townships.

Structurally, the County lies in a broad shallow gently pitching synclinal trough, the axis of which trends from southeast to northwest. (See Pl. 4). However, local folding is known to occur, and especially near Breckenridge in the northeast corner, the rocks have been found to dip steeply in a number of places. These dips are also apparently associated with some faulting and represent the typical small areas of marked folding described elsewhere in this report. The town of Breckenridge lies on a small but rather well-developed dome, as shown on the accompanying structure map, plate 10.

Layers of the Bethany Falls limestone, locally saturated with asphalt, outcrop in a few localities, including sec. 34, T. 57 N., R. 27 W.; three miles south of Nettleton; and the quarry north of Breckenridge.

Neither oil nor gas in commercial quantities has been encountered in Caldwell County. However, at several localities in the eastern part showings of heavy oil or asphalt have been found in very shallow wells near Braymer, one is sec. 4, T. 55N., R. 25W., on the Davis farm; one in sec. 33, T. 56N., R. 26W., and one about eight miles north in sec. 33, T. 57N., R. 26W. In these wells, the asphalt was found about 20 feet below the surface, in the Pleasanton formation. A well near Braymer, penetrating the entire thickness of the Pennsylvanian, encountered no deeper asphaltic beds.

The occurrence of the shallow asphaltic sandstone on the Davis farm (SW. 1-4 sec. 4, T. 55N., R. 26W.) was responsible for the sinking of a test well in 1910, which reached a depth of 1410 feet without further results than showings of oil at 34, 68, and 95 feet, all in the Pleasanton shale. A well 4 miles east in sec. 1, T. 55N., R. 26W., sunk to 446 feet, did not encounter any showings. The following is the record of the Davis well.

RECORD OF WELL ON FARM OF M. F. DAVIS,

NE. ¼, SW. ¼ SEC. 4, T. 55 N., R. 26 W.

	Thickness.	Depth.
	Feet.	*Feet.*
Clay	14	14
PENNSYLVANIAN SYSTEM:		
Limestone	5	19
Sandstone	1	20
Limestone	4	24
Sandstone	10	34
Shale, oil	8	42
Soapstone	2	44
Shale	12	56
Limestone	6	62
"Slate" and sandstone	6	68
Sandstone, oil	8	76
Sandstone and shale	11	87
Sandstone and shale	8	95
Sandstone, oil	4	99
Soapstone	36	135
Soapstone and shale	36	171
Limestone	8	179
Soapstone	11	190
Limestone	20	210
Sandstone	25	235
Limestone	2	237
Shale	6	243
Limestone	1	244
Shale	2	246
Limestone	5	251
Shale	19	270
Limestone	31	301
Shale and soapstone	29	330
Limestone	15	345
Soapstone	5	350
Hard limestone	25	375
Soapstone	2	377
Sandy shale	5	382
Limestone	1	383
Soapstone	11	394
Limestone	1	395
Coal	1	396
Soapstone and dark clay	14	410
Limestone, soft	10	420
Soapstone	11	431
Limestone	2	433
Coal	1	434
"Slate"	3	437
Limestone	4	441
Shale	29	470
Limestone	3	473
Shale, dark	28	501
Limestone, soft	6	507
Shale, dark	10	517
Limestone, hard	1	518
Shale	10	528
Limestone	6	534
Soapstone	9	543
Limestone	1	544
Soapstone	19	563
Limestone	6	569
Shale, dark	30	599

RECORD OF WELL ON FARM OF M. F. DAVIS—Continued.

	Thickness.	Depth.
PENNSYLVANIAN SYSTEM—Continued.	*Feet.*	*Feet.*
Sandstone, salt water	30	629
Soapstone	5	634
Sandstone	18	652
Shale, clayey	8	660
Sandstone, hard	13	673
MISSISSIPPIAN SYSTEM:		
Limestone, salt water	124	797
Blue shale	1	798
Limestone	88	886
"Slate" (?)	30	916
Limestone	25	941
UNDIFFERENTIATED: SYSTEMS OLDER THAN MISSISSIPPIAN:		
Unrecorded	344	1285
Limestone, brown, and grit	5	1290
Sandstone, white (Roubidoux (?) sandstone)	68	1358
Shale, black	5	1363
Limestone and flint	12	1375
Shale, light	17	1392
Limestone, gray	18	1410

CLAY COUNTY.

The Pennsylvanian entirely underlies Clay County. The Pleasanton, the lowest formation exposed, outcrops along the Missouri River bluffs and in a wide zone on both sides of Fishing Creek, almost as far north as Kearney. On the uplands the Kansas City and Lansing formations form the country rocks over nearly all of the County; but in the extreme northwest corner, north of Smithville, is a small area underlain by the Douglas. The rocks dip at a low angle to the northwest, and have been folded locally into low anticlines or domes similar to those shown on the accompanying structure map, plate 9.

The minimum thickness of the Pennsylvanian occurs in the southeast corner of the County. Four miles south of Excelsior Springs, the Mississippian limestones have been reached at a depth of 560 feet, by a drilling started in the Pleasanton shale. At Randolph Station a drill hole hear the edge of the bluff, starting in the Kansas City formation, penetrated 705 feet before reaching the base of the Pennsylvanian. Six miles west of Kearney, a well starting in the Douglas formation reached the Mississippian, according to a fair record, at 1022 feet; and at Smithville, a well 803 feet deep finished in the Cherokee shale. The maximum thickness of Pennsylvanian present in the extreme northwest corner is probably about 1150 feet.

RECORD OF HARRIS WELL, SW. 1/4 SEC. 26, T. 52 N., R. 30 W.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil and clay	20	20
Quicksand and blue mud	40	60
Sand and gravel	20	80
PENNSYLVANIA SYSTEM:		
Henrietta and Cherokee formations:		
Limestone, shelly	3	83
Shale, blue	7	90
Limestone	5	95
Shale, white	20	115
Shale and limestone, seam of coal	35	150
Shale, white	25	175
Limestone	10	185
Shale, white and blue	215	400
Limestone	5	405
Shale, white	25	430
Shale, dark	65	495
Sandstone, salt water	45	540
Shale, dark	20	560
MISSISSIPPIAN SYSTEM AND OLDER SYSTEMS:		
Limestone	140	700
Limestone, salt water	5	705
Limestone and flint	138	843
Limestone, dark	113	956
Shale	8	964
Limestone and flint	72	1036

Both oil and gas have been found in Clay County, the oil chiefly in the western part near North Kansas City and Smithville, and the gas at Holt. However, showings of oil have been reported from several localities and small quantities of gas have been obtained at widely scattered points. The oil and gas occur in the Pleasanton and Cherokee shales and are reached at depths ranging chiefly from 130 to 325 feet, though showings of oil are reported as deep as 590 feet.

The most significant find of oil up to the present time is in the well on the J. M. Evans farm in SW. 1-4 sec. 2, T. 50 N., R. 33 W., located in the hills just north of North Kansas City. This well, drilled in 1908 to a depth of 324 feet, starts in the Winterset limestone of the Kansas City formation and penetrates 7 feet of oil sand near the top of the Cherokee shale. It is reported that a consecutive 10-day test shortly after the well was drilled showed a capacity of about 3 barrels a day. Another well drilled within the past few years is said to have encountered similar conditions.

RECORD OF WELL ON J. M. EVANS FARM, NORTH KANSAS CITY, SW. ¼ SEC. 2, T. 50 N., R. 33 W.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	12	12
PENNSYLVANIAN SYSTEM:		
Kansas City and Pleasanton formations:		
Limestone (Winterset)	4	16
Shale (Galesburg)	20	36
Limestone (Bethany Falls)	21	57
Shale and limestone	103	160
Shale	100	260
Henrietta formation:		
Limestone and shale	64	324
Cherokee shale:		
Sandstone, oil	5	329

The Evans well is situated on the west flank of a low but rather well-defined anticline as shown on the accompanying structure map, plate 9.

Wells drilled many years ago at Randolph, starting at about the same geologic horizon as the well above-mentioned, are reported to have found oil in a thin sandstone in the Pleasanton shale at a depth of approximately 120 feet. Sandstones were found in the Cherokee shale, but no mention is made in the records that these contained oil

Of two wells sunk near Smithville, one reached a depth of 803 feet without encountering either oil or gas; in the other, 488 feet deep, some oil is reported to have been found.

RECORD OF TEST WELL AT SMITHVILLE.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	10	10
Clay, sandy, brown	25	35
Gravel	5	40
PENNSYLVANIAN SYSTEM:		
Kansas City formation:		
Limestone	10	50
Shale, blue, soft	30	80
Limestone, brown, hard	20	100
Shale, dark, soft	10	110
Limestone, soft, white	25	135
"Slate"	5	140
Limestone, hard, brown	40	180
"Slate," soft, black	4	184
Limestone, gray, hard (Hertha)	5	189

RECORD OF TEST WELL AT SMITHVILLE—Continued.

	Thickness.	Depth.
	Feet.	*Feet.*
PENNSYLVANIAN SYSTEM—Continued.		
Pleasanton formation:		
Sandstone, gray	6	195
Shale, dark, soft	55	250
Limestone, hard, brown	5	255
Shale, dark, soft	35	290
Shale, white, soft	18	308
Henrietta formation:		
Limestone, gray, hard (Pawnee)	12	320
"Slate," white, soft	10	330
Limestone, brown, hard	5	335
Shale, white, soft	35	370
Limestone, brown, hard	20	390
Cherokee shale:		
Shale, dark, soft	15	405
Lime, gray, hard	10	415
Shale, dark, soft	20	435
Sandstone, dark, hard	3	438
Shale, light, soft	22	460
"Slate," black, and coal	15	475
Shale, dark, soft	175	650
Sandstone, dark (water)	10	660
Sandstone, light	15	675
Shale, light	25	700
Shale, black	10	710
Sandstone, light	10	720
Shale, brown	10	730
Sandstone, light	74	804

RECORD OF WELL SIX MILES WEST OF KEARNEY.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	25	25
PENNSYLVANIAN SYSTEM:		
Limestone	56	81
Sandstone	10	91
Shale	35	126
Sandstone, water	15	141
Limestone	20	161
Shale, muddy	28	189
Limestone	12	201
Shale	6	207
Limestone	24	231
Shale	6	237
Sandstone	12	249
Limestone and shale	120	369
Shale	22	391
Sandstone	22	413
Shale	28	441
Sandstone	40	481
Flinty limestone, dark	10	491
Shale, light	4	495
Limestone, brown	4	499
Shale	4	503
Limestone, gray	10	513
Shale, black	12	525

RECORD OF WELL SIX MILES WEST OF KEARNEY—Continued.

	Thickness.	Depth.
PENNSYLVANIAN SYSTEM—Continued.	*Feet.*	*Feet.*
Sandstone, gray	12	537
Shale	24	561
Limestone	6	567
Shale	6	573
Sandy shale	40	613
Sandstone	10	623
Coal seam	..	...
Shale	12	635
Limestone and coal	6	641
Limestone	6	647
Sandstone	24	671
Shale	6	677
Sandstone	18	695
Shale	131	826
Sandstone, white, coarse	12	838
Shale, blue	18	856
Sandstone	30	886
Oil sandstone	12	898
"Slate," black	18	916
Sandstone, traces of oil	36	952
Sandstone, salt water	40	992
Shale, black, rotten	30	1022
MISSISSIPPIAN SYSTEM:		
Limestone	10	1032

The town of Holt on the north edge of the County was for about three years supplied with natural gas from a group of five wells drilled at the edge of the town in 1904. The wells are, with one exception, only 130 to 150 feet deep, the gas sand in all being encountered at a depth of about 130 feet, in the Pleasanton shale. No records of these wells are available but reports indicate that the gas sand was thin, very fine-grained, and hard. Though the initial gas pressure in the wells was about 50 pounds to the square inch, the sand contained water which proved to be troublesome almost from the start, and led to the abandonment of the group in 1907, after three years of use. The wells were all well cased to the gas sand and a small amount of gas still rises through the water in them, but they are all idle. One of the group of wells, on the Isley property, was sunk to a depth of 872 feet, but no further showings of oil or gas were encountered below the 130-foot gas sand. A heavy flow of water was found in this well, at a depth of about 400 feet.

The structure of this vicinity is shown on the accompanying map*. Strangely, the discovery of gas at Holt excited little interest in the surrounding territory, and there have been practi-

* Pl. 9.

cally no other wells drilled to prove the extent of the shallow field.

*DEEP WELLS IN CLAY COUNTY.

Owner	Location	Depth.	Date	Depth to Miss. ls.	Remarks.
A. W. Stubbs...........	6 mi. W. of Kearney...	1032	....	1022	Trace of oil reported at 886 and 916
Jno. Harris.............	SW. ¼ sec. 26, T. 52 N. R. 30 W...........	1036	1914	566	....
Gordon & Martin........	Smithville............	804	....	Not reached.	....
Excelsior Springs Mineral Water Co............	Excelsior Springs......	1400	....	....	....
Randolph Coal Co.......	Randolph Staton......	848	1888	701	Trace of oil at 148.

*There have been several deep tests sunk in Clay county, regarding which no data has been made available. Also there are several deep mineral water wells in Excelsior Springs, and three deep wells besides the one mentioned were sunk at Randolph Station.

RECORD OF RANDOLPH COAL AND GAS COMPANY, PROSPECT NO. 2, RANDOLPH STATION.

	Thickness.		Depth.	
	Ft.	*In.*	*Ft.*	*In.*
Sandy loam	7		7	
Blue clay	16		23	
Quicksand	6		29	
PENNSYLVANIAN SYSTEM:				
Limestone, very hard	3		32	
Shale, soft	13		45	
Limestone	3		48	
Sandstone	22		70	
Clay, shale, and sandstone	47		117	
Sandstone	12		129	
Clay shale	4		133	
Fire clay, red	4		137	
Sandstone	5		142	
Shale, sandy	6		148	
Sandstone, oil	4		152	
Clay, shale	12		164	
Sandstone	3		167	
Limestone	4		171	
Sandstone, salt water	36		237	
Shale, fossiliferous	5		242	
Limestone	4		246	
"Slate," black, fissile	1	3	247	3
Coal		9	248	
Shale, fossil	5		253	
Fire clay	4		257	
Shale	20		277	
Limestone	1		278	
Shale, fossil	1	8	279	8
Coal		10	280	6
Fire clay	10	6	291	
Limestone	5		296	
"Slate"	5		301	
Shale, blue	11		312	
Clay, shale	7		319	
Shale	10		329	

RECORD OF RANDOLPH COAL AND GAS COMPANY—Continued.

	Thickness.		Depth.	
PENNSYLVANIAN SYSTEM—Continued.	*Ft.*	*In.*	*Ft.*	*In.*
Sandstone	3		332	
Shale and "slate"	21		353	
Clay shale	8		361	
Sandstone	11		372	
Clay shale	13		385	
Fissile shale	1	8	386	8
Coal (worked)	1	9	388	5
Black fire clay	1	7	390	
Limestone	2		392	
Fissile shale	3		395	
Shale and sandy shale	12		407	
Sandstone	8		415	
Clay shale	4		419	
Sandy shale and sandstone	16		435	
Shale	16		451	
"Slate"	4		455	
Coal		5	455	5
Fire clay	2	7	458	
Fissile shale	16		474	
Coal		8	474	8
Fire clay	4	4	479	
Shale	11	8	490	8
Coal		4	491	
Fire clay and shale	12	9	503	9
Coal	1	1	504	10
Sandstone, shale partings	1	2	506	
Black fire clay	1		507	
Sandstone, shale partings	23		530	
Sandstone	1		531	
"Slate"	3	6	534	6
Coal	1	2	535	8
Fire clay and soapstone	9	4	545	
"Slate"	19		564	
Coal		8	564	8
Fire clay	7	4	572	
"Slate"	12	3	584	3
Coal	1	2	585	5
Sandstone	7	7	593	
Shale and "slate"	32		625	
Sandstone	11	4	636	4
Coal		10	637	2
Sandstone	19	10	657	
Shale	13		670	
Sandstone, shale partings	32		702	
Shale	20		722	
MISSISSIPPIAN SYSTEM:				
Limestone, very hard	16		738	
Limestone, fire clay partings	12		750	
Limestone	110		860	

RAY COUNTY.

The Pennsylvanian underlies all of Ray County. The Cherokee outcrops only in the valleys east of Richmond, and along the river bluffs to the east edge of the County. The higher formations outcrop successively in irregular southwest to northeast belts, the Lansing in the northwest corner. The minimum thickness of the Pennsylvanian, therefore, occurs east of Richmond where only the Cherokee overlies the Mississippian limestones, which are reached at a depth of approximately 400 feet. Near Millville, a well starting near the top of the Pleasanton, encountered Mississippian at a depth of about 550 feet. About the same depth is reported 8 miles west of Richmond, but in the northwest corner of the County where the maximum thickness is present, it will probably require 800 or 900 feet of drilling to completely penetrate the Pennsylvanian.

The strata underlying the County dip at a low angle to the northwest. The general folding consists of the elongate southeast to northwest anticlines characteristic of this area, one prominent fold passing centrally across the County. (See structure Pl. 4). No detailed structure maps of the area have been made, though local folding is known to occur.

No commercial quantities of oil or gas have yet been found in Ray County, the known indications being restricted to showings of oil and gas in several shallow wells, and to the presence of asphaltic sandstone outcrops.

A well on the farm of D. K. Michael, NE. 1-4 sec. 34, T. 52N., R. 29W., three miles north of Orrick, was sunk prior to 1872 to a depth of 802 feet. At the surface, five feet of sandstone in the Pleasanton formation has been described by Broadhead as "showing oil on surface and thoroughly impregnated with it." On this property about 15 feet of asphaltic sandstone outcrops and in places the bitumen seeps out between the layers forming the so-called "Tar Springs." A second asphaltic sandstone is reported at a depth of 79 feet, apparently in the Henrietta, also a little gas at a depth of 480 feet, near the base of the Cherokee.

RECORD OF WELL ON M FARM, (NE. ¼ SEC. 34, T. 52 N., R. 29 W.)

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	4	4
PENNSYLVANIAN SYSTEM:		
Pleasanton formation:		
Sandstone, black, bituminous; showing oil on surface, and thoroughly impregnated with it	5	9
Henrietta formation:		
Limestone, greenish, rough fracture	40	49
Shale, dark, sandy	30	79
Sandstone, dark gray, coarse, bituminous	27	106
Coal, probably some fissile shale	4	110
Limestone, drab	6	116
Clay shale, greenish drab	16	132
Limestone, dark	2	134
Cherokee shale:		
Shale, greenish and bituminous	8	142
Clay, ash-blue, calcareous	4	146
Limestone, gray, fine-grained	6	152
Sandstone, light gray, coarse	25	177
Clay, indurated, green	6	183
Sandstone, hard, fine-grained	22	205
Clay, light dove-colored	12	217
Coal, probably some shale	4	221
Sandstone, bluish-gray, shaly	5	226
Shale, blue to black, with seam of coal	27	253
Limestone, gray, nodular	10	263
Clay, smooth, limy	23	286
Sandstone, soft	19	305
Shale, chocolate-colored, hard	4	309
Sandstone, bluish-black	54	363
Shale, dove-colored	12	375
Sandstone, fine, micaceous	17	392
Shale, blue	23	415
Sandstone, fine to coarse	67	482
Shale, soft, dove-colored	10	492
Sandstone, fine to coarse	53	545
MISSISSIPPIAN SYSTEM:		
Burlington-Keokuk limestone:		
Limestone, very fine-grained	16	561
Limestone, coarse crystalline, cherty	118	679
Limestone and chert, with sandstone	133	802

A well drilled near Millville, SE. 1-4 sec. 2, T. 53 N., R. 27 W., encountered a sandstone in the Pleasanton carrying oil at a depth of only 35 feet. At Tines Point, in the northeast corner of the County, very small quantities of oil were discovered in a well at a depth of 200 feet. In sec. 9, T. 53N., R. 28W., three miles southwest of Knoxville, small amounts of both oil and gas were struck between 100 and 150 feet in two wells drilled there. These and other shallow occurrences, though unimportant, may be suggestive of better finds. It is probable that asphaltic sandstone outcrops at a number of points in the belt occupied by the Pleasanton shale, other than in sec. 2, T. 52N., R. 29W., north of Orrick.

RECORD OF WELL OF WESTERN OIL AND DEVELOPMENT COMPANY NEAR MILLVILLE (NE. ¼, SEC. 2. ¼ SEC. 2, T. 53 N., R. 27 W.)

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	3	3
Clay	8	11
PENNSYLVANIAN SYSTEM:		
Pleasanton and Henrietta formations:		
Shale, blue	6	17
Limestone	3	20
Shale, blue	15	35
Sandstone (trace of oil)	18	53
Shale, blue	95	148
Sandstone	3	151
Shale, blue	19	170
"Slate"	5	175
Limestone, white	10	185
Cherokee shale:		
Shale, light	20	205
Coal (Lexington)	3	208
Limestone, hard	6	214
Shale, blue	15	229
Sandstone	25	254
Shale, blue	30	284
Limestone, white	2	286
Shale, blue	9	295
Limestone	3	298
Clay, blue	28	326
Limestone	10	336
Shale, blue	15	351
Limestone	5	356
"Slate,' black	7	363
Sandstone	9	372
Shale, blue	10	382
Shale, sandy, blue	14	396
Sandstone	25	421
Shale, black	32	453
Limestone, sandy	8	461
Shale, black	15	476
Sandstone	3	479
Shale, black	20	499
Sandstone	45	544
Shale, black	10	554
MISSISSIPPIAN SYSTEM:		
Limestone	49	603

Very little deep drilling, on which data are obtainable, has been done in Ray County. A coal prospect in the SE. 1-4 sec. 6, T. 51N., R. 27W., reached a depth of 409 feet, entering the Mississippian linestones near its base. In the SE. 1-4 sec. 2, T. 53N., R. 27W., northeast of Millville, a test hole 603 feet deep is said to be one of several deep wells in this locality. In this well a sandstone was penetrated from 35 to 53 feet, showing oil, but no further discoveries were made and the well entered the Mississippian formations at a depth of 554 feet. In 1917, a test well was put down about one mile north of Rayville, to a depth of approximately 1200 feet. No record of this well could be obtained, though there is not much doubt that its base is in the Lower Ordovician. No oil or gas was found. So far as known, this and the Michaels well are the two deepest in the County.

CARROLL COUNTY.

The Pennsylvanian rocks entirely underlie Carroll County, the Cherokee occupying the eastern part and the low valleys of the southern part. The Henrietta, Pleasanton, and Kansas City formations underlie the upland in the central, north and west portions. The strata dip at a low angle to the northwest.

Wells, starting in the Cherokee, west of Carrollton and near Norborne have reached the Mississippian limestones at depths of 254 and 284 feet, respectively; near Tina at 385 feet; and near Mandeville at 530 feet. The maximum thickness of Pennsylvanian, 600 to 700 feet, underlies the northwest corner of the County. Just across the Caldwell County line, near Braymer, the Mississippian limestones were reached at a depth of 673 feet.

No detailed structure mapping has been done in the County, though the greater part of it is known to lie in a broad shallow syncline, flanked in the southeast portion by a well-defined anticlinal fold. (See structure Pl. 4).

Neither oil nor gas has been found in commercial quantities in Carroll County, although showings have been reported at a number of localities. The finds have been restricted chiefly to the northwest part of the area, particularly to the two northwest townships. Asphaltic sandstone, of Pleasanton age, from which small seepages of bitumen are reported, has been observed in sec. 30, T. 55N., R. 24W., and in a sandstone quarry in sec. 7, T. 55N., R. 25W. In sec. 24, T. 55N., R. 25W., and in sec. 32, T. 55N., R. 24W., traces of very heavy black oil have been found in wells at a depth of about 20 feet. The conditions here are the same as those around Braymer, Caldwell County. Outcrops of asphaltic sandstone may occur at many points yet unobserved, and asphaltic beds in the Pleasanton may be reached near the surface in wells scattered over the northwest part of the County.

Deeper occurrences of oil, though limited to traces at depths shallower than 250 feet, are reported in sec. 3, T. 54 N., R. 23 W., sec. 17, T. 55N., R. 24W., and sec. 5, T. 55 N., R. 25W.

A small quantity of gas was struck about 4 miles southwest of Mandeville, sec. 24, T. 54N., R. 24W., at a depth of 310 feet, in a sandstone of the Cherokee shale. This is the deepest occurrence of either oil or gas yet reported. Four miles northwest of Coloma in sec. 25, T. 55N., R. 24W., some gas was found in a black "slate" at a depth of 191 feet. There are probably similar traces of both oil and gas at relatively shallow depths which have not been reported.

There have been a considerable number of wells drilled in Carroll County with depths of from 400 to 600 feet, but very few that are deeper. A well on the Kugler Ranch, in Sec. 30, T. 52N., R. 25W., reached a depth of 784 feet, resulting in a strong natural flow of salt water.

RECORD OF KUGLER RANCH WELL, NORBORNE, SEC. 30, T. 52 N., R. 25 W.

	Thickness.	Depth.
	Feet.	*Feet.*
Gumbo	4	4
Gravel	70	74
PENNSYLVANIAN SYSTEM:		
Fire clay	40	114
Shale and clay	150	264
Sandstone	20	284
MISSISSIPPIAN SYSTEMS (and older systems):		
Limestone and flint	183	467
White sand (?)	50	517
Limestone and flint	267	784

The C. W. Nuss well near Tina, 675 feet deep, reached the Mississippian limestones at a depth of 385 feet, but without the discovery of oil or gas. Also three test wells, the deepest about 650 feet, sunk by the Liquid Wealth Oil Company, near Tina, in 1918, resulted in failure. In most of the wells over 400 feet deep salt water has been encountered. The following is a tabulation of typical wells in the County.

PARTIAL LIST OF DEEP WELLS IN CARROLL COUNTY.

Owner.	Location.	Depth.	Date.	Base of Pennsylvanian.	Remarks.
Kugler Ranch..............	Sec. 30, T. 52 N., R. 25 W........	784	....	284	Flowing well
C. W Nuss................	Tina.........................	675	....	385	....
Lquid Wealth Oil Company..	Several wells near Tina, no data ..	....	....	....	....
H. Minnis.................	Sec. 25, T. 54 N., R. 24 W.......	550	1913	542	Sulphur water
W. H Graham.............	NW. ¼ sec. 7, T. 53 N., R. 25 W..	530	1908	....	Dry hole.
J P. Stanley...............	NE. ¼ sec. 12, T. 54 N., R. 24 W.	511	1910	Not reached.	Salt water.
W. H. Manser.............	SW. ¼ sec. 3, T. 55 N., R. 24 W..	502	....	Not reached.	Salt water.
Wm. Forsyth...............	Tina.........................	520	1913	420	Salt water.
Jno. S. Sherley.............	Mandeville.....................	500	....	Not reached.	Salt water.
Carrollton.................	Carrollton.....................	475	1912	270	Salt water.
Anthony Key..............	Bogard........................	488	1910	Not reached.	Salt water.

RECORD OF C. W. NUSS WELL, TINA.

	Thickness.	Deth.
	Feet.	*Feet.*
Clay and sand..	40	40
PENNSYLVANIAN SYSTEM:		
Flint (?)...	4	44
Coal..	4	48
Shale...	20	68
Limestone..	5	73
Coal..	2	75
Shale...	215	290
Sandstone..	40	330
Slate, black..	55	385
MISSISSIPPIAN SYSTEM:		
Limestone, brown..	40	425
Flint (probably cherty limestone).........................	95	520
"Slate"...	5	525
Gravei (?)...	2	527
Limestone, very hard, and chert.........................	148	675

LAFAYETTE COUNTY.

Pennsylvanian rocks entirely underlie Lafayette County. The Cherokee outcrops in the eastern part and in the deeper valleys at the west. The Henrietta and Pleasanton formations underlie most of the central and western uplands, and the Kansas City limestones cap prominent ridges from the southwest corner north to Lexington. The Warrensburg channel sandstone occupies an ancient river valley having a maximum depth of about 300 feet and a width varying from less than a mile at the southern edge of the County to over 6 miles at the northern edge. It passes through Higginsville and is shown on the accompanying geologic map.

At Concordia the base of the Pennsylvanian has been reached in a deep well at 240 feet, at Higginsville at 370 feet, at Lexington at 465 feet, and in the western part near Odessa at about 600 feet. From the tops of the high ridges in the western townships the depth to the Mississippian would be still greater.

The rocks in the County dip to the northwest at a very low angle and are folded into anticlines trending southeast to northwest as shown on plate 4. The local structural features have not been determined.

