STATE GEOLOGICAL SURVEY OF KANSAS

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BULLETIN 23

ORIGIN OF THE SHOESTRING SANDS OF GREENWOOD AND BUTLER COUNTIES, KANSAS

By
N. WOOD BASS

Investigation conducted under a coöperative agreement between the United States Geological Survey and the State Geological Survey of Kansas

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CONTENTS

ILLUSTRATIONS

ABSTRACT

High-grade oil, occurring in the shoestring sands in the Cherokee shale of Pennsylvanian age, has been produced for fifteen years in Greenwood, Butler and adjacent counties, in southeast central Kansas. The shoestring sand bodies are lens-shaped and elongated, and range in thickness from 50 to more than 100 feet, in width from ½ to 1½ miles, and in length from 1 to 7 miles; they are systematically arranged approximately end to end and form several systems, or trends, each 25 to 45 or more miles long. Two systems with parallel trends in a northeast-southwest direction are known locally as the main trends; two others, also approximately parallel, known as cross trends, extend northwest-southeast. A fifth system having a north-south trend is 35 miles long.

The area in Greenwood, Butler and adjacent counties is especially appropriate for a study of such sand bodies, because several of the shoestring sand systems have been completely developed by oil wells throughout their lengths of 25 to 45 miles, and because the oil wells, together with hundreds of dry holes, have closely defined the outlines and distribution of the sand bodies. There are, however, some undrilled areas of considerable extent wherein the sand systems may be present. The methods here used for studying the sands, and the conclusions obtained from the studies, are believed to be applicable not only to undeveloped areas in Kansas but to many areas in Oklahoma and Texas, and probably elsewhere.

The composition, shapes and sizes of the sand grains were studied and compared with those of sand grains in modern sands of known origin, in the channel sandstone deposits of Pennsylvanian age exposed in Missouri, and in the sandstone lenses in the Cherokee shale exposed in eastern Kansas and northeastern Oklahoma. Most of the shoestring sand lenses are composed of very fine to fine grains of subangular quartz, with minor amounts of feldspar and mica; silt and clay comprise 15 to 30 percent of the material. Coarse and very coarse sand, composed largely of well-rounded quartz grains, characterize the sand bodies in a portion of one cross trend.

The shapes of the sand bodies were studied by means of scores of cross sections constructed from well logs, and by block diagrams of the individual sand bodies, a few of which are reproduced

here. The studies show that the sand bodies are flat-bottomed lenses with convex tops, and that the individual lenses are separated by narrow stretches of country barren of sand. The cross sections show also that the sands of one system are somewhat higher stratigraphically than those of another. A map of Greenwood, Butler and adjacent counties showing the distribution of the shoestring sands, reveals that each sand body is arranged *en echelon* with respect to the adjacent bodies, a feature which is believed to be highly significant in determining the origin of the sand lenses.

The distribution of the shoestring sands indicates clearly that they are either stream channel deposits or offshore bars. The high content of silt and clay suggests that the sands were not formed as offshore bars, but may represent stream deposits; on the other hand, the well-rounded, coarse sand found in parts of the area is more characteristic of offshore bar sand. The cross sections, the block diagrams, and the maps showing the distribution of the sand indicate that the sand bodics are similar in outline and form to modern offshore bars and are dissimilar to stream channel deposits. The conclusion from available evidence is that the sand bodies are offshore bars that accumulated in a broad bay on the western shore of the Cherokee sea. Most of the sand bodies are included in two systems that were deposited at slightly different times; each system is composed of a main trend, and a cross trend, as referred to locally.

During the last of the two stages of bar building the newly formed shoreline cut diagonally across the old shore line and a part of the earlier offshore bar system lay seaward below the surface of the water. The waves and currents that built the second system of bars partly destroyed the seaward portions of the sand bodies of the older system. The probable distribution of land and sea during the time the offshore bars were being deposited is illustrated by maps of eastern Kansas. There are many areas in the region that may contain undiscovered oil fields.

Origin of the Shoestring Sands of Greenwood and Butler Counties, Kansas[a]

By N. Wood Bass

INTRODUCTION

Elongated lenses of quartz sand that are prolific bearers of high-grade oil are found in the lower part of the Cherokee shale, of Pennsylvanian age, at depths ranging around 2,000 feet in Greenwood, Butler and adjacent counties, Kansas. Some lenses are between six and eight times, and many are as much as four times greater in length than width. The individual lenses are arranged approximately end to end, separated by narrow gaps so that they form collectively long narrow systems, each 20 to 50 miles long and only a half mile to 1½ miles wide. Because of the great lengths of the belts compared with their widths the sand bodies are commonly referred to as shoestring sands; also, the oil and gas fields developed in the sands are likewise referred to as shoestring pools. In Kansas the belts of shoestring sand lenses and also the shoestring pools, are referred to as "trends." Small elliptical and circular lenses of sandstone that produce oil and gas in T. 24 S., R. 12 E., and T. 25 S., R. 13 E., Greenwood county, are regarded as shoestring sands also, and the oil pools as shoestring pools, because the sand bodies occur not only at the stratigraphic horizon of other shoestring sands in the region, but also in the trend of other shoestring pools. Two sand trends, one 15 miles and the other 45 to 50 miles long, extend as parallel bands, about 6 miles apart, from eastern Butler county in a direction of north 40 to 45 degrees east across northwestern Greenwood county into Lyon county (see Plate 1). These are locally referred to as the main trends. Two other sand trends, about 8 to 10 miles apart, extend in a direction of north 40 to 50 degrees west from western Woodson county across northern Greenwood county into Lyon county. These are locally called "cross trends." One of the cross trends crosses at right angles the longer main trend in the northwestern-most part of T. 23 S., R. 11 E. A fifth sand trend, somewhat removed from the four trends just mentioned, extends slightly west of north for more than 30 miles from north-central Cowley county through south-central Butler county, but it is broken by comparatively wide gaps.

a. A preliminary report on this subject, prepared by the author, was published in Am. Assoc. Petroleum Geologists Bull., vol. 18, pp. 1313-1345, 1934. Discussion by F. G. Holl, J. L. Rich and others appeared on pp. 1343-1345, and by R. S. Tarr on pp. 1710-1712.

For convenience in referring to the sand trends they are designated in this report the Teeter, Sallyards, Quincy, Lamont and Haverhill trends (see Plate 1). The sand lenses are not all at one stratigraphic horizon, but all are confined to a restricted stratigraphic zone. The great expanses of country between the narrow sand trends contain little sand at the horizon of the lenses; there, gray to black shale, red rock, or very fine sandy shale are the most common rock types at this horizon.

The chief problem in the present study of these sand bodies is that of their origin. The correct interpretation of this problem is not only of scientific interest, but it has much commercial importance because of the economic application of the interpretation to Greenwood, Butler and adjacent counties and to other portions of Kansas, as well as to areas in Oklahoma and other states where oil deposits of similar type remain to be drilled. As information has accumulated during the exploration in the oil-producing states, particularly Kansas, Oklahoma and Texas, oil-bearing sand lenses not wholly unlike these Greenwood-Butler county shoestrings have been found to be much more numerous than was earlier believed. Their very limited dimensions and lack of expression at the surface make them difficult to locate with the drill, but the high quality of the oil, the longevity of the production, and the relative shallowness of the drilling in many localities make their exploitation attractive to the oil producer.

Location of the Area

The shoestring sands described in this report occur in southeast-central Kansas, chiefly in Greenwood and Butler counties, and to a lesser extent in Woodson, Lyon, Chase and Cowley counties. (See Fig. 1.) Shoestring sands are of common occurrence throughout a much larger region, including much of southeastern and east-central Kansas. Those in Miami, Franklin, Linn, Anderson and Allen counties have been studied by Rich,[1] and those in Anderson county by Charles.[2]

Surface Features

The surface of the eastern third of Kansas is characterized by a series of parallel plains trending in a northeasterly direction and separated in steplike succession by eastward facing rises or escarpments. The plains, therefore, form a succession of steps that in-

1. Rich, John L., Shoestrings of eastern Kansas: Am. Assoc. Petroleum Geologists Bull., vol. 7, pp. 103-113, 1923, also vol. 10, pp. 568-580, 1926.
2. Charles, Homer H., Oil and gas resources of Kansas, Anderson county: Kansas Geol. Survey Bull. 6, pt. 7, 1927.

crease in altitude progressively westward. The Flint Hills, a strip of country that has comparatively high relief for the plains country, constitute the most pronounced step in eastern Kansas. They trend slightly east of north across the eastern parts of Cowley and Butler counties and across the western part of Greenwood county. They are characterized by steep, eastward slopes with a relief of 150 to 300 feet in a distance of 2 to 3 miles, and a plain sloping from the crest of the Hills westward at a low grade. The westward sloping plain is floored by resistant chert-bearing limestone. Thick shale and thin limestone strata occupy the steep east-facing slopes. The Browning, Teeter, Scott and Sallyards shoestring oil fields, shown on Plate 1, lie within the Flint Hills.

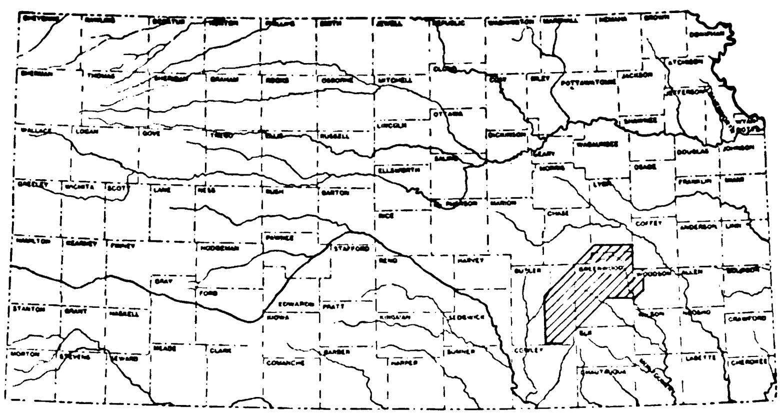


FIGURE 1.—Index map of Kansas showing the area described in this report.

The surface of the region ranges in altitude from a little less than 900 feet to a little more than 1,600 feet above sea level. The Flint Hills attain an altitude of a little more than 1,500 feet above sea level over large areas and reach an altitude of a little greater than 1,600 feet in a few localities; much of the surface of the plains country west of the Flint Hills in Butler and Cowley counties is slightly below 1,500 feet and the plains east of the Flint hills range between 1,100 and 1,250 feet in much of Greenwood county. The channels of some of the streams in the eastern part of Greenwood county have an altitude of only 900 feet.

The Verdigris river and its tributary, Fall river, are the main streams east of the Flint Hills in Greenwood county and the Walnut river is the chief stream west of the Flint Hills in Butler and Cowley counties.

Field and Office Work

This report contains the results of about two and one half years' study; about a quarter of the time was spent in the field in structural and stratigraphic studies of the surface rocks in several of the shoestring oil pools; much of the time in office was devoted to studies of records of approximately 5,000 wells and to laboratory studies of chunk samples (large samples usually resulting from shooting the wells), cores and drill cuttings, mainly from the oil-producing sands.

The actual field work for the report was limited to a study of the relation of the attitude of the surface rocks to the buried sand lenses; in other words, the object of the field work was to determine whether or not the buried sand lenses have produced folds in the surface beds. The field mapping was conducted by means of a plane table and telescopic alidade in accordance with the usual procedure employed by petroleum geologists. Datum points were, however, more closely spaced than is the common practice; this was done for the purpose of providing detailed control for elevations on the structure contour maps, the contour interval being 2 feet instead of the more commonly used interval of 10 feet. Stratigraphic studies outside the oil fields mapped in this way, were made at numerous localities between the Oklahoma-Kansas boundary and the Cottonwood river in the northern part of Chase county in order to determine the correlation of the beds exposed in oil fields of Greenwood county with described stratigraphic sections in Osage county, Oklahoma, and in the Cottonwood river valley, Kansas.

The well logs that were studied in the office were furnished by the Well Log Bureau of the Kansas Geological Society, the Prairie Oil & Gas Co., the Empire Oil & Refining Co., the Skelly Oil Co., the Shell Petroleum Corporation, and other oil companies. These well records supplied data for drawing several hundred stratigraphic sections across the sand bodies and a few longitudinal sections through some of the sand lenses, for drawing block diagrams of the sand bodies of several of the oil fields, and for delimiting the areas that contain the shoestring sands. Studies with the aid of a binocular microscope were made of numerous sets of drill cuttings from the producing sand, which were supplied by the oil companies and individual operators in the region. Also a compilation was made of a large number of microscopic examinations that had been made of drill cuttings by oil company geologists. A few core samples from the sand bodies were studied; thin sections were made from the core samples and studied with a petrographic microscope; also samples of the sands were classified as to grain size by passing them through a series of sieves.

In the course of the field study visits were made to outcrops of elongated, lenticular sand deposits of Pennsylvanian age near Warrensburg, Moberly, Lawrenceburg, and other localities in Missouri. These have, therefore, been compared with the shoestring sands in Greenwood and Butler counties, Kansas. Also, the forms of the shoestring sand trends have been compared with the meander patterns of rivers and also with shore features shown by maps of the coasts of the United States. Shortly before this report was submitted for publication the Atlantic coast between Cape Henry, Va., and Atlantic City, N. J., which includes an almost continuous succession of offshore bars and accompanying marshes, was visited by H. D. Miser and me for the purpose of studying modern coast features that appear to be similar to those that prevailed during the time of deposition of the shoestring sands.

Acknowledgments

It is with a feeling of genuine pleasure that I take this opportunity of expressing my appreciation for the wholehearted coöperation of the many geologists and executives of the operating oil companies and geologists engaged in independent work. Without this coöperation the study resulting in this report would have been impossible to complete. Information that had been obtained through many years was placed so freely at my disposal by so many individuals and companies that space is not available to mention all. In the free discussion that I had with several geologists, no doubt ideas were borrowed that are now incorporated in this report. Wherever it has been possible to segregate the ideas of others, acknowledgment is made at appropriate places in this text.

Special acknowledgment should be made to the companies and individuals named below: John M. Nisbet, Frank T. Clark and George F. Berry, of the Empire Oil & Refining Co., supplied drill cuttings, core samples, descriptions of samples and base maps showing wells in the shoestring sand region; in addition Mr. Clark reviewed the illustrations that were prepared by me for this report. The Skelly Oil Co., through the courtesy of R. B. Rutledge, provided a very complete set of base maps of the shoestring sand region and a base map showing the distribution of the sand lenses; and, through the courtesy of Howard S. Bryant, I made repeated use of the

company's file of logs in connection with the detailed subsurface studies of the shoestring sands. The Shell Petroleum Corporation made available well cuttings and well logs. The Prairie Oil & Gas Co., through Richard Foley and Raymond A. Whortan, and the Sinclair Oil & Gas Co., through L. W. Kesler, permitted me to use plotted logs in much of the region studied in detail. The Sinclair Prairie Oil & Gas Co., through Messrs. Kesler and Foley, made available maps showing wells in the region; Plate 1 was prepared largely from these maps. The Mid-Kansas Oil and Gas Co., through A. E. Cheyney, permitted me to use the company's log file. W. K. Cadman,[3] who described the region several years ago, gave me maps of Greenwood and Butler counties, showing by symbol all wells that found sand, and by a different symbol all wells that failed to find sand at the horizon of the shoestring sand zone; these maps were a great aid in the preparation of Plate 1. R. E. Bending supplied many surface and subsurface structure contour maps of parts of the region. Edward A. Koester supplied the locations of wells in central Kansas that have been drilled to granite. John S. Barwick reviewed the illustrations for the report. The Kansas Geological Society, through Harvel E. White, manager of its Well Log Bureau, made available its file of well logs. The Mid-Continent Petroleum Corporation, through L. S. Youngs, permitted the use of well logs. The Pure Oil Co., through Theron Wasson, A. A. Langworthy and Ira H. Cram, supplied surface structure maps and other data on Greenwood county. J. L. Garlough supplied structure contour maps of parts of Greenwood county. George H. Norton gave me a surface structure contour map of the region that had been compiled by him; he also gave me a map showing the distribution of the sand lenses. The Union Gas Corporation, through C. W. Studt, made available its file of well logs in southeastern Kansas. Theodore Gore, drilling contractor of Wichita, Kansas, supplied chunk samples of the producing sand from wells drilled in the sand trends. W. H. Rex, El Dorado, Kansas, permitted me to use maps from his files. R. J. Conley examined for me a thin section of sand from the Madison oil field. John L. Rich gave me a map of an eastern Kansas stream channel sand; Walter W. Larsh and L. L. Bechtel, of the Stanolind Oil & Gas Co., gave me descriptions of cores taken from the sand in the Edwards Extension oil field. Many of the persons mentioned above, as well as many others, including F. G. Holl, Roy H. Hall,

3. Cadman, W. K., The Golden Lanes of Greenwood County, Kansas: Am. Assoc. Petroleum Geologists Bull., vol. 11, pp. 1151-1172, 1927.

L. C. Hay, T. E. Weirich, Alex W. McCoy, Fritz L. Aurin, J. V. Howell, Douglas W. Johnson, W. H. Twenhofel, and K. C. Heald, discussed with me the problems of the shoestring sands and gave me helpful suggestions and ideas. G. L. Knight, of the Geology Department of the University of Kansas, assisted me in the study of the thin sections of the sands. W. L. Stryker provided data concerning the oil and gas producing sands of Woodson county.

In addition I wish to express my appreciation for the competent assistance in the field mapping of the Browning oil field given by Joseph L. Borden during two months in 1931, and in the mapping of the Thrall and Fankhouser oil fields given by Richard V. Henderson during three months in 1932; for the laboratory studies of core samples of the sand made by P. G. Nutting, of the United States Geological Survey; for suggestions and criticism by Hugh D. Miser, of the United States Geological Survey, and Raymond C. Moore, state geologist of Kansas, under whose joint direction the work was carried on; for criticism of the report by R. W. Richards and P. D. Trask of the United States Geological Survey.

Previous Reports

The Sallyards and Blankenship oil fields, two shoestring oil fields that are parts of the shoestring trends of this report, were described by Berger[4] in 1921. Loomis[5] wrote an article in 1923 on the Burkett-Seeley oil pools which were then being developed. Cadman[6] is the author of the first comprehensive report on the shoestring sands of the Greenwood county region; his report was published in 1927, after development of more than 80 percent of the present known oil fields had been largely completed. This was followed in 1929 by a detailed report on the Madison shoestring by Cheyney,[7] which contains a brief discussion of the origin of the sand bodies that comprise the chief shoestring sand trends. Cheyney's conclusions differ from those reached by Cadman.

Rich's[8] conclusions on the origin of the shoestring sands in the eastern-most part of Kansas, were published in 1923 and 1926, and

4. Berger, W. R., The relation between the structure and production in the Sallyards field, Kansas: Am. Assoc. Petroleum Geologists Bull., vol. 5, pp. 276-281, 1921.

5. Loomis, Harve, The Burkett-Seeley pool, Greenwood county, Kansas: Am. Assoc. Petroleum Geologists Bull., vol. 7, pp. 482-487, 1923.

6. Cadman, W. K., The Golden Lanes of Greenwood County, Kansas: Am. Assoc. Petroleum Geologists Bull., vol. 11, pp. 1151-1172, 1927.

7. Cheyney, A. E., Madison shoestring pool, Greenwood county, Kansas: Am. Assoc. Petroleum Geologists, Structure of Typical American Oil Fields, A Symposium, vol. 2, pp. 150-159, 1929.

8. Rich, J. L., Shoestring sands of eastern Kansas: Am. Assoc. Petroleum Geologists Bull., vol. 7, pp. 103-113, 1923; Further observations on shoestring oil pools of eastern Kansas: Am. Assoc. Petroleum Geologists Bull., vol. 10, pp. 568-580, 1926.

have been of much value to the studies in the Greenwood county region. In 1927 Charles[9] described the shoestring sands of Anderson county, in the eastern part of the state. Other lenticular sand bodies that are further removed from the Greenwood-Butler county region, but related to it in a general way, are mentioned below. The extent and interpretation of the Hogshooter gas sand of northeastern Oklahoma were described by Berger[10] in 1919, and the sand body of the Burbank oil field in Osage county, Oklahoma, was described in 1924 and again in 1927 by Sands.[11] The producing sand body of the Rainbow Bend pool in Cowley county, Kansas, was described by Snow and Dean[12] in 1925 and again in 1929. Snow's[13] more recent article describing the Bartlesville sand in northeastern Oklahoma, and Weirich's[14] article on the character of the sands of the Cherokee shale in northeastern Oklahoma, have a bearing on the Greenwood county shoestring sand study, inasmuch as they describe sandstones that in general are of the same age as, and are similar in some characters to the Kansas sands. A preliminary report on the shoestring sands in Greenwood and Butler counties, Kansas, by Bass[15] has been discussed by Holl,[16] Rich,[17] and Tarr.[18] Since the preparation of this report a channel sandstone in Pennsylvanian beds in southeastern Kansas has been described by Pierce[19] and Courtier.

THE ROCK FORMATIONS

The sedimentary rocks, including those exposed at the surface and those penetrated in wells in this part of Kansas, range in thickness from about 2,800 feet in east-central Greenwood county to more than 4,500 feet in the northwestern part of this county and in the

9. Charles, H. H., Oil and gas resources of Kansas, Anderson county: Kansas Geol. Survey Bull., 6, pt. 7, 1927.

10. Berger, W. R., The extent and interpretation of the Hogshooter gas field: Am. Assoc. Petroleum Geologists Bull., vol. 3, pp. 212-216, 1919.

11. Sands, J. M., Burbank field, Osage county, Oklahoma: Am. Assoc. Petroleum Geologists Bull., vol. 7, pp. 584-592, 1924; vol. 11, pp. 1045-1054, 1927.

12. Snow, D. R., and Dean, David, Rainbow Bend field, Cowley county, Kansas: Am. Assoc. Petroleum Geologists Bull., vol. 9, pp. 794-982, 1925; Structure of Typical American Oil Fields, A Symposium, vol. 1, pp. 52-59, 1929.

13. Snow, D. R., Water encroachment in Bartlesville sand pools of northeastern Oklahoma and its bearing on East Texas recovery problem: Am. Assoc., Petroleum Geologists Bull., vol. 16, pp. 881-890, 1932.

14. Weirich, Gene, The Burbank sand of Kansas and Oklahoma: Oil Weekly, vol. 66, No. 10, pp. 25-28, August 22, 1932.

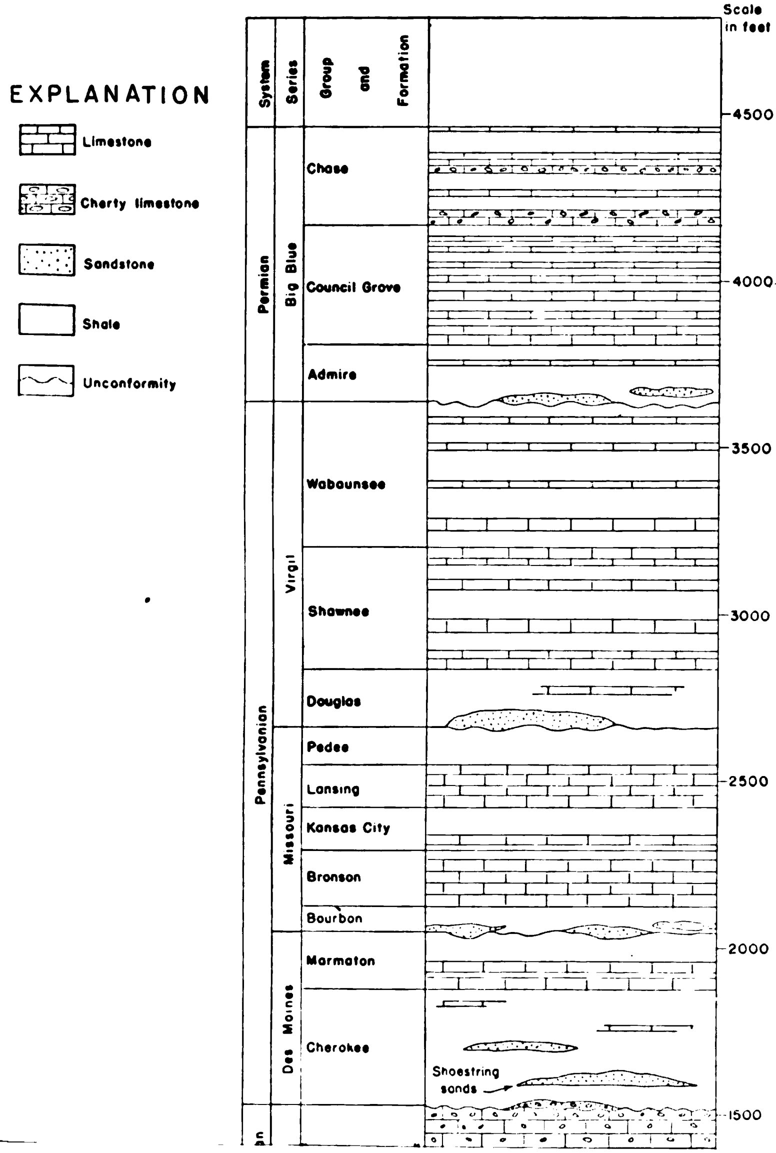
15. Bass, N. W., Origin of Bartlesville shoestring sands, Greenwood and Butler counties, Kansas: Am. Assoc. Petroleum Geologists Bull., vol. 18, No. 10, pp. 1313-1345, 1934.