No commercial quantities of oil or gas have ever been found in Lafayette County, and interest centers principally in a deposit of asphaltic sandstone underlying a large part of the S. 1-2 sec. 36, T. 50N., R. 25W., and the N. 1-2 sec. 1, T. 49N., R. 25W., three-fourths of a mile northwest of Higginsville. It occurs in the Warrensburg sandstone and forms the only occurrence of asphalt known in this horizon. Drill holes are said to have penetrated these asphaltic beds to a depth of over 100 feet, but a well sunk on the property in about 1870, to a depth of 800 feet, encountered no beds containing asphalt nor any further evidences of oil or gas below this depth. This well reached the base of the Pennsylvanian at about 300 feet.

RECORD OF WELL OF HIGGINSVILLE PROSPECTING COMPANY, HIGGINSVILLE, MO.

	Thickness.	Depth.
	Feet.	*Feet.*
Earth and clay	68	68
PENNSYLVANIAN SYSTEM:		
Warrensburg sandstone:		
Sandstone	112	180
"Asphaltum," asphaltic sandstone	8	188
"Slate"	5	193
Cherokee shale:		
Soapstone, dark	147	340
Soapstone, light	10	350
Sandstone	20	370
MISSISSIPPIAN SYSTEM:		
Burlington-Keokuk limestone:		
Limestone	80	450
"Asphalt and quartz rock"	7	457
Limestone	199	656
Phelps sandstone (?), possibly St. Peter:		
Sandstone, white; fresh water	35	691

RECORD OF WELL OF HIGGINSVILLE PROSPECTING COMPANY—Continued.

	Thickness.	Depth.
ORDOVICIAN SYSTEM:	*Feet.*	*Feet.*
Jefferson City formation:		
Limestone	51	742
Sandstone, white to dark brown	28	770
Limestone	195	965
Limestone, coarse to fine texture	80	1045
Roubidoux formation:		
Sandstone, salt water	150	1195
OZARKIAN SYSTEM:		
Gasconade formation:		
Limestone, salt water	145	1340
Sandstone, salt water	25	1365
Limestone, white, very hard	142	1507

The asphaltic beds northwest of Higginsville carry 6.5 per cent to 8.5 per cent bitumen, a recent test showing 7.4 per cent. The bitumen is present partly as a solid asphalt, partly as a thin amber-colored oil, but chiefly as a heavy, black tar. The rock is soft and thick-bedded, and can be easily obtained in great quantities.

A well sunk near the Missouri Pacific depot in Higginsville, found 8 feet of asphaltic sandstone at a depth of 180 feet, apparently also in the Warrensburg channel in this locality. This deposit is described in greater detail on page 257.

A showing of oil is reported in a well in sec. 19, T. 49N., R. 27W., at a depth of 130 feet, probably in the Pleasanton, and small quantities of gas have been reported at shallow depths from several localities.

Very little drilling for oil has been done in Lafayette County, though several deep wells have been sunk, as shown in following partial list.

PARTIAL LIST OF DEEP WELLS IN LAFAYETTE COUNTY.

Owner.	Location.	Depth.	Date.	Base of Pennsylvanian.	Remarks.
City of Higginsville	Near Mo. Pac. R. R.	1507	1898	370	Asphaltic sandstone bed at 180-188 feet.
City of Higgnsville	Higginsville Power House	830	1902	311	Salt water.
Concordia	Concordia	532	1914	240	Sulphur water.
Lexington Brewery Company	Lexington	960	1902	465	Salt water
Western Coal & Mining Company	5 mi. south of Lexington	1300	1914	460	Salt water.
McCausland	2 mi. north of Higginsville	800	1870±	350±	.....
J. E. Weber	NW. ¼ sec. 33, T. 48 N., R. 28 W.	680	1914	500±	Salt water.
Blackburn Creamery	Blackburn	495	.....	200	.....

JOHNSON COUNTY.

Pennsylvanian rocks underlie all of Johnson County except one point in the extreme northeast corner where the Mississippian limestones are exposed. The Cherokee outcrops over most of the east third, and in the important valleys of the central part. On the western uplands the Henrietta and Pleasanton form the country rock, with the Kanasas City limestones capping some of the high ridges. North and south, through Warrensburg, extends a narrow strip of sandstone, one to three miles wide, filling an ancient river valley and known as the Warrensburg sandstone. In the eastern part of the County the Mississippian limestones are reached at depths of less than 100 to 200 feet, at Warrensburg at about 300 feet, and at Holden at 500 feet, the maximum in the northwest part of the County being a little more than 600 feet.

The rocks dip gently to the northwest and a pronounced fold crosses the county centrally from southeast to northwest (see structure Pl. 4). The detailed structural features have not been worked out.

RECORD OF GOWAN WELL, CENTERVIEW, SE. ¼ SEC. 27, T. 46 N., R. 27 W.

	Thickness.	Depth.
	Feet.	*Feet.*
Clay	16	16
PENNSYLVANIAN SYSTEM:		
Henrietta formation:		
Limestone, gray to blue	12	28
Shale, light colored	10	38
Limestone	21	59
Shale	15	74
Limestone	4	78
Cherokee shale:		
Shale and "slate"	6	84
Coal (Lexington)	2	86
Shale	71	157
Limestone	2	159
Shale and limestone	12	171
Sandstone	12	183
Shale	48	231
Sandstone	13	244
Shale	81	325
Sandstone	10	335
Shale	10	345
Sandstone	10	355
Shale	45	400
Sandstone	5	405
Shale	35	440
MISSISSIPPIAN SYSTEM:		
Burlington-Keokuk limestones:		
Limestone, gray, crystalline, cherty	30	470
Limestone, white, crystalline, cherty	35	505

There has been considerable drilling for oil and gas in the west part of the county around Holden and Kingsville, and showings are reported in several wells at shallow depths. On the Rickett farm south of Kingsville, sec. 7, T. 45N., R. 28W., oil was found at a depth of 110 feet in a sandstone probably in the lower part of the Pleasanton, or possibly in the Henrietta. The oil was of high gravity and exceptionally good quality, similar to that found a few miles to the southwest in Cass County, but the quantity was very small. None of the finds up to the present time have been commercially important.

Small amounts of gas are said to have been found in shallow wells in the north central part of the County. North of Warrensburg several wells have encountered very light flows of gas at depths of 100 to 300 feet in the Cherokee shale. When the water was kept down in the wells, the gas flowed in sufficient quantity to burn continuously, but the pressure was very low, which fact combined with the water difficulties, prohibited the use of the gas for domestic purposes.

HENRY COUNTY.

Most of Henry County is underlain by the Cherokee, but the Henrietta overlies it in limited areas in the west and north parts of the county and a small patch of the Pleasanton occurs in the northwest corner. In the southeast corner Mississippian and even Ordovician strata are exposed. The Mississippian extends up the valley of Grand River almost to Browningtom and up the valley of Tebo Creek to within five miles of Calhoun. The average thickness of the Pennsylvanian is less than 250 feet, but to the west it reaches 300 to 310 feet, and in the northwest part possibly 400 feet.

Neither oil nor gas has been found in commercial quantities in Henry County, but showings of gas have been reported in the northeast corner around Windsor and Calhoun at shallow depths, in the Cherokee shale.

Near Windsor, sec. 12, T. 43N., R. 25W., gas was found at a depth of 175 feet. Ignited, this gas burned with a strong flame for several hours until extinguished. It was not utilized. The occurrences reported around Calhoun are all shallow, 40 to 75 feet, and the gas probably does not occur in sufficient quantities to be utilized.

A number of deep wells have been sunk in Henry County at Clinton, Windsor, Deepwater, and Hartwell. However, all of these, except one 1500-foot test well near Clinton, were sunk for water. None of the wells revealed showings of oil or gas.

RECORD OF CLINTON ICE COMPANY WELL, CLINTON, MO.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil and yellow clay	14	14
PENNSYLVANIAN SYSTEM:		
Cherokee shale:		
Sandstone, yellow, soft	5	19
Shale	25	44
Sandstone, gray	6	50
Shale, black, soft	25	75
Sandstone, gray (water)	10	85
Shale, dark gray	20	105
Sandstone, grayish, water	5	110
Shale, grayish	27	137
MISSISSIPPIAN SYSTEM:		
Burlington-Keokuk limestone:		
Limestone, cherty	163	300
Phelps sandstone:		
Sandstone, white, rounded grains	5	305
ORDOVICIAN SYSTEM:		
Jefferson City and Roubidoux* formations:		
"Cotton rock," oolitic chert	35	340
Dolomite, gray, fine-grained	94	434
No record	6	440
Dolomite, gray, cherty	143	583
Dolomite, gray, with some sandstone	88	671
OZARKIAN SYSTEM: Contact doubtful.		
Gasconade formation:		
Dolomite, gray, crystalline, cherty; some oolite	236	907
Gunter sandstone:		
Sandstone, white	23	930

*From 575 to 671 is sandy, and probably represents the horizon of the Roubidoux.

ST. CLAIR COUNTY.

The western part of St. Clair County is chiefly underlain by a thin veneer of the Cherokee shale. Near Appleton City in the northwest corner, where the maximum thickness occurs, the underlying Mississippian limestones are reached at about 300 feet. Over the remainder of the Pennsylvanian area these limestones are reached at a less depth, and in the eastern half of the county they outcrop extensively. Even the older Ordovician rocks appear at the surface over considerable portions of the southern and eastern parts of the county.

There have been no important discoveries of oil or gas in St. Clair County. Beds of asphaltic sandstone which outcrop in the western townships are similar to those in Vernon and southeast Bates County. At Appleton City a well 1,190 feet deep reached the base of the Pennsylvanian at 295 feet, and finished in Ordovician or older formations without having encountered either oil or gas. An unsuccessful test well on the W. M. Love farm (NW. 1/4 sec. 21, T. 38N., R. 25W.) one mile east of Osceola, sunk in 1905, began in the Mississippian and finished in granite at a depth of 1800 feet.

RECORD OF DEEP WELL AT APPLETON CITY.

	Thickness.	Depth.
	Feet.	*Feet.*
Clay, yellow to blue	12	12
PENNSYLVANIAN SYSTEM:		
Cherokee shale:		
Shale, blue	8	20
Coal	1	21
Fire clay	4	25
Limestone and gray shale	4	29
Shale	71	100
Sandstone, gray to red	14	114
Shale, blue to gray	34	148
Coal	1	149
Fire clay	11	160
Sandstone, dark gray	5	165
Sandy shale, bluish black	9	174
Coal	..	...
"Slate," black	23	197
Shale, bluish	30	227
Coal	1	228
Fire clay	15	243
Sandstone, soft, white	21	264
Shale, blue; limestone, hard, white	21	285
Sandstone, and black shale	10	295
MISSISSIPPIAN SYSTEM:		
Limestone, gray, crystalline, cherty	97	392
Shale, blue, sandy	6	398
Limestone, crystalline with chert	242	640
ORDOVICIAN AND OLDER SYSTEMS:		
Limestone, fine-grained, gray to brown, some oolitic chert	150	790
Sandstone, fine-grained, white	10	800
Limestone, crystalline, light gray, with white chert	390	1190

CEDAR COUNTY.

Pennsylvanian rocks are represented in Cedar County only by the Cherokee, which occupies the western part and isolated patches on some of the uplands to the east, and which has a maximum thickness, possibly as great as 200 feet, south of Eldorado Springs. Over half of the county is directly underlain by the Mississippian or older rocks.

Beds of asphaltic sandstone similar to those in southwestern Vernon County outcrop in the vicinity of Eldorado Springs, and are reported to occur elsewhere in the Pennsylvanian. In places these beds are thoroughly saturated with bitumen for a thickness of 20 feet or more. Locally the asphaltic material has seeped downward into the underlying Mississippian limestones and these have been noted to be bituminous in sec. 26, T. 34 N., R. 28. No important discoveries of oil or gas have been reported in any of the wells in the county.

RECORD OF THE ELDORADO CITY WELL.

	Thickness.	Depth.
	Feet.	*Feet.*
No record	62	62
MISSISSIPPIAN SYSTEM:		
Burlington-Keokuk limestones:		
Limestone, gray, crystalline, with chert	71	133
Shale, blue, clayey	7	140
Limestone, gray, crystalline, cherty	114	254
Limestone, cherty	136	390
Limestone, magnesian, shaley, fine-grained, dark gray	15	405
Northview shale:		
Shale, bluish gray	10	415
ORDOVICIAN SYSTEM:		
Jefferson City formation:		
Dolomitic limestone, fine-grained, gray, dark cherty	345	760
Roubidoux sandstone and Gasconade formation:		
Sandstone	45	805
Dolomite, light gray, crystalline, cherty	222.5	1027.5

HICKORY COUNTY.

Small patches of the Cherokee shale occur in the western part of Hickory County, and contain a little asphaltic sandstone near Weaubleau and near Quincy. In places the bitumen has seeped down into the underlying Mississippian limestones, which are especially asphaltic in the NE. 1/4 sec. 30, T. 38N., R. 23W.

SUMMARY.

The counties mentioned in the above discussion contain practically all of the important occurrences of oil or gas in the Pennsylvanian rocks known or reported up to the present time in Missouri. Gas in very small quantities has been reported, however, at shallow depths in Saline, Howard, Adair, Sullivan, and other counties underlain by Pennsylvanian. An investigation of these reports discloses nothing to excite much interest. In Saline County traces of oil were reported to have occurred on spring water, near Grand Pass, and near Elmwood a showing of gas is said to have been encountered at a very shallow depth. In

Howard County showings of gas are reported at depths of less than 100 feet just northwest of Glasgow. In Sullivan County, the small showings of gas reported near Harris apparently occur in the glacial drift, and the Adair County occurrence has been found to be marsh gas. With two or three exceptions, not even traces of either fuel are reported from the many wells, shallow or deep, sunk in the northwest counties of the state where the Pennsylvanian deposits attain their maximum thickness.

A resume of the occurrences by counties shows the most important oil discoveries to date to be restricted practically to the western tier of counties from Barton north to Platte inclusive, and in Clay. None of these have ever been important producers, though Jackson, Bates, Cass, Vernon, and Clay, mentioned in order of probable amount produced, have each yielded commercial quantities of oil, obtained from small-capacity wells 150 to 550 feet deep, in sandstones in the Cherokee and Pleasanton formations of the lower Pennsylvanian.

The asphaltic sandstones outcropping in these and adjoining counties mentioned, occur chiefly in the Cherokee and Pleasanton formations, though in Lafayette County a deposit occurs in the Warrensburg channel sandstone, and in Bates County, Henrietta beds are asphaltic. The only asphaltic rocks observed in the upper Pennsylvanian, occur near the top of the Bethany Falls limestone in Cass, Jackson, and Caldwell counties.

Relatively greater and more important amounts of gas have been found than oil, and it has been commercially produced in Jackson, Bates, Cass, Platte, Clay, Clinton, Vernon, and Barton, in their probable order of importance. The gas sand varies from 100 to 662 feet in depth, the initial pressure from individual sands ranging from 2 or 3 pounds to 250 pounds. The maximum flow of any of the wells reported is that of one of the Martin City (Jackson County) group, of which the owner states: "The man who tested the 522-foot gas said it made 1,580,000 cubic feet per day." Two of the Parkville (Platte County) wells were estimated to flow 1,000,000 cubic feet per day. Holt, Parkville, Kansas City, Independence, Martin City, Belton, West Line, Cleveland, Hume, Drexel, and Rich Hill have all, at times, been practically supplied with natural gas from local wells. The wells supplying Holt, West Line, Cleveland, and Rich Hill have now been abandoned, but some gas is still being obtained at the other localities. Most of it is obtained from sandstones in the Cherokee and Pleasanton formations, but the Henrietta sandstones or shales contribute a small part of the supply. Only meager amounts have been found in the upper Pennsylvanian rocks.

MINOR OCCURRENCES OF OIL AND GAS IN THE PENNSYLVANIAN ROCKS IN OTHER COUNTIES.

NORTHWEST COUNTIES IN THE PENNSYLVANIAN AREA.

The northwest counties, including those north of Missouri River and west of Carroll, Livingston, Grundy, and Mercer, have always been considered as favorable territory in which to prospect for oil and gas in the Pennsylvanian, from the fact that the area as a whole is underlain by the maximum thickness of these rocks, which reach 600 or 700 feet along the eastern border, and over 1600 feet in Holt, Nodaway, and Atchison Counties. Both to the east and south the Pennsylvanian rocks thin rapidly.

However, up to the present time, encouraging discoveries of oil or gas have been restricted to the southern part of the region, in Platte, Clay, and Clinton counties, with less important finds already mentioned in Caldwell and Ray counties. Of the large number of test wells scattered over the remainder of the area, showings of oil or gas have been reported from only a few. The others, so far as can be learned, have been completed without a trace of either oil or gas. At Cainsville, Harrison County, a well completely penetrating the Pennsylvanian is stated to have passed through "sandstone showing oil" at depths of 600 and 780 feet, in the Cherokee shale. Reports from reliable sources seem to substantiate this, though they indicate that only a very small amount of oil was found. At Burlington Junction, Nodaway County, in a deep test, 30 feet, "gas sand" is reported at a depth of 1,125 feet, and "sand, peacock colors, and traces of oil" at 1,697 feet. The "gas sand" is probably in the Pleasanton, the "oil sand" at the base of the Cherokee. In this well, drilled in 1905, the occurrences have merely been reported and cannot now be authenticated. Other northwest Missouri Counties in which wells have been sunk completely penetrating the Pennsylvanian are Worth, Daviess, DeKalb, Buchanan, Gentry, Holt, Atchison, Caldwell, Ray, Clay, and Clinton. The following is a partial list of deep wells in this area. Many of them were sunk in search of oil and gas but a number are coal prospects or water wells.

DEEP WELLS IN NORTHWEST MISSOURI.

County.	Sunk by.	Location.	Date.	Depth.	Base of Pennsylvanian.	Bottomed in.
Andrew.....	Webb-Kirby Est....................	Rochester......................	1890	800	Not reached.	Cherokee.
Atchison....	W. F. Rankin....................	NE. ¼ sec. 11, T. 65 N., R. 40 W., near Tarkio..................	1915	2340	1640	Devonian.
	W. F. Rankin....................	Near above mentioned well.......	1914	1551	Not reached...	Cherokee shale.
	J. A. Beverly.....................	Rockport......................	1910	678	Not reached.	Kansas City formation.
Buchanan...	Frank Hopkins..................	Near St. Jos ph, SE. ¼ sec. 31, T. 58 N., R. 35 W...............	....	1258	1140	Mississippian.
	Goetz Brewery....................	St. Joseph.....................	1900	1800	1200	Below Mississippian.
	Turner Coal Co....................	Near St. Joseph, NW. ¼ sec. 29, T. 57 N., R. 35 W.............	1892	1308	1200	Mississippian.
	State of Missouri..................	Near Layton, NW. ¼ sec 21, T. 57 N., R. 35 W...............	....	1116	1077	Mississippian.
Caldwell.....	Braymer Oil Co....................	Near Braymer, SW. ¼ sec. 4, T. 58 N., R. 29 W.................	....	1410	673	Ozarkian.
	Mrs. A. Stevenson................	Sec. 35, T. 58 N., R. 29 W........	1909	826	820	Mississippian.
	Kidder Institute..................	Kidder........................	1912	575	Not reached.	Cherokee shale.
Clay........	A. W. Stubbs.....................	6 miles W. of Kearney...........	....	1032	1022	Mississippian.
	Smithville Oil Co..................	Smithville.....................	....	804	Not reached.	Cherokee shale.
	Randolph Coal & Gas Company.....	Randolph......................	1888	860	722	Mississippian

	John Harris	Near Excelsior Springs, SW. ¼ sec. 26, T. 52 N., R. 30 W	1914	1036	560	Ozarkian.
	Excelsior Springs Bottling Co	Excelsior Springs	....	1400	600	Ozarkian.
Clinton	Stewartville Development Co	Sec. 23, T. 57 N., R. 32 W	1911	1269	1170	Mississippian.
	Alfred Burdick	NE. ¼ sec. 20, T. 57 N., R. 32 W	1911	791	Not reached.	Cherokee.
		Cameron	....	600	Not reached.	Cherokee.
	Local Company	3 miles south of Plattsburg	1917	1400 ±	....	Probably near base of Mississippian.
Daviess	Daviess Oil Co	Near Gallatin	1917	860	680	Mississippian.
	Daviess Oil Co	Near Gallatin	1919	2320	....	Ozarkian.
	John Alsup	Sec. 16, T. 58 N., R. 27 W	1907	510	Not reached.	Cherokee.
DeKalb	Geo. Carl	Near Clarksdale, SE. ¼ sec. 23, T. 38 N., R. 37 W	1914	500	Not reached.	Cherokee.
Gentry	Berlin Oil & Gas Co	Near Berlin, SW. ¼ sec. 22, T. 61 N., R. 31 W	1913	1140	1140	Mississippian.
Harrison	Keystone Oil & Gas Co	Cainesville	1910	1110	858	Mississippian.
	C. A. Cannaday	SW. ¼ sec. 35, T. 66 N., R. 27 W., Blythedale	1914	610	Not reached.	Cherokee.
	Keystone Oil & Gas Co	Sec. 5, T. 64 N., R. 26 W	1908	1610	710	....
	Fred Morck	Near Mt. Moriah	1910	997	595	Mississippian.
	Bethany Improvement Company	Bethany, Sec. 16, T. 65 N., R. 28 W	1900	654	Not reached.	Cherokee.
	Grand River Coal and Coke Co	Cainesville	1915	616	Not reached.	Cherokee.

DEEP WELLS IN NORTHWEST MISSOURI—Continued.

County.	Sunk by.	Location.	Date.	Depth.	Base of Pennsylvanian.	Bottomed in.
Harrison	New Hampton Coal and Mineral Co.	New Hampton	1915	778	Not reached.	Cherokee.
	Blythedale Prospecting Co.	Near Blythedale, NE. ¼ sec. 35, T. 66 N., R. 27 W.	1914	629	Not reached.	Cherokee.
Holt	State of Missouri	Forest City	1901	2500	1620	Silurian.
	Kimbell	1 mile east of Oregon	1870	566	Not reached.	....
Nodaway	Nodaway Oil, Gas & Mineral Co.	Burlington Junction	1905	1903	1717 (?)	Mississippian.
		Near Maryville, SE. ¼ sec. 17, T. 64 N., R. 35 W.	....	1003	Not reached.	Cherokee.
	St. James Industrial School	Conception, SW. ¼ sec. 24, T. 63 N., R. 34 W.	1913	1037	Not reached.	Cherokee.
	Hopkins Gas & Development Co.	Hopkins	1912	1000	Not reached.	Cherokee.
Platte	Danciger Bros	Near Weston, NE. ¼ sec. 2, T. 53 N., R. 36 W.	1915	1033	Not reached.	Cherokee.
	Danciger Bros	Near Platte City, sec. 3, T. 52 N., R. 35 W.	1915	955	Not reached.	Cherokee.
	Tiffany Springs Oil Co.	SE. ¼ sec. 8, T. 51 N., R. 34 W.	1910	840	Not reached.	Cherokee.
	Parkville Gas Co.	NW. ¼ sec. 17, T. 51 N., R. 34 W.	1915	595	Not reached.	Cherokee.
	Parkville Gas Co.	SW. ¼ sec. 9, T. 51 N., R. 34 W.	1916	595	Not reached.	Cherokee.
	Mr. Wilson	SE. ¼ sec. 1, T. 51 N., R. 34 W.	....	600	Not reached.	Cherokee.
	LaSalle Oil Co.	SW. ¼ sec. 29, T. 52 N., R. 34 W.	1918	2400±	1060	Cambrian or Ordovician.

Ray........	Michaels well......................	NE. ¼ sec. 34, T. 52 N., R. 29 W.	1870	802	545	Mississippian.
	Western Oil Co....................	SE. ¼ sec. 2, T. 53 N., R. 27 W...	1914	603	544	Mississippian.
	John Gibson......................	SE. ¼ sec. 6, T. 61 N., R. 27 W...	....	409	404	Mississippian.
	Ray County Oil Co................	....	1917	1200	....	....
Worth......	Allendale Oil & Gas Company.......	Allendale, SE. ¼ sec. 23, T. 66 N., R. 30 W....................	....	950	Not reached.	Cherokee.
	Allendale Oil & Gas Company.......	Near Allendale, sec. 27, T. 66 N., R. 30 W....................	....	1135	Not reached.	Cherokee.

The above list is very nearly complete for wells over 600 feet in depth in Northwest Missouri, except that in most cases, where groups have been drilled in one locality, a single well has been listed as representative. In spite of the fact that the list appears large, only a very small portion of the area can be said to have been tested. In most counties the wells are segregated in some one part, and less than 50 per cent of them have reached the base of the Pennsylvanian. Furthermore, it is definitely known that a great many of those sunk for oil and gas were purely wildcat tests, located without any knowledge of local structural conditions. Under these circumstances failures are not surprising and, without attempting to make predictions for the future of the area, it is certainly not to be condemned on the strength of the previous drilling.

The urgent need of this area at the present time is detailed geologic structural mapping, in order to locate the most favorable place for testing. In this respect it is largely virgin territory. Without this information, future tests must be carried on with no more enlightenment than those of the past, and with no greater chances of success. Locally, limestone outcrops are abundant, and detailed structural mapping is a comparatively easy matter, but over most of the area it is difficult, because of the lack of good rock outcrops. A relatively heavy mantle of glacial drift, and the absence of limestones in the exposed sections, form the chief obstacles to detailed work over considerable portions of the region.

There is no doubt that the rocks have been subjected to some folding, as illustrated by the general structure map (Pl. 4) and that locally the folding is sufficiently prominent to warrant investigation. Previous study of the area would indicate, however, that even the most prominent folds are probably low and not easily outlined without considerable detailed work. In but few localities are the rock dips great enough to be easily distinguished by the eye, and the average northwest regional dip is less than 10 feet to the mile.

BUCHANAN COUNTY.

The Lansing is exposed only in the valleys of Platte River and Castill Creek in the southwest townships, the Shawnee covers a portion of the uplands of the western townships, while the Douglas occupies the greater part of the area. This formation is nearly 300 feet thick in the county and consists chiefly of shale and sandstone. At its top is the conspicuous limestone known as the Oread, which is a useful horizon marker. On the upland divides a thick mantle of loess and drift commonly conceals the bed rock, but good exposures occur along the Missouri bluffs and along other streams of importance. The wide bottoms of the Missouri are covered with alluvium.

The thickness of the Pennsylvanian rocks at St. Joseph is about 1200 feet and at Saxton about 1100 feet. In the southeast corner of the county where the Lansing outcrops, it is somewhat less, and where the Shawnee occurs, somewhat greater.

No work has been done on the detailed geologic structure of the county. The general dip of the rocks is to the west and a little north, though considerable variation from the normal is produced by the Richmond-St. Joseph anticline which crosses the northern part of the county (see Pl. 4). The fold here is very broad, affecting practically the entire county.

Several deep wells have been sunk in various parts of the area, most of them near St. Joseph. The well at the Goetz Brewery in the city reached a depth of 1800 feet but no accurate record was kept. However, it seems certain that this well penetrated the full thickness of both the Pennsylvanian and Mississippian rocks and finished in older beds. A deep test for coal, sunk in 1884 near St. Joseph, in the NE. 1–4 NW. 1–4 sec. 29, T. 57N., R. 35W., reached a depth of 1308 feet. The mouth of the well is about 50 feet above the river and at 1200 feet the Mississippian limestones were reached. The Hopkins well north of the city in the SE. 1–4 SE. 1–4 sec. 31, T. 38N., R. 35W., reached these limestones at 1225 feet and bottomed at 1258 feet. About 6 miles southeast of St. Joseph hear Saxton, in the SE. 1–4 NW. 1–4 sec. 21, T. 57N., R. 34W., a diamond drill core shows the Mississippian limestones to have been reached at a depth of 1077 feet.

RECORD OF TURNER COAL COMPANY WELL, NE. ¼, NW. ¼ SEC. 29, T. 57 N., R. 35 W.

	Thickness.	Depth.
	Feet.	*Feet.*
Loess, dry and sandy	26	26
PENNSYLVANIAN SYSTEM:		
Shale, vitrious	76	102
Limestone, white to reddish	12	114
Shale, soft and dark	6	120
Shale, black, bituminous	2	122
Limestone, dark and shaley	9	131
Shale, sandy, gray	6	137
Snale, gray, slaty	33	170
Shale, gray to black, soft	14	184
Shale, dark, thin layers of limestone	34	218
Shale, hard	10	228
Shale, black, bituminous	13	241
Shale, hard to soft	10	251
Limestone	20	271
Shale, drab	28	299
Limestone, white	32	331
Shale, dark	7	338
Limestone	2	340
Shale, dark, bituminous at base	21	361
Limestone, hard	22	383
Shale, limestone layers	8	391
Shale, pyrite near top	136	527
Shale, black, bituminous	33	560
Limestone, gray	5	565
Shale, contains pyrite	126	691
Shale, contains coal	2	693
Shale, dark drab	4	697
Limestone, soft, drab	5	702
Shale, limestone layers	4	706
Limestone, light gray	4	710
Shale	14	724
Sandstone, sulpho-saline water	63	787
Shale, dark drab, sandy	63	850
Shale, light to dark	53	903
Shale, contains sandstone and limestone	47	950
Shale, contains coal	1	951
Shale, sandy	9	960
Sandstone	48	1008
Shale	75	1083
Coal	..	...
Shale, dark	10	1093
Sandstone	107	1200
MISSISSIPPIAN SYSTEM:		
Limestone	108	1308

None of the wells drilled are reported to have encountered showings of oil or gas except the Saxton well, and all of them encountered salt water horizons at depths less than 1000 feet before the base of the Pennsylvanian rocks was reached. In the Saxton drilling a slight flow of gas is reported but the quantity was evidently too small to be of importance.

CONDENSED RECORD OF SAXTON (CONNETT) WELL*, SE. ¼, SW. ¼ SEC. 21, T. 54 N., R. 34 W.

Stratum.	Thickness.		Depth.	
	Ft.	*In.*	*Ft.*	*In.*
Clay	23		23	
Sand	2		25	
Gravel	4		29	
PENNSYLVANIAN SYSTEM:				
Douglas formation:				
Weston shale:				
Shale, blue	1		30	
Lansing formation:				
Stanton limestone:				
Limestone	1		31	
Shale, blue	1		32	
Limestone	20		52	
Vilas shale:				
Shale, blue	4	6	56	6
Plattsburg limestone:				
Limestone	16	6	73	
Lane shale:				
Shale, blue	6		79	
Limestone	1		80	
Sandstone	17		97	
Shale, blue	1		98	
Limestone	2		100	
Shale, blue	9		109	
Limestone	4		113	
Shale, blue	4		117	
Limestone	1		118	
Shale, blue	38		156	
Kansas City formation:				
Iola limestone and Chanute shale:				
Limestone	7	6	163	6
Limestone, fossilferous	4		167	6
Shale	5		172	6
Limestone		6	173	
Shale	9		182	
Limestone	4		186	
Shale, blue	8		194	
Drum limestone:†				
Limestone	6		200	
Cherryvale shale:				
Shale, blue	1	6	201	6
Limestone	1		202	6
Shale, blue	3	6	206	
Limestone	5		211	
Shale, blue	13		224	
Limestone	2		226	
Shale, blue	7		233	
Limestone	5		238	
Shale, blue	6		244	
Winterset limestone:				
Limestone	8		252	
Shale, blue	1		253	
Limestone	20		273	
Galesburg shale:				
Shale	6		279	

*Drilled between May 3 and June 26, 1900.
†May include some of the thin beds below.

CONDENSED RECORD OF SAXTON (CONNETT) WELL—Continued.

	Thickness.		Depth.	
	Ft.	*In.*	*Ft.*	*In.*
PENNSYLVANIAN SYSTEM—Continued.				
Kansas City formation—Continued.				
Bethany Falls limestone:				
Limestone	21	6	300	6
Ladore shale:				
Shale, blue	2		302	6
Hertha limestone:				
Limestone	18	6	321	
Pleasanton formation:				
Shale, black	1		222	
Coal (Ovid)		1	322	1
Shale	127	11	440	
Limestone	1		441	
Shale, blue	8		449	
Henrietta formation:				
Limestone	3		452	
Shale, sandy	6		458	
Limestone	2		460	
Shale	23		483	
Limestone, conglomeratic	2		485	
Shale, black	3		488	
Limestone	1		489	
Sandstone	6		495	
Shale, black	11	6	506	6
Limestone, blue	1	6	508	
Shale	2	5	510	5
Coal		7	511	
Shale, blue	8		519	
Limestone	7		526	
Shale, blue	9		535	
Limestone	3		538	
Shale, mixed with limestone	5		543	
Limestone	4	6	547	6
Cherokee shale:				
Shale	5	6	553	
Sandstone	5		558	
Shale, clayey	4		562	
Sandstone	3		565	
Shale, blue	22		587	
Sandstone	3		590	
Shale, blue	6		596	
Sandstone	2		598	
Shale, blue	16		614	
"Cap rock"	1		615	
Coal (Bedford)	1	8	616	8
Sandstone	11	4	628	
Shale, blue	17		645	
Coal (Bevier)	1	9	646	9
Shale, blue	3	3	650	
Limestone	3		653	
Shale	14		667	
Sandstone	8		675	
Shale	13	4	688	4
Coal	1	5	689	9
Shale	28	9	718	6
Coal	1	6	720	
Shale	22	9	742	9
Coal	1	6	744	3
Shale	12	9	757	
Coal, slaty		3	757	3
Shale, blue	11	9	769	

CONDENSED RECORD OF SAXTON (CONNETT) WELL—Continued.

	Thickness.		Depth.	
	Ft.	*In.*	*Ft.*	*In.*
PENNSYLVANIAN SYSTEM—Continued.				
Cherokee shale—Continued.				
Sandstone	11		780	
Shale, blue	4		784	
Sandstone	2		786	
Shale, blue	80		866	
Sandstone	1		867	
Shale, blue	3		870	
Sandstone	12		882	
Conglomerate	5		887	
Shale, blue	22		909	
Sandstone	9		918	
Shale, sandy	1		919	
Sandstone	9		928	
Coal		6	928	6
Shale, blue	20	6	949	
Coal		7	949	7
Shale, sandy	6	5	956	
Shale, blue	4	4	960	4
Coal	1	4	961	8
Sandstone	3	4	965	
Shale, blue	7		972	
Limestone	3		975	
Shale, blue	7		982	
Sandstone	2		984	
Shale, sandy	9		993	
Coal		10	993	10
Sandstone	3	2	997	
Shale, sandy	1		998	
Sandstone	5		1003	
Shale	43		1046	
Sandstone	4		1050	
Shale, blue	1		1051	
Sandstone	26		1077	
MISSISSIPPIAN SYSTEM:				
Limestone	39		1116	

HOLT COUNTY.

Practically the entire upland surface of Holt County is underlain by the Shawnee formation. The Oread limestone at the top of the Douglas, just beneath the Shawnee, is the lowest outcropping rock in the area and is found only low down in the valleys of Missouri and Nodaway Rivers near the mouth of the latter. The Shawnee consists chiefly of shale, though it includes four limestone members, principally thin limestone beds alternating with shale. The western third of Holt County is entirely included in the Missouri bottoms and is covered with alluvium.

The base of the Pennsylvanian rocks has been reached at only one locality, near Forest City, at a depth of 1622 feet. This probably represents an average beneath the upland area.

No detailed structural mapping has been done in the county. The rocks have a low westerly dip.

Interest in deep drilling in this region centers in the diamond drill hole sunk in 1901, on the W. M. Davis farm, near Forest City. This well, which reached a depth of 2500 feet, is not only the deepest in the county, but the deepest in northwest Missouri. The cores were carefully kept and have been thoroughly studied so the record of the well is reliable and may be used as an excellent reference for the Pennsylvanian section in the northwest counties. No other wells of important depths have been sunk in Holt County, though just across the river at Rulo, Nebraska, a 1300-foot test hole was sunk in 1887. The Forest City well encountered no showings of oil or gas, so far as could be told, and salt water horizons were reached about the base of the Pennsylvanian rocks.

CONDENSED LOG OF DIAMOND DRILL HOLE ON W. F. DAVIS' FARM NEAR FOREST CITY, MO. DRILLED IN 1901.*

Stratum.	Thickness.		Depth.	
PLEISTOCENE SYSTEM:	*Ft.*	*In.*	*Ft.*	*In.*
Sandy clay, no core (loess)	65		65	
Clay and bowlders, no core (drift)	10		75	
PENNSYLVANIAN SYSTEM:				
Shawnee formation:				
Tecumseh shale:				
Clay shale (no core)	15		90	
Lecompton limestone:				
Limestone, dark gray to green, argillaceous, very fossiliferous, especially Fusulina	6	8	96	8
Limestone, gray, fine-grained, much calcite, very fosiliferous, especially Fusulina	4	7	101	3
Shale, gray to black	3	5	104	8
Limestone, dark gray, Fusulina		9	105	5
Limestone, gray, fine-grained	10	4	115	9
Limestone and shale	3	10	119	7
Limestone	4	10	124	5
Kanwaka shale:				
Shale, greenish-gray, fossiliferous	16	10	141	3
Limestone, dark gray	4	2	145	5
Shale, gray; with a thin one-half inch seam of coal	13	1	158	6
Douglas formation:				
Oread limestone:				
Limestone, dark gray, granular to oolitic	9	9	168	3
Limestone, dark gray	21		189	3
Shale	3	10	193	1
Limestone, gray	2	6	195	7
Shale, gray and greenish	11	3	206	10
Limestone	6	8	213	6
Lawrence shale:				
Shale	19	1	232	7
Limestone, mottled gray and brown	4	11	237	6
Shale, dark gray, arenaceous	12	8	250	2

*Detailed log published in: The Stratigraphy of the Pennsylvanian Series, Missouri Bureau of Geology and Mines, vol. xiii, 2nd series, pp. 215-239, 1915.

CONDENSED LOG OF DIAMOND DRILL HOLE ON W. F. DAVIS' FARM—Cont'd.

	Thickness.		Depth.	
PENNSYLVANIAN SYSTEM—Continued.	*Ft.*	*In.*	*Ft.*	*In.*
Douglas formation—Continued.				
Lawrence shale—Continued.				
Sandstone and sandy shale interbedded	77	8	327	10
Shale	9		336	10
Limestone, soft, very fossiliferous	1		337	10
Shale	10		347	10
Iatan limestone:				
Limestone, gray, nodular	9		356	10
Weston shale:				
Shale	61	3	418	1
Lansing formation:				
Stanton limestone:				
Limestone, medium-grained, gray	8	5	426	6
Clay shale, greenish	2	1	428	7
Limestone	17	2	445	9
Shale	8	5	454	2
Limestone, buff	3	2	457	4
Vilas shale:				
Shale, dark	12	1	469	5
Plattsburg limestone:				
Limestone	4	9	474	2
Shale, black, calcareous		11	475	1
Limestone, gray	9	6	484	7
Shale, gray to dark-gray	1	10	486	5
Limestone, dark-gray, argillaceous	8	3	494	8
Shale, greenish		7	495	3
Limestone, light-gray, fine-grained	1	8	496	11
Lane shale:				
Shale, dark-blue, fossiliferous	2	3	499	2
Limestone	4	4	503	6
Shale	38	9	542	3
Kansas City formation:				
Iola limestone:				
Limestone, light-gray	11		553	3
Chanute shale:				
Limestone, very argillaceous	5	8	558	11
Shale	15	3	574	2
Limestone, gray, argillaceous	4	1	578	3
Shale, green, calcareous	4	2	582	5
Drum limestone:				
Limestone, gray, argillaceous	8	6	590	11
Cherryvale shale:				
Shale, gray, calcareous	1	11	592	10
Limestone, shaly	1	11	594	9
Shale, dark, bituminous, calcareous		10	595	7
Limestone, mottled light and dark-gray	1	3	596	10
Shale, dark-gray, calcareous, bituminous	6	8	603	6
Shale	17	1	620	7
Winterset limestone:				
Limestone, light-gray, compact, crystalline	7		627	7
Shale	7	2	634	9
Limestone, light-gray, medium-grained, fossiliferous	34	9	669	6
Galesburg shale:				
Shale, black to gray	5	8	675	2
Bethany Falls limestone:				
Limestone, gray, nodular at top	23		698	2
Ladore shale:				
Shale, dark, bituminous, calcareous	3	5	701	7
Limestone, very argillaceous		7	702	2
Shale, greenish, calcareous	5	4	707	6
Limestone, argillaceous, with shale beds	4	8	712	2

CONDENSED LOG OF DIAMOND DRILL HOLE ON W. F. DAVIS' FARM—Cont'd

	Thickness.		Depth.	
PENNSYLVANIAN SYSTEM—Continued.	*Ft.*	*In.*	*Ft.*	*In.*
Kansas City formation—Continued.				
Hertha limestone:				
Limestone, gray, with shaly partings	12	11	725	1
Pleasanton and Henrietta formations:				
Shale, blue-gray, calcareous, sandy	1	6	726	7
Sandstone, dark and light bands, shaly	4	11	731	6
Coal, contains fossil plants (Ovid)		6	732	
Clay, blue-gray, arenaceous	2	4	734	4
Sandstone, grayish, fine-grained, calcareous	17	10	752	2
Shale, grayish-blue	19	7	771	9
Limestone, dark-gray, argillaceous	3	5	775	2
Shale	4	2	779	4
Limestone, light-colored; argillaceous	1	9	781	1
Shale, green, upper half calcareous	1	3	782	4
Clay and shale, blue, green, black	9	2	791	6
Limestone and shale, nodular	3	2	794	8
Shale, greenish	4	5	799	1
Limestone	1	5	800	6
Sandstone, light-green, fine-grained	9	6	810	
Shale, gray, banded with red and green	5	2	815	2
Limestone, greenish, mottled, argillaceous	6	4	821	6
Shale	14	6	836	
Cherokee shale:				
Shale, black, with a thin layer of coal (Lexington) at bottom		10	836	10
Clay shale	6	7	843	5
Limestone, gray, argillaceous	5	7	849	
Clay, light gray, calcareous	2		851	
Shale	14	11	865	11
Limestone, dark-gray, fine-grained	2		867	11
Sandstone, dark bluish-gray, fine-grained	5	5	873	4
Shale, black, slaty	15	8	889	
Coal, bony (Summit)		4	889	4
Sandstone	5	7	894	11
Shale, dark-gray, arenaceous	4	4	899	3
Limestone	8	9	908	
Shale	11	10	919	10
Limestone, greenish, argillaceous	2	2	922	
Shale, green, calcareous; slightly arenaceous	4	2	926	2
Limestone, light-gray, very argillaceous	2	3	928	5
Shale	8	2	936	7
Sandstone, fine-grained, argillaceous, calcareous in places; pyritiferous	7	5	944	
Shale	40	6	984	6
Limestone	1	8	986	2
Coal, rotten (Bedford)		4	986	6
Shale, gray, pyritiferous	6	9	993	3
Sandstone, micaceous	1	3	994	6
Coal, pyritiferous (Bevier)	1	2	995	8
Shale, bluish-gray, micaceous	1	4	997	
Sandstone, gray, soft, argillaceous	7		1004	
Shale	26	7	1030	7
Limestone, greenish-gray, compact		8	1031	3
Shale, slaty, calcareous and carbonaceous	1	10	1033	1
Limestone, dark, bituminous, fossiliferous, argillaceous		11	1034	
Shale, black, slaty, carbonaceous	1	1	1035	1
Limestone, brownish-black, compact, argillaceous, fossiliferous		4	1035	5
Shale, black, slaty, carbonaceous	1	9	1037	2

CONDENSED LOG OF DIAMOND DRILL HOLE ON W. F. DAVIS' FARM—Cont'd.

	Thickness.		Depth.	
	Ft.	*In.*	*Ft.*	*In.*
PENNSYLVANIAN SYSTEM—Continued.				
Cherokee shale—Continued.				
Limestone, brownish-black, compact, argillaceous, fossiliferous		8	1037	10
Shale, black, slaty, carbonaceous	2	2	1040	
Coal (Tebo)	1	3	1041	3
Clay	4		1045	3
Sandstone, fine-grained, greenish	6	3	1051	6
Shale	7	11	1059	5
Coal	1		1060	5
Shale, dark gray, clayey		4	1060	9
Sandstone, gray, fine-grained	4		1064	9
Shale, black, slaty toward bottom	5	8	1070	5
Coal		9	1071	2
Shale	11	4	1082	6
Clay, brownish, very sandy; grading to sandstone below	2	4	1084	10
Sandstone	25	10	1110	8
Shale	30	4	1141	
Coal, pyritiferous		9	1141	9
Clay, gray, pyritiferous	4	3	1146	
Shale, brown, iron-stained, very hard		5	1146	5
Sandstone, dark, argillaceous; slickensided	1	2	1147	7
Shale, dark	10	6	1158	1
Clay, light-colored, sandy	1	11	1160	
Sandstone	8	2	1168	2
Shale, dark-colored, arenaceous at top	2	6	1170	8
Sandstone, light-colored, fine-grained	1	10	1172	6
Shale	10		1182	6
Sandstone, very argillaceous		6	1183	
Shale, dark-blue to nearly black	3	4	1186	4
Wasted core	2	2	1188	6
Sandstone, brownish-black	2	3	1190	9
Shale	23	5	1214	2
Sandstone, light-gray	1	6	1215	8
Shale, greenish-gray		10	1216	6
Sandstone, greenish	1	4	1217	10
Shale, greenish-gray	4	6	1222	4
Sandstone, light bluish-gray	5	3	1227	7
Shale, black, slaty, carbonaceous, with thin coal seams	2		1229	7
Sandstone, gray	6	9	1236	4
Shale	15		1251	4
Coal		5	1251	9
Clay, dark-gray, sandy, with coal partings		4	1252	1
Sandstone, fine-grained, has thin coal partings usually diagonal to the core	5	11	1258	
Shale, black	5	5	1263	5
Coal, rotten		3	1263	8
Sandstone, gray, fine-grained	5	10	1269	6
Shale	2	6	1272	
Sandstone, argillaceous	6	4	1278	4
Shale, black	3		1281	4
Sandstone, banded, shaly		5	1281	9
Shale. An inch of coal occurs in the lower part of the bed	5	2	1286	11
Sandstone, gray	4	9	1291	8
Shale, dark brownish-black	10		1301	8
Sandstone	42	1	1343	9
Shale	12	10	1356	7
Sandstone, brownish-black	1		1357	7

CONDENSED LOG OF DIAMOND DRILL HOLE ON W. F. DAVIS' FARM—Cont'd.

	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
PENNSYLVANIAN SYSTEM—Continued.				
Cherokee shale—Continued.				
Shale, dark brownish-gray	3	5	1361	
Sandstone	22	1	1383	1
Shale, black	1	4	1384	5
Coal		5	1384	10
Clay, gray, sandy at top	2	6	1387	4
Shale, black	2	9	1390	1
Coal		10	1390	11
Clay, gray, soft	1	1	1392	
Wasted core	1	4	1393	4
Clay, gray, grading to black below	1	4	1394	8
Shale, black	17	11	1412	7
Sandstone	22	5	1435	
Shale, black	5		1440	
Clay shale, dark-gray	4		1444	
Sandstone, dark-gray	1	8	1445	8
Shale, dark-gray	8	4	1454	
Sandstone, brown		3	1454	3
Clay, dark gray	3	6	1457	9
Sandstone, brown, coarse		7	1458	4
Shale	30	2	1488	6
Sandstone, light-colored	4	8	1493	2
Shale	2	4	1495	6
Sandstone	11	2	1506	8
Shale, black	11	6	1518	2
Sandstone	11	10	1530	
Coal		2	1530	2
Shale, dark		4	1530	6
Sandstone	15	3	1545	9
Shale, banded	6	2	1551	11
Sandstone	5	4	1557	3
Shale, black; contains a one-half inch bed of coal five inches from the base	2	10	1560	1
Sandstone, light-colored	6	2	1566	3
Shale, dark-gray to black	14		1580	3
Sandstone, fine-grained	1	11	1582	2
Shale, black	4	3	1586	5
Sandstone, black	1	3	1587	8
Shale	25	8	1613	4
Sandstone, light gray to white	4	10	1618	2
Limestone, argillaceous, crystalline		7	1618	9
Sandstone	3	2	1621	11
MISSISSIPPIAN SYSTEM:				
St. Louis limestone:				
Limestone, gray to brownish-gray, cherty	11	7	1633	6
Limestone, gray, dense	9	10	1643	4
Limestone, dark-gray, fine-grained	17	10	1661	2
Warsaw shale:				
Limestone, light-gray, fine grained	5		1666	2
Dolomite, gray, soft, argillaceous	1	6	1667	8
Shale, dark greenish-gray	4	5	1672	1
Sandstone, blue-green, calcareous	1	3	1673	4
Shale	5	1	1678	5
Sandstone, light, argillaceous, calcareous	1	7	1680	
Limestone, light-gray	10	11	1690	11
Shale, dark greenish-gray	1	9	1692	8
Limestone, fine-grained, very arenaceous	5	4	1698	
Wasted core	2		1700	
Sandstone, very fine-grained, argillaceous	1	6	1701	6

CONDENSED LOG OF DIAMOND DRILL HOLE ON W. F. DAVIS' FARM—Cont'd.

Stratum.	Thickness.		Depth.	
	Ft.	*In.*	*Ft.*	*In.*
MISSISSIPPIAN SYSTEM—Continued.				
Burlington and Keokuk limestones:				
Limestone, light to dark-gray, cherty	112	2	1813	8
Wasted core	7	5	1821	1
Kinderhook group*:				
Dolomitic limestone, light-gray	16		1837	1
Chert, light and dark-gray	1	9	1838	10
Limestone, gray	75	1	1913	11
Shale, blue-gray to greenish	39	6	1953	5
Hematite, dark-red, flat oolites resembling typical "flaxseed" iron ore	4	1	1957	6
Shale, bluish-gray, pyritiferous	83	7	2041	1
DEVONIAN SYSTEM:**				
Limestone	15	8	2056	9
Shale, dark bluish-gray	5	11	2062	8
Upper Devonian Series:				
Limestone, light to dark gray	71	10	2134	6
Middle Devonian Series:				
Dolomite	35		2169	6
Limestone	10	10	2180	4
Dolomite	52	3	2232	7
Chert, partly decomposed and chalky	1	8	2234	3
Dolomite, cherty in part	130	10	2365	1
SILURIAN SYSTEM (Lockport group of Niagran series):				
Dolomite, bluish-gray, crystalline to shaly	134	11	2500	

*May include other beds below 1800 feet.
**Correlations below 2041-1, by E. O. Ulrich.

ATCHISON COUNTY.

Atchison County, lying in the northwest corner of the state, contains the highest and youngest Pennsylvanian rocks and the maximum thickness of these rocks of any Missouri county. The Shawnee and Wabaunees formations underlie the upland area, the latter occupying by far the greater portion. Owing to a heavy covering of glacial drift, outcrops of either formation are rare and are confined to the bluffs of the larger streams. The western part of the area lies in the wide alluvial bottoms of the Missouri. As revealed by one drill record the thickness of the Pennsylvanian deposits is between 1600 and 1700 feet. From some of the higher points it may be slightly more.

RECORD OF WELL AT TARKIO, MO., SW. ¼, NE. ¼ SEC. 11, T. 65 N., R. 40 W.

	Thickness.	Depth.
	Feet.	*Feet.*
Alluvium	28	28
Sandstone, water	15	43
Blue clay	30	73
Sand and water	40	113
Shale, very soft	40	153
Sand and water	10	163
PENNSYLVANIAN SYSTEM:		
Shawnee formation:		
Shale	7	170
Limestone	15	185
Shale, white	23	208
Limestone	4	212
Shale, blue	38	250
Limestone	23	273
Shale, blue	4	277
Limestone	9	286
Shale, white	40	326
Douglas formation:		
Limestone (Oread)	4	330
Shale, white (Oread)	5	335
Limestone (Oread)	4	339
Shale	11	350
Shale, very red, soft	20	370
Shale	70	440
"Lime shells" in shale	11	451
Shale, soft, partly red	25	476
Limestone	10	486
Shale	10	496
Lansing formation:		
Limestone, grayish blue	29	525
Shale, dark gray to reddish, calcareous	40	565
Limestone, light gray	10	575
Shale, dark gray to light gray, calcareous	62	637
Kansas City formation:		
Limestone, light gray, fine-grained	25	662
Shale, dark gray to black, slaty streak	10	672
Shale, gray, soft	20	692
Limestone, gray	25	717
Shale, soft, gray	10	727
Limestone, light gray (Winterset)	38	765
Shale, light blue	5	770
Limestone, light gray (Bethany Falls)	10	780
Shale, dark gray, slaty	5	785
Limestone, light gray	15	800
Pleasanton and Henrietta formations:		
Shale, light to dark gray	10	810
Limestone, light gray	25	835
Shale, soft, bluish-gray	8	843
Limestone, light gray, with some shale	12	855
Shale, light bluish-gray	20	875
Limestone, light gray	10	885
Shale, light bluish-gray, soft	35	920
Limestone	17	937
Cherokee shale:		
Shale, light gray, soft	93	1030
Sandstone, gray, hard	28	1058
Shale, black	7	1065
Sandstone, dark gray, micaceous	30	1095
Shale, light to dark, soft	110	1205
No record	50	1255

RECORD OF WELL AT TARKIO, MO.—Continued.

	Thickness.	Depth.
PENNSYLVANIAN SYSTEM—Continued.	*Feet.*	*Feet.*
Cherokee shale—Continued.		
Shale, gray to black	40	1295
Sandstone, dark gray, fine-grained	30	1325
Shale, soft, bluish-gray to black	30	1355
Limestone, gray, with pyrite	10	1365
Sandstone, light gray, fine-grained, micaceous	85	1450
Limestone, gray, with sandstone and shale	20	1470
Shale, black	17	1487
Shale, light gray	15	1502
Sandstone, light gray, fine-grained	40	1542
Shale, dark blue	13	1555
Sandstone, fine-grained, gray	15	1570
Sandy shale	5	1575
Limestone, gray, crystalline, and black fissile shale	5	1580
Sandstone, gray	10	1590
Shale, light gray to dark blue	50	1640
MISSISSIPPIAN SYSTEM:		
St. Louis limestone and Warsaw shale:		
Limestone, gray, fine-grained	15	1655
Shale, light gray, clayey	4	1659
Limestone, gray, fine-grained, a little chert	5	1664
Limestone, gray to yellowish, a small amount of gray shale and blue chert	41	1705
Burlington-Keokuk limestone:		
Limestone, crystalline, cherty; limestone partly dolomitic	215	1920
Kinderhook shales:		
Shale, sandy, greenish	10	1930
Hematite, oolitic, red	15	1945
Shale, green-stained, reddish from above	15	1960
Limestone and shale, mixed	5	1965
Shale, gray, arenaceous, hard	59	2024
Shale, gray, soft	4	2028
Limestone and shale, mixed	4	2032
Shale, arenaceous	12	2044
Shale, gray, clayey	126	2170
Shale, gray	5	2175
DEVONIAN SYSTEM:		
Limestone, dolomitic	165	2340

Practically nothing is known of the the detailed structural features of the rocks of this area except that the general dip is a little south of west at a very low angle. The lack of exposures makes detailed mapping impossible over most of the area.

In 1914 and 1915 two test wells for oil were sunk on the Rankin estate near Tarkio. Well No. 1 reached a depth of 1551 feet and bottomed in the Cherokee shale but well No. 2, in the SW. 1/4 NE. 1/4 sec. 11, T. 65N., R. 40 W., was sunk to a depth of 2340 feet, reaching the Mississippian limestones at 1640 feet, and bottoming in the Devonian. No showing of oil or gas were encountered in either well and the first salt water was reached in Well No. 2, at 1030 feet. From 103 feet to 1030 feet there was not enough water in this hole to drill with. A coal prospect near Rockport, in the NE. 1/4 sec. 33 T. 65 N., R. 41W. sunk to a depth of 679 feet, and a deep water well at Rockport, constitute the only other important drillings of the county.

RECORD OF WELL AT ROCKPORT, MO.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil and clay	98	98
Gray sand, and clay	42	140
Gravel and sand with abundance of water	3	143
Blue clay	25	168
PENNSYLVANIAN SYSTEM:		
Limestone	3	171
Shale, gray	2	173
Limestone and sandstone, including coal seam	3	176
Shale, dark, bituminous, in part	110	286
Limestone, gray	4	290
Soapstone	58	348
Limestone, gray, dark	9	357
Coal	1	358
Soapstone	20	378
Limestone, gray	21	399
Black "slate"	3	402
Shale	88	490
Limestone, light gray	60	550
Light and dark shale	23	573
Shale, red	11	584
Shale, dark	40	624
Limestone, water	6	630
Coal	2-8″	632-8″
Shale	46	678-8″

NODAWAY COUNTY.

Nodaway County, like Atchison and Worth, is heavily covered with drift, but the larger streams have cut through this mantle and exposed beds of the Shawnee formation, which underlies the entire county just beneath the drift. The Topeka and Deer Creek limestone members are easily recognized in most of the outcrops, and the latter forms low escarpments along 102 River north of Bernard. The thickness of the Pennsylvanian probably varies from 1450 to 1700 feet.

Structurally, a broad, shallow syncline pitching west crosses the region centrally from east to west. On the north of this depression the rocks dip at a very low angle to the southwest on the south the dip swings to the west and northwest.