16. Holl, F. G., Discussion, ibid., vol. 18, No. 10, pp. 1343-1344, 1934.

17. Rich, J. L., Discussion, ibid., vol. 18, No. 10, pp. 1344-1345, 1934.

18. Tarr, R. S., Discussion, ibid., vol. 18, No. 12, pp. 1710-1712, 1934.

19. Pierce, W. G., and Courtier, W. H., Englevale channel sandstone of Pennsylvanian age, southeastern Kansas, ibid., vol. 19, No. 7, pp. 1061-1064, 1935.


EXPLANATION
Limestone
Cherty limestone
Sandstone
Shale
Unconformity
System
Series
Group and Formation
Scale in feet
4500
4000
3500
3000
2500
2000
1500
Permian
Pennsylvanian
Big Blue
Virgil
Missouri
Des Moines
Chase
Council Grove
Admire
Wabaunsee
Shawnee
Douglas
Pedee
Lansing
Kansas City
Bronson
Bourbon
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northeastern part of Butler county. According to Kellett[20] they are 3,500 to 4,000 feet in thickness at most places. A detailed study was made only of the portion of the sedimentary sequence that contains the shoestring sand lenses and beds. The Council Grove group of the Permian (?) system[b] is included in the portion of the sequence studied. It is exposed in several shoestring sand oil fields in the western part of Greenwood county. The columnar section shown in figure 2, largely after Kellett, shows the general character of the main divisions of the stratigraphic column.

Pre-Cambrian Rocks

The sedimentary rocks in Kansas are underlain at varying depths by igneous and metamorphic rocks.[c] But little is known about the distribution of the several types of igneous and metamorphic rocks in Kansas, because they are buried by a thick column of sediments, and so they are collectively referred to as the "crystalline and metamorphic complex," or, because of their position beneath the comparatively regular stratified rocks, as the "basement complex." Our only direct knowledge of these rocks has come from studies, by geologists,[21] of drill cuttings from wells that have been drilled through the sedimentary sequence into the complex beneath. These studies show that these rocks consist chiefly of granite and schist,

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20. Kellett, Betty, Kansas Geol. Society 6th annual field conference Guidebook, cross section, 1932.

b. Following present usage of the Kansas Geological Survey the rocks of the Big Blue series, previously classed as Permian, are here designated as Permian (?) in order to indicate that, although they have generally been considered as Permian, there is now doubt as to proper definition of this term in Kansas. R. C. Moore, State Geologist.

c. Igneous rocks comprise one of the three main classes of rocks that constitute the earth's crust; the other two are the metamorphic and sedimentary classes. Igneous rocks are those that formed by the cooling and solidification of molten masses. Metamorphic rocks are those that were originally either igneous or sedimentary, but were subsequently so much changed in form by heat and pressure that they no longer resemble their original character. The sedimentary class includes rocks derived from preëxisting rocks; stratified rocks, such as limestone, shale and sandstone, that occupy practically the entire surface of Kansas, belong to this class.

21. Haworth, Erasmus, The crystalline rocks of Kansas: Kansas University Geol. Survey Bull. 1, 1915.

Powers, Sidney, Granite in Kansas: Am. Jour. Science, 4th ser., vol. 44, pp. 146-150, 1917.

Wright, Park, Granite in Kansas wells: Am. Inst. Min. Engrs. Bull. 128, pp. 1113-1120, 1917.

Taylor, C. H., The granites of Kansas: Am. Assoc. Petroleum Geologists Bull., vol. 1, pp. 111-126, 1917.

Moore, R. C., Geologic history of the crystalline rocks of Kansas: Am. Assoc. Petroleum Geologists Bull., vol. 2, pp. 98-113, 1918; The relation of the granite in Kansas to oil production: Am. Assoc. Petroleum Geologists Bull., vol. 4, pp. 255-261, 1920; Oil and Gas resources of Kansas: Kansas Geol. Survey Bull., 6, p. 9, 1920.

Moore, R. C., and Haynes, W. P., Oil and gas resources of Kansas: Kansas Geol. Survey Bull., 3, pp. 81, 82, 140-173, 1917.

Fath, A. E., Geology of the El Dorado oil and gas field: Kansas Geol. Survey Bull., 7, pp. 25-27, 1920.

Greene, F. C., Granite wells in the northern Mid-Continent region: Am. Assoc. Petroleum Geologists Bull., vol. 9, pp. 351-354, 1925.

Landes, K. K., A study of the pre-Cambrian rocks of Kansas: Am. Assoc. Petroleum Geologists Bull., vol. 11, pp. 821-824, 1927.

but also include quartzite, quartz porphyry, diabase, and other rocks; that their upper surface is an ancient irregular land surface with considerable relief that was subjected to the agencies of erosion for a very long time. These rocks, which are, therefore, very old, may be regarded as forming an irregular floor or basement upon which the sedimentary strata accumulated. They are, as previously stated, not exposed at the surface any place in Kansas, but they come to the surface in Missouri, where exposures show that they are overlain unconformably by rocks of Cambrian age. Studies of samples from wells in Kansas show that Cambrian and younger rocks unconformably overlie them here. These ancient basement rocks are referred to the pre-Cambrian division in the time scale, which merely means that their time of origin is prior to the Cambrian period of the Paleozoic era.

In general the pre-Cambrian basement is not so deep below the surface in eastern as in western Kansas, and is not so deep in northern as in southern Kansas. A well drilled a few miles southwest of Fort Scott, in Bourbon county, near the eastern boundary of the state, encountered the basement complex a little below a depth of 2,000 feet;[22] but a well drilled recently in Finney county, in the southwestern part of the state, to a depth of 5,872 feet, and another drilled nearby in Clark county to a depth of 6,906 feet, did not pass through the sedimentary rocks. A sufficient number of wells have, however, penetrated the uppermost part of the basement complex in the eastern half of the state so that information is available for showing that an old ridge of low hills, commonly referred to as the Nemaha granite ridge,[23] extends from Oklahoma in a north-northeasterly direction across Kansas into Nebraska. The ridge crosses the central part of Butler county, passing beneath Augusta, and just west of El Dorado, both of which are only a few miles west of some of the shoestring sand bodies. The granite surface of the Nemaha granite ridge lies at a depth of only about 600 feet in Nemaha county, near the northern boundary of the state, but as the ridge is followed toward the south it becomes deeper and deeper. Near El Dorado it lies at a depth of about 2,700 feet, and it is still deeper to the southwest of that place. The Nemaha granite ridge is of interest in connection with the study of the shoestring sand lenses because it probably was subjected to minor crustal

22. Kellett, Betty, op. cit.

23. Moore, R. C., and Haynes, W. P., Oil and gas resources of Kansas: Kansas Geol. Survey Bull., 3, pp. 81, 82, 140-173, 1917. Moore, R. C., and Landes, K. K., Underground resources of Kansas: Kansas Geol. Survey Bull., 13, fig. 54, p. 72, 1927.

movement during the time the Cherokee shale, which contains the shoestring sand bodies, was accumulating in Kansas, and because it, therefore, may have influenced the distribution of sediments in Butler and Greenwood counties and in adjacent areas. Geologic evidence furnished by rock samples from wells indicates that the Nemaha granite ridge was not in existence until Late Mississippian or Early Pennsylvanian time.[24]

Cambrian and Ordovician Systems

Well records show that massive beds of dolomite, limestone, and sandstone, with a total thickness of 700 to 1,000 feet, referred to the Cambrian and Ordovician systems, overlie the pre-Cambrian complex in Greenwood and Butler counties, but the rocks of these ages are locally absent over the Nemaha granite ridge in Butler county. These rocks have not been subdivided in detail in this part of Kansas, although work by McQueen[25] in Missouri, which he recently extended into Kansas, indicates that they probably can be subdivided and correlated with subdivisions that have been recognized on the surface in southwestern Missouri. McQueen's correlations are based largely upon the study of siliceous residues that are obtained by boiling rock samples in acid, and he has found that each formation has distinctly characteristic residues. By a study of residues obtained from drill cuttings and from outcrop samples he has identified the subdivisions of the Cambrian and Ordovician rocks throughout much of Missouri, where they are concealed beneath younger beds. In 1931 McQueen[26] extended his work into Leavenworth, Jefferson and Shawnee counties, in northeastern Kansas, by examining cuttings from the No. 1 Oak Mills well of the Indian Mounds Oil Co., in sec. 13, T. 7 S., R. 21 E., from the No. 1 Edwards well of the Northern Counties Oil & Gas Co., in sec. 13, T. 9 S., R. 19 E., and from the No. 1 Hummer well of Forrester et al., in sec. 14, T. 11 S., R. 16 E. In 1932 McQueen[27] studied cuttings from the Stephenson No. 1 well of the Oklahoma Natural Gas Co., drilled in sec. 16, T. 26 S., R. 24 E., Bourbon county, in southeastern Kansas. In the northeastern Kansas area the Lamotte, Bonneterre and Eminence formations of the Cambrian system were recognized

24. Moore, R. C., and Haynes, W. P., op. cit., p. 172, 1917.

25. McQueen, H. S., Insoluble residues as a guide in stratigraphic studies: Missouri Bur. of Geology and Mines, Appendix 1, 56th Biennial rept., 1931.

26. Folger, Anthony, Geologic cross section of the central United States; Kansas section by Roy H. Hall, (in part by H. S. McQueen): Kansas Geol. Soc. 5th annual field conference Guidebook, 1931.

27. Kellett, Betty, Geologic cross section from western Missouri to western Kansas, (H. S. McQueen contributor): Kansas Geol. Soc. 6th annual field conference Guidebook, 1932.

by McQueen and the Ordovician system was divided by him into the Gasconade-Van Buren, Roubidoux, Cotter, St. Peter, Decorah, Galena and Moquoketa formations. In Bourbon county the Cambrian and Ordovician systems are represented by about 900 feet of dolomite, sandstone and limestone. The lower 350 feet of this sequence has been subdivided by McQueen from the base upward into the Lamotte, Bonneterre, Eminence, and Proctor formations[28] of the Cambrian system; and the upper 550 feet has been subdivided by him into the Gunter, Gasconade-Van Buren, Roubidoux, Cotter-Jefferson City formations of the Ordovician system. The uppermost formations recognized in northeastern Kansas are, therefore, not present in Bourbon county. Studies have not been made in Greenwood and Butler counties for subdividing the Cambrian and Ordovician rocks to a portion of which the term "Siliceous lime" is in common use, but some geologists, who recognize that these rocks are equivalent to parts of the Arbuckle limestone of southern Oklahoma, apply to them the name Arbuckle limestone.

Studies of drill cuttings made by Messrs. McClellan, Howell, and others have shown that at some localities in southern Greenwood county and southeastern Butler county only the "Siliceous lime" is present, but that throughout much of the remainder of the two counties the "Siliceous lime" is overlain by a sandstone succeeded by a limestone. The sandstone is commonly referred to as Simpson sand, St. Peter sandstone, or "Wilcox" sand, and the limestone as the Viola limestone—names, except the St. Peter, that are applied to parts of the Ordovician system in Oklahoma. The correlation and distribution of these beds in Kansas and Oklahoma have been discussed by Barwick,[29] Edson,[30] McClellan,[31] Howell[32] and others.

Mississippian System[d]

Rocks of Silurian and unquestioned Devonian age, which normally directly overlie Ordovician rocks, appear to be absent[33] everywhere in Greenwood and Butler counties, although they are known to be

28. For description of these formations in Missouri see Dake, C. L., The geology of Potosi and Edgehill quadrangles: Missouri Bur. Geology and Mines, 2d ser., vol. 23, 1930; Bridge, Josiah, Geology of the Eminence and Cardareva quadrangles: Missouri Bur. Geology and Mines, 2d ser., vol. 24, 1930.

d. The U. S. Geological Survey classifies Mississippian as a series of the Carboniferous system.

29. Barwick, J. S., The Salina basin of north-central Kansas: Am. Assoc. Petroleum Geologists Bull., vol. 12, pp. 177-199, 1928.

30. Edson, F. C., Pre-Mississippian sediments in central Kansas: Am. Assoc. Petroleum Geologists Bull., vol. 13, pp. 441-458, 1929.

31. McClellan, H. W., Subsurface distribution of pre-Mississippian rocks of Kansas and Oklahoma: Am. Assoc. Petroleum Geologists Bull., vol. 14, pp. 1535-1556, 1930.

32. Howell, J. V., Map showing areal geology of the pre-Chattanooga surface in northeastern Kansas: Kansas Geol. Soc. 6th annual field conference Guidebook, 1932.

33. McClellan, H. W., op. cit. Howell, J. V., op. cit.

present in other parts of the state. The Ordovician beds in the two counties are directly overlain by about 100 feet of black and gray shale, which is widespread, and has a remarkably uniform thickness. It is known as the Chattanooga shale[e] in southern Kansas and in northern Oklahoma. Northward and northwestward in Kansas beds of gray shale that may be somewhat younger than or in part equivalent to the Chattanooga shale occupy approximately this position in the stratigraphic column.[34]

The unquestioned Mississippian rocks in this area are about 300 feet thick, and are composed largely of gray and dark gray limestone that contains much chert, especially in the uppermost part. They are locally absent over the Nemaha granite ridge. They are commonly called the "Mississippi lime," and are one of the most widely recognized buried rock units in Kansas. In northeastern Oklahoma and in Missouri, where they are exposed, they have been divided into a number of units; but little work has been done in Kansas in an attempt to correlate most of the concealed rocks of Mississippian age with the recognized units in Oklahoma and Missouri.

Pennsylvanian System[f]

The Pennsylvanian rocks of Greenwood and Butler counties consist of interbedded shale and limestone, and minor amounts of sandstone, and a very little coal, having a total estimated thickness of 2,150 feet. The thickness of the rocks of this system increases toward the southeast. Locally, over the Nemaha granite ridge in Butler county, it is about 400 feet less in thickness than the average thickness in the region. Most of the Cherokee shale, the lowermost formation, is absent there.[35] The Pennsylvanian rocks are separated from the Mississippian rocks by an unconformity; the relief on the surface of the Mississippian, as indicated by well records, rarely exceeds 100 feet in a township.

Moore and Condra[36] have recently proposed to rename most of the subdivisions of the Pennsylvanian rocks in Kansas on the basis of recent field work by them and other members of the Kansas and

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e. The Chattanooga shale is classified by the U. S. Geological Survey as Devonian (?).

34. Leatherock, Constance, and Bass, N. W., Chattanooga shale in Osage county, Oklahoma, and adjacent areas: Am. Assoc. Petroleum Geologists, Bull. Vol. 20, No. 1, pp. 99-100, 1936.

f. The U. S. Geological Survey classifies Pennsylvanian as a series of the Carboniferous system.

35. Reeves, J. R., El Dorado oil field, Butler county, Kansas: Am. Assoc. Petroleum Geologists, Symposium, Structure of typical American oil fields, vol. 2, fig. 1, p. 161, 1929.

36. Moore, R. C., and Condra, G. E., Classification of the lower Permian and Pennsylvanian systems of Kansas and Nebraska: Kansas Geol. Soc. 6th annual field conference Guidebook, 1932; Condra, G. E., The stratigraphy of the Pennsylvanian system in Nebraska: Nebraska Geol. Survey Bull., 1, 2d ser., 1927.

Nebraska Geological Surveys' staffs. The classification and nomenclature of the Pennsylvanian and Permian rocks in this report follows that of the Kansas Geological Survey[37] published in 1934. The classification used here differs somewhat from that given in former reports of the United States Geological Survey, and these differences have not been considered and adopted by the United States Geological Survey.

Under the present classification of the Kansas Geological Survey, the Pennsylvanian-Permian boundary is lowered from the contact of the Elmdale shale with the Cottonwood limestone of former Kansas geologic reports to an unconformity that in most nearly complete sections occurs between the Brownville limestone, below, and the Towle shale, above. In northwestern Greenwood county, where these rocks are exposed, the boundary has been lowered about 260 feet. This change transfers from the Pennsylvanian to the Permian the Eskridge shale, Grenola limestone, Roca shale, Red Eagle limestone, Johnson shale, Foraker limestone, and the entire Admire group, which is defined to include the beds from the unconformity beneath the Towle shale to the base of the Foraker limestone.

Des Moines Series

The Des Moines series includes the beds in the lower part of the Pennsylvanian system of Kansas, extending from the unconformity between the Mississippian and Pennsylvanian rocks upward to another unconformity that marks the boundary between the Marmaton group and the Bourbon formation. The Des Moines series is divided into two main parts, the lower consisting mostly of shale (Cherokee shale) and the upper containing prominent limestones interbedded with shale (Marmaton group).

CHEROKEE SHALE

The shoestring sand lenses (known to operators in Kansas and Oklahoma as the Bartlesville sand) occur in the lower part of the Cherokee shale, which, in Kansas, is the lowermost formation of the Pennsylvanian system. The Cherokee shale overlies the "Mississippi lime" unconformably, but the strata above and below the unconformity are essentially parallel except at a few places. In the Greenwood-Butler county region the Cherokee is composed of light and dark gray shale, with lesser amounts of black shale, lenses of sandstone, and a few thin beds of limestone, red rock, and coal;

37. Moore, R. C., Elias, M. K., and Newell, N. D., Pennsylvanian and Permian rocks of Kansas (stratigraphic chart), Kansas Geol Survey, 1934.

shale which varies somewhat in composition and color makes up by far the greater part of the formation. Well logs record much of the shale as light gray and fine-grained clay shale. Many areas contain some very fine-grained sandy shale. Some beds of black shale and dark blue shale are reported in much of the region; the beds of black shale are believed to be most abundant in the lower half of the formation in Greenwood and Butler counties. Haworth[38] describes the formation at the outcrop in southeastern Kansas as follows:

> The character of the Cherokee shales varies materially, both vertically and longitudinally. Shale of almost all descriptions may be found. . . . Portions of them are as black as coal. . . . Variations may be noted through different degress of black and gray and greenish gray into a very light-colored, ashen-gray shale. . . . Composition shows a great variation, ranging from a fairly good clay shale, composed almost entirely of clay, into a perfect sandstone, with all intervening grades.

Hinds and Greene[39] state that in western Missouri contemporaneous beds in the lower part of the Cherokee shale vary greatly from place to place; that the upper part of the formation consists of strata that are more uniform and can be identified throughout Missouri, and parts of Kansas and Iowa. The records of wells in the Greenwood-Butler county region indicate that there the lower part of the Cherokee shale varies less in character laterally than it does along the outcrops in western Missouri and eastern Kansas. Sandstone beds form as much as one fourth of the total thickness of the Cherokee shale in only a few localities in Greenwood and Butler counties, and in most localities where the shoestring sands are present sandstone comprises only a fifth or less of the total thickness. The logs of some wells in these counties record no sandstone whatever in the Cherokee shale.

The shoestring sands, the subject of this report, are narrow elongated lenses in the lower part of the formation. Throughout the northern part of Greenwood county the sand lenses are separated from the underlying "Mississippi lime" by a thickness of shale varying from 50 to 150 feet, but averaging a little less than 100 feet. The sand bodies are separated from the underlying limestone by a thickness of shale less than 100 feet in southeastern Butler county, and actually rest directly on it in parts of the Keighley, Fox-Bush, and Smock-Sluss oil fields in that county. Red rock 10 to 30 feet

38. Haworth, Erasmus, Special report on coal: Kansas Univ. Geol. Survey, Vol. III, pp. 23-24, 1898.

39. Hinds, Henry, and Greene, F. C., The stratigraphy of the Pennsylvanian series in Missouri; Missouri Bur. Geol. and Mines, Vol. 13, 2d ser., p. 40, 1915.

in thickness is recorded at the horizon of the shoestring sands in the logs of most wells that are outside the shoestring oil fields, and so found no shoestring sands in southern Butler county, where only a small thickness of shale intervenes between the sand zone and the "Mississippi lime." The apparent absence of the lowermost part of the Cherokee shale, and the abundance of red rock at about the horizon of the shoestring sands in the southeastern part of Butler county suggests that a portion of the south half of the county may have been land during a part of the time that the Cherokee sea occupied Greenwood county and adjacent areas. The "Mississippi lime" would have formed the land surface of that time and the source[40] of the material for the red rock may have been old soils that were largely derived from the "Mississippi lime."

At places in the Greenwood-Butler county region, particularly in the eastern part of Greenwood county, a sandstone unit is present at the base of the Cherokee shale. It lies below the shoestring sands described here and is separated from them by beds of shale. In many parts of Kansas a conglomerate, composed largely of chert and lesser amounts of limestone, forms the lowermost beds of the Cherokee shale. Sandstone occurs locally above the main shoestring sand horizon, also, and contains commercially valuable amounts of oil in the Wiggins and Wilkerson fields in Greenwood county and at localities in northwestern Cowley county. The Wiggins and Gaffney fields, 6 to 12 miles north of Eureka, produce oil from beds of sandstone that occur 50 to 75 feet above the main shoestring sand horizon, and are known as the upper and lower Cattleman sands. Sandstone at about the horizon of the sand in the Wiggins oil field is oil-bearing in the Wilkerson pool in secs. 6 and 7, T. 25 S., R. 9 E., also in secs. 9, 10, 15, and 16, T. 23 S., R. 10 E. Sandstone at approximately the horizon of the Wiggins sand is the chief oil reservoir in the Rock, Clarke and Smith fields in northwestern Cowley county. Thick beds of sandstone at about this horizon were found to contain water in several wells in the southern part of Lyon county. Even higher sands in the Cherokee shale are recorded in some well logs in the Greenwood-Butler county region, but they appear to be of only local extent. Beds of sandstone in the Cherokee shale are more numerous in eastern Kansas and in western Missouri than in the Greenwood-Butler county region. The sandstone content of the Cherokee increases greatly, and also the thick-

40. For a discussion of red rock derived from limestone see Tomlinson, C. W., The origin of the red beds: Jour. Geology, vol. 24, pp. 153-179, 238-253, 1916.

ness of the formation increases, southeastward from Kansas into eastern Oklahoma.

The aggregate thickness of limestone in the Cherokee shale is even much less than that of sandstone. The records of most of the wells in Greenwood and Butler counties show no limestone, but there are some carefully kept logs which record thin beds of limestone in the upper half of the formation. Drillers have informed me that in many localities thin beds of limestone are present in the Cherokee shale, but the beds are as a rule so thin that they are regarded as of no importance and are therefore seldom recorded in the well logs. Thin beds of limestone that persist over wide areas occur in the Cherokee shale in western Missouri[41] and southeastern Kansas[42] and are particularly well developed in northeastern Oklahoma, where the formation crops out, and west of the outcrops where the beds are penetrated by oil wells.[43] Hinds and Greene[44] reported that the limestone beds in Missouri contain abundant invertebrate fossils, and Haworth[45] reported the limestone beds in Kansas to be folssiliferous. Several fossiliferous limestone beds occur in the Cherokee shale in northeastern Oklahoma and are recorded in most well logs.

Beds of coal ranging up to 5 feet thick, but more commonly 1 to 2 feet or less thick, occur throughout the Cherokee shale in the easternmost part of Kansas and in the western part of Missouri. Coal is mined from these beds at Pittsburg, Kan., and a number of other localities in southeastern Kansas, northeastern Oklahoma, western Missouri, and at Leavenworth and Lansing in northeastern Kansas. Thin beds of coal are recorded in well logs in a few localities in the Greenwood-Butler county region; the most abundant occurrence is in the Theta oil field in secs. 8 and 17, T. 22 S., R. 10 E., where coal overlies the producing sand of the oil field at a depth of about 2,300 feet.

A unit of red shale ranging up to 50 feet thick, but commonly only 5 to 15 feet thick, is present locally in the Cherokee shale in Greenwood, Butler, Cowley and other counties. It most commonly occurs at or close to the stratigraphic horizon of the shoestring sands in the localities that contain no sands, but other parts of the Chero-

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41. Hinds, Henry, and Greene, F. C., The stratigraphy of the Pennsylvanian series in Missouri: Missouri Bur. Geology and Mines, vol. 13, 2d ser., pp. 38-39, 1915.

42. Haworth, Erasmus, Special report on coal: University Geol. Survey of Kansas, vol. 3, pp. 23-29, 1898.

43. Bass, N. W., Kennedy, L. E., Dillard, W. R., and Leatherock, Constance, Subsurface geology of Osage county, Oklahoma: U. S. Geol. Survey Press notice 105368, p. 7, Jan., 1936.

44. Hinds, Henry, and Greene, F. C., op. cit., p. 39.

45. Haworth, Erasmus, op. cit., p. 29.

kee shale contain thin beds of red shale in some localities. The areal distribution of the red shale that occurs at the horizon of the shoestring sands is patchy, and appears to be unsystematically distributed over the region. However, red shale at this horizon is fairly persistent in the southeastern fourth of Butler county.

The Cherokee shale ranges in thickness in Greenwood and Butler counties from a feather edge to a little more than 350 feet. The thickness of the Cherokee shale in eastern Kansas and northeastern Oklahoma is shown by a sketch map on Plate 1. It is very thin in some, and totally absent in other localities situated over the Nemaha granite ridge in northwestern Butler county. The formation thickens at a fairly rapid rate through the first few miles eastward from the granite ridge, thence at a less rapid rate eastward, the rate of thickening becoming very low in an eastward direction east of Butler county. The shale is 300 feet thick along the Greenwood-Butler county boundary, and it is 350 feet thick along the eastern boundary of Greenwood county. Because the shale directly overlies the irregular erosion surface on top of the "Mississippi lime," its thickness varies somewhat locally, but variations in thickness due to the relief on the Mississippian surface are rarely as great as 100 feet in a township.

The character of the sediments and the fauna and flora preserved in the rocks indicate that the Cherokee shale is composed of rocks that were deposited under a succession of alternating continental and marine environments. It is believed that the delicate balance between marine and nonmarine conditions in eastern Kansas was disturbed repeatedly during the long time in which the Cherokee shale was accumulating. That changing conditions prevailed during Cherokee shale time is indicated by (1) marine fossils that have been gleaned[46] from well cuttings from the lowermost part of the formation, and (2) by the fossils reported[g] from limestone beds in the middle part of the formation, (3) by the lenticular character of the beds of sandstone closely associated with red rock, (4) by the lenses of coal, and (5) by the presence of fossil plants. The character of the sediments exposed in eastern Kansas and western Missouri indicates that the balance between marine and nonmarine conditions was particularly unstable in early Cherokee time. The more uniform and more widespread persistence of the strata in the

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46. Tarr, R. S., The Red Beds near the base of the Cherokee shale: Am. Assoc. Petroleum Geologists Bull., vol. 9, pp. 350-351, 1925; Buchanan, G. S., Early Pennsylvanian "Red Beds" in the Mid-Continent region: Am. Assoc. Petroleum Geologists Bull., vol. 9, p. 814, 1925.

g. Noted in unpublished reports of oil company micropaleontologists, based on studies of well cuttings.

upper part of the formation than in the lower part suggests that the marine waters were not only more widespread in late Cherokee time, but that the Cherokee basin had been leveled with sediments, permitting the accumulation of sheetlike deposits of uniform thickness and character. The widespread distribution of the coal beds that are so closely associated with beds of marine limestone in the Cherokee shale indicates that at times when the marine water body withdrew from eastern Kansas its shore was closely followed by fresh-water swamps. The entire land area probably presented an expanse of swamps or marsh flats; the coal beds and plant fragments indicate that the land supported much vegetation.

AGE OF THE SHOESTRING SANDS.—The shoestring sand bodies in the lower part of the Cherokee shale in Greenwood and Butler counties and adjacent areas are designated as the Bartlesville sand by operators, drillers, geologists and others connected with the production of oil in this region. This name implies that the sand bodies are of the same age as the Bartlesville sand of the vicinity of Bartlesville, Okla., which has been an important producer of oil and gas for many years. The Bartlesville sand near the town of Bartlesville occurs in the lower part of the Cherokee shale, but is separated from the "Mississippi lime" by a relatively small thickness of shale. The earliest mention of the term Bartlesville sand found by me in a geologic publication is that by Buttram[47] in 1914, but he indicates that the name had been in common use for some time prior to 1914. As oil and gas development progressed rapidly in northeastern Oklahoma and southeastern Kansas 20 or more years ago, most of the oil was found in beds of sandstone in the lower part of the Cherokee shale. In each new field the name Bartlesville was applied to the sand, although it was recognized fairly early by several geologists that not all the sands called Bartlesville are equivalent, but that they are really numerous lenses occupying the same general stratigraphic position in the Cherokee shale. Berger stated, in 1918, in discussing a paper by Greene[48] which describes the geology of eastern Osage county, Oklahoma, that what was considered the Bartlesville sand in Osage and Washington counties is not the same sand throughout; and that any producing sand found between 200 and 600 feet below the Fort Scott limestone was called the Bartlesville. Ross[49] also expressed the opinion that oil or gas

47. Buttram, Frank: Okla. Geol. Survey, Bull. 18, p. 43, pl. 12, 1914.

48. Greene, F. C., A contribution to the geology of eastern Osage county; (with discussion by W. R. Berger): Am. Assoc. Petroleum Geologists Bull., vol. 2, p. 123, 1918.

49. Ross, C. S., Structure and oil and gas resources of the Osage Reservation, Okla.: U. S. Geol. Survey Bull. 686, p. 184, 1919.

productive sands, that seem in a broad way to occupy stratigraphic positions similar to that of the productive sand at Bartlesville, are referred to as the Bartlesville sand, even though they probably are not equivalents.

Greene[50] correlated productive sands in eastern Osage county with the Bartlesville sand in 1918, and stated that in all probability the † Clear Creek sandstone that occurs uniformly 45 feet above the Mississippian rocks and crops out in Vernon and Barton counties, Missouri, is the equivalent to the Bartlesville sand. About this time detailed stratigraphic studies in northeastern Oklahoma and southeastern Kansas were being conducted by McCoy, and others working with him, along the outcrops of the Cherokee shale. Also, the records of hundreds of wells were studied by them. The results of these studies convinced McCoy[51] that the Bartlesville sand accumulated along the margins of the Cherokee sea during the early stages of its northward advance in a broad trough extending through eastern Oklahoma into southeastern Kansas. The advance of the sea was very slow, and it halted at times, and the shore of the sea migrated back and forth over a narrow strip of country. During periods when the shore was stationary the Bartlesville sand accumulated. This strip of country, as described by McCoy, includes eastern Osage county and western Washington county, Oklahoma, and extends thence northeastward into Kansas across southeastern Montgomery county, and across Labette county into northwestern Neosho county to the vicinity of Chanute, whence it passes eastward to possibly the westernmost part of Missouri, where it turns southward and follows along or near the Missouri-Kansas boundary. McCoy agrees with Greene that the † Clear Creek sandstone which crops out in Vernon and Barton counties, Missouri, and which there supplies many oil seeps, is probably the equivalent of the Bartlesville sand.

The supposition is that the advance of the sea upon eastern Kansas was continued subsequent to the deposition of the Bartlesville sand, but was no doubt accomplished very slowly and accompanied by many fluctuations of the shore lines. As the water advanced over the featureless plains that are believed to have characterized the region, the old soils that had accumulated on the land, and sediments from more remote areas, brought to the sea by rivers, were washed into the sea and distributed widely by waves and currents to form the Cherokee shale. The close association of marine and

50. Greene, F. C., op. cit., pp. 118-119.
51. McCoy, A. W., oral communication.

nonmarine beds and the widespread distribution of some of the beds suggest that the sea was at all times very shallow. By the time the advancing northwestern shore of the sea had reached the Greenwood-Butler county region the Bartlesville sand of northeastern Oklahoma and southeastern Kansas was buried beneath younger mud and sand, and the country occupied by the old Bartlesville shore line was out in the midst of the Cherokee sea, which had expanded far beyond its former boundaries and now occupied most of eastern Oklahoma, eastern Kansas, western and northwestern Missouri. During periods when the shore line was temporarily stationary, the sand deposits were made in the Greenwood-Butler county region and western Osage and eastern Kay counties, Oklahoma (includes oil productive sands of the Burbank, South Burbank, and Naval Reserve oil fields).

In other words, as pointed out by Weirick,[52] the shoestring sands of western Osage and eastern Kay counties, Oklahoma, and Cowley, Butler and Greenwood counties, Kansas, are younger than and stratigraphically higher than the Bartlesville sand of eastern Osage-Washington counties, Oklahoma, and also younger than the sands in the southeasternmost part of Kansas.

MARMATON GROUP

The Marmaton group as restricted by Moore[53] consists of about 250 feet of alternately bedded limestone and shale overlying the Cherokee shale. The lowermost formation is the Fort Scott limestone, one of the most widely recognized formations in wells throughout eastern Kansas and northern Oklahoma. Most of the individual members in the Marmaton group cannot be correlated readily in well logs throughout large areas, but the group as a whole is persistent and recognizable in much of the state.

Missouri Series

The Missouri series, as redefined by the Kansas Geological Survey,[54] includes the beds from the unconformity at the top of the Marmaton group to another unconformity which occurs between the Stanton limestone or overlying rocks of the Pedee group, below, and sandy deposits of the Douglas group, above. The Missouri series is divided in eastern and northeastern Kansas into the following main

52. Weirick, Gene, The Burbank sand of Kansas and Oklahoma: Oil Weekly, vol. 66, No. 10, pp. 25-28, August 22, 1932.

53. Moore, R. C., Elias, M. K., and Newell, N. D., Pennsylvanian and Permian rocks of Kansas, (stratigraphic chart), Kansas Geol. Survey, 1934.

54. Moore, R. C., Elias, M. K., and Newell, N. D., op. cit.

parts, named in upward order: Bourbon formation, Bronson group, Kansas City group, Lansing group, and Pedee group. In the Greenwood-Butler county area it is not possible to recognize clearly all of these divisions in the well logs.

BOURBON FORMATION

The name Bourbon formation has been applied[55] to the beds, about 200 feet thick on the outcrop in eastern Kansas, that overlie the Marmaton group as now defined. Equivalent beds in Greenwood and Butler counties appear to be about 50 feet thick. In former reports the Bourbon formation was regarded as a part of the Marmaton group. Sandy shale and sandstone, commonly reported in logs of wells drilled in eastern Kansas, have been assumed to overlie the disconformity at the base of the Bourbon formation, and on this basis Kellett[56] has traced the Bourbon beds from well to well from near the outcrop westward across Greenwood and Butler counties into the western part of McPherson county.

BRONSON GROUP

The Bronson group, about 150 feet thick in Greenwood county, consists mostly of thick beds of limestone. The name Bronson is applied to the lower prominent limestones and included shales that formerly have been included in the Kansas City formation. The Bronson limestones can be recognized as a distinct group throughout much of Greenwood and Butler counties.

KANSAS CITY GROUP

The Kansas City group includes a series of beds about 150 feet thick, composed laregly of shale in the region of Greenwood and Butler counties, although it contains thick beds of limestone farther east in the state. A persistent limestone unit about 25 feet thick, that is recorded in most wells in Greenwood county as occupying a position 25 to 35 feet above the base of the group, is correlated with the Drum limestone by Kellett.[57] The main shale unit that overlies the Drum limestone was included with the Lansing group in some former reports,[58] but the Drum limestone was included in the Kansas City group.

55. Moore, R. C., A reclassification of the Pennsylvanian system in the northern Mid-Continent region, Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conference, p. 89, 1932.

56. Kellett, Betty, op. cit.

57. Kellett, Betty, op. cit.

58. Fath, A. E., Geology of the El Dorado oil and gas field; Kansas Geol. Survey Bull. 7, pp. 41-42, and pl. 7, 1920. Bass, N. W., The geology of Cowley county, Kansas: Kansas Geol. Survey Bull. 12, pp. 34-35, and pl. 2, 1929.

LANSING GROUP

The Lansing group, approximately 135 feet thick, overlies the Kansas City group and, according to the records of wells drilled in Greenwood and Butler counties, is composed almost entirely of limestone. It contains considerable shale at the outcrop, but is reported in well logs as limestone, and is a persistent and widespread unit.

In the southern part of Greenwood and Butler counties and on southward in Cowley county the thick limestone beds of the Lansing group, and to some extent those of the Bronson group, contain increasing amounts of sandstone and sandy shale.[59] West of the region of this report the (new) Kansas City group contains an increasing proportion of limestone so that the Bronson, Kansas City, and Lansing groups, being practically all limestone, as reported in well records, are commonly combined in one thick limestone unit. The Kellett cross section shows that these groups coalesce in T. 22 S., R. 3 E., Marion county. A study of logs of wells in the region extending southwest from Marion county shows that a line drawn from T. 22 S., R. 3 E., southwestward through Valley Center, Garden Plain, Cheney, and thence to about the middle of the south boundary of Kingman county, forms approximately the boundary between a region to the south and east in which the three groups can be separated readily by the presence of shale "breaks," and a region to the northwest where all three groups are combined as one limestone unit which may be designated as the Bronson-Lansing limestone.

PEDEE GROUP

The Pedee group comprises shale, together with some limestone and sandstone, that conformably overlies the Lansing limestone. It is unconformably overlain by sandstone and shale belonging to the Douglas group, which is the lowermost division of the Virgil series. In many localities it is not possible to identify in well records the unconformity at the top of the Pedee group, but according to the Kellett cross section the Pedee is recognizable in part of Greenwood county. It is convenient to designate the combined Pedee and Douglas beds as Pedee-Douglas in well records which do not furnish indication of the location of the boundary.

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59. Bass, N. W., op. cit., pp. 34-35 and pl. 2.

Virgil Series

The Virgil series, according to classification of the Kansas Geological Survey, includes the uppermost beds of the Pennsylvanian system, extending from the unconformity at the base of the Douglas group to another unconformity that is recognized above the Brownville limestone. This series contains the Douglas group at the base, the Shawnee group in the middle, and the Wabaunsee group at the top.

DOUGLAS GROUP

Shale, sandstone, and lesser amounts of limestone, with an aggregate thickness of about 300 feet in the Greenwood and Butler county area, overlies the Lansing group. Thick beds of sandstone that carry water most commonly occur in the lower 100 feet of this sequence, and a persistent zone of red shale occurs in the upper 100 feet of the sequence in southern Kansas and northern Oklahoma. The upper part of these sandstones and shales, and in some places all of them, belong to the Douglas group. As previously noted, shale that appears referable to the Pedee group occurs in Greenwood county, but farther west, in Butler county, sandstone of the Douglas group rests directly on beds of the Lansing group. Sandstone and shale of the Douglas group are exposed in southeastern Greenwood county.

SHAWNEE GROUP

The Shawnee group in Greenwood and Butler counties embraces about 400 feet of interbedded limestone and shale. This group includes the strata from the base of the Oread limestone to the top of the Topeka limestone. It contains such widely known formations as the Oread, Lecompton, Deer Creek and Topeka limestones, which have furnished key beds for surface geologic mapping in eastern Kansas carried on by many petroleum geologists. These formations exhibit especially well certain rhythmic successions of shale and limestone beds, which have been described by Moore.[60] The Shawnee group crops out in the eastern part of Greenwood county,[61] but was not studied in connection with the shoestring sand investigation.

WABAUNSEE GROUP

The Wabaunsee group includes 450 or more feet of strata between the Topeka limestone and a disconformity just above the Brownville limestone. Shale is the predominant rock, but there are thin beds

60. Moore, R. C., Pennsylvanian cycles in the northern Mid-Continent region: Illinois State Geol. Survey Bull., No. 60, pp. 247-257, 1931.

61. Haworth, Erasmus, et al., special report on oil and gas: The University Geological Survey of Kansas, vol. 9, pls. 7-*B* and *C*, 1908. Geologic map of Kansas. Kansas Geol. Survey, 1937.

of coal, minor amounts of sandstone, and persistent units of fossiliferous limestone that characteristically weather tan to tannish brown. The Wabaunsee group as a whole forms a broad lowland that occupies the surface of most of Greenwood county. Some of the limestone beds form fairly prominent ledges. The conspicuous ledge near Madison and in the Fankhouser oil field northeast of Madison, in northern Greenwood county, is formed by the Burlingame and Wakarusa limestones, formations in the Wabaunsee group.

Permian System[h]

Only the three lower groups of the Permian system, with a combined thickness of approximately 700 feet, are present in the shoestring sand region of Greenwood and Butler counties

Big Blue Series

The lower part of the Permian system in Kansas consists of limestone and interbedded shale that is mostly of marine origin. These rocks are termed the Big Blue series. The upper part of the Permian, consisting chiefly of red beds (Cimarron series), is not represented in the area treated in this report. The Big Blue series includes the beds from the unconformity between the Brownville limestone, or other uppermost Wabaunsee beds, and the overlying Towle shale to the top of the Wellington shale. It is divided into four groups, which, named in upward order, are as follows: Admire, Council Grove, Chase and Sumner.

ADMIRE GROUP

The Admire group includes the lowermost beds of the Big Blue series, as now defined, extending from the unconformity above the Brownville limestone to the base of the Foraker limestone. The Admire beds crop out along the foot of the Flint Hills, at the base of the east-facing escarpment. They were not studied especially in the course of my field work.

COUNCIL GROVE GROUP

The Council Grove group, particularly the lower half of it, was studied in detail because numerous beds of limestone make conspicuous outcrops in several of the shoestring sand oil fields. De-

h. The rocks here designated under the term Permian system are those (excepting certain beds at the base) that have long been classed in Kansas as Lower Permian. It now seems doubtful whether these beds are properly regarded as Permian, and until the problem of defining the type Permian system in Europe is worked out, it appears desirable to query the use of Permian as applied to the Big Blue series of Kansas. The U. S. Geological Survey classifies the Permian as a series of the Carboniferous system. R. C. Moore, State Geologist.

tailed stratigraphic studies were made of the rocks of this group in and near the Thrall and Browning oil fields, in connection with the surface structural mapping of these fields. In order to correlate the beds exposed in the Thrall and Browning oil fields with those exposed on the Cottonwood river to the north and those exposed in Cowley county to the south and in northernmost Oklahoma, sections were measured at intervals of 5 to 10 miles, extending from the Cottonwood river to the Kansas-Oklahoma boundary. This correlation was necessary because the stratigraphic section exposed in Cowley county[62] had been studied in detail and because many of the type exposures for the subdivisions of this group, as originally defined by Prosser, Beède and others, are in the Cottonwood valley. The results of this study in the correlation of the rocks between the Kansas-Oklahoma boundary and the Cottonwood river valley are shown on Plate 2. All limestone units between the Admire group and the Morrill limestone were correlated in detail; not so much detail was obtained for the rocks above the Morrill limestone, although the Crouse limestone and a persistent limestone between the Morrill and the Crouse were identified in all measured sections. The upper part of the Council Grove group has been studied in Kansas by Condra and Upp,[63] who have given new names to many of the units.

The subdivisions of the lower half of the Council Grove group are characterized by thick beds of limestone in southern Kansas, each of which splits northward into two limestone members separated by shale. This characteristic feature is modified somewhat in the Foraker limestone, which splits into four limestone units instead of two.

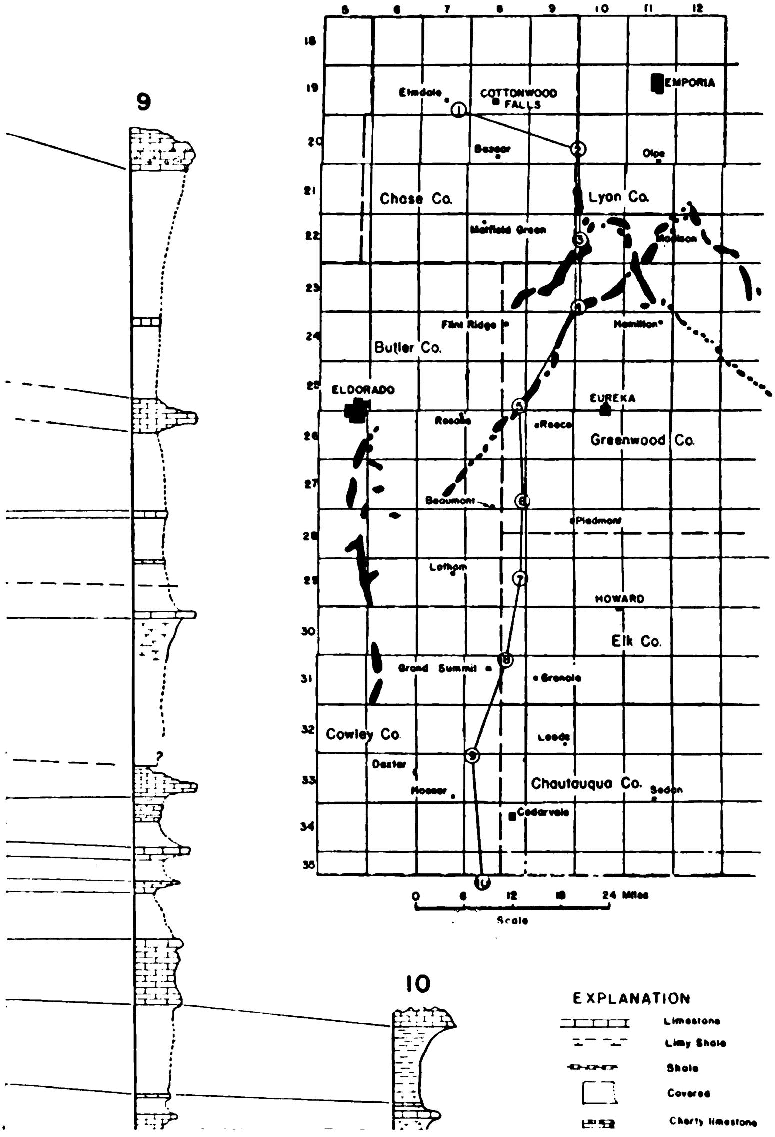
Foraker limestone.—The Foraker limestone of southern Kansas[64] is about 50 feet thick and is composed chiefly of thick beds of light-gray limestone. The limestone contains fusulinids in abundance in all beds and fossiliferous chert in some beds. This formation was identified at numerous places in the belt of country extending from its type locality[65] in Osage county, Oklahoma, northward to the Cottonwood river, a distance of about 100 miles, in a straight line. As shown on Plate 2, the amount of shale increases and the

62. Bass, N. W., The geology of Cowley county, Kansas: Kansas Geol. Survey Bull. 12, pp. 58-67, 1929.

63. Condra, C. E., and Upp, J. E., Correlation of the Big Blue series in Nebraska: Nebraska Geol. Survey Bull. 6, 2d ser., 1931.

64. Bass, N. W., The geology of Cowley county, Kansas: Kansas Geol. Survey Bull. 12, pp. 45-52, 1929.

65. Heald, K. C., The oil and gas of the Foraker quadrangle, Osage county, Okla.: U. S. Geol. Survey Bull. 641, pp. 21, 25, 1916.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Lyon Co.
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Flint Ridge
Hamilton
Butler Co.
ELDORADO
EUREKA
Rosalia
Reece
Greenwood Co.
Beaumont
Piedmont
Latham
HOWARD
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amount of limestone decreases toward the north, and the formation is divisible into several limestone and shale members which are, from the base upward, the Americus limestone, Hughes Creek shale containing the Thrall limestone bed, and the Long Creek limestone.

The two lowermost limestone beds, with the intervening shale, constitute the *Americus limestone member.*[66] The lower bed of the Americus limestone is massive, dense, bluish-gray, fossiliferous, and about 2 feet in thickness. It contains minor amounts of chert in some localities. Fossils are most numerous in the lowermost part of the bed. The limestone crops out as a hard, blocky rock that forms a prominent ledge. Thick blocks of limestone that have become separated from the main ledge and lie strewn on the slope below form a characteristic feature of the member. The smooth upper surface of the outcropping ledge makes an ideal key for structural mapping. The lower limestone is characteristically exposed in Greenwood county, about 200 feet southwest of the north quarter corner of sec. 21, T. 22 S., R. 10 E., about 200 feet south of the main road leading to the Browning oil field (see pl. 3); and in the southeast bank of the stream near the center of the NW¼ sec. 5, T. 24 S., R. 10 E.; and on both sides of the gulch east of the center of sec. 5, T. 24 S., R. 10 E. (see pl. 5), about half a mile south of the Thrall oil field.

The shale between the two limestone units of the Americus limestone is gray to drab, and is in part limy; it is 6 to 8 feet thick near Elmdale (see column 1, pl. 2), 3 feet thick in the Thrall oil field (see column 4, pl. 2), and as much as 13 feet thick in the southern part of Cowley county and in the northern part of Oklahoma (see column 10, pl. 2).

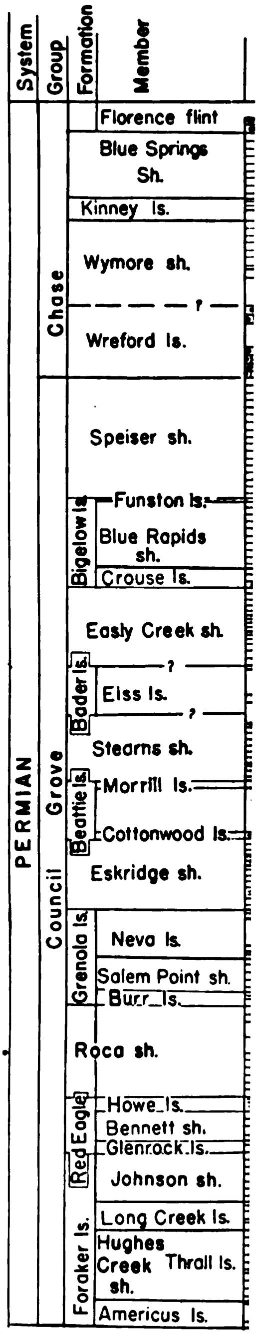
The upper limestone of the Americus member is persistent from the Cottonwood river valley southward to the east-central part of Cowley county. It ranges in thickness from 1 foot 4 inches near Elmdale (see column 1, pl. 2) to 4 feet 5 inches near Grand Summit, in Cowley county (see column 8, pl. 2). A short distance south of Grand Summit the limestone beds of the upper Americus coalesce with limy beds adjacent below and above, and the unit loses its identity. It consists of light gray abundantly fossiliferous limestone that is characteristically thinner bedded than the lower limestone of the Americus member and forms much less prominent outcrops than the lower limestone; in fact, in most localities in western Greenwood county it forms only a rocky shoulder a few feet above

66. Bass, N. W., op. cit., pp. 50-52.

the ledge of the lower Americus. At the outcrops in southwestern Lyon county, shown in column 2 on Plate 2, the bed is blocky, similar to the lower Americus. The upper bed of the Americus contains a persistent chert zone that extends southward from southwestern Greenwood county. The limestone is exposed in the creek bank just below the fork near the center of NW¼ NW¼ sec. 21, and in the creek bank in the southern part of the NE¼ SW¼ sec. 21, T. 22 S., R. 10 E., (see pl. 3), a short distance east of the Browning oil field, which is north of the area wherein it is chert-bearing. The upper limestone is used relatively little in structural geologic mapping, because it is separated by so small an interval from the lower limestone, which furnishes such excellent datum points for this part of the stratigraphic column.