In 1905 a deep test was sunk at Burlington Junction in the northwest part of the county. The well bottomed at 1903 feet, apparently in the Mississippian limestones.

DRILLERS LOG OF WELL OF NODAWAY COUNTY OIL, GAS AND MINERAL COMPANY, BURLINGTON JUNCTION.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil and clay	68	68
PENNSYLVANIAN SYSTEM:		
Coal	..	...
Shale, blue	459	527
Yellow ocher	18	545
Sand shells	100	645
Salt sand	20	665
Lime shells	30	695
Shale	40	735
Limestone, hard, blue	30	765
Lime shells	15	780
Shale	66	846
Limestone	25	871
Shale	40	911
Limestone	15	926
Shale	30	956
Limestone	20	976
Sandstone	2	978
White rock (Trenton)?	117	1095
Gas sand (?)	30	1125
Black shale	114	1239
Brown sand	1	1240
Black shale	17	1257
White "talc"	3	1260
Lime shells	10	1270
Black shale	300	1570
Lime shells	30	1600
Black shale and sand	40	1640
Black shale and sand mixed	30	1670
"Red Dakota sand"	2	1672
Black shale and fine sand	20	1692
Brown sand	5	1697
Black shale, sand, with peacock colors and traces of oil	20	1717
MISSISSIPPIAN SYSTEM:		
Lime sand	11	1728
Pebble sand	10	1738
"Red Trenton rock" or "cap rock"	165	1903

The above record is probably incorrect, but it is the only record available for this well, of which traces of oil and gas have been reported at 1697 feet, just above the Mississippi lime.

In a prospect well drilled 1,000 feet deep at Hopkins, salt water was encountered at 600 and 960 feet and in a 1037-foot well drilled for water at Conception, salt water was first encountered at 714 feet. The only other deep wells reported in the county are a diamond drill hole 1003 feet deep near Marysville in the NE. 1/4 SE. 1/4 sec. 17, T. 46N., R. 35W., and a water well somewhat less than 1000 feet deep in Marysville. No showings of oil or gas have been reported in any of these wells, though none of them have reached the base of the Pennsylvanian strata.

CONDENSED RECORD OF STRATA IN CORE DRILLING AT MARYVILLE*
(Altitude of Surface at Curb, 1051 Feet.)

	Thickness.		Depth.	
	Ft.	*In.*	*Ft.*	*In.*
Clay, sand, and a little gravel	50		50	
Soft shale (probably glacial clay)	120		170	
PENNSYLVANIAN SYSTEM:				
Shawnee formation:				
Tecumseh shale:				
Shale, dark, argillaceous, and calcareous	6		176	
Lecompton limestone:				
Limestone	14		190	
Kanwaka shale:				
Shale	7		197	
Limestone	6		203	
Shale, dark	13		216	
Douglas formation:				
Oread limestone:				
Limestone, dark, earthy, and coarse	2		218	
Shale, dark, smooth, noncalcareous	5	6	223	6
Limestone, white, coarse, hard	10	6	234	
Shale, dark, argillaceous		3	234	3
Limestone, white	10	9	245	
Shale, dark, argillaceous	7		252	
Limestone, drab, shaly, grading into calcareous shale	3		255	
Lawrence shale:				
Shale, drab, soft, clayey, calcareous	9		264	
Shale, red, concretionary, calcareous and argillaceous, with drab bands	13		277	
Limestone, drab and dark, with flint	1		278	
Clay, dark red, argillaceous and calcareous	12		290	
Shale, arenaceous, slightly calcareous	5		295	
Sandstone, coarse, rough, micaceous	2		297	
Shale, dark drab, argillaceous, noncalcareous	9		306	
Coal		3	306	3
Shale, drab, argillaceous	4	9	311	
Shale, red, clayey	12		323	
Shale, drab, somewhat arenaceous	27		350	
Sandstone, or sandy shale	11		361	
Shale, drab	42		403	
Shale, red, argillaceous, noncalcareous	2		405	
Shale, drab, argillaceous, noncalcareous	7		412	
Iatan (?) limestone:				
Limestone, gray, hard, fossiliferous	4		416	
Weston (?) shale:				
Shale, drab, argillaceous, noncalcareous	38		454	
Lansing formation:				
Stanton-Plattsburg limestone:				
Limestone, dark drab, compact and rough	4		458	
Shale, drab, calcareous, argillaceous	3		461	
Limestone, very hard, compact	14		475	
Shale	7		482	
Limestone, dark, flinty, hard	5		487	
Shale, dark gray, sandy, calcareous	1		488	
Limestone, gray, coarse, shaly	2		490	
Shale, dark gray, argillaceous, noncalcareous	1		491	
Limestone, white and gray	12		503	
Lane shale:				
Shale, light and dark drab, argillaceous	10		513	
Limestone, gray, compact, hard	2		515	

*Drilled in the year 1888, 1 ½ blocks north of Burlington depot (NE. ¼, SE. ¼ sec. 17, T. 64 N., R. 35 W.). Core examined and tested with acid by Arthur Winslow and record made by him. Detailed log given in vol. XIII, 2nd series, Bureau of Geology and Mines.

CONDENSED RECORD OF STRATA IN CORE DRILLING AT MARYVILLE—Con.

	Thickness.	Depth.
PENNSYLVANIAN SYSTEM—Continued.	*Feet.*	*Feet.*
Lansing formation—Continued.		
Lane shale—Continued.		
Shale, dark drab, calcareous	10	525
Limestone	17	542
Shale, light drab and dark gray	25	567
Kansas City formation:		
Iola limestone and Chanute shale:		
Limestone, drab, hard, coarse-grained	10	577
Shale	21	598
Limestone, light gray or white, compact	4	602
Shale, light drab, argillaceous, calcareous	6	608
Limestone, light drab, hard, compact	6	614
Shale, dark, bituminous, calcareous	2	616
Drum limestone:		
Limestone, dark, hard, semicrystalline	4	620
Cherryvale shale:		
Shale, dark, argillaceous, calcareous	20	640
Limestone, dark, granular	3	643
Shale, dark, hard, calcareous	8	651
Winterset limestone:		
Limestone	28	679
Galesburg shale:		
Shale	14	693
Bethany Falls limestone:		
Limestone, gray, compact, very hard	19	712
Ladore shale:		
Shale, black, bituminous, slightly calcareous	1	713
Limestone, drab, compact, shaly	4	717
Shale, clayey	5	722
Hertha limestone:		
Limestone, white, gray, very hard	6	728
Pleasanton formation:		
Limestone, reddish, sandy, friable spots	2	730
Shale, dark, argillaceous, barely calcareous	1	731
Limestone	6	737
Limestone, drab, compact granular	3	740
Shale, black, bituminous	2	742
Limestone, nodular	11	753
Shale, arenaceous, a little mica	14	767
Limestone, drab, compact	7	774
Shale, drab, slightly argillaceous, arenaceous	6	780
Limestone, white, hard, semicrystalline	4	784
Shale, dark, argillaceous, slightly calcareous	2	786
Shale, drab and greenish	13	799
Limestone, white	4	803
Shale, greenish, argillaceous, noncalcareous	6	809
Limestone, drab, hard, compact, granular	1	810
Shale	36	846
Henrietta formation:		
Limestone, granular	5	851
Shale, drab, somewhat arenaceous	11	862
Shale, argillaceous	13	875
Limestone	4	879
Shale, dark, argillaceous	15	894
Limestone	11	905
Cherokee shale:		
Shale, drab	38	943
Shale, drab	60	1003

ANDREW COUNTY.

The surface formations of Andrew County are the Shawnee, which directly underlies the drift over most of the upland area, and the Douglas which occurs chiefly bordering Missouri, 102, Nodaway, and Platte Rivers, where its top may be recognized by good outcrops of the Oread limestone. The glacial drift conceals both formations nearly everywhere except along the streams. No wells in the County have reached the base of the Pennsylvanian, which will be encountered at depths of from 1250 to 1550 feet.

The rocks dip at a low angle in a westerly direction.

A number of water wells, 300 to 500 feet deep, have been drilled in Andrew County. The only hole of any considerable depth is a diamond drill bore 800 feet deep, one and one-half miles northwest of Rochester (W. ½ sec. 14. T. 59N., R. 34W.) drilled in 1890 by the Rochester Coal, Mining and Prospecting Company in search of coal. The record follows:

RECORD OF ROCHESTER COAL MINING AND PROSPECTING COMPANY WELL, W. ½ SEC. 14, T. 59 N., R. 34 W.

	Thickness.		Depth.	
	Ft.	*In.*	*Ft.*	*In.*
Black soil	6		6	
Yellow clay	6		12	
Sand	9		21	
Blue clay	7		28	
PENNSYLVANIAN SYSTEM:				
Douglas formation:				
Limestone, gray, with clay seams	7		35	
Shale, blue, sandy (Weston)	86		121	
Lansing formation:				
Limestone	2		123	
Shale, light blue	10		133	
Limestone, gray	22		155	
Shale, light blue		7	155	7
Shale, black and gray	2	9	158	4
Limestone	1	10	160	2
Shale, gray	1	2	161	4
Limestone		7	161	11
Clay, white		5	162	4
Limestone, impure	3	4	165	8
Shale, gray	1	6	167	2
Limestone, light gray	4	2	171	4
Shale, blue	4	7	175	11
Limestone		7	176	6
Shale, blue to gray	12	5	188	11
Limestone	1		189	11
Shale, blue	6		195	11
Limestone		6	196	5
Shale, gray	3	11	200	4
Limestone	5	10	206	2
Shale, dark	28	11	235	1

RECORD OF ROCHESTER COAL MINING ND PROSPECTING CO. WELL—Con.

	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
PENNSYLVANIAN SYSTEM—Continued.				
Kansas City formation:				
Limestone	4		239	1
Shale, blue	9	5	248	6
Limestone	4	4	252	10
Shale, blue	1	8	254	6
Limestone	1	2	255	8
Shale, blue to dark	3	5	259	1
Limestone		8	259	9
Shale, blue	5	11	265	8
Limestone, white	8	3	273	11
Shale, blue to red	6	10	280	9
Limestone, impure	10	4	291	1
Shale, dark	2	4	293	5
Limestone	2	9	296	2
Shale, dark	3	1	299	3
Limestone		6	299	9
Shale, dark	6	3	306	
Limestone	2	1	308	1
Shale, blue	1	5	309	6
Limestone	6		315	6
Shale, dark	2	6	318	
Limestone	1	7	319	7
Shale, dark	3	3	322	10
Limestone, white	32	5	355	3
Shale, light blue to black	5	6	360	9
Limestone, impure	22	2	382	11
Shale, blue to black	11	5	394	4
Limestone, impure	10	2	404	6
Pleasanton formation:				
Shale, light blue to dark, with seam of coal at 405	61	7	467	1
Limestone, dark brown, hard	2	8	469	9
Shale, light to dark, with seam of coal	5	7	475	4
Limestone and shale	4	3	479	7
Shale, dark	19	10	499	5
Limestone, impure	23		522	5
Shale, blue	4		526	5
Limestone	5		531	5
Shale, dark	12	5	543	10
Limestone	1	2	545	
Shale, red, blue, and black	2	6	547	6
Shale, light blue	7	10	555	4
Henrietta and Cherokee formations:				
Limestone, impure	16	1	571	5
Shale, blue to black	42		613	5
Coal		10	614	3
Shale, clayey	1	3	615	6
Limestone	5		620	6
Shale, blue	1	5	621	11
Limestone, impure	9	11	631	10
Shale, blue	9	7	641	5
Limestone and shale	11	10	653	3
Shale, with some limestone	46	9	700	
Shale, light and dark	100		800	

WORTH COUNTY.

A thick mantle of glacial drift conceals bed rock over nearly all of Worth County, though a few isolated exposures of shale and limestones occur along East Fork of Grand River in the southeast part. It is probable that the drift is underlain in the western townships by the Shawnee formation while in the eastern half of the county, except near Denver, it is underlain by the Douglas. A small area bordering East Fork of Grand River, just north of Denver, shows outcrops of the Stanton limestone member of the Lansing formation, which appear to have been raised above their normal position here by folding. The limestone is divided into a number of thin beds separated by shale, and inasmuch as the underlying shale member also exposes thin beds of limestone, the section is somewhat confusing.

The maximum thickness of Pennsylvanian underlying Worth County has not been determined by drill records. The deepest well in the county, near Allenton in the eastern part, reached a depth of 1135 feet without encountering the base. At Bedford, Iowa, near the northwest corner of the county, a well reached the underlying Mississippian limestones at a depth of 1340 feet and it is probable that these same limestones would be reached under most of Worth County at depths of 1200 to 1350 feet.

Very little is known of the structural features of the county. The normal dip of the strata is slightly south of west at a very low angle. The exposure of Lansing beds along East Fork of Grand River near Denver at horizons which it is presumed should be occupied by younger beds, suggests the presence of an anticline in this locality.

No oil or gas has ever been found in Worth County and only two deep test wells have been sunk. In 1911, the Allendale Coal, Oil and Gas Company drilled two diamond drill holes near Allendale, in the eastern part of the county. The record of hole No. 1 follows:

CONDENSED RECORD OF DRILL HOLE NO. 1, ALLENDALE COAL, OIL AND GAS COMPANY, SW. ¼ SEC. 27, T. 66 N., R. 30 W.

	Thickness		Depth.	
	Ft.	*In.*	*Ft.*	*In.*
Clay and sand	70		70	
Hard pan	32		102	
PENNSYLVANIAN SYSTEM:				
Douglas formation:				
Clay shale, soft	20		122	
Shale, fossiliferous	11		133	
Sandstone and shale	40		173	
Shale, sandy and tough	11		184	
Lansing formation:				
Limestone	6		190	
Shale, with hard bands	15		205	
Limestone	14		219	
Shale, dark	6		225	
Limestone	2	6	227	6
Shale, gray	6		233	6
Limestone	7		240	6
Shale, gray	2	6	243	
Limestone	1	6	244	6
Shale with limestone bands	25	6	270	
Shale, dark	53		323	
Kansas City formation:				
Limestone and shale	10		333	
Shale, blue	4		337	
Limestone	6		343	
Shale, dark	2		345	
Limestone	5		350	
Shale, dark, with limestone bands	16		366	
Limestone	2		368	
Shale, dark, with limestone bands	7		375	
Limestone, with shale partings	29	6	404	6
Shale, dark gray	9	6	414	
Limestone	21		435	
Shale, dark, fossiliferous	15		450	
Limestone, shale partings	11		461	
Pleasanton formation:				
Shale, dark, sandy	39		500	
Sandstone, soft	7		507	
Shale	36		543	
Limestone	3		546	
Shale, dark gray	4		550	
Limestone and shale mixed	5	6	555	6
Shale, blue to red	7		562	6
Henrietta formation:				
Shale and limestone	3		565	6
Limestone	3	6	569	
Shale, sandy and dark	25		594	
Limestone	6		600	
Cherokee formation:				
Shale, red	7	6	607	6
Coal	1		608	6
Shale, light colored, fossiliferous	3	6	612	
Limestone and shale	12		624	
Shale	36		660	
Sandstone, soft	10		670	
Shale	52		722	
Coal		3	722	3
Fire clay	7	3	729	6
Limestone	2		731	6
Shale, dark	7	6	739	

CONDENSED RECORD OF DRILL HOLE NO. 1, ALLENDALE COAL, OIL AND GAS COMPANY—Continued.

	Thickness.		Depth.	
PENNSYLVANIAN SYSTEM—Continued.	*Ft.*	*In.*	*Ft.*	*In.*
Cherokee formation—Continued.				
Limestone, blue		10	739	10
Shale, black		9	740	7
Coal		11	741	6
Fire clay	2		743	6
Sandstone	10		753	6
Shale	29	6	783	
Fire clay	4		787	
Shale	31	6	818	6
Coal	1	6	820	
Fire clay	2	6	822	6
Limestone	1		823	6
Shale, soft, light to dark	12	6	836	
Limestone	2		838	
Shale, light to dark, soft	6		844	
Limestone	1		845	
Sandstone	4		849	
Shale, light to dark	12		861	
Coal	1	4	862	4
Dirty coal	1	8	864	
Sandstone	39		903	
Shale, blue to dark, pyrite	28	6	931	6
Coal	2		933	6
Shale, gray, sandy	8	6	942	
Fire clay and dark shale	3		945	
Coal	1	6	946	6
Shale seam		6	947	
Coal	1	4	948	4
Fire clay		8	949	
Sandstone, shaly	13		962	
Shale, light to dark	35	3	997	3
Sandstone, streaks of shale	80	3	1077	6
Shale	32	6	1110	
Sandstone, hard	3		1113	
Shale, dark	2	6	1115	6
Sandstone, soft	4	6	1120	
Shale, dark, sandy	15		1135	

GENTRY COUNTY.

The surface rocks of Gentry County are partially concealed under a thick mantle of glacial drift. The Shawnee and Douglas formations, which underlie the western and northern parts of the County, though poorly exposed on the drift-covered uplands, occupy a much greater area than the Lansing and Kansas City formations, which are well exposed along Grand River and other stream valleys in the southeastern part.

The total thickness of the Pennsylvanian beds in Gentry County probably ranges from about 1100 feet in the southeast corner to 1300 to 1500 feet below the uplands of the northwest corner.

The rocks of the county dip very gently in a westerly direction. The Salisbury-Quitman fold or anticline, however, which extends from Chariton into Nodaway County, crosses the southern part of Gentry in a southeast to northwest direction, paralleled on the north by a shallow syncline. These general structural features cause some variation in the direction of the regional dip.

The general character of the underlying strata is shown by the following log of a hole drilled by the Berlin Oil and Gas Prospecting Co. in 1913:

CONDENSED RECORD OF STRATA IN DRILLING NEAR BERLIN.*
NE. ¼, SW. ¼ SEC. 22, T. 61N., R. 31W.

(Altitude of surface at curb about 870 feet.)

Stratum.	Thickness.	Depth.
	Feet.	*Feet.*
Soil and gravel	14	14
PENNSYLVANIAN SYSTEM:		
Lansing formation:		
Plattsburg limestone:		
Limestone, hard	12	26
Shale, light blue	3	29
Limestone, soft	2	31
Lane shale:		
Shale	3	34
Limestone	3	37
Shale	2	39
Limestone	2	41
Shale	4	45
Limestone	2	47
Shale, blue	31	78
Kansas City formation:		
Iola limestone:		
Limestone and sand	2½	80½
Chanute shale:		
Shale	9½	90
Limestone, shelly	1	91
Shale	1	92
Sand	3	95
Shale	25	120
Drum limestone (probably includes Cement City limestone bed near base of Chanute shale):		
Limestone	18	138
Cherryvale shale:		
Shale	19	157
Limestone	3	160
Shale	4	164
Winterset limestone:		
Limestone	40	204
Galesburg shale:		
Shale	6	210
Bethany Falls limestone:		
Limestone	20	230

*Prospect well for coal, oil and gas, made with a churn drill in 1913 for the Berlin Coal, Oil and Gas Prospecting Co., in the NE. ¼, SW. ¼ sec. 22, T. 61N., R. 31W.

CONDENSED RECORD OF STRATA IN DRILLING NEAR BERLIN—Continued.

	Thickness.	Depth.
PENNSYLVANIAN SYSTEM—Continued.	*Feet.*	*Feet.*
Kansas City formation—Continued.		
Ladore shale:		
Shale	10	240
Hertha limestone:		
Limestone	10	250
Pleasanton formation:		
Shale	145	395
Henrietta formation:		
Limestone	2	397
Shale	35	432
Cherokee shale:		
Shale, black and coal (Lexington)	6	438
Shale, sandy	5	443
Limestone	6	449
Shale	121	570
Sandstone, red	6	576
Shale, blue	70	646
Sandstone, white	24	670
Shale, sandy	10	680
Sandstone	23	703
Slate, black	2	705
Shale, white and dark	38	743
Limestone	6	749
Shale, sandy	16	765
Limestone	2	767
Shale, sandy	3	770
Limestone	1	771
Shale	58	829
Coal	2	831
Slate	1	832
Coal	2	834
Sandstone	6	840
Shale	25	865
Limestone	2	867
Shale	16	883
Sandstone, white	56	939
Shale, dark	12	951
Sandstone	2	953
Shale, black	68	1021
Shale	71	1092
Sandstone	40	1132
MISSISSIPPIAN SYSTEM:		
Limestone	8	1140

Men in charge of the well claim driller made a mistake between 957 and 1,092 and that total depth should be 1,092 feet.

DEKALB COUNTY.

The Shawnee occupies a very small area in the extreme northwest corner, the Douglas underlies nearly all of the western half and portions of the upland in the eastern half of the area, the Lansing beds underlie most of the eastern tier of townships, while the Kansas City limestones are confined to the valley of Grindstone Creek, along the eastern border. As in most of the counties of this area, glacial drift deeply conceals the bed rock over the uplands and exposures are confined to the main stream valleys.

No wells in this county are known to have been drilled to the base of the Pennsylvanian. However, near Stewartsville, in the southwest corner, a well just over the line in Clinton County which started in the Douglas reached the Mississippian limestones at a depth of 1185 feet. The Berlin well, just north of DeKalb in southeastern Gentry County, started in the Lansing formation and reached the Mississippian formations at 1138 feet. Wells starting in the Kansas City formation in Grindstone Creek bottoms would doubtless reach the base of the Pennsylvanian, at depths of less than 1000 feet, probably less than 900 feet, but from the uplands of the western and northwestern townships it would probably require 1200 to 1300 feet of drilling to reach the Mississippian limestones.

No data are available concerning the detailed structural features of this county. In general, a rather well-defined syncline enters the county at the southeast corner and passes northwest. On the north the rocks slowly rise to the crest of the Salisbury-Quitman fold in Gentry County, and on the south to the crest of the Richmond-St. Joseph fold in Clinton County. The regional dip is to the northwest, though the general structural features have affected this to some extent.

DeKalb* is one of the very few counties in northwest Missouri where no tests for oil or gas have been made. The deepest well reported for the county is a water well 500 feet in depth on the farm of George Carl in the SE. ¼ sec. 23, T. 58N., R. 33W., near Clarksdale. In the SW. ¼ sec. 23, T. 60N., R. 32 W., near King City, a drill hole for coal has been sunk to a depth of 419 feet. So far as can be learned, these are the deepest borings in the county. No showings of oil or gas were reported in these or any of the shallower drillings in the area.

HARRISON COUNTY.

On the uplands bed rock is concealed nearly everywhere by the drift and occurs only sparingly along the larger streams. The best exposures are along Big Creek near Bethany and along Grand River, north and south of Cainesville, where the Kansas City limestones, especially the Bethany Falls member, appear.

*For deep wells near DeKalb county see paragraphs on Clinton and Gentry counties.

From these exposures near Bethany the Bethany Falls limestone takes its name. Grand River, along the entire eastern border of the county, has cut its valley into the Pleasanton shale, exposing the oldest beds which appear in the county. The Kansas City limestones, which, roughly speaking, form the country rock over the eastern half of the county west to Big Creek, are overlain in the western portion by the Lansing and Douglas formations. Outcrops of the two latter are almost negligible because of the drift covering.

The thickness of the Pennsylvanian rocks has been recorded at Cainesville in a deep well as 858 feet. This well, however, started in the Pleasanton shale in Grand River valley and the thickness does not include the higher formations on the upland to the west. The maximum thickness or depth, to the Mississippian limestones, is not less than 1200 feet in the northwest part of the county and probably from 1000 to 1200 feet over the greater part of the upland.

In general the strata of the County dip slightly to the southwest though several folds interfere with this dip. The Trenton anticline enters the County at the southeast corner and passes in a northwest direction into Worth, paralleled on the north by a rather well-marked syncline. A notable rise of the rocks takes place from this syncline north to the Iowa line.

The following logs indicate the character of strata penetrated with depth. A second well drilled by the Keystone Co. in the SE. ¼ Sec. 5, T. 64N., R. 26W. reached a depth of 1610 feet. In 1910 a well 997 feet deep located in the SW. ¼ NW. ¼ Sec. 12, T. 64N., R. 26W. was drilled to the Mississippi lime. One mile west of Bethany a well 654 feet deep yields artesian water. At Blythedale a coal prospect was sunk 610 feet, at New Hampton prospecting revealed 778 feet, and at Gilman City 450 feet. No showings are reported in these drillings.

DRILLING AT SOUTH EDGE OF CAINESVILLE (NW. ¼ NE. ¼ SEC. 13, T. 65N. R. 26W.)

	Thickness.	Depth.
	Ft. In.	*Ft. In.*
Drift	24	24
PENNSYLVANIAN SYSTEM:		
Pleasanton shale:		
Shale, blue, sandy	76	100
Shale, light gray	36	136
Shale, blue, sandy at top, with limestone nodules below	20	156

DRILLING AT SOUTH EDGE OF CAINESVILLE—Continued.

	Thickness.		Depth.	
	Ft.	*In.*	*Ft.*	*In.*
PENNSYLVANIAN SYSTEM—Continued.				
Henrietta formation:				
Limestone (Pawnee)	4		160	
Shale, black and bituminous at top, blue below	4		164	
Limestone	5		169	
Shale, gray, nodular	15		184	
Shale, black and bituminous at top, blue below	7		191	
Limestone	5		196	
Shale, black, sandy	4		200	
Limestone	2		202	
Cherokee shale:				
Shale, black, bituminous	3		205	
Coal (Lexington)	1		206	
Clay shale, black	7		213	
Shale and sand	21		234	
Sandstone	9		243	
Shale	21		264	
Coal (Mulky)	1	6	265	6
Shale, black, sandy in upper part	29		294	6
Coal (Bedford)	1	3	295	9
Shale	9		304	9
Coal (Bevier)		6	305	3
Shale	36		341	3
Coal (Tebo)		9	342	
Shale, blue, sandy	17		359	
Coal		6	359	6
Shale	23		382	6
Coal	1	8	384	2
Shale	12		396	2
Coal	1	2	397	4
Shale, blue, sandy	3		400	4
Coal		6	400	10
Shale	21		421	10
Coal	1		422	10
Shale	53		475	10
Coal (Cainesville), mined	4	4	480	2
Shale	36		516	2
Coal	2	2	518	4
Shale, light blue	4		522	4
Coal	3	6	525	10
Shale, light blue	17	7	543	5
Sandstone and shale, black and gray	9		552	5
Shale, blue	1	6	553	11
Coal	1	6	555	5
Shale, blue, sandy	19	3	574	8
Coal		6	575	2
Shale, blue, sandy	5		580	2
Sandstone	20	4	600	6
Sandstone, oil	49	6	650	
Shale	90		740	
Sandstone, water	20		760	
Shale	20		780	
Sandstone, showing of oil	48		828	
Shale	27		855	
Sandstone	3		858	
Limestone	232		1090	
Sandy shale	20		1110	

Record to 600 feet is from diamond drill hole sunk by Grand River Coal & Coke Co. Below 600 feet the record is from the drillers' log of the Keystone Oil & Gas Company's well. The two holes are very close together.

DRILLERS' RECORD OF KEYSTONE OIL & GAS CO., NEAR MURPHY SCHOOL HOUSE (SE. ¼ SEC. 5, T. 64 N., R. 26 W.)

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	15	15
Lime shell	4	19
Blue slate	31	50
Brown shale	20	70
Blue slate	25	95
Coal	4	99
Red rock (shale)	43	142
Brown slate	41	183
Brown shale	32	215
Sand, fresh water	28	243
Blue slate	27	270
White fire clay	25	295
Blue slate	32	327
Brown shale	28	355
Blue slate	18	373
White lime	37	410
Fresh water, sand	45	455
Blue slate	25	480
Gray shale	60	540
Blue slate	39	579
Fresh water sand	21	600
Brown shale	37	637
Brown water sand	14	651
Blue slate	19	670
Brown shale	18	698
Sand dry	12	710
White lime	70	780
Shale and lime shells	35	815
Lime	30	855
Sand	13	868
Lime	82	950
Blue slate	2	952
Fresh water sand	14	966
Lime	6	972
Sand	23	995
Lime	72	1067
Red rock shale	17	1084
Lime	46	1130
White shale	25	1155
Lime	15	1170
Brown shale	6	1176
Lime	6	1182
Red shale	7	1189
Lime	184	1373
Brown lime	77	1450
White lime	15	1465
Brown lime	105	1570
Sandy lime	40	1610

DAVIESS COUNTY.

The Lansing beds lie beneath the drift on the uplands of the southwest part of the County and are not well exposed. The Kansas City limestones underlie the greater part of the area and are conspicuously exposed along Grand River and Muddy Creek south from Jameson. Both of these streams have, however, cut down below the Kansas City formation well into the Pleasanton shale which underlies the bottoms. The thickness of Pennsylvanian deposits underlying Grand River bottoms south of Gallatin cannot greatly exceed 550 to 600 feet. A recent drilling near Gallatin, starting in the lower part of the Kansas City limestone formation, reached the Mississippian limestones at a depth of approximately 680 feet. From the uplands in the western and northern parts of the county, however, the depth to the base of these deposits would be considerably greater, in places as much as 1000 feet.