The Hughes Creek shale, which overlies the Americus limestone, is composed of fossiliferous, limy, gray shale and limestone. A limestone (Thrall) above the middle of the Hughes Creek shale forms a prominent ledge and gives the member a three-fold division. The lower part of the Hughes Creek shale is concealed in most localities; where seen it is a light gray to light tan limy shale, increasing in lime content southward, and it contains a few thin beds of limestone that are abundantly fossiliferous. About 500 feet west of the S¼ corner sec. 28, T. 22 S., R. 10 E., southeast of the Browning oil field, the Thrall limestone bed forms a small falls in the stream; the shale beds for several feet below it are so limy that here, where they are fairly freshly exposed, it is questionable whether they should be designated as limy shale or shaly limestone. The limy beds, which are 2 feet below the massive bed of the Thrall limestone, are ripple marked, layer upon layer, through a thickness of about a foot. The ripples have a relief of about one fourth of an inch; they average about 2½ inches from crest to crest; they appear to be symmetrical in cross section, and they trend about north 38° east. There are slight differences in the trend of the ripples of the several beds, but the general direction is the same.

The next higher ledge-forming limestone, here named the *Thrall limestone bed,* from the Thrall post office in the Thrall oil field in western Greenwood county, persists from Elmdale, Kan., southward into Oklahoma, but in the southern part of Kansas it thickens greatly and appears to coalesce with adjacent beds and thus loses its individual identity. It is only 1 foot 4 inches thick near Elmdale on Cottonwood river, where it makes a very inconspicuous outcrop, but in western Greenwood county it forms a prominent rock ledge about



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3 feet thick; in the Sallyards oil field, in T. 25 S., R. 8 E. (see column 5, pl. 2), it is about 9 feet thick but contains some limy shale; and in the exposure east of Beaumont, Kan., it is represented by 13 feet of massive limestone (see column 6, pl. 2). The Thrall limestone at the type locality, where it is 11 to 12 feet above the Americus limestone, is about 4 feet thick and is composed of light gray limestone that weathers cream-colored. The lowermost half foot and uppermost foot of the rock is thin-bedded and inclined to be shaly. The middle part of the member, 2 to 2½ feet thick, occurs in two to three beds that commonly form a prominent ledge (see pl. 4-C). Its most distinguishing feature is a layer of blue-gray, dense chert nodules which occurs 4 to 6 inches below the top of the ledge-forming part of the member. In most exposures the limestone overlying the chert has been eroded away and the chert caps the ledge. The chert nodules are for the most part confined to a single stratigraphic horizon; they are separated by limestone; most of them are 4 to 5 inches in length and 1 to 3½ inches in thickness; rarely single nodules or coalesced nodules reach a length of 10 to 11 inches. The limestone and the chert contain specimens of a large fusulinid. The chert becomes more abundant southward, and in the southern part of Cowley county the Thrall bed, together with the upper limestone of the Americus member, forms the chief chert-bearing part of the Foraker limestone.

The Thrall limestone bed is exposed as a prominent ledge in the east bank of the principal creek that flows southwest through the SW¼ sec. 32, T. 23 S., R. 10 E., a short distance east of the Thrall oil field. The chert bed and the ledge-forming part of the Thrall limestone are well exposed in the creek bed 500 to 1,000 feet southwest of the Phillips camp in the NW¼ sec. 33, T. 23 S., R. 10 E. Most of the ledge-forming part of the limestone and the uppermost beds are exposed in the road cut on the east side of the draw just east of the north quarter corner of sec. 5, and the lower part is exposed on the west side of the gulch, near the center of the SW¼ NE¼ sec. 5, T. 24 S., R. 10 E.

The Thrall limestone forms conspicuous outcrops in parts of the Browning oil field in western Greenwood county and was therefore used in parts of the area for structural geologic mapping. Locally, it is divided by joints into massive slabs 1½ feet thick and 10 to 15 feet broad. The slabs are conspicuous just south of the road in the slopes of a small gulch in the NW¼ NW¼ sec. 21, T. 22 S., R. 10 E.; this locality (see pl. 3) is 1½ miles east of the Browning camp

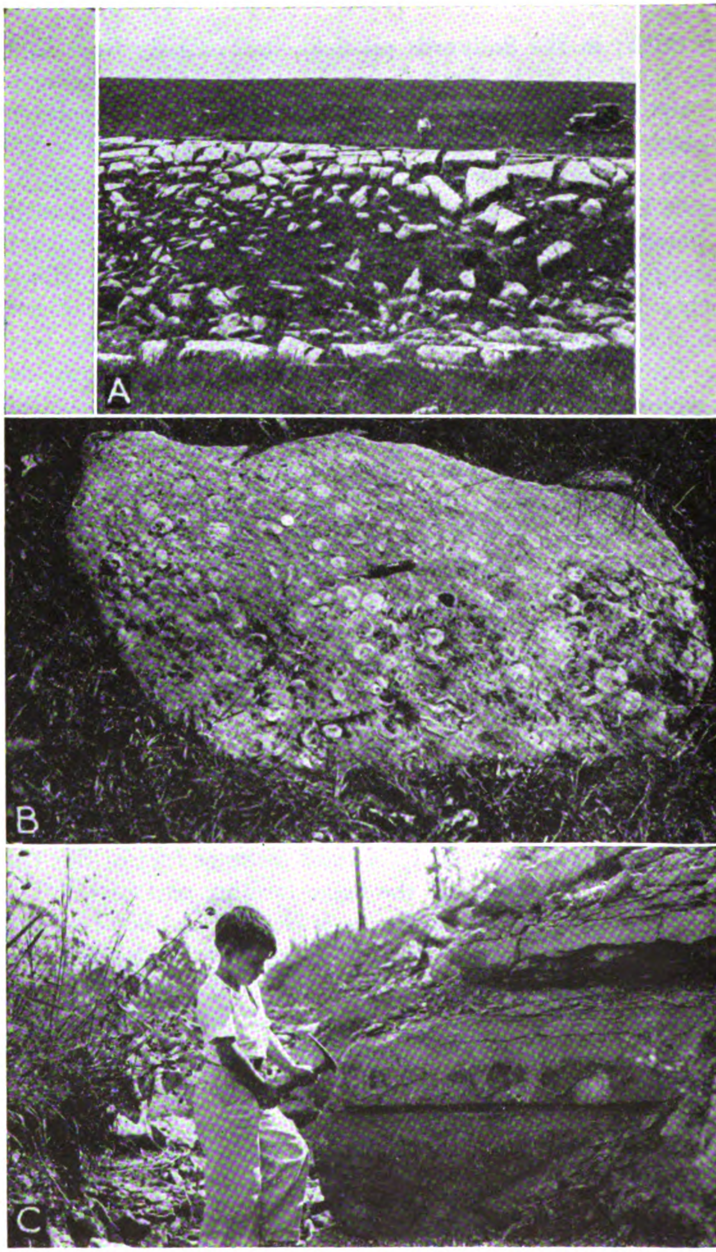

PLATE 4. *A,* The lower limestone of Americus member in the SE¼ sec. 5, T. 24 S., R. 10 E., south of the Thrall oil field. *B,* Slab of fossiliferous Morrill limestone in sec. 18, T. 22 S., R. 10 E. *C,* Thrall lime stone bed in the Thrall oil field; chert nodules shown at right of hammer head.

of the Sinclair Prairie Oil Co. The massive character of the bed is not persistent, however; it crops out as thin-bedded limestone in some localities in the Browning field. No chert was seen in the Thrall limestone in the Browning oil field.

The shale that separates the Thrall and Long Creek limestones and constitutes the upper part of the Hughes Creek shale is composed of limy shale that weathers gray to tan. It contains considerable calcareous material at all places where it was seen, and the content of lime increases southward. At many exposures in western Greenwood county, fusulinids weather out from this shale in such abundance that they coat the surface of the slopes with their wheat-like forms. The presence of fusulinids in abundance on such slopes is the most characteristic feature of the shale. In some localities the fossils are congregated in knotty concretions in very limy shale. The shale is exposed below the Long Creek limestone in the north bank of the creek, about 600 feet south of the northeast corner sec. 20, T. 22 S., R. 10 E., east of the Browning oil field.

The upper limestone of the Foraker formation has been identified near Elmdale, Kan., on Cottonwood river, by Moore[67] and Condra as equivalent to the Long Creek limestone[68] of Nebraska. It is composed of thick beds of friable light-buff limestone having a total thickness of about 8 feet near Elmdale, where it rarely forms conspicuous outcrops. The beds become harder southward, and the outcropping beds are thin and form a bench. In the Browning oil field the lower third of the Long Creek limestone, which is 7 or more feet thick, is composed of relatively soft, chalky, cream-colored or slightly buff beds, each 8 to 12 inches thick; the upper two thirds is made up of thin white beds, each 1½ to 2 inches thick. The limestone is exposed in part in the roadway less than a quarter of a mile east of the northwest corner sec. 21, T. 22 S., R. 10 E., and in the creek a few hundred feet north of this locality, which is a mile east of the Browning oil field. In southern Kansas this member is not so conspicuous as the Thrall limestone bed; there it commonly forms a slope, strewn with fragments of almost white limestone, above the rock ledge formed by the Thrall bed. The Long Creek limestone member contains no chert in the exposures examined.

Following is a section of the Foraker limestone, compiled from sections of parts of the formation measured in the following localities in and near the Thrall oil field: in the roadway near the south-

67. Moore, R. C., oral communication in the field.

68. Condra, G. E., The stratigraphy of the Pennsylvanian system in Nebraska: Nebraska Geol. Survey Bull. 1, 2d ser., pp. 85-86, 1927.

west corner sec. 36, and the southeast corner sec. 35, T. 23 S., R. 9 E.; on the road between sec. 32, T. 23 S., R. 10 E., and sec. 5, T. 24 S., R. 10 E.; and near the center of the SW¼ NE¼ sec. 5, T. 24 S., R. 10 E.

Section of the Foraker limestone in the Thrall oil field

	Thickness Ft.	In.
Johnson shale		
Foraker limestone		
Long Creek limestone member:		
Limestone, light cream-gray, soft, thin-bedded except lowermost part; only sparingly fossiliferous	7	6
Shale, weathers light tan	1	4
Limestone, light gray, thin-bedded; contains a few fossils	0	9
Hughes Creek shale member:		
Shale, very limy; contains abundant specimens of a large fusulinid, that weather out of the shale and lie thickly strewn on the surface	7	6
Thrall limestone bed:		
Limestone, light cream-gray, thin-bedded; contains fusulinids	1	0
Limestone, light cream-gray, thick-bedded; contains a layer of blue-gray chert nodules, each 3½ inches or less thick and 4 to 5 inches long; the limestone and chert contain abundant fusulinids	2	5
Shaly limestone, thin-bedded, fossiliferous	0	5
Shale, light tannish gray, weathered	3	2
Limestone, dark gray, fossiliferous, thin-bedded	0	2
Shale, dark gray, fissile; contains a few thin lenses of limestone,	1	5
Limestone, dark gray, fossiliferous, thin-bedded	0	10
Shale, weathers tan, fossiliferous, in part limy	6	0
Amercicus limestone member:		
Upper limestone		
Limestone, light gray, abundant fusulinids; weathers rough, like mortar	0	7
Limestone, dull gray, fossils and fossil fragments abundant, occurs in wavy surfaced thin beds	0	10
Limestone, light gray, thin-bedded and somewhat shaly; contains fusulinids	1	6
Shale, gray to dark gray; weathers tan; in part fissile	2	9
Lower limestone		
Limestone, dark gray, dense, smooth upper surface; contains fusulinids and other fossils; breaks into large blocky slabs	1	8
Total—Foraker limestone	39	10
Admire group.		

JOHNSON SHALE.—Overlying the Foraker limestone is a unit about 25 feet thick that is composed largely of beds of gray shale, some of which are very limy, and a few thin, inconspicuous beds of fossiliferous limestone. It persists across Kansas and is believed by Moore and Condra to be equivalent to the Johnson[69] shale of Nebraska.

RED EAGLE LIMESTONE.—The interval of 20 feet succeeding the Johnson shale contains limestone in southern Kansas and northern Oklahoma, where it is known as the Red Eagle limestone. It consists of relatively thin-bedded gray limestone that for the most part contains but few fossils; the uppermost 3 to 4 feet is massive, rather coarse-grained, soft limestone that weathers to a deep buff color. The lower 3 to 5 feet of the Red Eagle limestone forms a jagged wall-like rock ledge and the uppermost few feet forms nodular buff chunks of rock in the slope above. Shrubs characteristically grow in greater abundance along the outcrops of the lower part of the Red Eagle limestone than on other units.

The Red Eagle limestone persists from the northern part of Oklahoma—its type locality[70]—northward at least as far as the Cottonwood river valley; it is composed entirely of limestone as far north as the northwestern part of Elk county, where the middle part becomes somewhat shaly and splits the formation into two limestone members and an intervening shale. The lime content of the shale between the two limestone members decreases toward the northeast. The buff color and, in most localities, the massive bedding of the upper limestone member, persists northward to the Cottonwood river; this member characteristically crops out as a single bed of buff limestone that weathers in nodules about a foot thick. Near Elmdale, in the Cottonwood river valley, the upper member of the Red Eagle limestone has thinned to about a foot in thickness; it crops out there as small brownish-buff slabs not very conspicuous in the sodded slopes. The lower limestone member forms a conspicuous outcropping rock ledge in the river bluffs east of Elmdale, where it was noted and described by Prosser and Beede[71] as No. 6 in their section measured there. It maintains its characteristic features northward beyond the Cottonwood river valley.

The three members of the Red Eagle limestone were identified in Kansas by me as far northward as the Cottonwood river bluffs east of Elmdale. Moore and Condra[72] have identified these

69. Condra, G. E., op. cit., p. 86, 1927. Moore and Condra identified this unit at Elmdale, Kan., as the Johnson shale.

70. Heald, K. C., op. cit., pp. 24-25.

71. Prosser, C. S., and Beede, J. W., Description of the Cottonwood Falls quadrangle: U. S. Geol. Survey Geol. Atlas, Cottonwood Falls folio (No. 109), p. 2, 1904.

72. Moore, R. C., oral communication.

beds at the Elmdale locality as being equivalent to the Glenrock limestone (the oldest), Bennett shale, and Howe limestone of northern Kansas and Nebraska. Both of the limestone members of the Red Eagle have been used extensively in detailed geologic mapping in the oil fields in the western part of Greenwood county. They form prominent ledges in the Thrall oil field. The Glenrock limestone member at the base is 3½ feet thick; its outcrops form a bench strewn with thin white fragments of limestone. It is prominently exposed in the easternmost part of section 31, in section 32, and the western part of sec. 33, T. 23 S., R. 10 E. The Bennett shale member, just above the Glenrock, is not well exposed, but the Howe limestone member that overlies the Bennett forms two benches; the lower is composed of massive, light buff limestone; two feet above it white, fine-grained slabs of limestone form the upper bench. The massive bed of the Howe limestone is exposed a short distance east of the S¼ corner of sec. 28, and the overlying slabby beds are exposed near the road in the SE¼ NW¼ sec. 33, T. 23 S., R. 10 E.

Near the Browning oil field the Glenrock limestone ledge in the south bank of the creek near some large trees in the southern part of the NE¼ NE¼ sec. 20, T. 22 S., R. 10 E., can be seen from the road along the north boundary of the section. The limestone is composed of light gray, thin beds that weather into plates only half an inch or so thick. The Bennett shale, 9 feet thick, forms sod-covered slopes in most localities. An exposure above the ledge of the Glenrock limestone in the slope south of the creek in the southern part of the NE¼ NE¼ sec. 20, reveals the lowermost 3 to 4 feet to be an abundantly fossiliferous weathered tan shale. Exposures elsewhere in the Browning field show the uppermost 2 feet of the shale to be tan and fossiliferous. In the Browning oil field the Howe limestone consists of a lower massive bed 3 feet 4 inches thick, a middle greenish shale 1 foot 2 inches thick, and an upper limestone 1 foot 9 inches thick that is composed of beds 3 to 5 inches thick and is light gray on fresh surfaces and ocherous yellow on weathered surfaces. The lowermost foot of the lower massive limestone forms the outcropping ledge in all exposures except in recently cut stream channels; it weathers into chunks about 9 inches thick that have a very rough surface on which there are sharp prongs up to 1½ inches long. Such a surface is so characteristic that the bed was designated in the field notes as the "rough bed." The lowermost half foot of the ledge-forming bed is somewhat earthy and weathers ocherous yellow. Excellent exposures of the ledge-forming bed of the Howe limestone can be seen on both sides of the valley in the NE¼ NE¼ sec. 29, and in the SE¼ sec. 20, T. 22 S., R. 10 E.; complete exposures can be seen in the stream banks just east, also north of the N¼ corner sec. 29, and just west of the center of sec. 20, T. 22 S., R. 10 E.

Roca Shale.—A unit 20 to 35 feet thick, composed of somewhat limy gray shale, maroon shale, and a persistent limestone, overlies the Red Eagle limestone. Its most distinguishing features are the maroon color of the lower part of the shale, and the limestone near the middle of the formation. The Roca shale persists from the Oklahoma-Kansas boundary northward to the Cottonwood river valley, and Moore[73] states that it continues still farther northward into Nebraska, where it has been named by Condra.[74] The limestone near the middle of the Roca shale crops out in thin slabs that in many localities contain fossils in abundance. It persists from northern Oklahoma northward to the Cottonwood river. Although it forms a ledge in many localities, particularly in southern Kansas, in northern Greenwood county it makes only a slight shoulder strewn with limestone fragments about 10 to 15 feet below the ledge formed by the Burr limestone. Near Elmdale on Cottonwood river the limestone is very inconspicuous, and is represented by only a little less than two feet of shaly, thin-bedded limestone.

Grenola Limestone.—The Grenola limestone includes all beds between the Roca shale below and the Eskridge shale (as redefined) above. It embraces three ledge-forming limestones and the intervening shales: (1) At the base is a blocky limestone that forms a prominent ledge. (2) About 12 feet above it is a fairly thick limestone, which is the Neva limestone as named by Prosser at Neva station; it varies from a massive escarpment-forming rock, as shown near Neva and Elmdale, to a thin-bedded inconspicuous unit as revealed in the Browning oil field in Greenwood county; it contains some chert in many localities. (3) At the top is another massive limestone that weathers into a nodular ledge very similar in appearance to the limestone next below. The Grenola limestone was named by Condra and Busby[75] from exposures near Grenola in southwestern Elk county, Kansas.

The three limestones that are mentioned above persist along the outcrop from northern Oklahoma to the Cottonwood river valley;

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73. Moore, R. C., oral communication.

74. Condra, G. E., The stratigraphy of the Pennsylvanian system in Nebraska: Nebraska Geol. Survey Bull. 1, 2d ser., p. 86, 1927.

75. Condra, G. E., and Busby, C. E., The Grenola formation: Nebraska Geol. Survey paper No. 1, 1933.

each is composed of fossiliferous gray limestone that forms ledges in the slopes; each decreases in thickness northward, a feature common to most of the limestone units in this part of the stratigraphic column. The shale that separates the limestone beds becomes increasingly limy southward, and limestone predominates over shale near the southern boundary of the state. All members of the Grenola limestone are exposed in the bluffs north of the railroad track in the Grand Summit oil field near the Cowley county boundary, a few miles northeast of Grand Summit.

Burr limestone.—The Burr limestone is the lowest bed in the Grenola limestone. The middle part of the member characteristically crops out as a massive bed that forms a narrow pavement of smooth-surfaced blocks about a foot or more thick; abundant specimens of a large species of *Myalina* lie on its upper surface in many localities. The member makes clean-cut outcrops as far north as the northern part of Greenwood county. The limestone has a total thickness of 6½ feet, but only the middle part of it is exposed in most outcrops; its habit of forming blocky slabs persists from western Greenwood county southward into Oklahoma, but it is rarely exhibited north of Greenwood county; it forms a fairly conspicuous limestone-strewn terrace 12 to 15 feet below the escarpment of the Neva limestone about half a mile south of the highway along the bluffs southeast of Elmdale; it is No. 10 in Prosser and Beede's[76] section measured in the bluff east of Elmdale and was called lower Dunlap by these authors after Kirk,[77] who included the main ledge-forming member of the Neva limestone as the upper limestone unit of the Dunlap. The Burr limestone is exposed north of the railroad in the Grand Summit oil field in northeastern Cowley county.

In the Thrall oil field, in western Greenwood county, the Burr limestone and limestone beds above and below it are partially exposed immediately south of the Thrall No. 51 oil well in the center of the west line NE¼ SW¼ sec. 28, T. 23 S., R. 10 E. (pl. 5). There a limestone bed in the Roca shale forms a shoulder strewn with limestone fragments (elsewhere in the vicinity it forms a low ledge composed of thin plates); the next higher limestone, which is the Burr, forms a low ledge, and the next higher limestone, which is the lower limestone of the Neva, crops out only a few feet south of the oil well. In the Browning oil field, in northwestern Greenwood county, the Burr limestone caps a narrow ridge that trends eastward

76. Prosser, C. S., and Beede, J. W., op. cit., p. 2.

77. Kirk, M. Z., A geologic section along the Neosho and Cottonwood rivers: Kansas University Geol. Survey, vol. 1, p. 81, 1896.

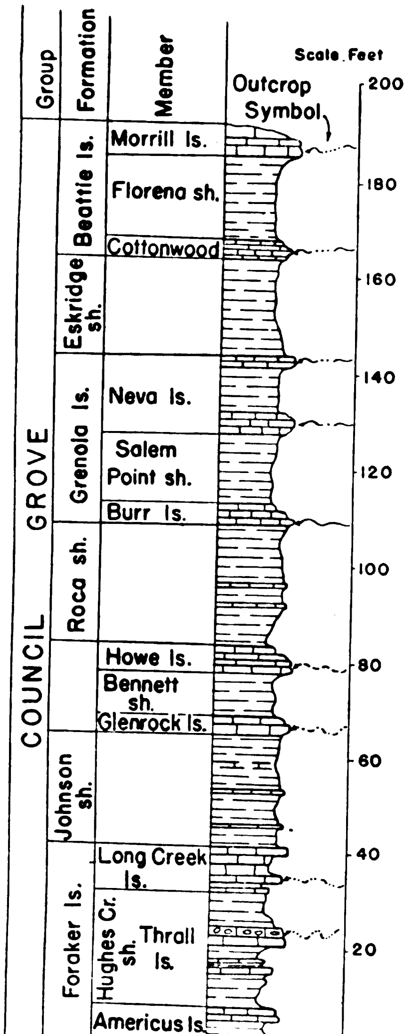

PLATE 5.—Structure contour map of t
on top of the Neva limestone. Outcrop
Kansas Geological Survey chart, 1934.

through the northern part of the S½ NE¼ sec. 20, T. 22 S., R. 10 E., and crops out in large slabs a foot or less thick, containing specimens of a *Mylina* that are from 2 to 3 inches long.

Salem Point shale.—The strata between the Burr limestone below and the Neva limestone above comprise the Salem Point shale. This member forms gentle slopes that are sod-covered in most localities. At a few places where the Salem Point shale beds were seen they consist largely of gray to drab shale, in part limy, and a few thin lenses of shaly limestone, with a total thickness of about 15 feet.

Neva limestone.—The type locality of the Neva limestone, as long used in stratigraphic descriptions[78] of Kansas rocks, is near Neva station in the Cottonwood river valley; there the Neva limestone is a prominent ledge-forming rock 11 feet thick; it is light gray with a light-buff hue, weathers to a pitted, sharply rough surface, and contains many fossils. About 4½ feet above the main ledge in this vicinity is a light-gray limestone a foot or less thick, separated from the main ledge by calcareous gray shale. Southward this upper thin limestone increases in thickness, becomes massively bedded, crops out with a slightly pitted, sharply rough surface, and closely resembles the main limestone of the type locality.

These two ledge-forming limestones—one 11 feet thick and the other 1 foot thick at Neva—are the two upper limestones of the Grenola limestone and comprise the Neva limestone as now classified by the Kansas Geological Survey. They form prominent outcrops 10 to 12 feet apart between Neva and localities in Cowley county. The upper unit maintains the massive character and crops out as a nodular, pitted, light-gray ledge that is more persistent than the ledge of the lower unit (the Neva limestone of old reports), which in some localities is thin bedded. Southward, in Cowley county, the shale between the two limestones becomes increasingly calcareous, finally joining the two limestones into one unit about 20 to 25 feet thick, which includes some additions of limestone beds above the upper unit and some below the lower unit; accordingly, the limestone beds appear to expand southward, both above and below. This relationship is shown on Plate 2. Although the early Kansas reports restricted the term Neva limestone to the main ledge-forming bed of the type locality, which is the lower one of the two just described, the geologic report on Cowley county[79] placed both the

78. Prosser, C. S., Revised classification of the upper Paleozoic formations of Kansas Jour. Geology, vol. 10, p. 709, 1902; U. S. Geol. Survey Geol. Atlas, Cottonwood Falls folio (No. 109), p. 2, 1904.

79. Bass, N. W., The geology of Cowley county, Kansas: Kansas Geol. Survey Bull. 12, pp. 55-56, 1929.

limestones and the intervening shale described above in the Neva limestone. This definition for Cowley county is believed to correspond closely with the usage in northern Oklahoma.[80]

In the southern part of Kansas and in the northern part of Oklahoma, where the two limestones of the Neva limestone are merged into one thick limestone unit, the uppermost part of the merged limestone contains rock that is more massive and is inclined to be more readily soluble than that in the lower part, a fact that was commented upon by Heald.[81] Because of the readily soluble nature of the upper part of the limestone, it forms rock outcrops in only a relatively few localities in the southern part of Kansas. Exposures in the bluffs north of the railroad track near the Cowley county boundary east of Grand summit, where section No. 8 on Plate 2 was measured, reveal these beds as well as other parts of the Grenola limestone. There, the upper limestones that form the Neva are joined by easily soluble limestone beds that occupy the position of the shale of the region to the north. The upper limestone is massive, porous, and easily soluble; it forms a rock outcrop for only a few hundred feet—elsewhere it is covered with soil and sod. The lower of the two benches of the Neva limestone contains chert and forms a prominent ledge on the north bank of the creek, north of the railroad and a short distance west of the Grand Summit oil field; it corresponds to the main ledge at Neva on Cottonwood river.

In the Thrall oil field, in western Greenwood county, the lower limestone of the Neva forms a ledge of white slabs near the crest of the divide that trends northeast-southwest through sec. 31, the SE¼ SE¼ sec. 30, and into sec. 29, T. 23 S., R. 10 E. The upper limestone of the Neva is exposed in the E½ sec. 29, T. 23 S., R. 10 E., near the crest of the divide in the northernmost part of the Thrall oil field, where it crops out as a massive nodular bed of light gray rock. It is better exposed on the north side of the draw in the SE¼ SW¼ sec. 21, T. 23 S., R. 10 E., half a mile north of the oil field. In the Browning oil field in northwestern Greenwood county the lower limestone of the Neva consists of a lower bed of limestone 8 inches thick that is fossiliferous in some localities, weathers brownish, and has irregularly shaped grooves and pits 1 to 1½ inches deep on its upper surface, a middle bed of gray limy shale 2 feet thick, and an upper bed of light-gray limestone 1 foot thick that crops out in large slabs. The beds of this limestone are

80. Heald, K. C., The oil and gas of the Foraker quadrangle, Osage county, Oklahoma: U. S. Geol. Survey Bull. 641, pp. 23-24, 1916.
81. Heald, K. C., op. cit., pp. 23-24.

well exposed and form the rim of the gulch due north of the Theta Oil Co.'s camp in the NW¼ sec. 17; they are well exposed, also, in the draw near the center of SW¼ NW¼ sec. 20, T. 22 S., R. 10 E.

In the Browning oil field the upper limestone of the Neva resembles the lower limestone of the type locality (Neva station) more closely than the next lower limestone which is believed to be equivalent to the bed of the type locality. The upper limestone of the Neva crops out in the Browning oil field as light gray to white nodular masses that have a granular texture. Exposures in sec. 17, T. 22 S., R. 10 E., immediately north of and about half way between the Theta Oil Co.'s camp and the oil well derrick that stands farther north near the rim of the gulch, are typical. The same limestone is exposed in the creek bank near the southwest corner of the NE¼ NE¼ sec. 18, T. 22 S., R. 10 E., where it is 2 feet 9 inches thick; here the lower 2 feet of the bed is thin-bedded, light gray, and abundantly fossiliferous, and the upper 9 inches is very porous, pumaceous-like, light gray to cream-colored rock. Maroon and gray shale occur above the limestone here.

Eskridge Shale.—The Eskridge shale consists of greenish-gray and dull maroon shale, in part limy, and a few thin beds of limestone. Only parts of it were seen in the localities shown on Plate 2. The Eskridge shale is partially exposed in the westernmost part of sec. 27, T. 23 S., R. 10 E., in the Thrall oil field, and in the creek banks in the NE¼ sec. 18, T. 22 S., R. 10 E., in the Browning oil field. The Eskridge shale includes all beds between the Neva and Cottonwood limestones, but 12 to 15 feet of shale and limestone beds that were formely placed in the lowermost part of the Eskridge shale have been transferred by the Kansas Geological Survey to the Neva limestone. Furthermore, the Cottonwood limestone pinches out in southernmost Kansas, in consequence of which the Eskridge and Florena shales form a continuous body called the Eskridge-Florena shale by the Kansas Geological Survey. The Eskridge-Florena shale includes all beds between the Neva limestone below and the Morrill limestone above. My work determined that the Cottonwood limestone ceases to be a recognizable limestone unit near Grand Summit in T. 31 S., R. 8 E., and from that place on southward into Oklahoma the Eskridge and Florena shales merge in a shale unit that ranges between 35 and 40 feet thick. The upper third or so of this combined unit is very limy and contains an abundance of fossils.

Beattie Limestone.—The Beattie limestone includes the Cottonwood limestone, Florena shale and Morrill limestone.

Cottonwood limestone.—The Cottonwood limestone was fittingly described by Prosser[82] as a yellowish-buff rock. It is 6 feet thick and forms a prominent rock ledge in the Cottonwood river valley and elsewhere in the northern part of Kansas. A short distance south of the Cottonwood river, however, it loses these striking features. There it becomes thin-bedded, forms only a shoulder strewn with white limestone chips in the grass-covered slopes, and is not particularly conspicuous among a series of limestone ledges. Locally, its outcrop forms a bolder ledge, such as that near Sallyards station and on highway 54 near Sallyards, in western Greenwood county. The Cottonwood limestone was identified from Cottonwood river southward to about the northern boundary of Cowley county, where it ceases to be a mappable unit. On southward through Cowley county and into Osage county, Oklahoma, the Cottonwood limestone is represented by very limy shale and a few "stringers" of easily soluble limestone beds a few inches thick, all abundantly fossiliferous and inclined to weather yellowish. A short distance farther south, in Osage county, Oklahoma, the horizon of the Cottonwood limestone of Kansas and of the overlying Florena shale is occupied by interbedded shale and fossiliferous limestone conglomerate; these beds comprise the lower part of the so-called Cottonwood limestone of Heald[83] in the Foraker quadrangle, Oklahoma. The uppermost part of Heald's Cottonwood includes the Morrill limestone of Kansas, which is the limestone that has been mapped and commonly called the Cottonwood limestone in northern Oklahoma. The Morrill limestone occurs 10 to 15 feet above the horizon of the Cottonwood limestone as described in this report. The limestone described and mapped as the Cottonwood in the geologic report on Cowley county[84] is actually the Morrill limestone. Condra and Upp[85] correctly correlated the strata in this part of the section and noted the erroneous application of the name Cottonwood to the Morrill limestone. An unpublished section measured by Beede,[86] in 1914, has recently come to my attention, showing that he recognized that the Cottonwood limestone and Florena shale are

82. Prosser, C. S., The classification of the upper Paleozoic rocks of central Kansas: Jour Geology, vol. 3, pp. 697-705, 1895.

83. Heald, K. C., op. cit., p. 23.

84. Bass, N. W., op. cit., pp. 59-62.

85. Condra, G. E., and Upp, J. E., Correlation of the Big Blue series in Nebraska: Nebraska Geol. Survey Bull. 6, 2d series, pp. 16-18, 1931.

86. Beede, J. W., Stratigraphic section between Cedarvale and Hooser, Kansas, unpublished notes.

represented in southern Kansas by calcareous beds in a shale that overlies the Neva limestone. Condra and Upp[87] attempted to segregate a certain part of the calcareous beds in the upper part of the combined Eskridge-Florena shale in Cowley county and designate it to the Cottonwood limestone. I believe it is impossible to segregate the beds that are definitely equivalent to the Cottonwood limestone, and believe also that the beds selected at one locality cannot be identified at other localities not far away. The discontinuance of the term Cottonwood limestone appears advisable south of northeastern Cowley county, where it ceases to be recognizable as a mappable limestone.

In the Thrall oil field, in western Greenwood county, the Cottonwood limestone forms a bench of white limestone fragments in the N½ sec. 28, and is exposed in a road cut near the southeast corner of the NE¼ NW¼ sec. 28, T. 23 S., R. 10 E. (pl. 5). In the Browning oil field the Cottonwood limestone contains a few small nodules of chert and its uppermost beds contain specimens of a small fusulinid, similar to those found in it near the type locality. It forms a shoulder strewn with white limestone fragments, that is conspicuous on the north face of the slope in the S½ SE¼ sec. 18, T. 22 S., R. 10 E.

Florena shale.—The Florena shale[88] consists of about 13 to 15 feet of yellowish, limy, abundantly fossiliferous shale in Lyon and Greenwood counties; it is somewhat thinner southward, and also northward[89] from the Cottonwood river valley. In the southernmost part of the state the Florena is not readily distinguishable from the underlying Cottonwood limestone because the Cottonwood has changed southward from limestone to limy shale and to lenses of limestone, a few inches thick. In southern Kansas all beds between the Neva limestone and the Morrill limestone are designated by the Kansas Geological Survey as the Eskridge-Florena shale. The upper part of this combined shale unit is cleanly exposed in a gulch below the ledge of the Morrill limestone in sec. 6, T. 33 S., R. 8 E., Cowley county. Maroon clay shale more than 6 feet thick, that is similar to the Eskridge shale elsewhere, forms the lowest beds exposed here; light gray slightly calcareous shale, 8 feet thick, overlies the maroon shale and very limy fossiliferous light gray

87. Op. cit., p. 28.

88. Prosser, C. S., and Beede, J. W., Description of the Cottonwood Falls quadrangle: U. S. Geol. Survey Atlas, Cottonwood Falls folio (No. 109) pp. 2-3, 1904.

89. Prosser, C. S., and Beede, J. W., op. cit., p. 3.

shale, 13 feet thick, occurs next above. The Florena shale is exposed in the Thrall oil field in a road cut near the center of the east line NW¼ sec. 28, T. 23 S., R. 10 E., and in the Browning oil field, near the center of sec. 18, T. 22 S., R. 10 E., in the south bank of the stream.

Morrill limestone.—The Morrill limestone[90] is one of the most persistent limestones in Kansas. It characteristically forms exposures consisting of brown chunks with rough surfaces. In Greenwood county the fossils in the lower part of the member weather in relief and are conspicuous because of their light-gray color in contrast with the brown background of the rock. This limestone forms a more conspicuous ledge than the Cottonwood limestone in most localities south of the Cottonwood river and, as stated previously, has been mapped as the Cottonwood limestone in Cowley county, Kansas, and in Kay and Osage counties, Oklahoma. The Morrill limestone forms one of the most prominent limestone ledges in the Browning oil field. It crops out in large brown chunks and slabs a foot or less thick, that have sharply irregular surfaces, over which it is difficult to drive an automobile. The fossils in the bed are particularly well exposed in the slopes that face southeastward, in about the middle of the N½ N½ sec. 18, T. 22 S., R. 10 E., where the photograph, Plate 4*B*, was made. The Morrill limestone is well exposed in the NW¼ NE¼ sec. 19, T. 22 S., R. 10 E., near where the automobile trail crosses the north-south fence and the creek. The limestone is jointed into huge rectangular blocks 2½ feet thick and forms a ledge capping the southeast bank of the gulch, near the center of sec. 18, T. 22 S., R. 10 E.

STEARNS SHALE.—The rocks that occupy the interval that is 20 to 30 feet thick and occurs immediately above the Morrill limestone comprise the Stearns shale, but they were not well exposed in any of the localities visited. The beds seen consist of limy shale and a few beds of limestone, each only 3 to 5 inches thick.

BADER LIMESTONE AND EASLY CREEK SHALE.—The Bader limestone consists of three members, named from the base upward, the Eiss limestone, Hooser shale and Middleburg limestone. The Easly Creek shale, in turn embraces the beds between the Middleburg limestone below and the Crouse limestone above. Much of the strata that comprise these formations are concealed at the localities visited and little data concerning their character were gathered.

90. Named by Condra, G. E., The stratigraphy of the Pennsylvanian system in Nebraska: Nebraska Geol. Survey Bull. 1, 2d ser., p. 237, 1927.

Overlying the Stearns shale, however, is a limestone with a maximum exposed thickness of 4 feet that forms a ledge of dark-gray rock with an irregularly pitted and sharply rough surface. The limestone is persistent; it was found at every locality visited; and it appears to represent the ledge forming part of the Eiss limestone which has been described by Condra and Upp.[91]

BIGELOW LIMESTONE AND SPEISER SHALE.—A sequence of limestone and shale beds 40 feet thick, more or less, comprise the Bigelow limestone. The formation is separated into three members, named from the base upward the Crouse limestone, the Blue Rapids shale and the Funston limestone. Only the Crouse limestone was studied particularly for this report, although partial exposures of other parts of the Bigelow limestone were noted at some localities.

The Crouse limestone forms a conspicuous ledge northward from Osage county, Oklahoma, its type locality,[92] across southern Kansas to and beyond the Cottonwood river valley. It attains a thickness of more than 10 feet, although only about 3 feet of the member is exposed at most localities. In southern Kansas it is composed of relatively thick beds of very light gray limestone, but it becomes thinner bedded northward in Greenwood county, where it weathers ocherous brown. Some beds in the Crouse limestone are fossiliferous, but fossils are much less abundant in this member than in most of the other limestones in this part of the stratigraphic column.

The Crouse limestone is one of the chief bench formers in the western part of the Browning oil field in Greenwood county. It forms a ledge a foot or less high, of cinnamon-brown, vesicular, granular limestone that breaks into chunks and slabs. Very light-gray to white thin plates and fragments of fine-grained limestone mantle the surface for a distance of 3 to 4 feet back from the brown ledge. In fresh exposures the lower brown part of the Crouse limestone is 3 feet thick and the upper gray thin-bedded part is 3 feet thick. A part of the two divisions is exposed in the NE¼ NE¼ sec. 30, T. 22 S., R. 10 E., in the Browning oil field, where the road climbs the steep slope leading to the Tidal Oil Co.'s camp. More complete exposures are revealed 2½ miles southwest of this locality, in the deep gulches in the SW¼ sec. 6, T. 23 S., R. 10 E., and the N½ sec. 1, T. 23 S., R. 9 E.

The Speiser shale consists largely of red and gray shale. Lenticular sand bodies occur above red shale in the uppermost part of the

91. Condra, G. E., and Upp, J. E., op. cit., p. 19.

92. Heald, K. C., op. cit., p. 22.

Speiser shale in Cowley county; in some exposures the sand lenses have an uneven base, and are overlain by evenly bedded marine shale and by thin beds of fossiliferous limestone.

CHASE GROUP

The Chase group consists of alternately bedded limestone and shale, and varies little from 300 feet in thickness. Its most characteristic feature is the abundant chert that occurs in some of the limestones. It contains, from the base upward, the Wreford limestone, Wymore shale, Kinney limestone, Blue Springs shale, Barnston limestone, Holmesville shale, Towanda limestone, Gage shale, and the Winfield limestone. The two principle chert-bearing formations, the Wreford limestone and the Florence flint member of the Barnston limestone, exert a profound influence on the surface features of the state; they form the Flint Hills, and in a part of the state the Florence flint and elsewhere the Wreford limestone crown the Flint Hills escarpment. The Wreford limestone and the Florence flint can be identified by their chert content in the logs of wells as far as 150 miles west of the outcrops.[93] These two units, and particularly the Florence flint, yield water in wells throughout much of the state west of their outcrops. Other identifying features of the Chase group noted in well logs are its red shales.

The Wreford limestone consists of light gray limestone in relatively thick beds interbedded with chert, totaling 33 feet in thickness, in southernmost Cowley county. The chert is confined largely to a zone 6 feet thick about a third of the way above the base and another zone about 6 feet thick that lies 5 feet below the top. Northward in Kansas the middle part of the limestone changes to limy shale, thus making a threefold division of the formation, called from base upward, the Threemile limestone, the Havensville shale and the Schroyer limestone. The greater part of the Wreford limestone is exposed in the southwestern part of the SE¼ SE¼ sec. 36, T. 22 S., R. 9 E., and parts of the formation are exposed in the southern part of the SW¼ SW¼ sec. 19, T. 22 S., R. 10 E., near the Browning oil field.

The sequence of beds which occurs between the Wreford limestone below and the Florence flint above, and includes the Wymore shale, Kinney limestone and Blue Springs shale crops out in some of the shoestring sand oil fields. The sequence consists of red and gray shale and two fossiliferous limestones, each 2½ to 4 feet thick, and probably equivalent to the Kinney limestone. In the Browning oil

93. Kellett, Betty, op. cit.

field one of the limestones forms a conspicuous ledge of white blocks; about 1½ feet above it is a slab-forming, thin-bedded limestone. The blocky unit is one of the key beds used in mapping western Greenwood county.

The Florence flint, which is the lower member of the Barnston limestone, consists of interbedded light buff limestone and chert, having a total thickness of about 30 feet. The chert is sparingly fossiliferous and occurs in nodules 1 to 4 inches thick, most commonly arranged in layers parallel with the bedding; the nodules coalesce in some parts of the member, and thus form continuous lenses or nodular beds of chert.

The Fort Riley limestone, which is the upper member of the Barnston limestone, immediately overlies the Florence flint and is distinguishable from it only by its lack of chert. In southern Kansas it consists of thick and thin beds of light-buff limestone with a total thickness of about 50 feet. It thins somewhat northward and contains some limy shale. The Florence flint and the immediately overlying Fort Riley limestone occupy a broad strip of country, trending northeast-southwest in eastern Butler county and Cowley county, including parts of the shoestring sand region.

The formations and members of the upper part of the Chase group occupy only the westernmost part of the region containing shoestring oil fields. The strata consist of greenish-gray and red shale and gray fossiliferous limestone which, named in ascending order, are the Holmesville shale, Towanda limestone, Gage shale and the Winfield limestone. The Winfield limestone forms a conspicuous ledge capping steep slopes a short distance southwest of the Haverhill shoestring oil field in Butler county and throughout much of western Cowley county.

Relation Between the Structure of Surface Rocks and the Shoestring Sand Bodies

For many years after the discovery of oil in the shoestring sands in southeastern Butler county, geologists were engaged in mapping the structure of the surface strata in this general region. The anticlinal theory applied to the accumulation of oil and gas was so thoroughly established by experience in so many oil and gas fields in the United States and foreign areas, that it was the natural procedure to apply that concept to the geologic work that was carried on here in conjunction with the prospecting and development of the oil and gas fields. But as drilling progressed and additional oil-bearing shoestring sands were found in Butler, Greenwood, and

Cowley counties it became apparent that the oil is not related to surface structural features. Oil was found in synclines or anticlines, on structural slopes between anticlinal and synclinal axes, and on structural terraces. Also, many of the promising looking domes and anticlines had no sand at the horizon of the shoestring sands and were barren of oil and gas in commercial amounts. The drilling revealed that the oil and gas sands are narrow, elongated, lenticular bodies that bear little or no relation to the structural features of the surface strata. A corollary of this discovery is that the oil operator must determine in advance of development the trend of the longer axis of the sand lens. However, a few geologists yet believe that the attitude of the surface rocks reflects to a degree the location of the shoestring sands that contain the oil. Some geologists[94] have discussed the possibility of folds being caused by compaction of the sediments over lenses of sand. It has been pointed out that shale is much more compressible than sandstone and that the column of sediments including the sand, when subjected to the load of overlying sediments, would contract less than the columns of shale on either side of the sand body. In consequence of such differential compaction the rocks overlying the sand body would be deformed into a low-angle arch conforming in general to the upper surface of the sand body. The thick series of alternating limestone and shale strata that overlie the thick Cherokee shale containing the sand lenses is believed by some advocates of this theory to be capable of reflecting the arched figure with diminishing degree upward to the surface rocks.

In order to have at hand detailed information on the structural attitude of the surface strata overlying a few of the oil-producing sand bodies, a plane table survey was made of the geology of three of the shoestring sand oil fields in Greenwood county—namely, the Browning, Thrall, and Fankhouser fields. Reference to Plate 1 will show that one of these fields lies in each of the main shoestring sand trends and one field is in a cross trend. Fields were selected wherein the outcrops of readily identifiable strata are abundant, so that the structure contour maps that would result from the field surveys would be based on an abundance of data. Geologists familiar with the region suggested that, if elevation control points for structural mapping were more closely spaced than is commonly done in this

94. Gardescu, I. I., and Johnson, R. H., The effect of stratigraphic variation on folding: Am. Assoc. Petroleum Geologists Bull., vol. 5, No. 4, pp. 481-483, 1921. Monnett, V. E., Possible origin of some of the structures of the Mid-Continent oil field: Econ. Geology, vol. 17, pp. 194-200, 1922. Rubey, W. W., The geology of Russell county, Kansas: Kansas Geol. Survey Bull. 10, pp. 74-75, 1925.

type of geologic mapping, the data secured would furnish control for contouring with a smaller contour interval than is commonly used; that contours drawn at each 2 to 5 foot difference in elevation might reveal some structural features that would not be disclosed by contours spaced at 10-foot intervals. This suggestion was followed, and the resulting structural contour maps of two of the fields were drawn with a contour interval of 2 feet, and an interval of 5 feet was used on the map of the third field.

THE BROWNING OIL FIELD.—The Browning oil field, which occupies parts of secs. 17 to 20, and 29 to 31, T. 22 S., R. 10 E., in northwestern Greenwood county, is one of the shoestring sand oil fields that comprise the Teeter trend. It lies on the comparatively steep slopes that descend eastward from the crest of the Flint Hills, where the maximum relief of the surface is 350 feet in 1½ miles. The exposed strata form a stratigraphic section 400 feet thick, extending from the Americus limestone member of the Foraker limestone at the base upward to the Florence flint. No less than 16 of the limestone units of the stratigraphic column crop out as prominent rock ledges, and others form ledges of local extent. These strata are described in the chapter on stratigraphy.

The structural attitude of the surface strata in the Browning oil field is shown on Plate 3 by contours drawn on the Morrill limestone. The map is the result of a detailed survey of the field with a plane table and telescopic alidade conducted by stadia rod traverses. Elevations above sea level[1] were determined for all points on outcropping beds shown on the map; these elevations on beds other than the Morrill limestone were adjusted to the Morrill datum by addition or subtraction of the vertical interval between the determined bed and the Morrill datum plane. After all stations were resolved to the single datum, points of equal elevations were connected by lines, known as structure contours; a contour was drawn for each difference of 2 feet in elevation.

The structure contour map (pl. 3) shows that the rocks dip regionally toward the west and northwest, and that the regional dip of the beds is interrupted locally by minor anticlines and synclines that trend in general northeast-southwest across the mapped area. A low syncline crosses the NW¼ sec. 30, SE¼ sec. 19, NW¼ sec. 20, SE¼ SW¼ and SE¼ sec. 17 into NW¼ sec. 16. A low anticlinal nose crosses secs. 19, 20, and 17, trending in a direction approxi-

1. The datum elevation was furnished by Prairie Oil and Gas Co.; adjusted approximately to sea level datum.

mately parallel with the syncline. A somewhat deeper syncline trends northeast-southwest across sec. 18, and an anticline that trends approximately parallel with it lies northwest of the syncline and a short distance outside the area on Plate 3.

The oil productive shoestring sand body that occurs at a depth of about 2,300 feet in the Browning field trends approximately north-south for about 2 miles through parts of sections 29, 30, 20, 19, 17, and 18; its southernmost part appears to trend in a southwest direction across parts of sections 30 and 31. The margin of the sand body lies a short distance beyond the edge oil wells; it lies between oil wells and dry holes in several localities in the field. If the presence of the sand body in the column of sediments has modified the attitude of the surface beds, even though to only a slight amount, the structure contours drawn at intervals of 2 feet and based on elevations determined at every few hundred feet along the outcrops of the strata, such as was done for Plate 3, should reveal the fact by deviations in strike or width of spacing of the contours where they cross over the position of the underlying sand lens. However, the map (pl. 3) shows that the structure contours are not deflected where they trend across the area underlain by the sand body, and that the minor structural features, such as the synclines and anticlines, likewise show no deviations from normality in crossing this area.