The normal dip of the rock beds in this area is very gently to the northwest, much modified by general folding. The crest of the Salisbury-Quitman anticline crosses the County in a northwest direction from near the southeast corner to a point where the west line of Daviess meets the adjoining corners of Gentry and DeKalb Counties. The axis of this fold roughly follows Grand River across this area, and it is paralleled, on the north by a synclinal depression, north of which the rocks rise to the Harrison County line. To the south of the anticline the rocks fall to the Caldwell County line, dipping gently to the southwest.

The features above described constitute the general structural conditions of the area. There is evidence also that some local folding has taken place, especially near Gallatin, though this folding is very low and is not marked by any notable dips. Over most of the County nothing is known concerning the details of the local structure and the heavy drift covering makes detailed structural mapping impossible.

Up to the present time no oil of gas has been found in Daviess County. A test near Gallatin reached a depth of 680 feet, at which point Mississippian limestones were encountered and drilling was stopped. A second test near Gallatin, drilled by Oklahoma parties and completed in August, 1919, reached 2320. The base of the well undoubtedly rests in rock of Cambro-Ordovician age or older.

Several drill holes sunk in prospecting for coal near Gallatin reached depths of between 400 and 500 feet but in none of these were showings of oil or gas reported.

NORTH CENTRAL COUNTIES IN THE PENNSYLVANIAN AREA.

The north central counties include those east of Harrison, Davis, Caldwell, and Ray, and west of Scotland, Knox, Shelby, Monroe, Audrain, and Callaway, north of Missouri river, and comprise an area nearly everywhere underlain by the Lower Pennsylvanian. The Upper Pennsylvanian is practically absent except along the western edge in parts of Carroll, Livingston, Grundy, and Mercer counties. The underlying Mississippian rocks appear at the surface in southern Howard and Boone, and in eastern Macon and Adair Counties. To the east and south of this district, the Pennsylvanian despoits are absent or so thin as to be devoid of oil or gas possibilities.

Of the Lower Pennsylvanian formations present in the area, the Cherokee shale alone underlies most of the southern and eastern parts. A rather deep synclinal trough in Howard County contains the only Henrietta and Pleasanton beds in the southern portion. The central and southwest sections are underlain chiefly by the Pleasanton formation, bordered by a narrow fringe of Henrietta which separates the Pleasanton and Cherokee.

The Pennsylvanian formations vary greatly in thickness over this area, especially the Cherokee shale. In Boone County the total thickness of this formation remaining is only about 150 feet, in Howard it is about the same, but to the west in Carroll County it increases to 340 feet. In Macon and Randolph Counties the total thickness is less than 200 feet while to the west in Linn County it increases to 310 feet and in Livingston to 450 feet. The maximum thickness in Mercer County is not far from 650 feet. There is, therefore, a variation of some 520 feet in the thickness of the Cherokee formation remaining in this district. The Henrietta does not exceed 50 feet at any known point and is only 26 feet thick in Howard County. The formation varies between these limits in the district. The Pleasanton varies between these limits in the district. The Pleasanton is 100 to 125 feet thick in Adair and Putnam counties, and 150 feet thick in Mercer and Grundy. The total thickness of the Lower Pennsylvanian deposits in the area, therefore, shows the remarkable variation of from 256 feet to about 850 feet. The unconsolidated surface deposits of the area consist chiefly of glacial drift which is present in considerable thickness over the northern counties completely concealing the bed rock over wide area. This drift mantle must be taken into consideration in making estimates on the depths to the base of the Pennsylvanian.

The total depth to the base of the Pennsylvanian is least around the southern and eastern borders of the region, and increases toward the northwest norner. The maximum, in the northwest corner of Mercer County is about 900 feet. A deep well at Cainesville, on the Mercer-Harrison County line, starting from a valley elevation of 854 feet above sea level, reached the base of the Pennsylvanian rocks at a depth of 856 feet, or approximately at sea-level. The highest Pennsylvanian beds in this locality are about 50 feet above the mouth of this well. From Kirksville west to Cainesville, the depth to the base of the Pennsylvanian beds increases from 450 to 900 feet; from Moberly northwest to Cainesville, from 145 to 900 feet, from Fayette northwest to Cainsville, from 135 to 900 feet. Over much the greater part of the area, the Mississippian limestones are reached at depths of less than 500 feet, and only in a small portion of the northwest part of the district does this depth exceed 600 feet.

The general regional dip of the rocks is to the northwest at a very low angle (only a small fraction of 1 degree) but in the northern part in Putnam and Mercer Counties the dip swings to the southwest. Over a considerable part of the area in Macon, Linn, Sullivan, and Chariton counties, the rocks lie practically flat and it is necessary to work over a very large area to determine the presence of any regional dip.

The southeast to northwest folds are less prominent in this area than to the west. The more marked and persistant folding seems to die out east of Mercer, Grundy, and Livingston counties. There are, however, several well-defined but shorter anticlines present in the area with southeast to northwest trends. One of these passes from north central Adair County northwest through eastern Putnam. A second crosses Linn County from southwestern Macon and a third, in norther Boone, brings the Mississippian limestones to the surface.

The only locality where detailed structural mapping has been done is Mercer County.

Aside from meager showings of oil and gas in northwestern Carroll County (p.174) the many wells drilled in this entire district have been sunk without important results. The few reported discoveries of gas have peen investigated and found to be either without foundation or of such minor importance that no significance could be attached to them.

The following is a partial list of wells, including several sunk for other purposes than that of obtaining oil or gas.

PARTIAL LIST OF DEEP WELLS IN NORTH CENTRAL COUNTIES.

County.	Owner.	Location.	Depth.	Date.	Base of Pennsylvanian.	Remarks.
Mercer	W. H. Odneal	NE. ¼ sec. 33, T. 64 N., R. 22 W.	905	1911	....	Much water.
	Citizens of Lineville	Lineville	685	1911	Not reached.	Coal prospect.
	Citizens of Saline	Saline	533	1913	Not reached.	Coal prospect.
	T. W. Ballew	Princeton, 1 mile south	603	1905	Not reached.	Coal prospect.
	H. B. Stiles	Topsy, ¼-mile north	501	....	Not reached.	Water well.
Grundy	Trenton Oil, Gas & Mng. Company	Trenton, 1 mile west	1198	1911	640	Oil and gas prospect.
	Trenton Mng. Company	Trenton	605	1888	555	Coal prospect.
	John Kilburn	Chula, sec. 33, T. 60 N., R. 23 W.	565	....	....	Salt water.
	H. W. Lauman	Laredo, NW. ¼ sec. 15, T. 60 N., R. 23 W	515	1907	Not reached.	Salt water.
	A. Oyler	Brimson, NW. ¼ sec. 22, T. 63 N., R. 25 W	415	....	Not reached.	Dry hole.
Livingston	City of Chillicothe	Chillicothe	1205	....	408	Salt water.
	Adams well	Chillicothe, 3 miles northeast	1101	....	481	Salt water.
	Geo. Houx	Avalon, 3 miles east	700	....	320	Dry hole.
	G. H. Lawson	Utica	421	....	420	Salt water.
	J. J. Phillip	Chula	648	....	378	Salt water.
	S. R. McCreary	Mooresville	490	1914	Not reached.	Salt water.
	W. Walker	Dawn	538	1913	535	....

PARTIAL LIST OF DEEP WELLS IN NORTH CENTRAL COUNTIES—Continued.

County.	Owner.	Location.	Depth.	Date.	Base of Pennsylvanian.	Remarks.
Carroll	(See page 176.)					
Chariton	....	Brunswick	1505	1888	140	Flowing salt water well.
	....	Triplett	1475	1906	147	Flowing salt water well.
	John Heisel	Brunswick	447	....	180	Salt water.
Linn	....	Brookfield	800 +	1918	....	For oil and gas.
	....	Marceline	2004	1907	233	For oil and gas.
	T. Stevenson	Linneus, sec. 3, T. 58 N., R. 21 W	583	1909	378	Salt water.
	City of Brookfield	Brookfield	570	1901	....	Salt water.
	C. J. Searcy	Sec. 14, T. 60 N., R. 22 W	475	1907	Not reached.	Salt water.
Sullivan	J. T. Watson	Harris, sec. 34, T. 64, R. 21 W	515	1901	....	Small amount fresh water.
	John Moberly	Humphries, sec. 22, T. 62 N., R. 22 W	425	1897	....	Salt water.
	J. E. Murens	Sorrel, 2 miles east of	407	1914	....	Very little water.
Putnam	City of Unionville	Unionville	700	....	545	Very little water.
Schuyler	W. P. Hall	Lancaster	361	1905	Not reached.	Deepest well reported in county.
Adair	City of Kirksville	Kirksville	1290	90's	450	Salt water.

Macon	....	Macon	1000	1888	215	Salt water.
	R. Y. Powell	College Mound	953	1910	144	Salt water.
	J. M. Dennison	Ethel	522	1914	328	Fresh water.
	Northwestern Coal Co.	Bevier	450	1895	268	Coal prospect.
Randolph	....	Moberly	2100	....	136	Salt water.
	City of Moberly	Moberly	800	1914	145	Fresh water.
	....	Yates	509	1910	....	....
	E. D. Hammett	Huntsville, sec. 23, T. 54 N., R. 15 W.	1575	1905	57	Salt water.
	John Lamb	Jacksonville	360	1915	289	Showing of oil reported at 288 feet.
	B. Harding	Moberly, 2 ½ miles south	754	1915	228	....
	Chas. Damerson	Randolph Springs	960	1880	....	Salt water.
Howard	Fayette Mineral Well Co.	Fayette	870	90's	135	Salt water.
	Marshall Well	Boonslick	1002	80's	90	Salt water.
	Boonville Oil Prod. Co.	New Franklin	1400 ±	1917	Surface.	Salt water.
Boone	Centralia Development Co.	Centralia	1850	1910	242	Fresh water.
	City of Columbia	Columbia	818	1911	74	Fresh water.

The above list of deep wells is not quite complete and does not include the hundreds of shallower water wells 100 to 400 feet deep sunk in the area. Schuyler, Putnam and Sullivan Counties contain very few wells and none of any great depth, but in all of the other counties one or more deep borings have been sunk.

MERCER COUNTY.

The Kansas City and Pleasanton formations, though heavily covered with glacial drift on the uplands, are both well exposed along the "Breaks" of Weldon River from Princeton south, and locally along some of the smaller streams.

Only one well in the County has ever been drilled to the base of the Pennsylvanian deposits, but something of their general thickness can be told from deep wells near Cainesville, Harrison County, from which it would appear that a maximum of at least 900 feet of Pennsylvanian occurs beneath the upland of western Mercer. In the river bottoms near Princeton the records of drilling for coal indicate that the Mississippian limes stones lie 750 feet to 850 feet below the surface. In the southeast part of the County the total thickness of the Pennsylvanian rocks is affected by a thinning of the Cherokee shale in this direction and there are doubtless localities where the depth would be less than 750 feet.

The regional dip of the rocks is toward the southwest. The College Mound-Bucklin anticline crosses from southeast to northwest from Grundy into Harrison County as a rather narrow well-defined fold, flanked on the southwest and northeast by equally well-defined narrow synclines*. Over the remainder of the County the rocks rise gently in a northeast direction to the Iowa line.

A well located on the S. D. Odneal farm, in the NW. 1/4 NE. 1/4 sec. 33, T. 64 N., R. 22 W., about one-fourth of a mile west of the County line, was sunk in 1911. It has a total depth of 905 feet and must have entered the Mississippi lime. No records are available but so far as reported no showings of oil or gas were encountered.

Several drill holes for coal have been sunk in various parts of the County, near Princeton, Mercer, Saline, and Lineville. These tests reached depths of 400 to 682 feet, and most of the holes bottomed in the lower half of the Cherokee shale.

*See plate 11 for a small structure mapped in Princeton.

DRILLING THREE-FOURTHS MILE SOUTH OF LINEVILLE,* (SW. ¼ NW. ¼ SEC. 32, T. 67 N., R. 23 W.)

	Thickness.		Depth.	
	Ft.	*In.*	*Ft.*	*In.*
Drift, by driller's log	237		237	
Shale, sandy to argillaceous, green to drab	230		467	
Shale, red, purple and green	4		471	
Shale, black, soft		4	471	4
Shale, olive-green	3		474	4
Limestone, gray to green, fine-grained	4		478	4
Shale, dark gray or brown, streaks of black shale near bottom	6		484	4
Shale, blue-gray, sandy	3		487	4
Sandstone, light bluish-gray, micaceous	24		511	4
Shale, black, bituminous		3	511	7
Shale, gray at top, dark drab at base, sandy to argillaceous	14	3	525	10
Limestone, gray		10	526	8
Shale, dark drab, no sand or mica	2	2	528	10
Coal, bony, poor quality		10	529	8
Shale, drab, fine-textured	12	6	542	2
Sandstone, gray, shaly, fine-grained	2	4	544	6
Shale, dark gray, micaceous	17	2	561	8
Coal, fair		11	562	7
Shale, gray, fine-textured, some pyrite	15		577	7
Coal, bony, poor		4	577	11
Shale, gray, fine-grained	3	4	581	3
Sandstone, gray, fine-grained	6	2	587	5
Shale, gray, dark at base, sandy streak in middle	2	6	589	11
Shale, black, bituminous		6	590	5
Coal, only fair	2	9	592	2
Shale, dark gray to blue, argillaceous	12	4	604	6
Coal	1	9	606	3
Shale, light gray	4		610	3
Shale, dark blue	9		619	3
Coal		10	620	1
Shale, light gray	4	4	624	5
Shale, mostly dark blue	30	6	654	11
Shale, sandy, blue and white, with much water	27	5	682	4

*Slightly modified from record kindly furnished by J. H. Lees, Assistant State Geologist of Iowa, who examined the core.

No oil or gas showings are reported to have been encountered in any of these drillings. With the exception of one or two water wells near Half Rock, which are about 500 feet deep, no other drillings in the County are known to have reached an important depth. The area is therefore practically untested.

GRUNDY COUNTY.

The Kansas City limestone, the highest rocks beneath the glacial drift in Grundy County, occurs only beneath the upland west of Grand River; in the northwest part of the county on the divides between Grand River and Weldon River; and between Weldon River and East Muddy Creek. Over most of the county, the formation directly below the drift is the Pleasanton, consisting of about 150 feet of shale and sandstone with a few thin seams of limestone. In the southeast part of the area, south of Galt, and east of Laredo, Medicine Creek has cut through the Pleasanton and through the underlying Henrietta formation into the Cherokee shale. This is the only area, however, in which beds lower than the Pleasanton are exposed.

The base of the Pennsylvanian was reached in a deep drill hole at Trenton, at a depth of 555 feet; about one mile west of Trenton on the bank of Grand River, at a depth of 640 feet; and five and one-half miles southeast of Trenton at only about 500 feet. Over most of the County it is probable that from 500 to 650 feet of drilling would reach the base of the Pennsylvanian rocks, though on the uplands of the western and northwestern townships this depth may be increased to 750 feet or probably more, while it is certain that in the southern part, in Medicine Creek bottoms, the Mississippian limestones would be reached at depths of less than 500 feet.

The regional dip of the rocks in Grundy County is very gently to the northwest. The broad, well-defined Trenton anticline, the dominant structural feature, enters the County in the southeast corner and passes northwest through Trenton, bringing the rocks along this fold to a position notably higher than to the northeast and southwest. It is flanked on the northeast by a shallow parallel syncline which separates it from the College Mound-Bucklin anticline. No mapping has been done to determine the details of the more local structural features of the area.

In 1911, the Trenton Oil, Gas and Mining Company sunk two test wells for oil and gas near Trenton. The first well was drilled about one mile west of town at Grand River bridge in the SW. 1/4 sec. 18, T. 61N., R. 24W. This well reached a depth of 1198 feet, starting in the Pleasanton shale formation, encountering the Mississippian limestones at 640 feet, and bottoming in older beds. Well No. 2 was drilled about four and one-half miles southeast of Trenton on the McVey farm in sec. 10, T. 60N., R. 24W. This well was sunk to a depth of only 560 feet, but it is reported that the last 60 feet was drilled in the Mississippian limestones. No showings of oil or gas are reported to have been encountered in either well.

The Grundy County Coal Company sunk a diamond drill hole in the bottom of their shaft at Trenton to a depth of 605 feet, reaching the Mississippian limestones at 558 feet. A water well was also drilled near Dunlap, in the NE. 1/4 sec. 27, T. 62N., R. 33W., to a depth of about 650 feet, but no record was preserved. Water wells near Chula, Laredo, Alpha, and Brimson have been sunk to depths of 500 feet or more, reaching the base of the Cherokee shale, but no showings of oil or gas have ever been reported from any of the wells in the County.

CORE DRILLING IN OLD COAL SHAFT AT TRENTON.

	Thickness.		Depth.	
	Ft.	*In.*	*Ft.*	*In.*
Depth of shaft			234	5
Clay, sandy	1	5	235	10
Shale, black	6	6	242	4
Clay, shale and sandstone	15	3	257	7
Shale, blue, sandy	12		269	7
Shale, black, bituminous	7	9	277	4
Shale, brown and black	67	11	345	3
Coal		2	345	5
Clay and sandy shale	8	6	353	11
Shale, black	16	6	370	5
Limestone, with thin sandy shale partings	9	9	380	2
Shale, black at top, rest brown and sandy	23	11	404	1
Sandstone, micaceous	28		432	1
Shale, bituminous, sandy	4		436	1
Sandstone, micaceous	2		438	1
Shale, black, sandy in upper part	22	3	460	4
Sandstone, micaceous, with one-inch layers of black shale	44	11	505	3
Sandstone, coarse, friable	50		555	3
Limestone, cherty (Mississippian)	41	5	596	8
Limestone, crystalline (Mississippian)	9	2	605	10

LIVINGSTON COUNTY.

Though the County is for the most part heavily drift covered, the lower limestones of the Kansas City form a conspicuous escarpment in the south central, southwest, west central, and northwest parts. The total area underlain by these rocks is, however, relatively small, and consists of the highest uplands. The Pleasanton shale and the underlying Henrietta formation directly underlie the drift over the greater part of the County, with the Cherokee shale outcropping in a wide strip on both sides of Grand River and along Medicine Creek.

The northwest regional dip is very slight, the rocks lying almost horizontal. The Salisbury-Quitman anticline crosses the area from southeast to northwest through Chillicothe. The folding is low and broad, embracing the greater part of the County. On the north a parallel synclinal depression, passing near Wheeling, is much more sharply marked (see Pl. 4) and is probably accompanied by a little faulting. Although no detailed structural mapping has been done in the County, notably irregular dips near Graham's Mill, Spring Hill, Utica, Mooresville, and other places, suggest the possible presence of local anticlines or other structures which might be favorable to the accumulation of oil pools.

In 1901 a test well for oil and gas was sunk to a depth of 1101 feet, on the Adams farm three miles northeast of Chillicothe, in sec. 28, T. 58 N., R. 23 W., by the Chillicothe Mineral Mining Company. The well reached the base of the Pennsylvanian rocks at a depth of 481 feet and is bottomed in Lower Ordivician or Ozarkian. No oil or gas was found in the Pennsylvanian beds and the well was abandoned at 1101 feet with salt water standing within 125 feet of the surface. No other tests for oil were made in the County until 1918, when a well was drilled near Mooresville. This well was abandoned in the Mississippian limestones at about 620 feet.

A number of water wells have been drilled below the base of the Pennsylvanian rocks at Chillicothe, in search of a water supply for the City Light Plant. The following record gives a typical section of the Pennsylvanian which varies somewhat in thickness throughout the County.

RECORD OF DEEP WELL AT CHILLICOTHE, LIVINGSTON COUNTY, SEC. 28, T. 58 N., R. 23 W.

	Thickness.	Depth.
	Feet.	*Feet.*
Yellow clay	30	30
Soft yellow sandstone	15	45
Light colored shales	11	56
PENNSYLVANIAN SYSTEM:		
Des Moines (425 feet):		
Hard conglomerate, cased from top, 8¼-inch	2	58
Black "slate"	3	61
Soft light colored gray shales	69	130
Sandstone, with 6-inch coal	3	133
Light colored shales	57	190
Black "slate"	4	194
Gray shales	36	230
Red and greenish-gray shale; caved	8	238
Dark shales with barren coal seam; cased from top 7½ inch	13	251
Limestone	1	252
Gray shales	45	297
Brown "smut"	3	300
Drab and purple clays and shales, with coal particles	48	348
Soft, nearly white sandstone, rounded grains	3	351
Black sand shales; saline water at 406 feet	79	430
Porous conglomerate; saline water	12	442
White, plastic fire clay	10	452
Sandy coal and fire clay, gray to purplish	29	481

MAP SHOWING STRUCTURE BASED ON THE B

RECORD OF DEEP WELL AT CHILLICOTHE—Continued.

	Thickness.	Depth.
	Feet.	*Feet.*
MISSISSIPPIAN SYSTEM (and older?):		
White, very hard, flinty limestone	3	484
Soft, white limestone, with flinty layers and a soft white substance (gypsum) not a carbonate	38	522
Sandstone, fire clay, "slates" and pebbles, saline water	62	584
Soft, chalky limestone	12	596
Flint or quartizite sandstone, shales	6	602
Black shales, very little lime	14	616
Soft, sandy, gray, calcareous rock	20	636
White and blue calcareous shales and flint	9	645
Soft, sandy, gray, calcareous rock	69	714
Dark, plastic to hard, jointed clay, caved badly, cased 4 ½-inch, at 762 feet	48	762
White limestone	4	766
Dark "hydraulic" limestone	13	779
Pure, soft, white limestone	21	800
Brownish, mealy limestone, saline water	46	846
Crystalline limestone	8	854
Dark, impure limestone, saline water	27	881
Fine yellowish-gray lime sand	25	906
Light to dark gray limestone, with some yellowish sand	11	917
Gray to orange sandstone, with some lime, gas	65	982
Limestone, with black organic matter	8	990
Limestone, with gray sandstone at top	75	1065
Fine brown lime sand, with pyrite	11	1076
Hard quartzite	20	1096
Pure white sand, with saline water, caved	5	1101

Note.—From 481 to 800 is believed to be Burlington-Keokuk.

PUTNAM COUNTY.

The entire western half of Putnam County is so heavily covered with glacial drift that there are practically no outcrops of any kind. East of Unionville, Blackbird and Shoal Creeks have cut deeply through the drift exposing the Pleasanton, Henrietta and Cherokee formations. The Pleasanton shale underlies the drift over by far the greater part of the area and the lower formations are only exposed along the "breaks" and in the bottoms of the streams in the eastern townships. The Henrietta contains several thin limestone beds which mark the outcrop of this formation.

The maximum thickness of the Pennsylvanian is along the west edge of the County, eastward the Cherokee alone is present and at Mendota the Mississippian limestone was reached at a depth of 323 feet. Very little is known of the detailed structural fractures. The Kirksville-Mendota anticline crosses the eastern townships in a southeast northwest direction. It is a very low broad fold starting north of Kirksville and extending across the Iowa line. Drilling for coal has indicated another fold near Powersville extending through Lineville in Mercer County.

WELL AT POWER HOUSE, UNIONVILLE.

	Thickness.	Depth.
	Feet.	*Feet.*
Clay and soil, Lexington coal apparently replaced by drift	220	220
Shale, black, "slaty"	5	225
"Rock"	4	229
Clay	4	233
Shale, black "slaty"	12	245
Clay	32	277
Sandstone	30	307
Shale, black, "slaty"	3	310
Shale	42	352
Shale, clay and "slate"	57	409
Black cuttings	21	430
Shale, etc	90	520
Sandstone	25	545
White cuttings, hard, water-bearing, probably Mississippian limestone	..	700

In 1918, the Dome Development Company of Pittsburg, Pennsylvania, sunk a test well 1195 feet deep on the Alexander farm about two miles northwest of Worthington, on the Kirksville-Mendota anticline. A record of this well has been submitted to the Bureau by Mr. Roswell H. Johnson of Pittsburg, but the record was not kept in sufficient detail to allow a complete classification. The base of the Pennsylvanian deposits was reached at a depth of 367 feet and the base of the Mississippian beds, probably at 795 feet. Below this depth the well penetrated Devonian, Silurian and Ordovician rock but the limits of these systems cannot be outlined from the record. The sandstone reached at 1157 feet, according to Mr. Johnson, had the characteristic type of sand grains for the St. Peter, and probably is that formation.

No oil was encountered in the Pennsylvanian, but in a sand reached at a depth of 826 feet, a showing of oil is reported. This sand occurs only 33 feet below what is believed to be the base of the Mississippian formations, from an interpretation of the log, and is probably of Devonian age. In this case, the discovery is important both because it is the first oil to be found in Devonian beds in northern Missouri and because it suggests the possible importance of low folds such as the Kirksville-Mendota anticline in aiding accumulation.

Mr. Johnson states that a sample from this well is an "asphaltic oil without any strong sulphur odor, and of medium gravity." The amount of oil obtained cannot be stated at the present time as water difficulties have been encountered which will probably make exploitation of the well impossible.

Another well was drilled in SW. 1/4 S E. 1/4 Sec. 16, T. 64N., R. 16W., which reached the base of the Pennsylvanian at about 340 feet, and bottomed at 834.5 feet. Showings of oil were reported at 748 feet and 834.5 feet, but there has been no commercial production.

DRILLERS' LOG, DOME DEVELOPMENT CO., WELL NO. 1, ALEXANDER FARM, NE. ¼, SE. ¼ SEC. 19, T. 65 N., R. 16 W.

	Thickness.	Depth.
	Feet.	*Feet.*
Drift:		
Soil	5	5
Clay	95	100
PENNSYLVANIAN SYSTEM:		
Cherokee:		
Shale	150	250
Lime	5	255
Shale	45	300
Lime	6	306
Shale	61	367
MISSISSIPPIAN SYSTEM:		
Lime	38	405
Water sand	7	412
Shale	33	445
Lime	260	705
Sand	5	710
Lime	65	775
Blue clay	20	795
SYSTEMS OLDER THAN MISSISSIPPIAN:		
Lime, showing oil	33	828
Sand	7	835
Lime	185	1015
Sand	80	1095
Lime	10	1105
Sand	40	1145
Lime	12	1157
Sand (St. Peter), salt water	38	1195

Aside from the well above mentioned, a well at the City Power House, Unionville, which is 700 feet deep, and several drill holes for coal near Mendota, between 300 and 400 feet in depth constitute the only drillings of importance, in the County.

SULLIVAN COUNTY.

Sullivan County, especially the northern half, is heavily covered with glacial drift. Over most of the County, just below the drift lies the Pleasanton shale. The only higher beds occur in the central part around Milan, where, due to a synclinal depression, the basal Kansas City limestones are well exposed. Beds lower than the Pleasanton outcrop in narrow strips along Locust, Yellow, and Spring Creeks. Wells drilled over at least eight-tenths of the County will enter the Pleasanton beds at the surface or just beneath the drift.

At Milan, a coal shaft starting in the Pleasanton reached the Bevier coal at 220 feet. Drill records in surrounding counties show that from 200 to 300 feet of the Cherokee shale lies below this coal bed and above the Mississippian limestone. It would appear, therefore, that the Mississippian beds lie between 420 and 520 feet below the mouth of the coal shaft at Milan. It is believed that over much of the upland area in the County, depths of 450 to 550 feet would reach the base of the Pennsylvanian strata. This depth would doubtless be somewhat greater on the higher hills and less in the valleys.

So far as has been observed, the rocks in Sullivan County lie almost flat. However, a syncline passing southeast to northwest, through Milan, is shown by the low position of the Kansas City limestones at that point, and an anticline known as the College Mound-Bucklin anticline is revealed by the relatively high position of certain beds in the southwest corner of the County.

In the northwest part of Sullivan County near Harris small amounts of gas have been reported from one or two water wells, at depths of about 200 feet, and from the descriptions of the materials penetrated, it is believed that the gas comes from the glacial drift. The amount was small and has never been utilized. Occurrences of gas in glacial drift and other unconsolidated deposits containing buried vegetable matter are not uncommon, but such occurrences are usually not of commercial importance. Wells sunk in the thick drift deposits of north Missouri often encounter buried logs, twigs and even leaves which, through slow decay, would form the source for small quantities of gas.

LINN COUNTY.

The Cherokee shale alone underlies the southern townships, except along the eastern edge, and is exposed along the principal streams north to the County line. Along the main valleys the full thickness of the Henrietta shales and limestones is exposed, and on the uplands in the northern half of the County exposures of the Pleasanton shale and sandstone appear where the drift has been removed.