It is noteworthy that the presence of oil in the shoestring sand is not controlled by the shallow syncline and anticline that are revealed in the surface rocks in the northern part of the oil field. The oil producing area includes the syncline in sections 19 and 20, the anticline in sections 17, 18, 19, and 20, and the northwest and west dipping monocline in sections 20, 29, 30, and 31. Holes drilled outside the boundaries of the sand lens failed to find oil in commercial amounts, whether drilled on an anticline, a syncline, or a monocline—namely, the dry hole in the NE¼ NW¼ NW¼ sec. 20; the dry hole in the southwest corner of the NE¼ sec. 20; the dry hole in the E½ SW¼ NE¼ sec. 19. The logs of some of these wells reported sand, as shown on the block diagram (plate 13), but in most cases the sand was reported to be shaly and broken by shale streaks. Moreover, experience throughout this region indicates that it is a fair assumption that a well log that records thick sand in a dry hole near the edge of a shoestring sand oil pool probably is incorrectly logged, and that the material is actually very fine sandy shale, having such a low porosity that it is incapable of serving as an oil reservoir.

THE THRALL OIL FIELD.—The surface structure of the Thrall oil field, in Greenwood county, was studied because of abundant outcrops of readily mappable strata. The field is in the southwesternmost part of T. 23 S., R. 10 E., and extends southward into T. 24 S., R. 10 E.; it joins the Agard oil field on the southwest (see pl. 1). The oil-producing shoestring sand of the two fields appears to be a continuous body.

The rocks that are exposed in the Thrall oil field extend upward from the Americus limestone member of the Foraker limestone to the Morrill limestone member of the Beattie limestone. They are shown graphically in the columnar section on Plate 5.

The structure contour map shown on Plate 5 was prepared by methods similar to those used in the preparation of the map of the Browning oil field (pl. 3). The contour interval is 5 feet and the datum bed is the Neva limestone, a member of the Grenola limestone. The main structural features are a broad westward-trending anticlinal nose that occupies most of the oil field, a southeast-northwest trending syncline in the northeastern part of section 28, a syncline in section 5, and a structural terrace in parts of sections 31 and 6. The trends of the synclines and anticlinal nose are northwest-southeast, which is approximately at right angles to the northeast-southwest trend of the oil productive shoestring sand body, which lies at a depth of about 2,250 feet. The contour lines show no irregularities in crossing the area underlain by the sand body, except in sections 31 and 6, where the contours are deflected around a structural terrace that coincides approximately with the surface trace of the buried shoestring sand body.

The regional structure contour map (pl. 7) shows that the anticlinal nose and the synclines in sections 28 and 5 are parts of an extensive structural pattern in the surface rocks of this part of the state. Maps prepared by petroleum geologists, not reproduced here, show that these main anticlines and synclines persist in the buried rocks that lie above, as well as those that lie below the shoestring sands. A sketch of the structure of the base of the oil-producing sand in the Thrall field, not reproduced, shows that in the main the attitude of the base of the sand is similar to that of the surface beds. The main anticlinal nose is present in the producing sand in the central part of the field and a terrace of only slightly different shape than that in the sufrace beds is present in the southwestern part of the field. These facts appear to leave little doubt that the forces that formed the structural features of the surface rocks also acted on the buried rocks and produced features in them similar to those shown in the surface beds, and that the buried shoestring sand body has not altered the structural features of the surface rocks. Therefore, the attitude of the surface beds does not reveal the presence of a buried sand lens in the locality of the Thrall oil field.

THE FANKHOUSER OIL FIELD.—The surface structure of the Fankhouser oil field in Lyon and Greenwood counties was mapped because of its abundance of rock outcrops. The field extends through parts of sec. 9, 10, 4, and 5, T. 22 S., R. 12 E., and secs. 32 and 33, T. 21 S., R. 12 E. Plate 6 is a map of the area covered by the detailed plane table survey.

The rocks that are exposed in the Fankhouser oil field include the Burlingame limestone and beds above and below it in the Wabaunsee group of the Pennsylvanian system. They are shown graphically in a columnar section on Plate 6.

The structural attitude of the surface rocks in the Fankhouser oil field is shown on Plate 6 by structure contours drawn on the Burlingame limestone. The map is the result of a plane table survey. Many control points were determined so that contours with a 2-foot interval could be drawn. The chief feature shown by the map is a broad anticlinal nose whose axis trends northwest, diagonally across the trend of the oil field. The oil-producing sand in the Fankhouser field is a lens-shaped sand body less than a mile wide and about 3 miles long, lying in the Cherokee shale. Its boundaries are a short distance outside the oil wells shown on the map. The trend of the anticlinal nose shown on Plate 6 coincides with the trend of the buried sand body through a part of the oil field, a fact that may suggest to some that the flexure in the surface rocks was produced by arching of the beds over the sand lens. If the flexure was caused in this manner, it should directly overlie the sand body instead of trending diagonally across it as it does. Moreover, the anticlinal nose appears to be a part of a general system of folds in this part of Greenwood and Lyon counties and it extends southeastward beyond the area occupied by the sand lens. The position of the anticlinal nose over the oil productive sand body through a part of the Fankhouser field is believed to be accidental and to bear no relation to the presence of the shoestring sand.

STRUCTURE OF THE SURFACE ROCKS IN THE GREENWOOD-BUTLER COUNTY REGION.—Plate 7 is a mosaic of structure contour maps of the Greenwood-Butler county region that contains the shoestring

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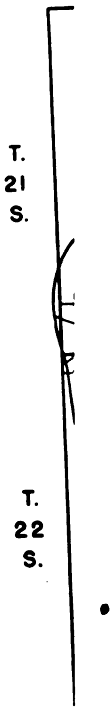

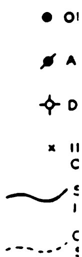

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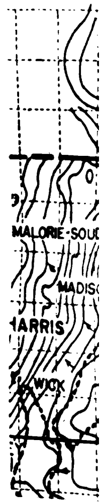
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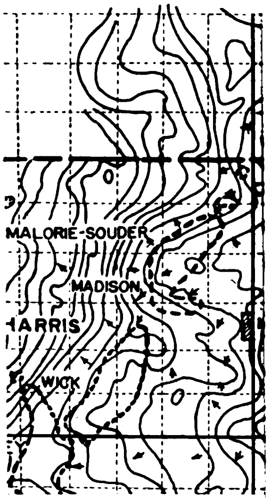
MALORIE-SOUDER
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sand oil fields; it was compiled from many maps, each of which covered a small area. The contours are drawn on key beds ranging upward from about the Oread limestone to beds in the Chase group—that is, different beds were contoured in different areas. The vertical interval between contours is 10 feet. The contours are broken and offset in numerous parts of the map where two or more maps of local areas were joined, and little attempt was made to smooth out the contours at the junctions of the small maps. Because elevation figures are omitted from the contours, arrows were added to Plate 7 to show the direction of dips.

If the reader will imagine that the contours of the entire region are adjusted to one datum, the structural picture represented is that of a monocline that dips essentially westward in the south half of the area and slightly north of west in the north half. The monocline has superposed on it numerous anticlines, anticlinal noses, synclines, structural basins and terraces, the most prominent of which is the Beamount anticline that extends from the southwestern part of T. 29 S., R. 8 E., slightly east of north to sec. 32, T. 26 S., R. 9 E., thence northeast toward Eureka. The Virgil anticline that is largely in T. 24 S., R. 12 E., the anticline in T. 23 S., R. 13 E., and that in T. 24 S., Rs. 13 and 14 E., and T. 23 S., R. 14 E., and the anticline that lies close to the range line between T. 22 S., R. 12 E., and T. 22 S., R. 13 E., are other prominent folds.

The purpose of the map is not simply to show the structural features of the region, but is mainly to show the relation of surface structure to the buried shoestring sand bodies. Many pronounced structural features, including anticlines, domes, synclines, terraces, and basins, cross the Lamont and Quincy sand trends at approximately right angles, and others cross the Teeter and Sallyards trends. Prominent examples are (1) the anticlines whose axes trend northeast, respectively, through sec. 23, T. 24 S., R. 12 E., sec. 27, T. 23 S., R. 13 E., sec. 30, T. 22 S., R. 13 E., (2) the anticline whose axis trends northwest through sec. 29, and the basin whose axis trends northwest through sec. 24, T. 23 S., R. 10 E., (3) the anticline that trends northwest through secs. 15 and 16, T. 23 S., R. 9 E., and (4) the syncline 1½ miles northeast of it.

In only a few localities the shapes of local surface structural features appear to conform to the outline of a buried sand lens. The most striking is perhaps the anticlinal nose, in secs. 9, 5, and 6, T. 25 S., R. 13 E., sec. 31, T. 24 S., R. 13 E., and sec. 36, T. 24 S., R. 12 E., that closely follows the Quincy trend of sand. An anticlinal nose coincides essentially with the location of the sand body of the Madison oil field in T. 22 S., R. 11 E., and synclinal noses that flank each end of the Madison oil field show a rather close conformation of the structural features over the sand lens. Other similar cases can be found. However, the surface structural features appear to lack any suggestion of conformation with the shape of the buried sand bodies throughout so large a part of the area that the few exceptions wherein structural features do follow sand trends are believed to be the result of chance. It is therefore concluded that the buried shoestring sand bodies are not reflected in the attitude of the surface rocks.

History of the Development of the Shoestring Oil Fields and Ultimate Yields of Some Fields

The discovery of shoestring oil pools in the southern part of Butler county followed closely the rapid development of the El Dorado oil and gas field in which the first oil well was completed in October, 1915. Oil was found in 1917[95] in sec. 26, T. 26 S., R. 5 E., and in sec. 2, T. 27 S., R. 5 E., in what later became known as the Smock-Sluss oil field, shown on Plate 1. A well drilled in 1917 in sec. 1, T. 28 S., R. 5 E., discovered the Weaver pool; wells with small production were drilled in secs. 13 and 24, T. 29 S., R. 5 E., in 1917, in what was later destined to be the large Fox-Bush oil field. Each of these wells found oil in a shoestring sand body. Drilling in 1917 in sec. 2, T. 26 S., R. 8 E., Greenwood county, discovered the Sallyards oil field.

Development of the shoestring sand pools continued in Butler county in 1918, but drilling in that year in Greenwood county proved disappointing. Lloyd[96] states that Greenwood county was thoroughly prospected in 1918, but "proved very spotted and discouraging"; out of 186 wells drilled, 80 (43 percent) were dry holes. According to Berger,[97] by late 1921 the Sallyards oil field covered an area about 6 miles long extending from sec. 25, T. 25 S., R. 8 E., to sec. 20, T. 26 S., R. 8 E. This district is now commonly divided into the Blankenship and Sallyards fields (pl. 1).

Other fields were opened in rapid succession, the Teeter and Agard

95. Northrop, J. D., U. S. Geol. Survey, Mineral Resources of the United States, 1917, pt. 2, p. 769, 1920.

96. Lloyd, E. R., U. S. Geol. Survey, Mineral Resources of the United States, pt. 2, p. 1060, 1918.

97. Berger, W. R., The relation between the structure and production in the Sallyards field, Kansas: Am. Assoc. Petroleum Geologists Bull., vol. 5, p. 276, 1921.

fields in 1921, and the Seeley, Burkett, and Browning[98] fields in 1922. The area between the Blankenship oil field on the southwest and the newly discovered Madison pool on the northeast witnessed the most active[99] drilling campaign in Kansas in 1923. By the end of the year the Polhamus, Thrall, Burkett, Seeley, Wick and Madison oil fields were being developed. Because the oil fields formed an area many miles long, but only a mile or less wide, and because of the richness of the productive area, it became known as the Golden Lane.

The Harris oil pool in secs. 18 and 19, T. 22 S., R. 11 E., was discovered early in 1923. A well in the southwest corner SE ¼SE¼ sec. 24, T. 24 S., R. 9 E., was reported[100] in April, 1923, producing oil from shoestring sand. Later, additional holes were drilled nearby and failed to find sand of appreciable thickness and were dry holes. An oil well with only 15 barrels a day production was drilled in by Joe Nathan on the Halverson farm in the center of the NE¼ NE¼ NW¼ sec. 26, T. 24 S., R. 9 E., in early June, 1923.[101] Later in 1923, however, the Agard oil pool was discovered by Bason et al., No. 1 Agard, drilled in the northwest corner SE¼ sec. 14, T. 24 S., R. 9 E. Press reports[102] in January, 1924, state that the well was then producing 400 barrels of oil a day from sand at 2,134 to 2,169 feet. Extension of the Agard pool rapidly followed its discovery. This district was the most actively developed area in Greenwood county in 1924.[103]

In 1924 the Browning oil pool in T. 22 S., R. 10 E., was discovered and oil was found in sec. 2, T. 23 S., R. 9 E., northeast of the then Teeter pool; the operators were quick to discern that a trend of oil sand parallel with the Blankenship-Sallyards Burkett-Madison trend was developing in the Teeter-Browning district and it became known locally as the Little Golden Lane. The Teeter oil pool was extended northeast to the NW¼ sec. 15, T. 23 S., R. 9 E., but there was yet a large gap between this locality and the new well in section 2 of the same township. The De Malorie-Souder pool in T. 22 S., R. 10 E., was opened early in 1924, and was developed rapidly in 1925.

The Atyco oil field in T. 21 S., R. 10 E., the Scott field in T. 23 S.,

98. Loomis, Harve, The Burkett-Seeley pool, Greenwood county, Kansas: Am. Assoc. Petroleum Geologists Bull., vol. 7, p. 482, 1923.

99. Sands, J. M., Production of petroleum in 1923: Am. Inst. Min. and Met. Engrs. Trans., p. 65, 1923.

100. Oil Weekly, p. 25, April 7, 1923.

101. Oil Weekly, June 9, 1923.

102. Oil and Gas Journal, p. 54, January 3, 1924.

103. Carpenter, Everett, Petroleum development in Kansas during 1924: Am. Inst. Min. and Met. Engrs., Production of petroleum in 1924, pp. 154-155, 1925.

Rs. 8 and 9 E., and the Pixlee field in T. 22 S., R. 10 E., were opened in 1925. In 1926 the Fankhouser oil field in the extreme northern part of Greenwood county and the Keighley and Seward fields in the eastern part of Butler county were discovered. The Kramer field in T. 28 S., R. 6 E., which derives part of its oil from shoestring sand, was opened in 1926.[104] Many of the shoestring oil pools in northwestern Greenwood county were extended in 1926. According to Ley, development had definitely established by 1926, or earlier, the existence of two parallel main trends and two cross trends of productive shoestring sand bodies. It was in 1926 that ten or more dry holes were drilled in northeastern Butler county in search of the southwest extension of the Teeter trend (Little Golden Lane); several of the wells found the sand but it contained water. The southern part of Lyon county was actively prospected in 1926 with disappointing results.

The year 1927 witnessed the discovery of the Lamont oil field[105] in T. 22 S., Rs. 12 and 13 E., the Quincy oil and gas field in secs. 10 and 15, T. 25 S., R. 13 E., and the Haverhill oil field in T. 27 S., R. 5 E. Kesler states that Greenwood county shoestring sand pools produced nearly 28 percent of the total oil production of the state in 1927.

Development was extended in 1928 in the district near Quincy in T. 24 S., R. 13 E., and the Patterson field (later known as Hamilton) in sec. 36, T. 23 S., R. 11 E., and sec. 1, T. 24 S., R. 11 E., was opened and developed in 1928 and 1929.[106] The Garden oil field in secs. 5 and 6, T. 27 S., R. 6 E., was opened in March, 1928.[107] The Norton pool in secs. 15 and 22, T. 22 S., R. 12 E., was discovered in April, 1929.

During the past few years several small pools have been found in the Quincy trend, and oil and gas production has been extended southeastward along the trend in the extreme eastern part of Greenwood county and the westernmost part of Woodson county.

None of the oil fields in the region have been exhausted as yet; estimates indicate that some will ultimately attain a recovery of 7,000 to 10,000 barrels of oil per acre. Berry[108] has estimated an

104. Ley, Henry, Producton of petroleum in 1926: Am. Inst. Min. and Met. Engrs., p. 639, 1926.

105. Kesler, L. W., Oil and gas resources of Kansas in 1927: Kansas Geol. Survey Mineral Resources, Circ. I, pp. 17-21, 1928.

106. Straub, C. E., and Folger, A., Petroleum production and development in Kansas during 1928 and 1929: Am. Inst. Min. and Met. Engrs. Trans., Petroleum development and technology, p. 443, 1930.

107. Straub, C. E., and Folger, A., op. cit., p. 444.

108. Berry, G. F., Jr., Empire Oil and Refining Co., Letter of January 16, 1934.

ultimate recovery of 7,000 barrels of oil per acre in the Hamilton and the Edwards Extension fields; 8,000 barrels in the Teeter field, and 9,000 to 10,000 barrels in the Browning field. In 1930, Straub and Folger[109] estimated the ultimate recovery of the Lamont field as 7,000 barrels of oil per acre, the Haverhill field in southern Butler county as 4,000 barrels of oil per acre, and the Garden field in secs. 5 and 6, T. 27 S., R. 6 E., as 7,000 barrels of oil per acre.

Recently Hutchinson[110] has stated that although some leases will yield in excess of 10,000 barrels of oil per acre that the yield of others will not exceed 2,500 barrels per acre. It is his belief that an average of not more than 6,000 barrels of oil per acre is a fair estimate of the ultimate recovery for the 30,000 acres of shoestring sand fields in Butler and Greenwood counties.

Distribution of the Known Shoestring Sand Bodies

The attention of the oil industry was attracted to southeastern Butler county and western Greenwood county a short time prior to 1921, because the sands were found at moderate drilling depths, contained oil ranging between 39° and 42°, A. P. I. and yielded wells that produced more than 1,000 barrels of oil a day. Through the expensive method of drilling wells, a fairly large percentage of which yielded no oil and found no sand at the horizon of the oil-producing beds of the neighboring wells, it was found that the sand occurs in narrow, elongated lenses half a mile to 1½ miles wide but many times longer than they are wide, and that the separate bodies within a trend have an offset arrangement.

After development had extended over several years in Greenwood and eastern Butler counties, it was learned that the sand lenses are arranged mainly in four systems, locally called trends and cross trends, and that the sand bodies in south-central Butler county and north-central Cowley county constitute a fifth trend that is believed by some to be a part of one of the four. The present known distribution of the sand lenses that occur at the same general horizon in the lower part of the Cherokee shale in Butler, Greenwood and Cowley counties is shown on Plate 1. Two shoestring systems run in a northeasterly direction and are known locally as the main trends, and two run in a southeasterly direction and are known as cross trends. One trend has a northerly course through northern

109. Straub, C. E., and Folger, A., Petroleum production and development in Kansas during 1928 and 1929· Am. Inst. Min. and Met. Engrs. Trans., Petroleum development and technology, pp. 443-444, 1930.

110. Hutchinson, N. M., Program of gas and air repressuring in eastern Kansas proves profitable. Oil and Gas Journal, p. 33, February 27, 1936.

Cowley and southern Butler counties. For clarity in referring to these several systems in this report, they are designated by names selected arbitrarily from oil field names in the trend referred to; in each case the oil field name is also the name of a post office.

THE SALLYARDS TREND.—The longest trend extends from the Keighley oil pool in T. 27 S., R. 7 E., Butler county, northeastward through the Seward, Lucas, Blankenship, Sallyards, Polhamus, Agard, Thrall, Burkett, Wick and Madison oil pools. The logs of a few dry holes drilled farther northeast in Lyon county record sand carrying water at the general horizon of the sand of the oil pools, and many geologists believe that the sand in these wells represents a northeastward continuation of the sand lenses of the Sallyards trend. These Lyon county wells are, however, several miles apart and in several instances are as much as 3 miles apart; consequently, with such widely separated bits of information, no conclusion seems possible concerning the lateral extent and shape of the sand body or bodies that have been penetrated by the drill in these northern localities.

THE TEETER TREND.—A second sand trend lying about 6 miles northwest of, but roughly parallel to the Sallyards trend, extends from the Scott oil pool in the southeastern part of T. 23 S., R. 8 E., to the Theta pool in the northwestern part of T. 22 S., R. 10 E. It is herein called the Teeter trend. Oil-producing sand extends from the northeast end of the Teeter trend northwestward into Lyon county as far as sec. 19, T. 21 S., R. 10 E. The area is known as the Pixlee and Atyeo oil fields, and is not included as part of the Teeter trend. Several wells north of the Atyeo field recorded sand at the shoestring sand horizon, but with the exception of one well in sec. 29, T. 20 S., R. 10 E., which yielded a small amount of oil, the sand contained water instead of oil.

THE QUINCY AND LAMONT TRENDS.—Two systems of sand lenses, locally referred to as cross trends, traverse the northeastern part of Greenwood county in a northwesterly direction. One, which is referred to herein as the Quincy trend, begins in sec. 19, T. 25 S., R. 14 E., and probably even farther southeast, and runs in a northwesterly direction through the Quincy, Christy, Landon, Hamilton, Edwards Extension, Seeley, Harris and DeMalorie-Souder oil pools to sec. 10, T. 22 S., R. 10 E. This trend crosses the Sallyards trend in the Seeley field in T. 23 S., R. 11 E. The sand bodies in the southeastern two thirds of the Quincy trend are smaller and less continuous than those of the other trends just described.

The Lamont trend, about 8 miles northeast of the Quincy trend, includes the Shambaugh, Lamont, Norton, and Fankhouser oil fields and may include also the central part of the Stephenson oil field in sec. 12, T. 24 S., R. 13 E., and sec. 7, T. 24 S., R. 14 E.

THE HAVERHILL TREND.—The Haverhill trend which, except for parts of the Haverhill oil field, was not studied in detail for this report, extends from sec. 31, T. 31 S., R. 6 E., in a general northerly direction through the Burden and Eastman oil pools in Cowley county and the Fox-Bush, Haverhill and Smock-Sluss oil fields in Butler county, into the northwestern part of T. 26 S., R. 6 E.

OTHER SHOESTRING SAND LENSES.—Other extensive oil-producing shoestring sand lenses occur in Butler and Cowley counties, but were not studied in detail. The Garden oil pool in secs. 5 and 6, and the Leon oil pool in secs. 19 and 20, T. 27 S., R. 6 E., and the Weaver oil pool in sec. 36, T. 27 S., R. 5 E., and sec. 1, T. 28 S., R. 5 E., are also shoestring sand oil pools. A part of the oil production in the Winfield and State oil fields in T. 32 S., Rs. 4 and 5 E., Cowley county, and the oil in the Rainbow Bend oil field in T. 33 S., R. 3 E., and the Baird oil field in T. 34 S., R. 3 E., is from shoestring sand lenses in the lower part of the Cherokee shale, which are believed to occur at the same general stratigraphic horizon as the shoestring sand lenses in Butler and Greenwood counties.

THE EN ECHELON ARRANGEMENT OF THE SHOESTRING OIL FIELDS AND SAND BODIES

Though the individual shoestring sand bodies are aligned in definite trends in the region, the Sallyards trend takes more nearly a straight-line course than the other trends; it deviates from a straight line only in the Agard field, where it makes a broad curve to the west. The Teeter trend has a nearly straight-line course, except near the northeastern end where the Browning sand lens and the Theta lens deviate from the prevailing course of the trend. The Quincy trend leaves a straight-line course only by broad sweeping curves and by one abrupt offset between the sand bodies of the Edwards Extension and Hamilton fields in the southeastern part of T. 23 S., R. 11 E. In contrast to the close approach to straight-line courses shown by these trends, the Lamont trend has a very irregular course. The trend of the southern part of the sand body of the Shambaugh field has a slightly west of north direction, but parts of the sand lens of the Lamont field trend only slightly north of west and the course of the sand lens of the Fankhouser field swings to west of north.

The individual sand bodies in all trends, except the southeastern part of the Quincy trend, are several times longer than wide, and they are of somewhat the same dimensions. Much of the Quincy trend is composed of small sand lenses, many of which are elongated in the direction of the regional trend, but others are circular or elliptical and appear to be arranged haphazardly as to detail, but lie within the regional trend.

If lines are drawn lengthwise through the middle of each oil field (pl. 1), the projections of the lines will show an interesting relationship. In the Teeter trend a southwestward projection of the axial line of the Browning oil field falls southeast of the Teeter oil field; a southwestward projection of the axial line of the Teeter field in turn lies southeast of the Scott field. In the Sallyards trend a prolongation of the axial line of the Madison field coincides approximately with the axial line of the Wick field, and falls southeast of the axial line of the Burkett field. The median line of the Burkett field passes east of the Thrall field, and this relation of the offsetting of the axial lines holds for the Agard, Polhamus, Sallyards, Blankenship, and Keighley fields.

A similar offsetting of the axial lines can be seen in a few of the fields that comprise the Quincy and Lamont trends, but it is not so evident as it is in the Teeter and Sallyards trends. In the Quincy trend the northwestward prolongation of the axis of the Seeley field falls southwest of the DeMalorie-Souder field; an extension of the Seeley-Edwards Extension axis southeastward falls southwest of the Hamilton field; and an extension of the combined Hamilton and Landon fields' median line falls southwest of the trend of the Quincy pools. The oil fields farther southeast in this trend are small and irregularly spaced and they do not appear to have this prevailing offset arrangement. In the Lamont trend the extension northwestward of the axis of the Lamont and Norton fields falls southwest of the Fankhouser field. The relation between the Lamont and Shambaugh fields is vague because their extremities, as defined to date, are separated by so great a distance that the projection of the median line of either field becomes uncertain. However, a projection northwestward of the median line of the Shambaugh field, as developed to date, falls to the southwest of the Lamont field and so indicates that its trend is offset from the trend of the Lamont field in the same direction as the offset between the Lamont and Fankhouser fields. The extension southward of the axis of the Shambaugh field falls west of the small shoestring sand part of the Stephenson field in sec. 12, T. 24 S., R. 13 E., and sec. 7, T. 24 S., R. 14 E., which may be a part of the Lamont trend, indicating an offset in an opposite direction from that of the other fields in the Lamont trend.

Inasmuch as the boundaries of the oil fields coincide essentially with the boundaries of the oil-producing sand bodies, the axial lines of the oil fields constitute axial lines of the sand bodies, also. The echelon arrangement of the sand bodies within the shoestring trends is believed to be significant in indicating the mode of origin of the sand and is discussed on pages 102 and 103.

Stratigraphic Cross Sections Between the Shoestring Sand Trends

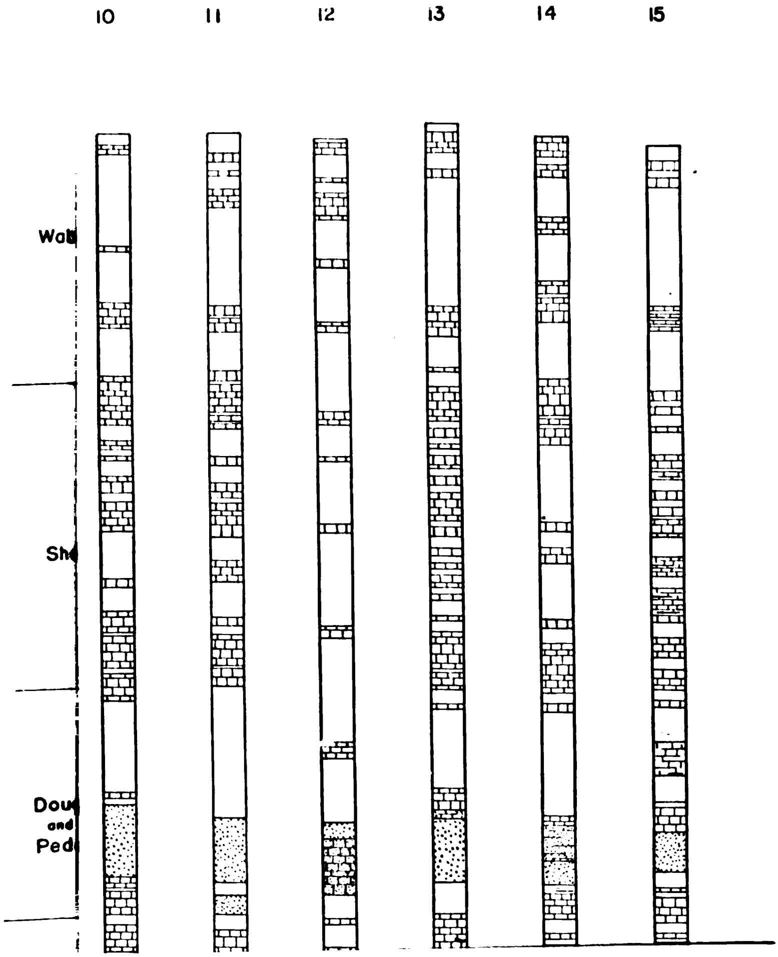
Well records in northern Greenwood county and in southeastern Butler county were studied for the purpose of ascertaining whether the sand bodies of the several shoestring trends occur at the same or at different stratigraphic horizons. Although many wells in the region penetrated the upper part of the "Mississippi lime," which lies 50 to 150 feet below the shoestring sand bodies, the study was based largely on the stratigraphic section extending upward from the shoestring sand horizon. The Cherokee shale below the shoestring sand horizon is irregular in thickness locally, because of the irregularities on the old erosion surface on the "Mississippi lime" on which it lies.

Numerous cross sections were made between the Sallyards and Teeter trends and the Quincy and Lamont trends. Because greater confidence apparently can be placed in the results of the correlations between trends that are separated by the shortest possible distance, particular attention has been given the area between the Thrall oil field in the southwestern part of T. 23 S., R. 10 E., and the Teeter oil field in the central part of T. 23 S., R. 9 E. In this locality the two main shoestring sand trends are only about four miles apart. The results from this study of well logs were inconclusive, however; the stratigraphic position of the sand in wells in the Teeter field corresponds so nearly to the position of the sand in the wells of the Thrall field that differences of position as recorded in the well logs are as great between nearby wells in the same oil field as between wells in different fields. Furthermore, regional studies of the thickness of the Cherokee shale, shown on Plate 1, indicate that there is an increase of about 25 feet in thickness of the Cherokee from west to east across this part of Greenwood county. On the basis of several of the cross sections studied one might conclude that the shoestring sand in the Thrall field was very slightly lower stratigraphically than the sand in the Teeter field, but if the divergence of the Cherokee shale is assumed to have been accomplished largely in the beds above the bases of the sand lenses, the conclusion that both sand bodies were deposited simultaneously on a surface that sloped eastward at about six feet a mile, is more reasonable. Even more confusing was the fact that some of the cross sections indicated that the sand of the Teeter field is stratigraphically lower than the sand of the Thrall field. Similarly conflicting data were procured from cross sections made between the Burkett and Browning fields, and between that part of the Lamont trend that includes the Lamont and Shambaugh fields and the fields in the southeastern part of the Quincy trend.

These studies indicated that the shoestring sands of the several trends were deposited at about the same time, but that the data are not sufficiently detailed to indicate small differences in stratigrahic positions or in age of the sand of the several trends.

In the area that includes the junction of the Sallyards and Quincy trends, however, wells that have penetrated the sand lenses of the Wick and Burkett fields of the Sallyards trend are but a short distance removed from wells in the Seeley field of the Quincy trend; in fact, the distance between the boundaries of the Wick and Seeley fields is but twice the distance between offset wells. Many cross sections based on the correlation of well logs were made between the Wick and Seeley fields, and a few were made between the Seeley and Burkett fields. A cross section along the north line of the S½ sec. 32 and the north line of the S½ sec. 33, T. 22 S., R. 11 E., in the Wick and Seeley fields, is shown on Plate 8. This cross section shows that the base of the sand lens of the Seeley field is 35 to 50 feet stratigraphically lower than the base of the sand in the Wick field. Other cross sections, not reproduced here, show that the sands of the Wick and Burkett fields are at the same stratigraphic horizon. It is concluded that the main sand body of the Seeley field is older than that of the Wick and Burkett fields.

Throughout most of the Wick field the sand is less than 50 feet thick and is commonly divided into two members by a thick bed of shale, but the sand is greater than 50 feet thick throughout most of the Seeley field. The sand ranges between 60 and 80 feet thick in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a small part of the Seeley field that lies in the general trend of the Burkett and Wick fields. It appears probable that the upper part of the Seeley sand was deposited in part at the same time as that of the Wick and Burkett sand bodies. Much of the blunt prong of sand which extends into the NE¼ sec. 7, T. 23 S., R. 11 E., on the southwestern margin of the sand body of the Seeley field, and is shown by the distribution of the oil wells on Plate 1, may have originated at this later stage.

Shapes of the Individual Sand Lenses

Aside from a study of the areal distribution and arrangement of the sand trends, several individual sand bodies were studied in detail from the records of the oil wells drilled into the sand and dry holes drilled nearby outside the boundaries of the sand bodies. The detailed studies were confined largely to the oil fields occurring in Tps. 22 and 23 S., Rs. 8 to 13 E. (see pl. 1), but some work was carried on in fields outside this area. Several score cross sections were made on a large scale (vertical scale, 50 ft. to the inch, and horizontal scale, 145 ft. to the inch) across the shorter dimensions of the sand bodies. The large scale of the cross sections revealed details of the curvature and slopes of the upper and lower surfaces and the stratigraphic irregularities of the sand that are not so evident on a smaller scale.

In many of the cross sections the sand appears to be an irregularly shaped body, lacking any systematic form of either its top or base. In a few localities the well logs show the sand at different stratigraphic horizons in offset wells. However, after making graphic cross sections along each row of wells in directions approximately at right angles to the longer axis of the oil fields, certain features appear to be common to the greater number of the cross sections and certain fairly definite conclusions were drawn from the study of all the sections. A few of the cross sections are reproduced in figure 3. A description of several sand bodies is given on the succeeding pages.

THE SAND BODY OF THE BURKETT OIL FIELD

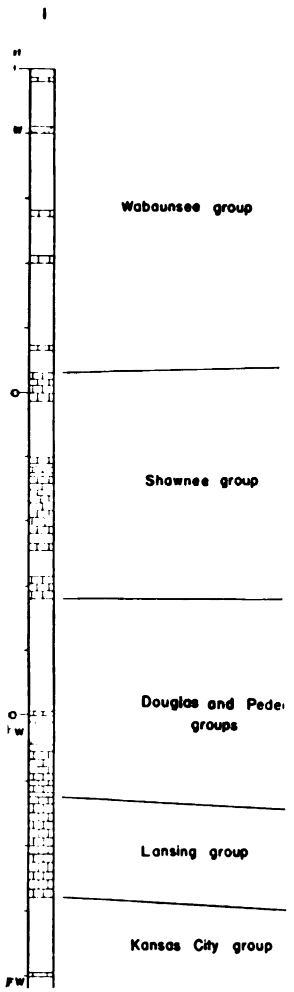
The wells in and adjacent to the Burkett oil field, which occupies parts of secs. 13, 14, 22, 23, 24, 26 and 27, T. 23 S., R. 10 E., and sec. 18, T. 23 S., R. 11 E., were drilled after most of the other shoestring sand fields in this part of the state had been developed. As the well logs were more accurately recorded than for some of the earlier wells, the data they make available are fairly reliable for study. Furthermore, the sand in the Burkett field contains so little water that most wells were drilled entirely through the sand into the shale below. Accordingly, the well logs record the total thickness of the sand body.

Numerous sections were made across the sand body by comparing graphic well logs, having a vertical scale of one inch equals 100 feet, by the usual method of laying the plotted log strips side by side and matching up the series of strata, chiefly limestone beds, recorded in the logs; two of these cross sections are shown on Plate 9. Numerous cross sections showing only the producing sand were plotted, using a vertical scale of one inch equals 50 feet; one of these is shown in fig. 3. Finally, the logs of all wells in the field and dry holes near the field were compared and the stratigraphic position of the sand was determined in each well.

It was found that the base of the producing sand has a lower stratigraphic position in the Phillips Petroleum Co.'s W. H. Edwards No. 10 well, in the northwest corner of the NE¼ SE¼ sec. 13, T. 23 S., R. 10 E., near the northeast margin of the field, than anywhere else in the field.

With the log strips matched and arranged side by side, a horizontal line drawn across all the log strips, so as to coincide with the base of the sand in the log of Edwards No. 10 well, fell below the base of the sand in all other logs, because the sand is not so low stratigraphically in any of them as it is in the Edwards No. 10. Inasmuch as the logs are correlated on stratigraphic horizons, the points on the logs where this horizontal line falls should represent points on a horizontal plane below the sand body at the time of deposition of the sand. (It is assumed that the limestones matched in the logs were horizontal when deposited.) Using this plane as a base, a block diagram showing the sand body and the shale immediately beneath the sand was drawn as shown on Plate 10; no logs were discarded and the sand was plotted just as recorded in the logs. The diagram is drawn in perspective and the vertical and horizontal scales diminish progressively toward the background. The diagram represents numerous cross sections running in an east-west direction and others running north-south.

The block diagram (pl. 10) shows that in general the base of the sand was higher (distance above the horizontal plane) in the westernmost part of the field at the time of deposition than in the easternmost part—that is, it was deposited on a surface that at the time of deposition sloped eastward at a very low angle. The diagram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shows that the sand is thickest in the central part of the field and thins toward the margins, forming a large lens-shaped body; the lowermost part of the sand is the most widespread. The upper surface of the sand body is convex upward; the lower surface approaches very closely a plane that had an initial dip of slight degree to the east. The position of the sand as recorded in a few wells in the field does not appear to fit the scheme developed by the others. The sand is shown much higher in the well in the NE¼ SE¼ SW¼ sec. 23 than in any of the wells close by. It is probable that the depth to the sand in this well was recorded incorrectly or that the log record was copied incorrectly. The sand is plotted on Plate 10 at the position recorded in the log but its probable correct position as interpreted by me is indicated by dashed lines.

The dry hole symbols in the northeasternmost part of the diagram show wells that encountered no sand at the horizon of the producing sand. A little farther south along the eastern margin of the field, a dry-hole symbol is shown beside a well that encountered a thin bed of sand in the lowermost few feet of the sand horizon but found it barren of oil. It is noteworthy that, after a few dry holes have been drilled near the margin or just outside the margin of a sand lens, the operators are able to define the boundaries of the field within certain limits and save the drilling costs for additional holes at the borderline locations. The diagram indicates that if a well were drilled in the northeast corner SW¼ sec. 24 it would find the producing sand body comparatively thick. The sand is 90 feet thick in the offset well to the north and in the offset well to the west, but each of these wells yielded only small amounts of oil. The low yield of oil suggests that parts of the beds reported as sand probably contained a large portion of sandy shale, or tightly cemented sand having very low permeability. It is probable that a well that would have produced a fair amount of oil could have been completed in the northeast corner SW¼ sec. 24 during the early development of the field, but it may be that much of the oil that earlier surrounded this location has by now migrated to the offset wells on the north and west. A well similarly situated was drilled recently in the Agard oil field in T. 24 S., R. 9 E., and yielded only a small daily volume of oil.

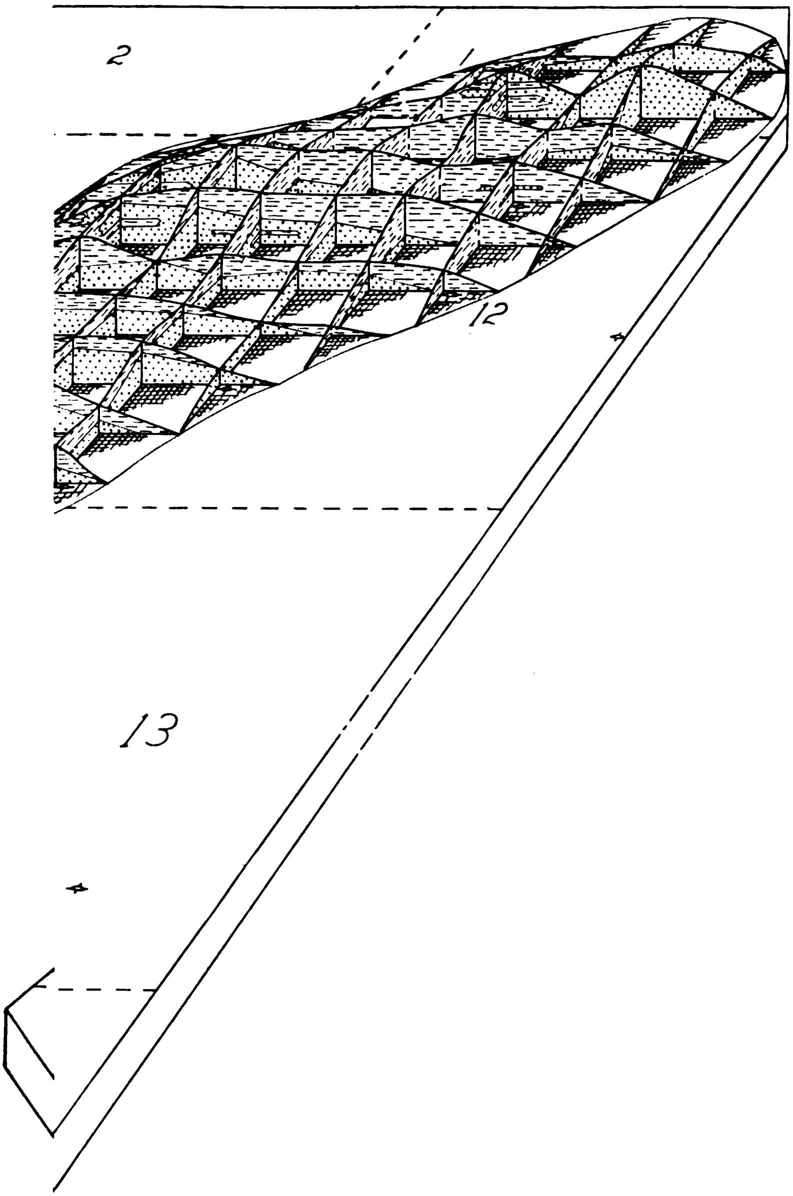
The sand body pinches out rather abruptly in the southeasternmost part of the Burkett field, and limestone and shale occupy its horizon. The margin of the sand lens probably crosses the northeasternmost part of section 26 and the southeasternmost part of section 23; it lies west of the two dry holes in the northwest corner of section 25 and the southwest corner of section 24. The logs of the wells indicate that the sand body is more variable in thickness and shale content in the western part of the field than in the eastern part. The sand body tapers southeastward toward the margin with a fairly uniform gradient, but in the western part of the field some wells show thick sand and offset wells record mostly sandy shale with only thin beds of sand.

THE SAND BODY OF THE MADISON OIL FIELD

The Madison oil field is the northernmost large field of the Sallyards shoestring trend; it occupies parts of secs. 1, 10, 11, 12, 14, 15, 22, and 23, T. 22 S., R. 11 E. A large number of cross sections, based on well logs, were drawn approximately at right angles to the longer axis of the field and the producing sand was found to be similar to that in the Burkett oil pool, in that the base of the sand forms approximately a plane surface that had an initial slope eastward at a low angle. After making a study of cross sections a block diagram, shown on Plate 11, was drawn of the sand body by a method similar to that used for the Burkett field diagram (pl. 10), except that the base of the sand was assumed to lie on a horizontal plane. This arbitrary assumption, of course, eliminates all the irregularities of well records, but it is justified after a thorough study of cross sections through the field had demonstrated to my satisfaction that the base of the sand actually forms a plane surface and that departures from it are probably due to poor well logs, or are due to the fact that some wells have not penetrated the entire thickness of the sand body.[j] Because this assumption was made, Plate 11 does not show the data as actually recorded in the well logs in every instance. In other words, it represents my interpretation of the shape of the producing sand body as it was originally deposited.

In the Madison field diagram (pl. 11) the upper and lower surfaces of the sand lens are projected to the margins of the lens, even though wells have not been drilled sufficiently near the boundaries to establish the exact thickness and position of the sand there. The vertical solid lines at the intersections of the sand sections represent wells, and the dashed vertical lines indicate locations where no wells have been drilled; the sand shown at these latter localities is there-

j. It is known that several wells in the central part of the field were drilled only part way through the sand body, and the Empire Oil and Refining Co. is engaged in deepening its wells in this part of the field at the present time—June, 1938.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fore speculative. Where dry holes have been drilled near the margin of the sand lens, such as at several locations in sections 12 and 14 along the eastern margin, the position of the edge of the sand body can be determined fairly accurately, but in localities where no wells have been drilled close to the margin the interpretation shown on Plate 11 is, of course, less dependable. However, there are a sufficient number of wells that record a convergence of the sand body toward the margins to indicate within reasonable limits the approximate position of the boundaries of the sand lens.

The sand body of the Madison field has an easterly-trending prong near its southern end that gives it an unusual shape. The position and limits of the prong of sand are controlled by numerous wells and the extent of the sand is limited on the east by the dry hole in the SW¼ SE¼ SE¼ sec. 14 that logged only a thin sand. Some geologists believe that the sand body is probably continuous across the area immediately north of the prong, where the margin of the main sand body, as shown on Plate 11, forms a deep embayment. However, the well drilled in the NW¼ SE¼ SW¼ sec. 14 had only a very thin bed of sand and produced only eight barrels of oil a day; this, together with the thinning of the sand toward this area shown by other wells, is probably the reason no test well has been drilled in this embayment. None of the dry holes shown on Plate 11, that are some distance from the oil pool, reported any appreciable thickness of sand at the horizon of the producing sand.

THE SAND BODY OF THE DE MALORIE-SOUDER OIL FIELD

The study of the producing sand body of the De Malorie-Souder field in the Quincy trend was made by a method similar to that used for the Madison field; numerous cross sections, based on well log correlations, were made along courses approximately at right angles to the longer axis of the field. Many of these cross sections, like those made in the Burkett and Madison fields, showed the upper and lower surfaces of the sand body to be somewhat irregular, but the prevailing shape found was a convex top and an almost straight line base that had an initial slope southwestward at a low angle. Therefore, in the block diagram of the sand body of the De Malorie-Souder field (pl. 12) the base of the sand is interpreted as resting on a horizontal plane. In some well logs, sandy shale is recorded overlying the main sand body but it is not shown in the diagram, because it appears to be equivalent to shale in most localities in the field and if shown would obscure many other features.

This field is more completely developed than several others in this region; most of the regular locations have been drilled, even those that lie very near the margin of the sand lens and found only a thin bed of sand. The margins of the sand body are defined by more wells in this field than in other fields of the region. Dry holes that lie just outside of the margin and that recorded "no sand," and others that are located just inside and recorded a very thin sand, have been drilled along the north border of the field at relatively short intervals from the northeast corner of the NW¼ sec. 18, T. 22 S., R. 11 E., to the northeast corner of the NW¼ sec. 10, T. 22 S., R. 10 E. Likewise, the position of the south margin of the sand lens is controlled by numerous wells having thin sand and dry holes that found no sand. Regular well locations that are believed to lie within the margins of the sand body but have not been drilled as yet are shown on the diagram by dashed vertical lines at the intersection of the cross sections. The NE¼ sec. 11 and the NW¼ sec. 12, T. 22 S., R. 10 E., constitute an undrilled area that probably contains sand, but some oil from at least the northern part of this area probably has been drained by nearby producing wells.

A narrow channel-shaped area extending southeastward through the S½ sec. 12, NE¼ sec. 13, and the NW¼ sec. 18, in which the logs of numerous wells indicate that no sand is present, is a rather unique feature for the sand bodies of the region. Thick sand occurs on both sides of the narrow area that contains no sand. The narrowness of the area devoid of sand, and the trend of the southwest margin of the main sand body in section 11 and of the smaller sand body in section 13 suggest that originally the sand beds were continuous across the narrow area that contains no sand. If such were true, it may be that following deposition and prior to burial of a large sand body in the area, a narrow channel was eroded across the sand body, and the channel was later filled with muds. It is perhaps equally as reasonable, on the basis of the facts at hand, to conclude that the sand bodies shown on the diagram were deposited originally as separate lenses.

Two dry holes, in the NE¼ SE¼ sec. 13, found no sand at the horizon of the producing sand of the oil field, which suggests that another channel may extend northeasterly through the NE¼ SE¼ sec. 13 into section 18. The extreme thinness of the sand as recorded in the logs of wells in the SW¼ SW¼ sec. 7 indicate that this area may be a part of a channel-like feature. Near the western end of the field a narrow area that contains no sand crosses the trend of the main sand body in the NE¼ sec. 10. The occurrence of this area containing no sand at the extremity of a large sand body, such as that of the De Malorie-Souder field, suggests that it may have originated as a tidal inlet, similar to those on our modern coasts. The small circular-shaped sand body in the NW¼ sec. 10 may have been separated from the main sand body originally. It is bounded on the north, east and west by dry holes that found only a thin zone of sand or no sand at the horizon of the producing beds, but future drilling may establish a prolongation of the sand body to the west.

THE SAND BODY OF THE BROWNING OIL FIELD

Numerous cross sections made from well log correlations in the Browning oil field in secs. 17, 18, 19, 20, 29, 30, and 31, T. 22 S., R. 10 E., gave somewhat confusing results. Many of the wells in this field were not drilled entirely through the sand body because the lower part of it contains water. This fact and the fact that some well logs appear to have been somewhat carelessly recorded cast some doubt on the results of the studies in this field. After studying cross sections drawn through nearly every row of wells across the fields, I concluded that, although the sections show more irregularities than are common to some of the other fields, the sand body is similar in shape to that of the Burkett, Madison, and De Malorie-Souder fields—namely, has an approximately plane base and a convex upper surface. The study indicated that the base of the sand had a low initial slope to the east.

A graphic picture of my interpretation of the shape of the sand body is shown on Plate 13, wherein the sand is represented as a lens-shaped body with a horizontal base and a convex upper surface. Only that part of the field that lies north of the S½ of secs. 29 and 30 is shown, because southwest of this area the sand is recorded in well logs as being extremely irregular in thickness and there was considerable confusion as to the correct location of several of the wells for which logs were available. Lack of sufficient time to investigate thoroughly these doubtful records made it expedient to eliminate this part of the field from the diagram shown on Plate 13. The irregularity of the diagram in the eastern part of the NE¼ sec. 30 is caused by the drilling of five wells at regularly spaced intervals in a distance of half a mile along the east line of section 30, and by the drilling of only four wells at regularly spaced intervals offsetting these on the west. Similar irregularities are shown in the southernmost part of the SW¼ sec. 20.