At Marceline and Brookfield, in the southern part of the area, drill holes have reached the Mississippian limestones at depths of 233 and 294 feet, respectively. The thickness of the Cherokee shale at several localities has been shown to vary from 225 to 300 feet the overlying Henrietta does not exceed about 25 feet, and the full thickness of the Pleasanton is estimated at about 100 feet. There are, therefore, about 350 to 425 feet of Pennsylvanian beds in the county. Considering the overlying drift, the maximum depth to the Mississippian limestones should not greatly exceed 550 feet at any point, and over most of the area these limestones will doubtless be encountered at shallower depths.

So far as known, the rocks over most of Linn County lie practically flat. The College Mound-Bucklin anticline, a very low fold passing in a southeast to northwest direction through Bucklin, is the most prominent general structural feature known. Very slight folding has also been recognized in the western part of the County. A few miles southeast of Laclede, at Woodland Mills (near center of Sec. 14, T. 57N., R. 21W.) over a small area the rocks dip as steeply as 80°, and there is evidence of sharp folding and faulting. This is one of the small areas of marked disturbance commonly found in the Pennsvlvanian region.

In 1907, a deep test for oil and gas was completed at Marceline. In a copy of the record furnished by Mr. Geo. W. Early, in charge of the drilling, a showing of gas is noted in sandy shale five feet thick which was reached at a depth of 183 feet.

LOG OF MARCELINE TEST WELL.

	Thickness.	Depth.
	Feet.	*Feet.*
Surface	20	20
PENNSYLVANIAN SYSTEM:		
Cherokee shale:		
Sandstone	5	25
Clay	2	27
Sand	5	32
White shale	18	50
Coal	1	51
Fire clay	2	53
Lime	2	55
Shale	2	57
Sandstone	6	63
Shale	7	70
Hard lime	2	72
Shale	56	128
Soapstone	2	130
Sandy shale	10	140
White shale	10	150
Black shale	28	178
Sandy shale, gas	5	183
Shale, dark	50	233
MISSISSIPPIAN SYSTEM:		
Limestone	40	273
Shelly lime and sand	10	283
Lime and flint	92	375
White sand	5	380
Lime, flinty	165	545
Green shale	2	547
Lime	45	592
Green shale	2	594
Lime	107	701
UNDIFFERENTIATED, DEVONIAN, ORDOVICIAN, AND OLDER BEDS:		
Green shale	3	704
Lime	20	724
Green shale	5	729
Lime	70	799
Green shale	5	804
Lime	46	850
Green shale	2	852
Lime	97	949
White sand	155	1104
Limestone	900	2004

CHARITON COUNTY.

A small tongue of Henrietta and Pleasanton extends into the north central part of the area south from Marceline, and a narrow channel sandstone occupies an east-west strip through Salisbury, but aside from these relatively unimportant patches, the Cherokee alone is present. There is, consequently, no great thickness of Pennsylvanian beds in the County.

Over the southern part of the area a number of wells have completely penetrated the Pennsylvanian rocks and entered the

Mississippian limestones at depths ranging from 140 to 180 feet, and in the northern townships at depths of from 200 to 300 feet. Probably nowhere in the area are the Pennsylvanian deposits much thicker than 350 feet.

The rocks of this County lie almost flat, though a low fold passes northwest from Salisbury and a synclinal depression occurs in the northeast part. The thickness of the Pennsylvanian beds in this County is hardly sufficient, over most of the area, to warrant the expectation that they are likely to carry important quantities of oil.

In 1887 a deep test well for oil and gas was sunk just north of Brunswick, (Sec. 3, T. 53N., R. 20W.) by S. Benecke and Company.

In 1906 two test wells were drilled near Triplett, one to a depth of 1475 feet. Neither of these wells found showings of oil or gas, and when completed both yielded strong natural flows of saline water. The following is the log of the Brunswick well.

RECORD OF DEEP WELL AT BRUNSWICK, MO.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	9	9
PENNSYLVANIAN SYSTEM:		
Cherokee shale:		
Shale, blue	4	13
Coal	1.5	14.5
Shale, gray	30.5	45
Shale, dark, chocolate-colored	65	110
Coal	1	111
Shale, bluish-gray	19	130
Variegated pebble-rock	10	140
MISSISSIPPIAN SYSTEM:		
Limestone	25	165
Limestone, chert, and pyrite	35	200
Clay	4	204
Limestone	11	215
Limestone, light-colored	160	375
Limestone and sand rock, mixed	60	435
Limestone, chocolate-colored	110	545
SYSTEMS OLDER THAN MISSISSIPPIAN:		
Limestone, gray	16	561
Limestone, yellowish	134	695
Sandstone, St. Peter (?)	65	760
Sandstone and shale mixed	15	775
Sandstone, limestone and shale	25	800
Sandstone	20	820
Limestone	65	885
No report	20	905
Limestone and sandstone (salt water)	20	925
Limestone and sandstone	260	1185
Sandstone	35	1220
Limestone	150	1370
Sandstone	90	1460
Limestone, dark	45	1505

SCHUYLER COUNTY.

That part of Schuyler County east of the Wabash Railroad is so thickly covered with glacial drift that no bed rock is known to outcrop, the drift in places being reported as thick as 300 feet, and commonly as much as 200 feet beneath the upland. West of the Wabash Railroad the drift thins somewhat and along Chariton River exposures of both Henrietta and Cherokee beds occur. The Cherokee shale is, however, the only Pennsylvanian formation of important extent in the County, and nearly everywhere underlies the drift, though in places it has been largely removed by pre-glacial eroson.

No wells have been sunk in Schuyler County which reveal the depth to the base of the Pennsylvanian rocks, which, however, cannot greatly exceed 400 to 500 feet as a maximum. The Mississippian limestone outcrops a few miles from the southeast corner of the County.

Aside from the presence of the Kirksville-Mendota anticline, the crest of which crosses the southwest corner of the County, nothing is known of the structural features of this area. The rocks appear to lie almost flat, though some local folding may occur.

No oil or gas has been reported in the few wells of this County, though no tests have been sunk.

ADAIR COUNTY.

Along the eastern border of the area, crystalline limestones of Mississippian age appear at the surface, and extend, as the country rock, eastward to Mississippi River. To the west these limestones dip beneath the Pennsylvanian. The Cherokee shale alone underlies most of the eastern and northern townships and directly underlies the bottoms of Chariton River. The overlying Henrietta and Pleasanton formations occupy the uplands of the central, south-central, and western townships, and the presence of the Henrietta may be noted in many localities in this area by the conspicuous outcrops of its several thin limestones. A few isolated patches of the Kansas City limestones appear on some of the high hills in the southern part of the County along the Chariton River, but their extent is unimportant.

The glacial drift forms a mantle of sufficient thickness to conceal the bed of rock over much of the area, and locally it is fully 200 feet thick.

Outcrops and deep well records have shown the various Pennsylvanian formations present in the County to have the following thicknesses: Cherokee shale, 280-335 feet; Henrietta formation, 30-50 feet; Pleasanton formation, 120-160 feet. The total thickness is, therefore, known to vary from 430 to 545 feet.

The most prominent structural feature known in the County is the Kirksville-Mendota anticline, consisting of a low broad fold extending from a point a short distance north of Kirksville in a northwest direction through Putnam County. The presence of this structure has been determined by relative elevations on the underlying coal beds.

The only deep well in Adair County, so far as known, was drilled many years ago at Kirksville for the purpose of obtaining a city water supply. The record of this well follows:

RECORD OF DEEP WELL AT KIRKSVILLE, MO.

	Thickness.	Depth.
	Feet.	*Feet.*
Clay (Glacial drift)	170	170
PENNSYLVANIAN SYSTEM:		
Henrietta and Cherokee formations:		
Limestone	8	178
Coal streak	..	...
Clay shale	30	208
Sandstone	22	230
Shale	15	245
Limestone, hard	2	247
Shale	20	267
Coal	1.5	268.5
Shale	30	298.5
Limestone, shelly, broken	20	318.5
Clay, soft, blue	20	338.5
Limestone	15	353.5
Coal	2	355.5
Shale	50	405.5
Sandstone, fine, white	45	450.5
MISSISSIPPIAN AND OLDER SYSTEMS:		
Limestone (solid) (?)	700	1150.5
Flint, very hard, limestone, and sandstone (St. Peter)	140	1290.5

(The record of this well is incomplete and inaccurate, below 450 feet, but it is the only deep well record available for Adair county.)

The only other drillings of any importance in this County consist chiefly of coal prospects, 200 to 300 feet in depth, and water wells 200 to 350 feet deep. A diamond drill hole on the farm of D. D. Novinger, in the NE. 1/4 sec. 10, T. 62N., R. 17W., reached a depth of 363 feet, finishing in 25 feet of limestone, probably of Mississippian age. One of the incentives for drilling on this property was the discovery of small amounts of inflammable gas found in the alluvium in the creek bed. By sinking a steel bar in the sands in this creek bed, to a depth of 5 to 8 feet, the gas emanations from the hole can be lighted, and will burn for a short time. There is no question, however, but that the gas is marsh gas and bears no relation to the possible occurrences of oil or gas which might be found by deep drilling in the indurated rocks.

MACON COUNTY.

Limestones of Mississippian age outcrop at points along the eastern border, especially in the northeast corner, and dip westward beneath the Pennsylvanian. The Cherokee shale outcrops over the eastern and southern townships and on both sides of Chariton River north into Adair County. Beneath the glacial drift on the divides in the northern half of the area, Pleasanton and Henrietta beds rest on the Cherokee shale, but outcrops are rarely seen. The distribution of the formations is best shown on the accompanying State geologic map.

The depth to the base of the Pennsylvanian deposits varies considerably in different parts of the County. At Macon, the Mississippian limestones have been reached at 185 feet; at College Mound at a depth of 144 feet; at Bevier at 240 feet; and 6 miles east of LaPlata at a depth of only 110 feet. Where the highest Pennsylvanian beds in the County are present depths of 400 to 550 feet would probably be required to reach the underlying Mississippian.

Two deep wells have been drilled in Macon County, one at Macon and the other at College Mound. The Macon well was sunk prior to 1897 in an effort to obtain a city water supply. This well is 1000 feet deep and it is believed, finished in Ordovician beds. No oil or gas was encountered in this drilling.

RECORD OF DEEP WELL AT MACON, MO.

	Thickness.		Depth.	
	Ft.	*In.*	*Ft.*	*In.*
Drift, no specimens preserved	36		36	
PENNSYLVANIAN SYSTEM:				
Blue calcareous-argillaceous shale	9		45	
Hard, brittle, blue, limestone	1		46	
Black shale	2		48	
Coal, with a few fragments of shale	1	1	49	1

RECORD OF DEEP WELL AT MACON, MO.—Continued.

	Thickness.		Depth.	
	Ft.	*In.*	*Ft.*	*In.*
PENNSYLVANIAN SYSTEM—Continued.				
Blue shale	5	11	55	
Tenacious blue clay	10		65	
Gray, calcareous shale	5		70	
Black shale	3	2.5	73	2.5
Coal	1	9.5	75	
Tenacious blue clay	33	8	108	8
Black clay	17	4	126	
Dark gray or black clay		6	126	6
Firm, black, carbonaceous shale	1	9	128	3
Gray clay	8	3	136	6
Calcareous gray clay	18	6	155	
Dark gray shale	30		185	
MISSISSIPPIAN AND OLDER SYSTEMS:				
Light gray limestone	28		213	
Light gray, subcrystalline limestone	7		220	
Light gray, slightly calcareous shale	53		273	
Dark gray, slightly calcareous clay	3		276	
Calcareous gray shale	5	6	281	6
Light gray, cherty limestone	38	6	320	
Blue-gray, calcareous shale	5		325	
Light cherty limestone	10	6	335	6
Light gray and dark calcareous shale	39	6	375	
Light gray limestone and chert	21		396	
Light buff pulverulent limestone	14		410	
Dark gray arenaceous shale	72		482	
Light gray arenaceous and calcareous shale	27		509	
Blue sparry limestone	23		532	
Shaly-blue limestone	43		575	
Light gray and dark blue shaly limestone	60		635	
Blue limestone	17		652	
Light blue sparry limestone	112		764	
Light blue, cherty and arenaceous limestone	36		800	
Gray limestone	95		895	
Massive blue shale	100		995	
Fine calcareous sand	5		1000	

A second well was sunk at College Mound, in 1910, by R. Y. Powell. It reached a depth of 3000 feet and probably finished in rock of Cambrian age. This well was also unsuccessful in finding showings of oil or gas. The record kept is rather incomplete, but because of its depth is given below for reference.

CONDENSED RECORD OF POWELL WELL, COLLEGE MOUND, MO.
SE. ¼, SE. ¼, SEC. 28, T. 56 N., R. 15 W.

	Thickness.	Depth.
	Feet.	*Feet.*
Clay	55	55
PENNSYLVANIAN SYSTEM:		
Cherokee shale:		
Limestone, white, medium	12	67
Coal, black, soft	2	69
Shale	55	124
Clay, yellow, soft	20	144

CONDENSED RECORD OF POWER WELL, COLLEGE MOUND, MO.—Continued.

	Thickness.	Depth.
MISSISSIPPIAN SYSTEM:	*Feet.*	*Feet.*
Limestone, white, medium	20	164
Shale, white, soft	40	204
Limestone	76	280
Limestone, and sandy shale (water)	50	330
Limestone	190	520
Shale, green, soft	20	540
DEVONIAN (?) AND ORDOVICIAN SYSTEMS:		
Limestone, white, hard	70	610
Limestone and sandstone, gray, medium	30	640
Limestone, white, medium	20	660
Limestone and sandstone	110	770
Sandstone, white, medium (St. Peter)	62	832
Shale	12	844
Limestone	470	1314
Sandstone, white	13	1327
Limestone, white	173	1500
OZARKIAN AND CAMBRIAN SYSTEMS:		
Limestone, white and gray, hard	570	2070
Shale, black	60	2130
Shale, greenish	15	2145
Limestone	47	2192
Sandstone, hard, dark	43	2235
Limestone, gray	15	2250
Limestone and sandstone	55	2305
Sandstone	501	2806
Limestone, gray	86	2892
Sandstone	108	3000

It is probable that much of the section reported to be sandstone from 2300 feet to the base of the well is in reality compact dolomite, which in the form of well cuttings closely resembles sand grains.

No oil or gas showings have been reported from any of the Macon county wells.

RANDOLPH COUNTY.

In all but the southwest quarter of the County the Cherokee shale directly underlies the unconsolidated surface deposits, except for a narrow east and west belt through Moberly, which is occupied by the Moberly channel sandstone. The Pleasanton and Henrietta formations overlie the Cherokee in a large portion of the southwest part of the County, but nowhere do these reach a great thickness.

At and near Moberly, Huntsville, Cairo, Clark, and other points in the Cherokee shale area, the Mississippian limestones have been reached in wells at depths of less than 100 to 200 feet. The thickness of the Cherokee in this area is not more than about 200 feet. The maximum thickness of all the Pennsylvanian beds in the County cannot greatly exceed 250 feet, if indeed this total is reached, though the overlying glacial drift adds considerably to the depth required to reach the base of these deposits with the drill.

A number of deep wells have been sunk near Moberly and Huntsville for water, and a great many shallower wells have nearly or completely penetrated the Pennsylvanian rocks in many parts of the County. A showing of oil is reported to have been found in one well near Jacksonville, but in view of the general thinness of the Pennsylvanian rocks in this County, it seems improbable that commercial pools of oil can be expected in them.

DRILLERS' LOG OF DEEP WELL AT MOBERLY, RANDOLPH COUNTY, MO.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil and gravel	38	38
PENNSYLVANIAN SYSTEM:		
Cherokee (79 feet):		
Shale	60	98
Fire clay	7	105
White sand	12	117
MISSISSIPPIAN SYSTEM:		
St. Louis limestone (19 feet):		
Blue and white limestone	19	136
Keokuk limestone (84 feet):		
Gray sand and limestone	84	220
Burlington limestone (75 feet):		
Blue and white marble	20	240
White marble	10	250
Limestone and sand	30	280
White limestone	15	295
Kinderhook (212 feet):		
Blue limestone	105	400
Blue limestone with "slate" seams	20	420
Blue "slate"	10	430
Gray limestone	5	435
Gray "slate"	2	437
Gray limestone	55	492
Blue sand	15	507
DEVONIAN SYSTEM (68 feet):		
Gray limestone	45	552
Yellow sand	18	570
White "slate"	5	575
SILURIAN (?) SYSTEM ("Niagara," 95 feet):		
White limestone	7	582
Blue limestone	12	594
Green "slate"	3	597
Gray limestone	5	602
White sand, water	20	622
Yellow sand	45	667
"Slate," cased 9 5/8-inch hole	3	670
ORDOVICIAN AND OLDER SYSTEMS:		
Maquoketa (?) (234 feet):		
Limestone	42	712
Flake or egg-shell limestone, soft water	10	722
Gray limestone with flint and iron seams	70	792
Gray sand	30	822
Gray limestone	8	830

DRILLERS' LOG OF DEEP WELL AT MOBERLY, MO.—Continued.

	Thickness.	Depth.
ORDOVICIAN AND OLDER SYSTEMS—Continued.		
Maquoketa (?) (234 feet)—Continued.	*Feet.*	*Feet.*
Pebble sand, showing of oil	10	840
Gray sand	20	860
Limestone	4	864
Gray sand	5	869
Yellow sand	10	879
Blue limestone	15	894
Blue sand	8	902
"Trenton" limestone (131 feet):		
Blue "slate"	2	904
Limestone	28	932
Sand	18	950
Flint and limestone	80	1030
White sand	5	1035
Joachim limestone (55 feet):		
Limestone, flint, and sand	55	1090
St. Peter sandstone (135 feet):		
White sand and flint	15	1105
Blue sand and gray limestone	35	1140
Sand, salt water	10	1150
White sand, some sulphur water	52	1202
Honeycombed sand	8	1210
White sand	15	1225
Jefferson City and older (465 feet):		
Limestone and flint	15	1240
White limestone	10	1250
White limestone and gray sand	72	1322
Gray sand	19	1341
Gray sand and limestone	27	1368
White sand	5	1373
Fine gray sand	12	1385
Gray limestone	31	1416
White sand	42	1458
Blue limestone	17	1475
Sand	163	1638
Dark limestone or "Trenton" rock	12	1650
Gray sand	40	1690
No record	310	2000

HOWARD, BOONE, CALLAWAY, AUDRAIN, SCOTLAND, CLARK, SALINE, PETTIS, AND OTHER COUNTIES.

Though the Pennsylvanian rocks underlie a very considerable portion of Pettis, Saline, Clark, Boone, Callaway and nearly all of Howard, Audrain and Scotland Counties, the thickness of these rocks in these Counties nowhere reaches a sufficient depth to warrant the hope that they might contain commercial pools of oil or gas. In all of these counties deep wells have completely penetrated the Pennsylvanian beds without finding significant indications of either oil or gas. The following well records indicate the strata penetrated in a number of the deep wells.

RECORD OF WELL OF BOONVILLE OIL PRODUCTION CO., NEW FRANKLIN, MO.

	Thickness.	Depth.
	Feet.	*Feet.*
Alluvial clay, sand, and gravel	120	120
MISSISSIPPIAN SYSTEM:		
Burlington-Keokuk limestone:		
Limestone, crystalline, fossiliferous, light gray to cream-colored, with white chert	45	165
Limestone, crystalline, gray to dark brown, with white to blue chert	45	210
Chert, white to blue	10	220
Limestone, light to dark gray, fine-grained, slightly argillaceous, with chert	15	235
Chouteau limestone:		
Argillaceous limestone, bluish-gray	90	325
Shale, blue, clayey	5	330
Limestone, dark gray, fine-grained, slightly argillaceous	25	355
Phelps sandstone:		
Sandstone, white, rounded, etched quartz grains, mixed with some bluish chert	20	375
ORDOVICIAN SYSTEM:		
Jefferson City formation:		
Argillaceous dolomite, light gray	5	380
Dolomite, gray, fine-grained, with blue chert, partly oolitic	30	410
Argillaceous dolomite, light gray	20	430
Dolomite, light gray, fine-grained to crystalline	50	480
Argillaceous dolomite (cotton rock), some white chert	25	505
Dolomite, light gray and "cotton rock"	25	530
Sandstone, hard, quartzitic	5	535
Dolomite, gray, crystalline to fine-grained, with chert	50	585
Argillaceous dolomite, with some chert	15	600
Dolomite, gray, fine to crystalline, with some chert	125	725
Roubidoux sandstone:		
Sandstone, angular to rounded quartz grains	10	735
Dolomite, light gray, with much chert	25	760
Sandstone and dolomite; sand grains fine, angular to well-rounded	12	772
Dolomite, gray, fine-grained, with much chert and some sand grains	38	810
Sandstone, coarse to fine, angular to well-rounded quartz grains	10	820
OZARKIAN SYSTEM:		
Gasconade formation:		
Dolomite, light to dark gray, crystalline with much white to blue chert	105	925
Dolomite, very dark gray, with much white chert	45	970
Dolomite, light to dark gray, crystalline, with white chert	57	1027
Shale, blue	2	1029
Chert, white	9	1038
Dolomite, gray, crystalline, with chert	24	1062
Sandstone (Gunter), rounded to angular quartz grains	18	1080
Proctor formation:		
Dolomite, very dark gray to brown, slightly crystalline, noncherty	38	1118
Poor record	17	1135
Dolomite, gray to very dark gray, noncherty	20	1155
Dolomite, crystalline, light to dark gray, noncherty	95	1250
Undifferentiated:		
Dolomite, crystalline, light to dark gray	40	1290
Dolomite, crystalline to granular, gray	30	1320
Dolomite, gray to pinkish	30	1350

RECORD OF FULTON CITY WELL NO. 3, FULTON, MO.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil and clay	50	50
PENNSYLVANIAN SYSTEM:		
Fire clay, light colored with red streaks	40	90
"Shell rocks," with clay seams	10	100
MISSISSIPPIAN SYSTEM:		
Burlington limestone:		
Chert, white, some crystalline limestone	20	120
Limestone, crystalline, gray, with white chert	20	140
MISSISSIPPIAN AND DEVONIAN SYSTEMS:		
Limestone, argillaceous, fine-grained, soft	10	150
Limestone, gray, fine-grained, magnesian	10	160
Shale, blue, soft, calcareous	40	200
Limestone, gray, fine-grained, compact, fossiliferous	50	250
ORDOVICIAN SYSTEM:		
Jefferson City formation:		
Dolomite, light gray, fine-grained, with some "cotton rock" and much oolitic chert	50	300
Dolomite, gray, fine-grained	10	310
"Cotton rock," light gray	20	330
Dolomite, dark gray, fine-grained, oolitic chert	20	350
"Cotton rock," light to dark gray, with some fine-grained, gray dolomite	50	400
Dolomite, gray, much white chert, partly oolitic	70	470
"Cotton rock," almost white	10	480
Dolomite, gray, fine-grained, with chert in part oolitic	40	520
"Cotton rock," gray, with some dolomite	50	570
Dolomite, dark gray, fine-grained	20	590
Roubidoux sandstone:		
Sandstone, clear, fine angular quartz grains	20	610
Dolomite, and "cotton" rock, with some sand grains	20	630
Dolomite, light gray, fine-grained, with some chert, partly oolitic	20	650
Sandstone, angular to rounded quartz grains	10	660
Dolomite, light gray, fine-grained, with chert	70	730
Sandstone, fine-grained, angular, quartz grains	30	760
OZARKIAN SYSTEM:		
Gasconade formation (contact doubtful):		
Chert, white to blue, and dolomite	50	810
Dolomite, light gray, crystalline, with chert, white to blue in color	120	930
Dolomite, light gray to blue, crystalline, with chert	70	1000
Cuttings washed away	10	1010
Dolomite, light to dark gray, crystalline, with some chert	142	1152

RECORD OF WELL OF LAMONTE GAS & OIL CO., LAMONTE, PETTIS COUNTY, MISSOURI.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil and clay	15	15
PENNSYLVANIAN SYSTEM:		
Cherokee shale:		
Sandstone, red	5	20
Shale, blue	15	35
Shale, brown to blue	30	65

RECORD OF WELL OF LAMONTE GAS AND OIL COMPANY—Continued.

	Thickness.	Depth.
	Feet.	*Feet.*
MISSISSIPPIAN SYSTEM:		
Burlington limestone:		
Limestone, gray, crystalline and chert	13	78
Limestone, gray, finely crystalline	15	93
Limestone, gray, fine-grained, with bluish chert	17	110
Limestone, crystalline to fine-grained, gray	85	195
MISSISSIPPIAN AND DEVONIAN SYSTEMS:		
Sandstone, medium-grained, with white "dead" chert	15	210
Limestone, gray, crystalline, and chert	20	230
Limestone and chert, with some sandstone and green shale	13	243
Sandstone, with some chert	5	248
Shale	38	286
Sandstone, gray, with some chert	14	300
ORDOVICIAN SYSTEM:		
Jefferson City formation:		
Dolomite, gray, crystalline, and oolitic chert	30	330
Dolomite, and dark chert	15	345
Dolomite, gray, crystalline, with some white chert	195	540
ORDOVICIAN AND OZARKIAN SYSTEMS:		
Roubidoux and Gasconade formations:		
Sandstone, fine-grained	13	553
Dolomite, gray, crystalline	257	810
Sandstone, fine-grained	25	835
Dolomite, dark gray, crystalline	45	880

RECORD OF WELL OF WATER AND LIGHT CO., COLUMBIA, BOONE COUNTY. MISSOURI.

	Thickness.	Depth.
	Feet.	*Feet.*
Yellow clay with rounded pebbles	30	30
Sand and rounded pebbles	25	55
Sand, very fine-grained	5	60
MISSISSIPPIAN SYSTEM:		
Burlington limestone:		
Chert, some dense gray limestone	8	68
Limestone, crystalline, and chert	40	108
Limestone, dark gray and fine-grained to crystalline	47	155
Limestone, crystalline to fine-grained, with some black shale and chert	20	175
Limestone, crystalline, and chert	72	247
Chouteau limestone:		
Limestone, dark gray, fine-grained to dense, no chert	116	363
DEVONIAN SYSTEM (?):		
Limestone, gray, white, fine-grained to crystalline	54	417
ORDOVICIAN SYSTEM:		
Jefferson City formation:		
Dolomite, gray, finely crystalline, some white chert	48	465
Dolomite, dark gray and dense	94	559
Dolomite, gray, crystalline, and chert	54	613
"Cotton rock," some chert	42	655
Dolomite, argillaceous, and some oolitic chert	12	667
Roubidoux formation:		
Sandstone, some dolomite	9	676
Dolomite, gray, finely crystalline, and small amount of chert	84	760
"Cotton rock" and chert	6	766
Sandstone, some oolitic chert	5	771

RECORD OF WELL OF WATER AND LIGHT CO., COLUMBIA, MO.—Continued.

	Thickness.	Depth.
OZARKIAN SYSTEM:	*Feet.*	*Feet.*
Gasconade formation:		
Dolomite, some oolitic chert and sandstone	10	781
Dolomite, dark gray, finely crystalline	12	793
Dolomite, dark gray, finely crystalline with chert	86	879

Aside from the Counties just mentioned there are many Counties in which the Pennsylvanian deposits are not extensively present, but which contain small pockets of bituminous or cannel coal, which may be misleading as to extent. In none of these Counties do the Pennsylvanian beds underly large areas and usually do not cover more than a few acres. The coal pockets themselves, therefore, have no important bearing on the oil or gas possibilities of the areas in which they occur. In fact, where present, they signify the lack of persistent beds of Pennsylvanian.

QUALITY OF OIL FOUND IN THE PENNSYLVANIAN ROCK IN MISSOURI.

The lack of quantity has precluded any possible development in the case of many of the wells, and rarely has enough interest been taken in the matter to have tests made. However, from observations at a large number of the wells and from samples of oil received at the Bureau, it can be said that most of it observed has been thick, heavy, black oil of relatively low gravity. The Mastin Ranch oil, in Jackson County is said to have had a gravity about 26° Be when freshly pumped and had a semi-paraffin base. It was an excellent lubricating oil but the gasoline and kerosene content was very low. A sample of oil from the shallow well six miles northeast of Garden City, Cass County, tested 30.4° Be, had a semi-paraffin base and was lighter in color than most Missouri oils, but the gasoline and kerosene content was not high. An equally light oil was found in the well near Kingsville, Johnson County. However, these oils are exceptionally light, and are the only samples observed with a higher gravity than 30° Be. A well near Stotesberry, Vernon County, yields an oil stated to run when fresh about 22° Be, but a sample tested from the first pumping after the well had stood idle for some time ran 20° Be. For oils obtained from

MAP SHOWING ALTITUDE OF BASE OF PENNSYLVANIAN.

several other wells, gravity tests of 22° to 28° Be are reported. It is safe to state that very little oil has been found up to the present time in the Pennsylvanian rocks of Missouri which has a lighter gravity than 30° Be; some in Jackson and Clay counties ranges from 25° to 30°, but much of it is lower than 25° Be, and most of it is not higher than about 20° Be.

The Mastin Ranch, Belton, Bates, and Vernon County oils have been pronounced excellent lubricating oils, but low in gasoline content. The following analysis indicates the general character of the Mastin Ranch oil.

ANALYSIS OF OIL FROM MASTIN RANCH WELLS.*

Constituent.	Per cent.
Light oil between kerosene and gasoline	10
Burning oil (kerosene)	19
Lubricating oil with paraffin base	53
Residum, consisting of 10 per cent tar and 8 per cent paraffin with only trace of inorganic matter	18
Total	100

*Analysis from U. S. Geological Survey, Mineral Resources, 1902, p. 566. Made by Prof. Frankforter, University of Minnesota.

CHAPTER V.

ASPHALTIC SANDSTONE AND LIMESTONE IN THE PENNSYLVANIAN ROCKS.

In this report the rocks impregnated with bitumen, which outcrop extensively at many localities in western Missouri, are referred to as asphaltic sandstones or asphaltic limestones, or as rock saturated with asphalt; loosely construed terms, accepted because of their widespread and common use and the lack of analyses of the saturating bitumen. It is known, however, that the material is not commonly a true asphalt and that the so-called asphalt, tar, pitch, bitumen or oil present varies greatly in composition, even in a single locality. The bituminous material is the residue from the evaporation of petroleum which is known to be chiefly of a semi-paraffin base and in only a few localities has evaporation continued to such an extent as to carry off all the lighter and more volatile parts. The bitumen is really then a heavy, thick oil in most of the deposits.

GEOGRAPHIC OCCURRENCE.

Asphaltic sandstone is found in outcrop in Barton, Vernon, Bates, Cass, Caldwell, Ray, Carroll, Lafayette, Johnson, Cedar, St. Clair, Hickory and Barry counties. The deposits of northern Barton, southern Vernon, and those near Higginsville, Lafayette County, are known to be extensive, though possibly not more so than some in other counties. In Vernon and Bates, the outcrops are widely scattered, while in other Counties they are restricted to a particular portion. No other deposits are known in Lafayette County, besides the one at Higginsville; in Carroll County they are restricted to the northwest corner, so far as known; in Caldwell County, to the vicinity of Braymer; and in Ray County to an area about three miles north of Orrick. In Cass, Johnson St. Clair, and Cedar Counties asphaltic sandstone outcrops at only a few localities and in Hickory and Barry Counties the outcrops are small isolated erosion remnants of the Pennsylvanian.

In all, a very large number of deposits of asphaltic sandstones are scattered through at least 13 counties, and included in an area over 200 miles from north to south and over 50 miles from east to west.

Known outcrops of asphaltic limestone of Pennsylvanian age are restricted to Bates, Cass, Jackson and Caldwell Counties, the most important being those west central Cass. Where the bitumen in the asphaltic sandstones of the Pennsylvanian has seeped down into the underlying Mississippian limestones, these beds are bituminized and in such a state occur in Cedar, Dade, Hickory, Barton, Jasper, Barry and possibly in one or two other Counties bordering the Pennsylvanian area.

GEOLOGIC OCCURRENCE.

With the exception of the Mississippian limestone beds which have probably received their bitumen from the Pennsylvanian, the asphaltic sandstones and limestones are all of Pennsylvanian age. The asphaltic sandstones occur entirely in the Cherokee, Henrietta and Pleasanton formations, and the Warrensburg sandstone. The only occurrences of asphaltic rock in the Upper Pennsylvanian are in the Bethany Falls limestone in Cass, Jackson and Caldwell Counties. In all, the bituminized beds are distributed stratigraphically from the base of the Cherokee formation to the lower part of the Kansas City formation through a little more than 700 feet of strata. The most important and extensive deposits are in the Cherokee and Pleasanton formations and the Warrensburg sandstone.

Asphaltic rock in the Cherokee formation. Asphaltic sandstones, while occurring throughout the Cherokee shale, are apparently more extensive in the lower part. The asphaltic sandstone beds near Seligman, Barry County and near Weaubleau and Quincy, Hickory County, are of Cherokee age, but are only small isolated outliers from the main body. The principal deposits begin in Barton County near Lamar and Liberal and extend northward through Vernon and Cedar into Bates. No asphaltic beds of Cherokee age have been observed north of Bates County. The most notable deposits are near Liberal, Barton County, where the rock has been extensively quarried; near Sheldon, Vernon County, where an attempt has been made to commercially develop the deposits; and near Eldorado Springs, Cedar County. Other occurrences too numerous to mention are known, the greater number in Vernon County.

Asphaltic rock in the Henrietta formation. The Henrietta formation does not contain important or extensive deposits of asphaltic sandstone or limestone. Locally, as in northwest Vernon County, sandstone lenses in the Labette shale member are bituminized; and south of Butler, Bates County, the Fort Scott limestone member contains a small amount of bitumen, but there are only two localities where asphaltic Henrietta beds have been observed.

Asphaltic rock in the Pleasanton formation. The asphaltic sandstones of Pleasanton age have their southernmost outcrops in northwest Vernon County. At numerous places in Bates the exposed beds are asphaltic, and all of the asphaltic sandstones outcropping in Ray, Carroll and Caldwell Counties is of Pleasanton age. The asphaltic deposits of the Pleasanton have a much wider distribution than those of the Cherokee, are more numerous, and may occur at any horizon from top to bottom of the formation, not uncommonly in several beds one above another, with intervals between.

Asphaltic rock in the Warrensburg sandstone. The only known asphaltic deposit in the Warrensburg sandstone, north of Higginsville, Lafayette County, is believed to underlie the greater part of a square mile. The rock outcrops at several points and prospect holes near the outcrops have penetrated asphaltic beds at depths of over 150 feet.

Asphaltic rock in the Kansas City formation. The asphalt rock in the Kansas City formation consists entirely of asphaltic limestones, in the Bethany Falls member. An important deposit occurs in Cass County in a narrow east-west belt between the towns of Freeman and West Line. The bitumen has probably risen from the underlying Pleasanton shale to its position in the upper 3 to 7 feet of the Bethany Falls, through a fault or through well-developed joint planes. The Freeman-West Line asphaltic limestone has been quarried, with the intention of using the rock for paving. No other important deposits of similar type are known to occur, though the Bethany Falls shows an asphaltic phase near Cement City, Jackson County, and near Nettleton and Breckenridge, Caldwell County.

Bitumen in the Boone limestone. The bituminous matter commonly called tar, asphalt, bitumen or oil occurring in the Boone limestone of southwest Missouri has been observed in Jasper, Cedar, Hickory, Barry, Barton and other Counties. The most common occurrence is in bedding planes or fractures in the rocks at or near the surface. Locally beds of limestone are saturated and in Jasper County bitumen is found in the mine workings associated with the ore at depths of over 100 feet.

The Cherokee shale which covers the Boone formation over a considerable part of this area and originally covered the entire region, contains beds of sandstone saturated with heavy black oil or "asphalt" near its base. Locally these sandstones are exposed and during warm weather the oil oozes out along bedding planes, leaking downward into the adjacent Mississippian limestones. That this is the method by which most of the oil observed in the Boone was carried to its present position, there can be no doubt, and it is probable that the Cherokee sandstones were the original source of all the bitumen found in the Boone limestone of southwest Missouri.

Thickness of beds. The individual bituminized beds are of variable thickness and the impregnation is not uniform as a rule in the vertical section at any locality. A few miles east of Sheldon, in southeast Vernon County, a maximum of 30 feet is reported. Northeast of Liberal in Barton County, Broadhead* reports wells penetrating as much as fifty feet. One mile north of Higginsville, Lafayette County, 15 to 20 feet outcrops, and borings are said to have penetrated similar beds, separated by shale partings, to depths of from 120 to 181 feet. This is the thickest bituminized section reported. In southwest Ray County, 3 miles north of Orrick, the asphaltic sandstone outcrops with a thickness of but five feet although a few feet below it a 15-foot bed occurs.

At very few localities is the maximum thickness of the bituminized beds known. It is safe to say, however, that there are considerable areas where the rock close to the surface exceeds a thickness of 10 and possibly 20 feet.

While it is reported that the asphaltic limestone near Freeman, Cass County, reaches a thickness of 20 feet, the observed outcrop does not exceed 7 feet.

Character of rock. The bituminous sandstone on fresh fracture is chocolate brown to black in color and commonly soft and friable. That quarried near Liberal, Barton County, however, was exceptionally hard and firm. The bitumen constitutes practically all the cementing material and when removed the rocks crumble readily to a mass of sand grains. The sand grains are typical Pennsylvanian, very fine to fine in size, angular in shape and composed almost wholly of quartz. Most of the rock is micaceous. The asphaltic limestone, where sufficiently porous to absorb a considerable amount of bitumen, is

*Broadhead, G. C., Geological Survey of Missouri, 1873-74, p. 115.

similar in color to the sandstone. Most of the limestone is quite porous.

The bitumen is present in variable amounts, although the average for different tested localities is rather similar. From tests made at this Bureau, the content has been found to run from 6 to 15 per cent. Buckley* states that in Vernon County it frequently reaches 12 to 15 per cent. From an outlier in Barry County a sample has been received which contained 6.5 per cent. Three samples tested from the deposit near Sheldon, Vernon County, yielded 7 per cent, 7.45 per cent and 8.2 per cent. Samples from the Higginsville deposit tested, at the U. S. Geological Survey, contained from 6 to 8.5 per cent, and a sample from this same deposit recently tested carried 7.4 per cent. Several samples of asphaltic limestone from western Cass County, which were tested, carried from 6 to 11 per cent bitumen.

Nature of bitumen. There have been too few analyses of the asphaltic rocks, up to the present time, to be of general value. In fact no analyses are available except for the rock in Vernon County near Sheldon.

The bitumen present is without doubt the result of the evaporation of crude petroleum, originally contained in the sandstone. The composition of the material is therefore variable from one locality to another and even in the same locality, depending upon the extent to which the original oil has evaporated, and upon the original composition of the oil. Commonly the bitumen is of a black nature and in warm weather flows from the bedding planes in the rocks to form "Tar Springs." In some localities small particles of solid asphalt occur in the sandstones, the principal bitumen being a heavy, thick, black maltha. In most localities the bituminous matter is a heavy, thick, black oil which flows readily in warm weather. In the Lafayette County occurrence Broadhead† reports finding even thin amber-color oil together with heavy, thick, black oil and solid asphalt. Two analyses of the bitumen from typical asphaltic sandstone near Sheldon, Vernon County, show 11.5 and 9.6 per cent asphaltene and 80.3 and 81.6 per cent petrolene. The analyses of three samples from Sheldon, Vernon County, are as follows:

*Buckley, E. R., Mo. Bur. of Geol. and Mines, Forty-third Biennial Report of the State Geologist, p. 36, 1905.

†Broadhead, A. C., Geol. Survey of Mo., Iron Ores and Coal Fields, pt. 2, p. 41, 1872.

*BITUMEN FROM ASPHALTIC SANDSTONE, SHELDON, VERNON CO., MO.

	No. 1.	No. 2.	No. 3.
Asphaltine	11.5 %	9.6 %	9.2 %
Petrolene	80.3	81.1	86.1
Organic matter, not asphaltine or petroline	0.3	0.5	....
Inorganic matter	7.4	8.4	....
Water	0.5	0.4	4.6

*Analysis No. 1 and No. 2 by Prof. S. E. Swartz, at Fairmont College, Wichita, Kansas. Sample No. 3, partial analysis at Missouri Bureau of Geology and Mines.

COMMERCIAL ASPECTS

There has long been an interest in the possibilities of commercializing the asphaltic sandstone and limestone deposits of western Missouri, though to date no great success has come from the several endeavors to place the rock on the market. The commercial aspects considered or tested have been (1) the quarrying of the rock for curbing, flagging and sidewalk blocks; (2) the quarrying of the rocks for the extraction of the bitumen; and (3) the use of the rock for macadam and asphalt paving.

Quarrying for curbing, etc. Asphaltic sandstone has been extensively quarried about 2 miles north of Liberal, Barton County, in the SW. ¼ sec. 23, T. 33N., R. 33W., by the Liberal Stone and Coal Company. The rock, sawed into slabs, was used for road crossings, sidewalks and curbing, and possesses superior qualities for such use by virtue of the bitumen present. The rock is very fine-grained and micaceous. It varies from brown to black in color. As compared to a similar sandstone without the bituminous cement, the asphaltic rock shows a much higher tensile, transverse and crushing strength; the porosity is notably lower; and the rock stands extremes of temperature far better. It is easily handled when first cut from the quarry but indurates on exposure. It never loses a certain amount of flexibility, which property makes it especially adapted to withstand strains without fracturing. It is true, however, that the Liberal rock is much harder and firmer than the asphaltic rock found in most localities.

The asphaltic sandstone quarry of the Liberal Stone and Coal Company was closed because of litigation several years ago, and has not since been reopened. During the operation of the quarry a good market was said to have been obtained in the surrounding Counties and some stone was shipped to Kansas City and Omaha for sidewalks. It is the only locality in the State at which the asphaltic sandstone has been quarried for these uses.

Extraction of bitumen. As a source of petroleum it seems obvious that these bituminous rocks have no present value. The relatively small per cent and inferior quality of the oil, plus the expense of quarrying and extraction, would seem to make such an industry hopeless in competition with the oil fields of today; although this source may constitute a future reserve. Those interested in experimenting with the extraction of the bitumen from the rocks have had in mind special uses for the product such as making dyes or obtaining valuable ingredients like Ichthyol. Not enough analytical work has been done on the bitumen to afford a basis for intelligent discussion, but there is no reason whatever to believe that it possesses any special properties or contains ingredients not found in oil pumped from the fields in Kansas.

For paving material. The greatest interest in Missouri asphaltic rock attaches to its use for natural paving material. Tests with the sandstone have been made in Carthage, Springfield, and Higginsville; and with asphaltic limestone in St. Louis. The Carthage and Springfield experiments, conducted a number of years ago, were both pronounced failures. Of the former Buckley* stated:

> "Crushed sandstone containing a high percentage of asphalt (secured near Liberal) was used as surfacing material for a short distance on a macadam road in the northwest part of the city. When examined the surface was very soft and full of ruts. The material does not seem to have sufficient binding qualities to make a durable wearing surface and unless a suitable binder is added it will not withstand heavy traffic."

The Springfield experiment was said to have resulted like that at Carthage. It seems that the rock without treatment, simply crushed and rolled on the road, will not produce a durable surface. It may, in the natural state be used as the base of a bituminous concrete, and as such has been used with apparent success in Higginsville.

The paving done at Higginsville, using material from the asphaltic sandstone deposit just north of town, consists of a street two blocks long and about 30 feet wide, put down in October, 1917. In preparing the street a foundation of concrete was made in the usual way and on top of this was put a two and one half inch layer of asphalt prepared as follows:

*Buckley, E. R., Biennial report of the State Geologist to the 45th General Assembly, p. 38, 1908.

Bituminous sandstone	500 lbs.
Joplin "chat"	300 lbs.
Sand	80 lbs.
Limestone dust	60 lbs.
Asphalt cement	60 lbs.
	1000 lbs.

The bituminous sandstone was crushed and the whole mixed togethcr at 300° F. and rolled down while hot. This forms a hard but resilient surface. So far it has withstood traffic and extremes of temperature without much wear, cracking or flowing.

The failure of the bitumen in the rock to act as a binder is probably due to its quality rather than its quantity. The amount of bitumen present is as great as in the Kentucky sandstones used for paving, and only a little less than in the Oklahoma stone. However, the bitumen is generally more oily than that in the Oklahoma rock, which yields 21 to 28 per cent asphaltine, against 9.2 to 11.5 per cent in the Missouri stone tested. The relatively greater amount of petroleum in the Missouri bitumen would doubtless lessen its efficiency as a binder. For this reason some additional binder no doubt must be added to the Missouri rock for paving.

SCREEN ANALYSIS OF ASPHALTIC SANDSTONE, VERNON COUNTY.

Screen mesh.	Total per cent through.	Total per cent on.
20	100.00	......
40	97.42	2.58
60	88.87	11.13
80	46.14	53.86
100	42.74	57.26
120	8.56	91.44
200	3.01	96.99
Pan	......	100.00

The following are brief descriptions of two asphaltic sandstone deposits which offer an abundance of the rock at easily accessible localities.

The Higginsville deposit. This deposit of bituminous sandstone is exposed in a dry creek bed in the SE. 1/4 sec. 36, T. 50N., R. 25W., and the NE. 1/4 sec. 1, T. 49N., R. 25W., three-fourths of a mile northwest of Higginsville. Stratigraphically it occurs in the Warrensburg sandstone of the Pennsylvanian.*

On the right bank of the creek the sandstone forms a natural outcrop for a distance of sixty feet. Other outcrops occur in the neighboring valleys showing that it underlies at least a large part of the S. 1/2 sec. 36, and part of the N. 1/2 sec. 1. The outcropping ledge has a thickness of about 36 or 40 inches at this point, and is overlain by from 2 to 20 feet of a yellowish shale and surface soil and underlain by a bed of gray shale nine inches thick. Drill holes in the immediate vicinity are said to have penetrated from 120 to 181 feet of the sandstone, occurring in thick beds separated by shale partings from two to fourteen inches thick. In the deepest drill hole the lower twenty feet did not show any bitumen in the sandstone.

This deposit is very accessible since it occurs where the wagon road crosses the creek and is only three-fourths of a mile from Higginsville at the junction of the Missouri Pacific and Chicago and Alton Railroads.

The sandstone itself, where not filled with the bitumen, is light gray in color and is micaceous, fine-grained and even-textured. The individual grains are mostly well-rounded or subangular and cemented together rather loosely, so that the rock is friable and easily cut with a pick. Where it is saturated with bitumen, the color is dark brown to black.

Deposits near Sheldon.—Asphaltic sandstone occurs in a large number of localities in Vernon County, but the commercial possibilities of the rock have been investigated most thoroughly in the southeast part, about four miles east of Sheldon. Here the asphalt rock outcrops along the sides of the bluffs and near the heads of the ravines and has been found by means of wells and test pits to underlie a large but unknown area within a few feet of the surface. Buckley† stated it to be his belief that in this locality there is "an almost inexhaustible supply of bituminous or asphaltic sandstone of good quality."

A well sunk in the SE. 1/4 sec. 27, T. 43N., R. 30W., encountered 21 feet of asphaltic sandstone at a depth of about 15 feet. In the SW. 1/4 SW. 1/4 of the same section asphaltic

*Hinds, Henry, and Greene, F. C., The stratigraphy of the Pennsylvanian series in Missouri; Missouri Bureau of Geology and Mines, vol. 13, 2nd ser., p. 26, 1915.

Eldridge, Geo. H., The asphalt and bituminous rock deposits of the United States; Twenty-second Ann. Rept., U. S. Geol. Survey, pt. 1, pp. 259-261, 1901.

†E. R. Buckley, Biennial report of the Missouri State Geologist to the Forty-third General Assembly, p. 22.

sandstone outcrops at several points near the heads of ravines. Two test holes sunk in sec. 24, T. 34 N., R. 30 W., penetrated 16 and 11 feet of sandstone at depths of 22 and 21 feet respectively. Four test holes sunk in sec. 24, T. 34 N., R. 30 W. (exact locations not known) penetrated 30, 30, 26 and 30 feet respectively of asphaltic sandstone at depths of 5, 13, 9 and 11 feet, and in the NE. 1/4 SW. 1/4 of this same section 27 1/2 feet of asphaltic rock was encountered in a test at a depth of 12 feet, and the rock outcrops in a ravine near the test hole. There is thus sufficient evidence that in this locality a very considerable area is underlain by from 11 to 30 feet of asphaltic sandstone at depths varying from a foot or less to 25 feet below the surface. The overburden is chiefly residual clay and is easily removed.

The asphaltic sandstone in this locality occurs in the Cherokee shale. The rock is almost black on fresh fracture and chocolate or dark brown on a weathered surface. It is micaceous and very friable, apparently containing little or no cement other than the bitumen, and is composed of fine angular quartz grains of a light gray color when freed from the bituminous coating.

Two samples of the rock tested for the bituminous content have shown 7.5 and 8.2 per cent bitumen, although Buckley stated, referring to this locality, that the rock commonly contains 12 to 15 per cent asphaltic material. From the samples observed, however, it is believed that the average of the rock will carry between 7 and 10 per cent bitumen.

CHAPTER VII

OIL AND GAS IN ROCKS YOUNGER THAN THE PENNSYLVANIAN.

SOUTHEAST LOWLAND AREA.

Some attention has been attracted to the Southeast Lowlands of Missouri, through reported showings of oil and gas at very shallow depths, chiefly on Crowley's Ridge. The region also bears a certain topographic and geologic similarity to, and in fact is part of, the embayment area to the south in Louisiana and Texas, where large oil fields occur. Up to the present time very little exploration has taken place in this area, and so far as can be learned only 3 or 4 wells have been sunk in search of oil or gas. However, a number of other wells 500 to 1500 feet deep have been sunk in search of artesian water, and afford the best available data on the geology of the area.

TOPOGRAPHY.

The lowlands of Southeast Missouri are part of a broad arm of the Gulf Coastal Plain extending as far north as Cape Girardeau and known as the Tertiary embayment. Both topographically and geologically this area is unique for Missouri, as it is composed chiefly of wide, flat alluvial bottoms stretching from the border of the Ozark upland eastward to the Mississippi and beyond. These bottoms lie almost wholly between 225 and 350 above sea-level, and slope gently to the southeast.

The most conspicuous topographic feature of this lowland area is Crowley's Ridge, in many places rising abruptly from the flats on either side and extending from Commerce, Scott County, southwest through Bloomfield, Dexter, and Campbell into Arkansas. A few breaks occur in this ridge, the widest of which is the Little River gap just west of Oran, Scott County, dividing the true Crowley's Ridge from the Benton Hills on the east. In southern Stoddard and Dunklin Counties the ridge is very narrow, in places less than a mile in width, but to the north it widens to over 15 miles and becomes very irregular in outline. There are other so-called ridges in the lowland area but they are not to be compared with Crowley's Ridge, which at points rises more than 100 feet above the surrounding bottoms. The others are all very low, flat-topped elevations, as a rule scarcely rising above the flood-plain. On the west and north of Crowley's Ridge, flat bottoms extend to the Ozark border, and on the east and southeast, almost without interruption, to the Mississippi.

GEOLOGY.

The embayment area consists of a down-warped depression in old Paleozoic rocks, filled with Cretaceous, Tertiary, Pleistocene, and Recent deposits. The Pleistocene and Recent form a veneer only a few feet to 225 feet in thickness, above many hundred feet of Cretaceous and Tertiary sediments, with their greatest thickness under the center of the embayment. During the Cretaceous and Tertiary periods the seas in which these sediments were laid down advanced and receded many times. Some of the invasions extended to the northernmost limit of the embayment area, others did not. During each invasion, the deeper part of the depression was the first to be flooded and the last to emerge. There occurs, therefore, the greatest thickness of Cretaceous and Tertiary sediments near the center of the depressed area, which formed the deepest part, and was covered oftenest and for the greatest length of time by the invading seas in which the deposits were laid down. As the Missouri lowlands constitute the west side of the embayment area, its deepest part should underlie the southeast corner of Missouri. From this corner in Pemiscot County, the depression grows more shallow as the Ozark border to the west and north is approached, and the Cretaceous and Tertiary deposits consequently become thinner.

The embayment deposits are composed almost entirely of unconsolidated materials, chiefly sands, gravels, clay, marls and lignites. They differ from the dolomites and sandstones of the Ozark upland, in that they are very much younger and softer. A considerable part of the deposits were laid down in very shallow water where strong shifting currents were prevalent, and deposition was very irregular. While the formations in general are characterized by a dominance of one type of material such as sand or clay, the deposits are likely to show great irregularity in composition, with very little persistence of individual beds.

The following brief descriptions summarize the available information on the embayment deposits in Missouri.

Cretaceous formations.—The oldest deposits in the embayment, laid down in the Cretaceous seas, are not known to outcrop anywhere in the Missouri portion of the area, but are exposed to the east in Tennessee and to the south in Arkansas. There is not much doubt, however, that certain of the upper Cretaceous formations underlie much of the Missouri lowlands, especially the southern part. The complete absence of exposures and the lack of deep-well logs make correlation impossible, and the distribution, thickness and character of the Cretaceous formations are to a large extent a matter of conjecture.

The Eutaw, which in western Tennessee consists of 250 to 275 feet of loose sand, with lenses of clay containing lignite or brown coal and petrified wood, is believed to be the oldest Cretaceous formation in the area, and if present must be restricted chiefly to Pemiscot and Dunklin Counties. In northern New Madrid County wells have reached the old Paleozoic floor without penetrating the Eutaw beds. Purdue* states that while the lenses of clay enter rather largely into the composition of the Eutaw formation, its character as a whole, where it is exposed, would not interfere with the free circulation of oil, should it contain that product.

The next formation, the Selma, probably present under the Missouri portion of the embayment area, must be limited chiefly to southern Dunklin and Pemiscot and southeastern New Madrid Counties. In the northern part, the younger formations overlap the older. In western Tennessee the Selma is chiefly a leaden gray, green, or black clay 100 to 375 feet thick,† containing a large number of fossil shells. The nature of this formation where exposed would hardly indicate it to be a possible oil or gas container. It would serve, however, as an excellent cap for any oil or gas which might be continued in the underlying Eutaw sand.

Above the Selma occurs the Ripley formation, composed chiefly of sand with clay lenses and layers similar to the Eutaw. It is the only Cretaceous formation believed to have been identified in deep-well logs in the area. Wells at Clarkton and Caruthersville both probably penetrated the Ripley, possibly entering the Selma; but no records of either well are available for study. At Blythesville, Arkansas, just across the Pemiscot

*Purdue, A. H., Oil and gas conditions in the Reelfoot Lake District of Tennessee; The Resources of Tennessee, vol. III, 1916, p. 27.

†Glenn, L. C., Underground waters of Tennessee and Kentucky west of the Tennessee river, and of the adjacent area in Illinois; U. S. Geol. Survey, Water-Supply Paper No. 164, 1906, p. 26.

County line, a well drilled by the City apparently reached the Ripley formation at 1276 feet and penetrated the upper 150 feet of it. At Campbell, Dunklin County, two city wells 960 feet deep are believed by Shepard* to have reached the Ripley sand at a depth of 940 feet. At Morehouse, in northwestern New Madrid County, a well 780 feet deep encountered "fine, white sand," believed to be Ripley, at a depth of only 446 feet, under probable Wilcox of Tertiary age; and after penetrating 224 feet of the material, passed into the old Paleozoic rock floor below.

The thickness of the Ripley sand is reported to be 400 feet at Wickliffe, Ky., increasing to probably 500 feet farther south. It is believed that as great a thickness may underlie the southeast part of the Missouri lowlands, but this thickness must decrease to the northeast as shown by the Morehouse well log. The Ripley is unquestionably the most extensive of the Cretaceous deposits in the Missouri lowlands, and must overlap the older Selma clay, which in turn probably overlaps the Eutaw sand in the shallower portions of the embayment.

The presence or absence, extent, and thickness of the Cretaceous formations underlying the Lowlands have an important bearing on the oil and gas prospects. Cretaceous formations are productive of oil and gas in the Louisiana and Texas fields to the south and seem more likely to contain commercial quantities of oil or of gas than the overlying Tertiary beds.

Tertiary formations.—Unlike the Cretaceous, beds of Tertiary age outcrop on Crowley's Ridge from Commerce southwest into Arkansas. Two formations have been recognized, the Wilcox and the Lafayette. The Wilcox outcrops most commonly around the base of the ridge, but in places appears well toward the top. Only the upper beds are exposed, and they constitute the oldest embayment deposit yet recognized in outcrop in southeast Missouri.

The Wilcox formation, formerly included in the Lagrange, consists of irregularly bedded sands and clays, with inter-layered lignite. The sand becomes locally indurated to sandstones and even to extremely hard quartzites, observed on Crowley's Ridge near Commerce, Oran, Bell City, Bloomfield, Dexter and other points. Local cementation by iron oxide occurs. The sands are commonly very fine-grained, and white in color where freshly

*Shepard, E. M., Underground water resources of Missouri; U. S. Geol. Survey, Water-Supply Paper No. 195, 1906, p. 175.

exposed. The clays vary from almost white to very dark and are lignitic in places. Near Ardeola, Stoddard County, a small amount of lignite has been mined from the Wilcox.

Very little is known about the thickness of the formation in southeast Missouri. In northeast Arkansas, it is said to be probably* "not less than 500 feet nor greater than 1,000 feet." Where thickest in Pemiscot County, there cannot be much doubt that it exceeds 500 feet and probably closely approaches the maximum of 1,000 feet. In the City wells at Campbell, Dunklin County, 785 feet of the Wilcox is believed to have been penetrated and the well started below the highest beds. If, as seems probable, the Tertiary deposits beneath the Lafayette gravels underlying Crowley's Ridge near Campbell can be credited to the Wilcox, the full thickness may be close to 900 feet in this locality. To the north and northeast the formation thins and at Morehouse may not be much more than 200 feet thick.

It is believed that the Wilcox overlaps from the Cretaceous onto the Paleozoic rock floor. The Midway, chiefly limestone, below the Wilcox farther south, does not seem to be present in the Missouri area. Neither have the Claiborne and Jackson formations, which overlie the Wilcox in parts of northeast Arkansas, been recognized, though one or both may be present beneath the alluvium in the southeast corner.

On Crowley's Ridge, the next Tertiary formation above the Wilcox is the Lafayette. This is composed of from a few feet to 40 or 50 feet of coarse sand and gravel, usually red in color, present only on the Ridge. Above the Lafayette and capping the Ridge occurs a mantle of loess, younger than the Tertiary deposits.

Pleistocene and Recent deposits.—The Pleistocene and Recent deposits nearly everywhere cover the Lowland area, concealing the older sediments. On Crowley's Ridge these deposits consist of a capping of yellow loessial clay; on the surrounding bottoms Recent alluvium is spread out as a veneer with a thickness of from 50 to 200 feet. These deposits have no commercial oil and gas possibilities.

Total thickness of embayment deposits.—The exact thickness of the embayment deposits is known at only a few points. The old Paleozoic floor on which they rest becomes gradually depressed with distance from the Ozark border, and should be

*Stephenson, L. W., and Cuder, A. F., Geology and ground water of Northeastern Arkansas; U. S. Geol. Survey, Water-Supply Paper No. 399, 1916, p. 56.

deepest in the southeast part of the lowlands in Pemiscot County.

At Benton, Scott County, a well on the Benton Hills reached the Paleozoic floor at a depth of only 158 feet; near Dexter, a well at the base of Crowley's Ridge encountered it at 500 feet; at Morehouse and Sikeston this floor was reached at depths of 690 and 720 feet respectively. Further south the following wells have failed to reach the base of the Embayment deposits; at Campbell, 960 feet deep; at Clarkton, Dunklin County, 1400 to 1500 feet;* at Carruthersville, 1550 feet; and near Sanburg, Tenn., about 15 miles south of New Madrid, 2000 feet. There is no reason to believe that the Embayment deposits are thinner in eastern Pemiscot County than in western Tennessee, and it is probable that they have a maximum thickness in southeast Missouri of at least 2,000 feet and probably more.

STRUCTURE OF AREA.

Very little more than the general structure of the area is known, the mantle of alluvium which covers nearly the entire region making the problem of working out details of structure from surface observations almost hopeless. Deep wells are too few to be of any great assistance. Consequently the location of any anticlines or synclines which may occur in the area remains almost entirely unknown and will continue to do so until a large number of deep wells have been drilled and their logs made available for study.

The regional dip of the strata is to the southeast away from the Ozark border, at an angle much less than 1°. It is the normal dip of the rocks toward the center of the Embayment area, where it meets the southwest and west dip of the beds from Kentucky and Tennessee.

There is no reason to believe that any marked folding has taken place in the Embayment deposits, though crustal movement is known to have followed the Lower Cretaceous, Upper Cretaceous and Tertiary periods of deposition. It is possible that some folding resulted from these general movements but such has not been detected in southeast Missouri. Concerning the Tennessee area immediately to the east, Purdue† says,

"High folds, with strong dips cannot be expected in the Reelfoot Lake

*Information concerning this well is very contradictory and possibly not to be depended upon.

†Purdue, A. H., The resources of Tennessee; vol. VI, No. 1, 1913, p. 32.

District, or elsewhere in the Embayment area. The anticlines, if they exist, are low and flat."

It should be emphasized that Crowley's Ridge is an erosion reminant, pure and simple, not an anticline, and not the result of folding.

It is believed by many investigators, that the crustal movement accompanying the earthquake shocks of 1811-12 in this region produced uplifted or domed areas as well as sunken lands. Investigations by Fuller* led him to believe that locally, doming had actually taken place, and he terms two of the areas the Tiptonville and the Blytheville domes. The Tiptonville dome begins just south of New Madrid and extends south for a distance of 15 miles with a width of about 10 miles, as nearly as can be determined. It lies chiefly in Tennessee and the town of Tiptonville is near its center. The Blytheville dome is 7 to 10 miles in diameter and is rather similar in character to the Tiptonville dome. It surrounds the town of Blytheville, Arkansas. In both case the doming is very low, probably not over 10 to 20 feet at the most. Some have been very skeptical concerning the dome character of these low elevations, though most students of the region agree that slight elevation has taken place, and that doming was, in a large part at least, the result of the 1811 earthquake.

EVIDENCES OF OIL AND GAS.

Many reports have been received at this Bureau from the Lowlands area relative to the finding of small quantities of gas in drilling, driving or boring shallow water wells. Usually this gas has been found only a few feet from the surface, under circumstances which readily lead to the conclusion that it is marsh gas rather than petroleum gas. Most of these reported occurrences have come from localities underlain by alluvium, and the gas is no doubt the result of decaying vegetation in the alluvial sands and clays. No gas has been reported in the deep wells of this area, and nothing but marsh gas in the shallower wells. The amount of vegetable matter deposited in pockets in the alluvium is frequently shown along the Mississippi where undermining of the banks frequently exposes great masses of trees and other vegetable debris.

Recent drilling at Advance is reported to have encountered some oil and the well is said to have been pumped for some time.

*Fuller, M. L., The New Madrid Earthquake; U. S. Geol. Survey, Bull. No. 494.

WELLS DRILLED FOR OIL.

In 1910-11, a well was sunk one-half mile east of Clarkton, Dunklin County, for oil and gas. The reported depth was between 1400 and 1500 feet, and the well bottomed in unconsolidated deposits, probably Cretaceous. No oil or gas was encountered, and at completion a natural flow of water continued until the casing was removed, and the well ruined. The hole was drilled with a rotary rig by W. M. Shriver and John Sullivan, No log was kept.

A test well was started in 1913 about 3-1/2 miles northwest of Dexter, Stoddard County (SE. 1/4 sec. 7, T. 25 N., R. 10 E.) on the west slope of Crowley's Ridge. Local parties from Dexter and Bloomfield financed the drilling and the well had reached a depth of about 2275 feet when drilling was stopped in 1915. The drilling passed through unconsolidated sands for 545 feet, but below this depth Paleozoic dolomites and thin sandstones were penetrated to the bottom of the hole. Strong salt water was encountered but no oil or gas was found in this well.

In 1888 a well was drilled for oil and gas about 5 miles southwest of Naylor, Ripley County, by the Horton Lumber Company. The location is only about three miles from the edge of the embayment area but it is reported that the Paleozoic floor was reached at a depth of 700 feet and the hard rock penetrated to a depth of 900 feet. This great thickness of unconsolidated deposits so close to the old Ozark Bluff line is quite unusual, and it is probable that the reports concerning the wells are somewhat in error. No oil or gas was found in the drilling and no log was kept.

The above-mentioned wells constitute the only wells sun for oil and gas in the Lowlands of southeast Missouri. A few other wells sunk for water are included in the following tabulation. None of these are reported to have encountered oil or gas

DEEP WELLS IN LOWLANDS OF SOUTHEAST MISSOURI.

County.	Owner.	Location.	Depth.	Date.	Depth to rock floor.	Bottomed in.	Remarks.
Pemiscot....	City of Carruthersville.........	Carruthersville....	1550	1917	Not reached.	Ripley (?),.........	For city water supply.
	Mo. Pub. Utilities Company....	Caruthersville.....	1718	......	Not reached.	Wilcox formation (?).	For water supply
	Wisconsin Lumber Co..........	Deering...........	513	1913	Not reached.	Wilcox (?)..........	For water supply
New Madrid.	Himmelberger-Harrison Lumber Co........................	Morehouse........	780	1902	680	Ordovician or older...	Strong flow of salt water.
	....	Near Clarkton.....	1450	1911	Not reached.	(?)	Flowing well.
Dunklin....	City of Campbell..............	Campbell.........	960	1902	Not reached.	Ripley sand	One to 7 wells same depth. Flowing well.
Stoddard....	Dexter Oil & Gas Company.....	Dexter S. ½ sec. 7, T. 25 N., R. 10 E.	2275	1915	500	Cambrian..........	Test for oil and gas. Encountered salt water.
Scott.......	Malone Park..................	Sikeston..........	735	1907	720	Ordovician or older...	For water supply.
	County......................	Benton...........	1500	1904	158	Cambrian..........	On Benton Hills and for water supply.
Ripley......	Horton Lumber Co............	Nayler 5 miles S.W.	990	1888	700 (?)	Ordovician or older...	....

Up to the present time there is no direct evidence to indicate that any appreciable quantities of oil or gas underlie the Lowlands of southeast Missouri. No favorable structural features are known to occur, for though such structures may be present they are not detectable. The domes mentioned by Fuller as probably resulting from earthquake disturbances are too recent to be of probable importance. Drilling for oil and gas in this area is, therefore, at the present time only a highly speculative venture, which must be undertaken with very little geologic assistance.

OIL AND GAS IN PLEISTOCENE DEPOSITS.

Reports are frequently received from those Counties in northern Missouri underlain by glacial drift, that gas has been encountered at shallow depths in drilling wells for water. An investigation of a number of these reports indicates the occurrence of small quantities of gas at scattered points in the drift, at depths ranging from less than 100 feet to about 200 feet, chiefly in Sullivan, Putnam, Grundy and adjacent Counties. There may be many other occurrences still unrecorded.

Small quantities of gas in the glacial drift, while not at all uncommon, are rarely of commercial importance. However, in Champaign County, Illinois,* and elsewhere in that state, gas has been found in the drift under very similar conditions in sufficient quantities for lighting and heating country towns for several years. In Missouri such gas has never been utilized at any place, possibly the quantity in any one well has not been large enough. Still in at least one well, about 2 miles east of Harris, Sullivan County, enough gas was reported at a depth of about 200 feet, to blow with force from the cap of the well until the gas horizon was penetrated and water rose above it. It is possible that enough gas could have been obtained from such a well as this for heating and lighting a home, but the commonly brief life of such a gas supply and the water difficulties to be anticipated make any great outlay for equipment and installation a very precarious matter.

Concerning the details of any of the wells from which gas has been reported in the glacial drift, very little information is available. The source of gas is traceable to the presence of

*Knirk, Carl F., Natural gas in the glacial drift of Champaign County, Illinois Geol. Survey, Bulletin 14, 1908, pp. 272-275.

organic material imbedded in the drift. Drillers commonly encounter large logs, and less commonly black gummy clay, containing leaves, at depths of 100 feet or more. In certain localities these materials are especially abundant and, through decomposition, could be the source of supply for a considerable amount of gas. Many irregular lenses and pockets of sand and gravel scattered through the drift form excellent reservoirs for the accumulation of gas, since they are tightly sealed above by impervious clays.

With these requisite conditions, it is not at all surprising that small quantities of gas are found here and there in glacial deposits. It would, however, be considered exceptional, if large commercial quantities occurred. Any discoveries must be purely accidental, as there is no way of foretelling the presence or absence of the irregular lenses of sand, or of the organic materials in sufficient quantity to offer a source of gas. It should also be borne in mind that gas found in the drift deposits probably has no significance whatever, relative to the possibilities of finding oil or gas in the older consolidated rocks below.

ADDITIONAL MISCELLANEOUS WELL RECORDS.

LOG OF WELL AT ROLLA, PHELPS COUNTY.

	Thickness.	Depth.
Jefferson City limestone (279 feet):	*Feet.*	*Feet.*
Soil	25	25
Compact light gray "cotton rock" (dolomite)	10	35
Same, trace of chert	5	40
Compact "cotton rock"	5	45
Same, with a little chert	5	50
Buff-colored, fine-grained "cotton rock," some white chert	15	65
Gray splintery dolomite, some flint	20	85
Fine-grained, buff-colored, siliceous limestone, with white flint	5	90
Light gray, splintery limestone, some white flint	5	95
Light gray, splintery "cotton rock" (dolomite)	5	100
Fine-grained, splintery siliceous magnesian limestone	5	105
Fine-grained, white to gray, cherty limestone	5	110
Fine-grained, light gray, splintery, siliceous dolomite	10	120
Fine-grained, white dolomite, more compact	10	130
Fine-grained, light gray, splintery dolomite	15	145
Coarser-grained light gray, siliceous dolomite, granular, some chert, with little blue shale	25	170
Coarser-grained, gray, siliceous dolomite, increase of chert and quartzite	15	185
Fine-grained, dark gray, siliceous dolomite, some white chert and marcasite	20	205
Fine-grained dolomite, with some white chert and marcasite	19	224
Same, with dark-colored siliceous dolomite	5	229
Dark gray siliceous dolomite and white chert	25	254
Mottled siliceous dolomite, some white chert and marcasite	25	279

LOG OF WELL AT ROLLA, PHELPS COUNTY—Continued.

	Thickness.	Depth.
	Feet.	*Feet.*
Roubidoux sandstone (65 feet):		
Quartz sandstone, coarse, waterworn, little white chert and marcasite	20	299
Light gray dolomite, with marcasite and white chert	10	309
Fine sandstone, with white siliceous dolomite and marcasite	5	314
Light gray siliceous dolomite, with sandstone, white chert, and marcasite	20	334
Fine-grained white chert, with marcasite	5	339
White waterworn sand, white chert, and much marcasite	5	344
Gasconade limestone (256 feet):		
White to gray cherty quartzite, with marcasite	10	354
Gray siliceous dolomite, with some chert and marcasite	65	419
Light gray, fine-grained, cherty, quartzite sand, oolitic	15	434
Gray siliceous dolomite, with chert and more marcasite	39	473
Coarser blue and white chert, with some siliceous dolomite and grains of marcasite	5	478
Fine-grained, gray, siliceous dolomite, less white chert and marcasite	25	503
Fine-grained, gray, siliceous dolomite, with magnesian shale, white chert, and marcasite	10	513
Fine-grained siliceous dolomite, with cherty quartzite and some marcasite	15	528
Cherty siliceous dolomite and marcasite	65	593
Fine-grained, sandy dolomite, chert, and much marcasite	5	598

LOG OF WELL NEAR POMONA, HOWELL COUNTY, MO. POMONA OIL & GAS COMPANY.

(Well starts in Jefferson City dolomite.)

	Thickness.	Depth.
	Feet.	*Feet.*
Soil, clay and chert	45	45
Dolomite, cherty	20	65
Sandstone and quartzite	20	85
Dolomite, light brown and gray, cherty	65	150
Dolomite, sandy	40	190
Sandstone and quartzite	15	205
Dolomite, light gray and light brown, sandy in places	90	295
Dolomite, light gray and light brown, cherty	490	785
Dolomite, white, and rounded sand grains	50	835
Dolomite, white to light gray, becoming light brown towards bottom, no chert	300	1135
Dolomite, dark and light brown, crushed quartz and chalcedony	295	1430
Dolomite, gray and brown, some crushed quartz	235	1665
Dolomite, light gray, glauconitic, dark shale at 1790 and 1805	200	1865
Sandstone, light gray, and dolomite, light gray	15	1880
Dolomite, light and dark gray, glauconitic and shaly	60	1940
Limestone, slightly magnesian in places, glauconitic and shaly	195	2135
Dolomite, light gray, glauconitic	40	2175
Sandstone, gray, then buff, then pink, locally glauconitic and gray dolomite (2365-2495 pink, possibly Pre-Cam. quartzite)	320	2495
Granite; quartz, crushed, feldspar white and pink, much black mica	379	2874

LOG OF CARTHAGE WATERWORKS WELL NO. 6, CARTHAGE MO.

(Well starts in Mississippi limestone.)

	Thickness.	Depth.
	Feet.	*Feet.*
Clay and boulders	18	18
Limestone, gray crystalline cherty	157	175
Cherty, white to blue	35	200
Limestone, gray, cherty	173	373
Shale, bluish	13	386
Dolomite, cherty	154	540
Sandstone and dolomite	20	560
Dolomite, gray, cherty	220	780
Sandstone	15	795
Dolomite	95	890
Sandstone	25	915
Dolomite, gray, upper part cherty	695	1610
Sandstone	177	1787
Granite	67	1854

LOG OF WELL AT PACIFIC, MO. DRILLED BY PACIFIC OIL COMPANY. NW. ¼, SE. ¼, SEC. 13, T. 43, R. 2 E.

(Well starts in Jefferson City dolomite.)

	Thickness.	Depth.
	Feet.	*Feet.*
Clay and chert	43	43
Dolomite, cherty	434	477
Sandstone, white	15	492
Dolomite, sandy	8	500
Sandstone, white	5	505
Dolomite, cherty	12	517
Sandstone	18	535
Dolomite, cherty	565	1100
Dolomite, brown	150	1250
Dolomite	150	1400
Shale, drab	170	1570
Dolomite, brown and gray	275	1845
Dolomite, chloritic	35	1880
Sandstone, white to red	395	2275

LOG OF DEEP WELL NO. 1, SPRINGFIELD CITY WATER COMPANY.

Located at the Fulbright Spring pumping station, about 30 ft. south of the engine house, near the NE. corner sec. 3, T. 29 N., R. 22 W. Drilled in 1914. Log and correlations submitted by DR. E. M. SHEPARD.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil, clay and broken chert	10	10
Coarse-grained limestone, 20 % white compact chert	10	20
Coarse, gray limestone, 25 % white compact chert	10	30
Compact, gray limestone, 40 % white compact chert	10	40
Hard, white, compact, knife-blade chert	20	60
Dark gray, hard, compact, silicious limestone, trace of white chert	10	70
Coarse-grained, bluish, hard, silicious limestone, 30 % white chert	10	80
Dark bluish-gray, hard, compact limestone, 5 % hard, white chert	10	90
Light bluish-gray, compact limestone, 10 % hard white chert	10	100
Dark blue, silicious shale	5	105
Coarse fragments of light blue shale	35	140
Gray silicious shale and lime, some chert and considerable marcasite	5	145
Coarse particles light gray, silicious dolomite	7 ½	152 ½
Very light gray particles silicious dolomite with rounded dark, water-worn sand grains, considerable marcasite, some silicious particles	5	157 ½
Dark, silicious, dolomitic lime, small rounded grains of drusy quartz (sand), some marcasite, a few rounded dark pebbles	2 ½	160
Mixture of highly silicious gray dolomite, some silicious shale, some marcasite, small rounded quartz grains	2 ½	162 ½
Light gray, silicious dolomite	13 ½	176
Dark gray, silicious dolomite, few fragments of blue shale	4	180
Gray quartzite, some dolomite	5	185
Mixture of highly silicious dolomite, quartzite and some white flint	5	190
Light gray, highly silicious dolomite, larger particles of brown shale	10	200
Coarse fragments highly silicious gray dolomite	10	210
Coarse particles light gray, silicious dolomite	10	220
Fine particles gray, silicious dolomite, trace of marcasite	10	230
Fine particles white dolomite (cotton rock)	10	240
Irregular particles of bluish to light gray dolomite, trace of marcasite	10	250
Mixture of light gray dolomite, bluish chalcedonic flint and some marcasite	10	260
Light gray dolomite	10	270
Fine particles grayish, silicious dolomite, some marcasite, small amount chert	10	280
Fine particles mixture of light gray dolomite, white chalcedonic chert, some marcasite, trace of sand	10	290
Mixture of quartzite, sand-grains, silicious dolomite, marcasite, white chert	10	300
Mixture silicious dolomite, white and chalcedonic flint, some marcasite	5	305
Highly silicious, compact dolomite, some grains sandstone and zinc	2	307
Coarse, crystalline dolomite, some sand	13	320
Fine, light gray to white dolomite (cotton rock)	10	330
Fine, compact, light gray dolomite, 10 % chert or quartzite	20	350
Light gray to silicious white dolomite, 5 % blue to brown shale, large particles	10	360
Same, no chert	10	370
Very fine sandlike translucent dolomite	10	380
Coarser-grained, light gray to white silicious dolomite, traces chalcedonic chert	10	390
Gray, silicious dolomite, 5 % white chert	10	400
Gray to white silicious dolomite, 10 % white chert	10	410
Gray, silicious dolomite, 5 % milk-white chert	10	420
Dark gray, silicious dolomite, 2 % white chert	10	430
Dark gray, silicious dolomite, trace of glasslike quartz and granular chert	10	440
Mixture gray to white, silicious dolomite, 5 % shaly white chert	5	445

LOG OF DEEP WELL NO. 1, SPRINGFIELD CITY WATER COMPANY—Continued

	Thickness.	Depth.
	Feet.	*Feet.*
Light gray to white silicious dolomite, trace iron pyrites	5	450
Gray, silicious dolomite, 10 % white chert	10	460
Gray, silicious dolomite, translucent white chert	10	470
Dark gray, silicious dolomite, 20 % white chert	10	480
Fine pinkish sandstone, 10 % quartzite	10	490
Very fine reddish sandstone, Roubidoux sandstone	10	500
Honeycombed or pitted brown silicious dolomite and sandstone, 10 % chert	10	510
Very fine brown sandstone, rounded to angular grains	5	515
Very fine pellucid sandstone, rounded to angular grains	5	520
Chalcedonic to white quartzite and chert, some sandstone	10	530
Mixture of above, smaller particles, 20 % silicious dolomite	5	535
Mixture of above, with sandstone, quartzite and silicious dolomite	5	540
Fine, sandy, pellucid, silicious dolomite	10	550
Dark gray, silicious dolomite, white quartzite, translucent sandstone	5	555
Brownish silicious dolomite, some quartzite	5	560
Light gray, chalcedonic quartzite, some sandstone	5	565
Fine-grained, light brown, pellucid sandstone	10	575
Fine-grained sand and quartzite, trace chert	5	580
Fine-grained sandstone and quartzite, trace chert	10	590
Fine-grained chalcedonic quartzite, some oolite	5	595
Fine-grained chalcedonic quartzite, 20 % sandstone, some dolomite	5	600
Fine-grained grayish dolomite, some quartzite	5	605
Fine-grained sandstone, rounded to angular, some dolomite	13	618
Fine-grained, reddish-brown, silicious dolomite, 10 % white chert, trace iron	4	622
Light brown, fine-grained, silicious dolomite, 10 % white chert	5	627
Light gray, sandy, silicious dolomite, some sandstone	33	660
Light brown, compact, silicious dolomite	10	670
Light gray, compact, silicious dolomite	30	700
Light brown, silicious dolomite, some chalcedonic chert	10	710
Gray, silicious dolomite, some sand and white chert	10	720
Highly crystalline silicious dolomite, some white chert	5	725
Same, plus 20 % blue chalcedonic flint	2	727
Same, with small amount of flint	10	737
Light gray, crystalline, dolomitic limestone, trace of flint	10	747
Same, plus 15 % bluish chalcedonic flint	10	757
Same, plus 10 % bluish chalcedonic flint	8	765
Same, plus 5 % bluish chalcedonic flint	7	772
Brownish, silicious dolomite, 10 % white chert, 1 % quartzite	8	780
Light gray silicious dolomite, 5 % chalcedonic chert	10	790
Coarser particles of gray silicious dolomite, 30 % chalcedonic flint and white chert	10	800
Light brown silicious dolomite, 15 % chalcedonic flint and white chert	10	810
Light gray silicious dolomite, 20 % white chert and quartzite	10	820
Light gray silicious dolomite, fine-grained, 10 % white chert and quartzite	10	830
Fine-grained sandy dolomite, quartzite and foetid sandstone	10	840
Fine-grained sandy dolomite, foetid limestone, quartzite, and sand	25	865
Fine-grained dolomite, foetid limestone, quartzite and sand	10	875
Fine-grained pellucid dolomite	10	885
Fine-grained pellucid dolomite, trace chert and sand	25	910
Same as above, with trace of quartzite	10	920
Gray, granular, silicious dolomite, some chert	10	930
Mainly chert, quartzite, 10 % silicious lime, trace of sand	10	940
Fine particles grayish dolomite, 10 % chert	10	950
White, medium coarse, translucent to transparent, angular to rounded grains of quartz sand	14	964
Saccharoidal sandstone	3 ½	967 ½
Saccharoidal sandstone, more rounded grains	26 ½	994

LOG OF DEEP WELL NO. 1, SPRINGFIELD CITY WATER COMPANY—Continued.

	Thickness.	Depth.
	Feet.	*Feet.*
Pale-bluish quartzite sand, some dolomite	6	1000
Granular, bluish-gray, translucent, silicious dolomite	15	1015
Fine-grained to compact magnesian limestone (cotton rock)	25	1040
Milk-white cotton rock, slightly silicious	20	1060
Milk-white cotton rock, slightly silicious	40	1100
Minutely crystalline white silicious limestone (cotton rock)	5	1105
Finely granular to compact, white, silicious magnesian limestone	5	1110
Minutely granular, white, silicious magnesian limestone, dolomite	5	1115
Compact cotton rock, minute, translucent, white, silicious particles, dolomite	5	1120
Same as above, but less compact	5	1125
Same as above, but very fine-grained	5	1130
Same as above, but very fine-grained and slightly oolitic	10	1140
Silicious magnesian limestone (cotton rock), white and minutely crystalline	5	1145
Same as above, but more compact	5	1150
Very compact, minutely crystalline, dolomitic magnesian limestone (cotton rock)	5	1155
Coarser-grained, translucent, dolomitic, magnesian limestone (cotton rock)	5	1160
Same as above, but more silicious	5	1165
Soft, compact, dolomitic, magnesian limestone (cotton rock)	15	1180
Same as above, but minutely crystalline	20	1200
Same as above, chalky	10	1210
Same as above, but more granular and silicious	10	1220
Missing	10	1230
Soft, compact, magnesian limestone (cotton rock)	30	1260
Several 1 to 4-inch openings or crevices at this level and drillings difficult to obtain.		
Light grayish, fine-grained, dolomitic limestone	5	1265
Milk-white, chalklike, magnesian limestone (cotton rock)	5	1270
Light gray, fine-grained, silicious, magnesian limestone	15	1285
Same, but slightly darker gray	5	1290
Light gray, compact, chalky, magnesian limestone (cotton rock)	20	1310
Chalklike, white, dolomitic limestone	5	1315
Light brown, translucent, silicious, dolomitic limestone	5	1320
Gray, fine-grained, silicious, dolomitic limestone	5	1325
Very dark brown, silicious, magnesian limestone, 20 % nearly black granulated limestone	5	1330
Same, with 80 % light brown, granular, silicious limestone	20	1350
Dark brown, silicious limestone, composed of a few very dark particles scattered through the lighter brown material	5	1355
Very dark, silicious, magnesian limestone, with a few red particles and 10 % black granules—probably chert	5	1360
Dark brown, silicious, magnesian limestone, crystalline, with some darker particles	10	1370
Same, except darker	20	1390
Coarser, pitted, impure, magnesian limestone, with a mixture of irregularly disseminated darker or lighter particles, a structure producing the differential weathering or honeycomb structure seen wherever this rock appears on the surface	14½	1404½

SUMMARY OF GEOLOGICAL FORMATIONS PASSED THROUGH IN SPRINGFIELD WATER CO. DEEP WELL NO. 1.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	10	10
Upper Burlington	30	40
Lower Burlington	40	80
Chouteau limestone	20	100
Hannibal sandstone and shales	45	145
Louisiana limestone	7 ½	152 ½
Devonian limestone, sandstone and shale	27 ½	175
Joachim limestone	105	280
St. Peter sandstone	35	315
Jefferson City limestone	175?	490?
Roubidoux formation	300?	790?
Gasconade limestone	168	958
Gunter sandstone	35	993
Decaturville, or Proctor limestone	121	1114
Bonne Terre formation	290 ½	1404 ½

It is very difficult to accurately differentiate these lowest beds, with only the drillings as a guide, since they are so far removed from any surface exposures.

It is my opinion that the Decaturville, or Proctor, horizon, the lowest to be well differentiated, extends to a depth of 1114 feet, giving a thickness of 121 feet for this formation. The remainder of the well-section, 290 ½ feet, more closely resembles the Bonne Terre formation. It could hardly be the Potosi, because of the decided absence of chert and drusy quartz.

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