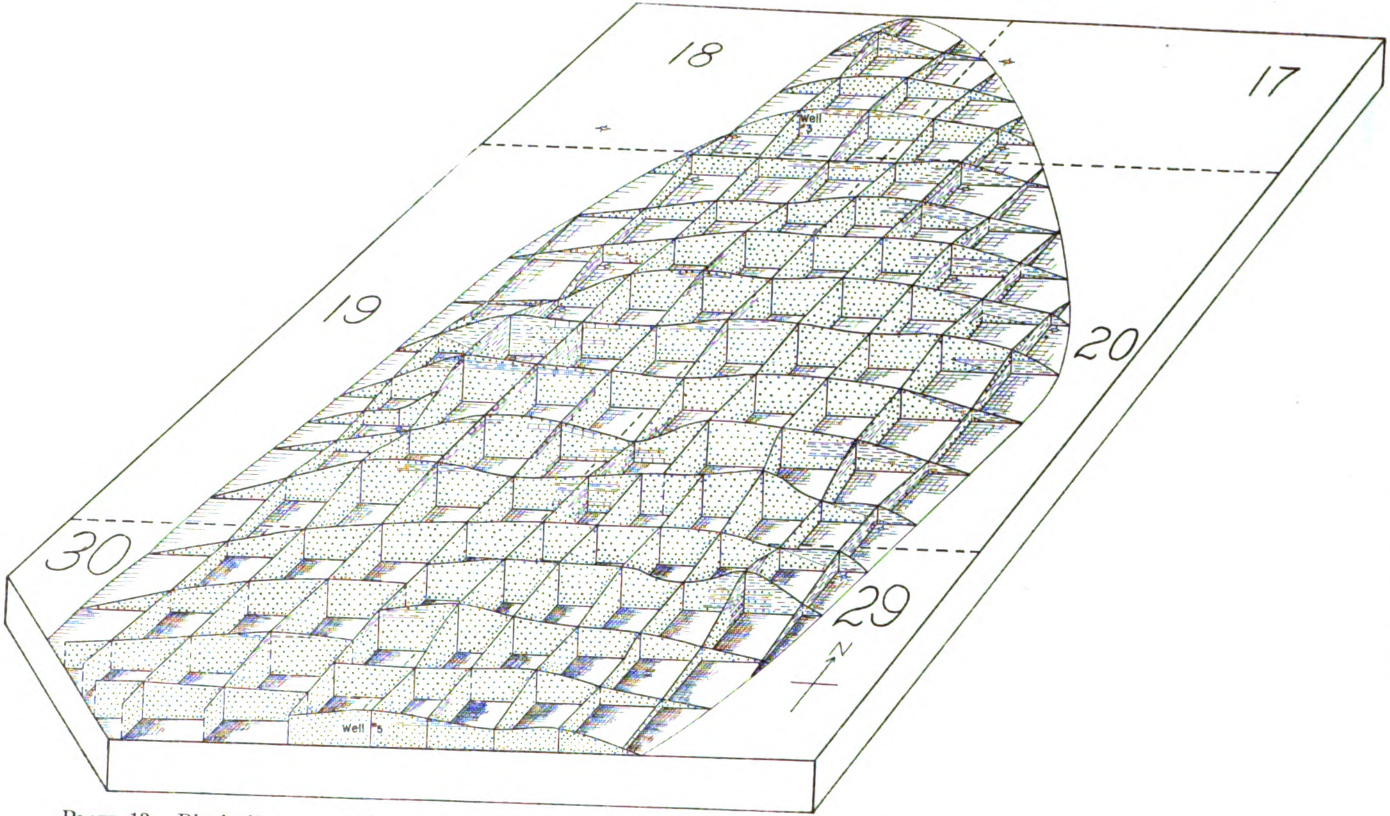

PLATE 13. Block diagram of the producing sand in the Browning oil field, T. 22 S., R. 10 E., Greenwood county. Scale, regularly spaced wells 660 feet apart. Vertical scale indicated by well 5 in middle foreground, SW corner sec. 29, in which sand is 55 feet thick, and by well 3 in SW¼, SE¼, SE¼ sec. 18, in which sand is 50 feet thick. Explanation same as in Plate 10.

Because the well logs indicate wide variations in the thickness of the sand in parts of this field, little confidence can be placed in the representation shown on Plate 13 outside the closely drilled area; for instance, the representation of the sand in the south-central part of sec. 19 and in the NE¼ sec. 30, in the westernmost part of the diagram, is highly speculative. Dry holes in the NE¼ sec. 19 furnish more adequate control for the representation there. It is suggested, however, that dry holes, such as the one in the northeast corner of the NW¼ NE¼ sec. 19 that shows a thick body of sand, probably represent incorrectly the actual conditions; it is likely that the sand contains considerable shale and should be classified, in part at least, as sandy shale rather than sand. The eastern and northeastern margins of the sand body are controlled by data furnished by several dry holes, and so greater confidence is placed in the interpretation in this part of the field. Throughout much of this field wells have been drilled on "five spot" locations, commonly in the center of a forty-acre legal land subdivision—that is, in the center of the squares formed by the alignments of the regular locations. The "five spot" wells are not shown on Plate 13, because their inclusion would add but little to the information and would obscure many features that are shown.

THE SAND BODY OF THE FANKHOUSER OIL FIELD

A graphic interpretation of the shape of the producing sand body of the Fankhouser oil field in Tps. 21 and 22 S., R. 12 E., is shown in perspective on Plate 14. It was drawn after numerous cross sections, made by the correlation of plotted well log graphs, indicated that the sand body is shaped approximately as shown. The study indicated that the base of the sand body was deposited on a plane surface that slopes to the southwest; the degree of slope is greater than in most other fields, except the Lamont field which lies adjacent to the Fankhouser field on the southeast. As shown on Plate 14, the sand body is irregular in thickness, except along the middle of the field where the sand is thickest. It probably is even more irregular than shown in the diagram, because in areas such as the SE¼ sec. 32, the NE¼ sec. 5, and the SW¼ sec. 4, that contain but few wells, the representation of the sand body is necessarily hypothetical. The largest production of oil was obtained from wells in the central part of the field where the thick sand occurs.

SAND BODIES OF OTHER OIL FIELDS

Series of cross sections were made of the producing sand bodies in the Thrall oil field in T. 23 S., R. 10 E., the Atyeo oil field in T. 21 S., Rs. 9 and 10 E., and T. 22 S., R. 10 E., and the Haverhill field in T. 27 S., R. 5 E. The conclusions drawn from the study of the cross sections of each one of these fields were similar to those made for the Burkett, De Malorie-Souder, and other fields described—namely, that the sand bodies have approximately horizontal bases and convex tops; the sand bodies are thickest in the central parts of the fields, and the lowermost part of the sand is most widespread. In the case of the Atyeo field these conclusions were drawn from somewhat meager data; all of the well logs of the field were not available and so a relatively few complete cross sections were made. Furthermore, this field is very narrow and small irregularities in log records were in many cases of greater magnitude than the differences in the stratigraphic position of the sand as recorded in the logs. Consequently, less confidence can be placed in the conclusions reached for this field than for the other fields where the data are more complete. The sand body in the Haverhill field is also very narrow, but carefully recorded well logs were available for this field and so the conclusions drawn are supported by sufficient evidence.

Physical Character of the Sand

A few chunks (large shot fragments), core samples, and a relatively small number of sets of drill cuttings of the shoestring sand bodies were studied. The sets of samples were selected so as to obtain data on most localities in the shoestring sand region of northern Greenwood county. Written reports made by oil company geologists, based on microscopic examinations of drill cuttings from 200 or more wells in the region, were studied. Detailed facts, conclusions, and generalizations concerning the character of the producing sand, such as composition, grain sizes, stratigraphic distribution of grain sizes, and porosity, were discussed with numerous geologists and operators who had become familiar with the region through many years of experience. Eight chunk samples from cores of the producing sand were analyzed as to composition, cementing material, density, porosity, and grain size by P. G. Nutting in the laboratory of the United States Geological Survey in Washington. About two dozen thin sections of sand samples were studied. I made several analyses of the grain sizes of chunk samples of Pennsylvanian sands

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of Missouri that I obtained from the outcrop. A short time prior to the completion of this report the thin sections of sand from this region and those of the Missouri sands were studied by Constance Leatherock, in connection with the study of the Bartlesville and Burbank sands of Osage county, Oklahoma,[111] and some of her findings have been incorporated in this report.

The sand bodies of the shoestring sand oil fields of the Greenwood-Butler county region range in thickness up to a little more than 100 feet; probably the most common thickness for the central part of each field is about 50 feet. However, the sand body of the Seeley oil field in Tps. 22 and 23 S., R. 11 E., is as great as 90 feet thick in parts of the field, and the sand bodies of the De Malorie-Souder and Madison oil fields in T. 22 S., Rs. 10 and 11 E., are more than 100 feet thick in parts of these fields. Cores of the oil-producing sand show that it is not everywhere a solid body of sand, but consists of thick beds of sand separated by much thinner beds of thinly laminated sandy shale, sandy carbonaceous shale, and shale. Walter W. Larsh, geologist, and L. L. Bechtel, production superintendent, witnessed the taking of cores of the sand in four wells by the Carter Oil Co., on its Ellis lease in sec. 27, T. 23 S., R. 11 E., in the Edwards Extension field, and reported that the sand body consisted of beds of sand several feet thick, separated by shale beds ranging from an inch to 5 or 6 inches thick, and thinly laminated shale and carbonaceous shale in beds ranging from a few inches up to half a foot thick; that the lowermost few inches of the sand contained well rounded pebbles of black and brown chert, ranging from one eighth to half an inch or more in diameter, enmeshed in fine sand. Parts of one of these cores containing the chert pebbles and fine sand representative of the main part of the sand body and some of the thinly laminated sandy shale, shale, carbonaceous material, and sand were studied by me. The several types of material in the core are well segregated, suggesting that the sediments were well sorted by the depositional agent.

As a rule, a sand body contains more partings near the margin of the field than in the central part. In the Fankhouser field in Tps. 21 and 22 S., R. 12 E., only a narrow strip of country down the middle of the field is underlain by a fairly thick body of sand; the oil-producing sand in most parts of this field occurs in fairly thin beds of sand interbedded with sandy shale and shale. The sand

111. Bass, N. W., Kennedy, L. E., Dillard, W. R., and Leatherock, Constance, Subsurface geology of Osage county, Oklahoma, U. S. Geol. Survey Press Report 105368, January, 1936.

body of the Wick field in T. 22 S., R. 11 E., is irregular in occurrence; the logs of some wells record all but a few of the beds that occupy the horizon of the sand body as sandy shale, and others record two bodies of sand 10 to 40 feet thick separated by shale from 10 to 50 feet thick.

Drillers, geologists, and others connected with the field operations reported that the sand in the De Malorie-Souder field in T. 22 S., Rs. 10 and 11 E., occurs in layers of coarse and very fine sand, the layers of coarse sand being largely confined to the lower part of the sand body; a similar arrangement of coarse and fine sand is reported to occur in the Shambaugh field in T. 23 S., R. 13 E., and in the Lamont field in T. 22 S., Rs. 12 and 13 E. The sand bodies of some fields, such as the Burkett field in T. 23 S., R. 10 E., and the Madison field in T. 22 S., R. 11 E., have fewer "breaks" of shale and sandy shale than others; recently cores of the lower 25 feet of the sand taken in the central part of the Madison field showed very little variation in the character of the sand; one zone, 2 feet or so thick, that contained a larger content of silt than the adjacent beds was the chief variation noted. Study of a core of the lower 25 feet of the sand in the Empire Oil & Refining Co.'s From No. 7 well in sec. 14, T. 22 S., R. 11 E., in the Madison field, shows that the sand is remarkably uniform in grain size throughout most of the 25 feet examined. A series of sieve analyses made by Nutting of samples from the core indicate that the lower part of the sand contains only slightly coarser sand grains than most of the remainder. The core contains chert pebbles up to half an inch in diameter in the lowermost few inches, however. The sand body rests on gray clay shale.

A dense unit of very fine material forms a hard cap rock over the more porous parts of the sand in most, but not all, of the fields; operators report that this upper part of the sand is very hard, and drills slowly. In most of the fields the full thickness of the sand is not saturated with oil; the upper part of the sand is commonly barren. Exceptions occur, particularly in several of the small oil fields in the Quincy trend that contain coarse sand; there the entire body of sand, as a rule, is saturated with oil.

COMPOSITION.—The sand of the shoestring oil fields is composed largely of grains of quartz. Feldspar, chert, and limestone comprise a fraction of one percent to a trace of the material. Constance Leatherock[112] found traces of magnetite, epidote, chlorite, glauco-

112. Bass, N. W., Kennedy, L. E., Dillard, W. R., and Leatherock, Constance, Subsurface geology of Osage county, Oklahoma: U. S. Geol. Survey Press Report 105368, January, 1936.

of Missouri that I obtained from the outcrop. A short time prior to the completion of this report the thin sections of sand from this region and those of the Missouri sands were studied by Constance Leatherock, in connection with the study of the Bartlesville and Burbank sands of Osage county, Oklahoma,[111] and some of her findings have been incorporated in this report.

The sand bodies of the shoestring sand oil fields of the Greenwood-Butler county region range in thickness up to a little more than 100 feet; probably the most common thickness for the central part of each field is about 50 feet. However, the sand body of the Seeley oil field in Tps. 22 and 23 S., R. 11 E., is as great as 90 feet thick in parts of the field, and the sand bodies of the De Malorie-Souder and Madison oil fields in T. 22 S., Rs. 10 and 11 E., are more than 100 feet thick in parts of these fields. Cores of the oil-producing sand show that it is not everywhere a solid body of sand, but consists of thick beds of sand separated by much thinner beds of thinly laminated sandy shale, sandy carbonaceous shale, and shale. Walter W. Larsh, geologist, and L. L. Bechtel, production superintendent, witnessed the taking of cores of the sand in four wells by the Carter Oil Co., on its Ellis lease in sec. 27, T. 23 S., R. 11 E., in the Edwards Extension field, and reported that the sand body consisted of beds of sand several feet thick, separated by shale beds ranging from an inch to 5 or 6 inches thick, and thinly laminated shale and carbonaceous shale in beds ranging from a few inches up to half a foot thick; that the lowermost few inches of the sand contained well rounded pebbles of black and brown chert, ranging from one eighth to half an inch or more in diameter, enmeshed in fine sand. Parts of one of these cores containing the chert pebbles and fine sand representative of the main part of the sand body and some of the thinly laminated sandy shale, shale, carbonaceous material, and sand were studied by me. The several types of material in the core are well segregated, suggesting that the sediments were well sorted by the depositional agent.

As a rule, a sand body contains more partings near the margin of the field than in the central part. In the Fankhouser field in Tps. 21 and 22 S., R. 12 E., only a narrow strip of country down the middle of the field is underlain by a fairly thick body of sand; the oil-producing sand in most parts of this field occurs in fairly thin [illegible] of sand interbedded with sandy shale and shale. The sand

[illegible] Bass, N. W., Kennedy, L. E., Dillard, W. R., and Leatherock, Constance, Sub- [illegible] geology of Osage county, Oklahoma, U. S. Geol. Survey Press Report 105368, January, trends. Much of the sand in the Atyeo lens, in T. 21 S., R. 10 E., falls in the grade of medium (¼ to ½ mm.) and coarse,[113] and a smaller part is very coarse, and some granules are present. The sand of the De Malorie-Souder field in T. 22 S., Rs. 10 and 11 E., is reported to be interbedded fine and coarse sand; most of the coarser material is in the lower part of the sand body. The sand in the main part of the Seeley field in Tps. 22 and 23 S., R. 11 E., is of very fine and fine sizes like that in the Sallyards and Teeter trends; but in the Edwards Extension field, which includes the southeastern part of the sand body of the Seeley field, a larger portion of coarse and very coarse sand is present. From the southeastern part of the Edwards Extension field on southeastward through the Hamilton, Landon, Quincy, and other fields of the Quincy trend the sand varies abruptly in size of grain; it is composed largely of medium and coarse sand in most of these fields. Microscopic examination made by me of the drill samples of the sand from the field in secs. 19 and 20, T. 25 S., R. 14 E., Woodson county, which is being developed, shows the sand there to be composed of medium and coarse, rounded and subrounded quartz grains, similar in every way to the sand near Quincy. Farther southeast in Woodson county the sand is reported to be of finer grain. However, there is some doubt as to whether the sand of these localities occurs at the exact horizon of the sand of the Quincy trend.

The sand in the Lamont trend contains more medium to coarse sand than is found in the Teeter and Sallyards trends, but much of it is similar to the sand elsewhere and is largely composed of very fine and fine sand. The sand body of the Fankhouser field, for instance, is composed mainly of fine and very fine, subangular and angular grains, but it contains scattered through it subrounded and rounded grains ranging from medium to coarse and very coarse sizes. The same features are true of the sand body of the Lamont field, except that the coarse grains are somewhat more abundant; pebbles with a maximum diameter of 4 millimeters are reported to occur in the sand body of the Lamont field. No details of actual grain sizes are available for the sand lens of the Shambaugh field, but operators reported that some coarse sand occurs in the lower part of the sand body and yields much of the oil in the field.

Shapes of Sand Grains.—The grains of the very fine and fine sand that make up much of the sand bodies of the Teeter, Sallyards,

113. Size classification after Wentworth, C. K., Grade and class terms for clastic sediments: Jour. Geology, vol. 30, pp. 377-392, 1922.

and Lamont trends and much of the sand bodies of the northwestern part of the Quincy trend, are most commonly subangular; a lesser number are angular[k] and a few are subrounded. Most of the flakes of mica (muscovite and biotite) in the fine sand are ragged; many have rounded corners; none are angular throughout and a few have rounded edges. Almost all of the coarse and very coarse sand grains are subrounded or well rounded. Medium and coarse, rounded and subrounded sand grains are abundant in the Quincy trend from the region near Hamilton farther southeast into Woodson county, and in the Atyeo oil field in T. 21 S., R. 10 E. Also, most of the coarse grains found sparsely distributed in the fine sand elsewhere are well rounded. Inspection of chunk samples fails to reveal the abundance of rounded grains because of the presence of new quartz growth surrounding the grains but thin sections of cores reveal the rounded shapes of the grains. The few coarse grains of feldspar that were seen are subangular. Most of the mica flakes in the coarse sand have ragged edges. Photomicrographs of thin sections of the shoestring sands and a few photographs of other sands are shown on Plates 15, 16, and 17.

The thin sections of sand from the Madison oil field in T. 22 S., R. 11 E., and the Edwards Extension oil field in T. 23 S., R. 11 E., were compared with thin sections of the sand of the Rainbow Bend oil field in T. 33 S., R. 3 E., in western Cowley county, Kansas, and with thin sections of the Warrensburg channel sandstone from near Warrensburg, Mo. This examination showed that the grains of the oil sands from the Madison and Edwards Extension oil fields are not so angular as those of the sand of the Rainbow Bend field or those of the Warrensburg sandstone. The grains of the Warrensburg sandstone are the most angular of the three, and the difference between the angularity of its grains and those of the sand of the Madison oil field is pronounced.

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k. The term angular is applied here to grains with relatively sharp edges and points; the edges of the grains are decidedly blunt in the subangular class; and the term subrounded is applied to grains on which the rounded surfaces occupy an appreciable part of the surface, and the original flat faces that are present are small; little or no parts of the original faces can be seen on the well-rounded grains.

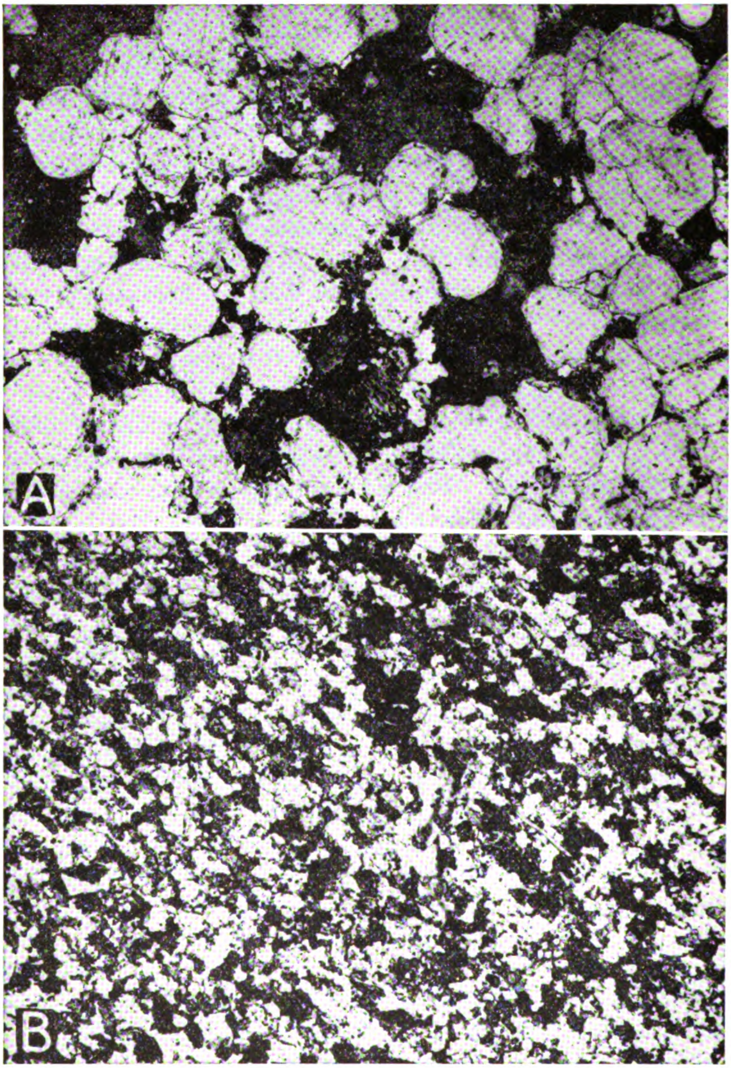

PLATE 15. *A,* Photomicrograph of thin section of shoestring sand from Empire Oil and Refining Co.'s Kolb No. 1 well, sec. 15, T. 25 S., R. 13 E., in the Quincy trend. Magnified seventeen times natural scale. *B,* Photomicrograph of thin section of shoestring sand from depth of 1,924 feet in the Empire Oil and Refining Co.'s From No. 7 well in sec. 14, T. 22 S., R. 11 E., Madison oil field. Magnified seventeen times natural scale.

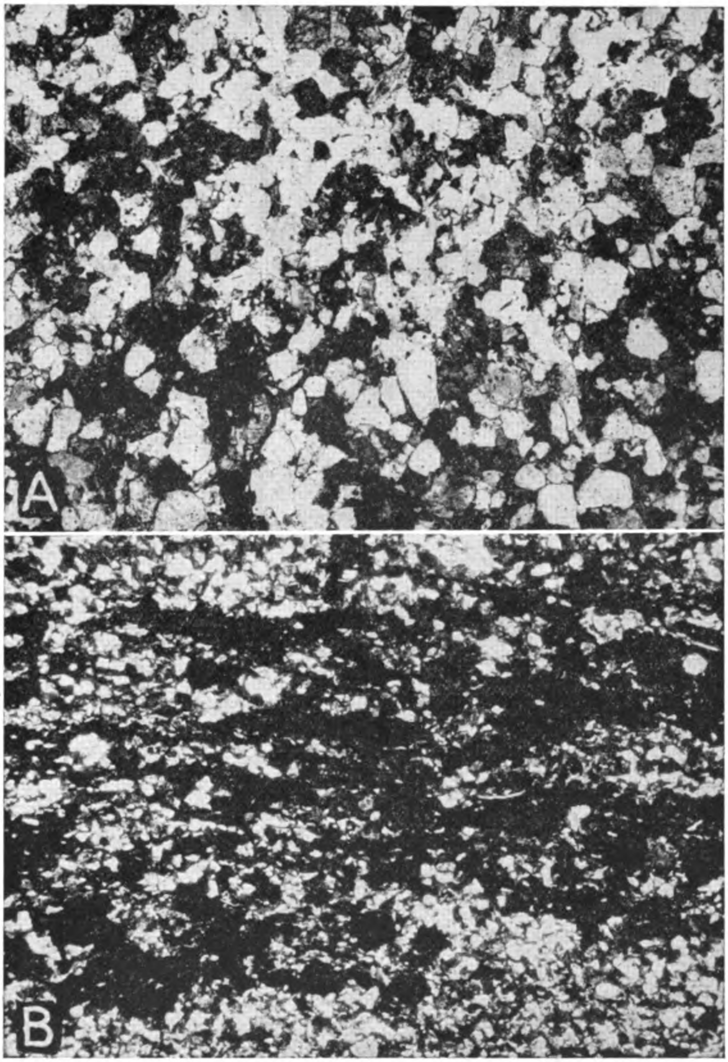

PLATE 16. *A,* Photomicrograph of thin section of Warrensburg channel sandstone from quarry near Warrensburg, Mo. Magnified seventeen times natural scale. *B,* Photomicrograph of thin section of shoestring sand from a chunk sample, containing lentils of carbonaceous material, from Gore et al., Carson 1-A well in sec. 33, T. 23 S., R. 11 E. Magnified seventeen times natural scale.

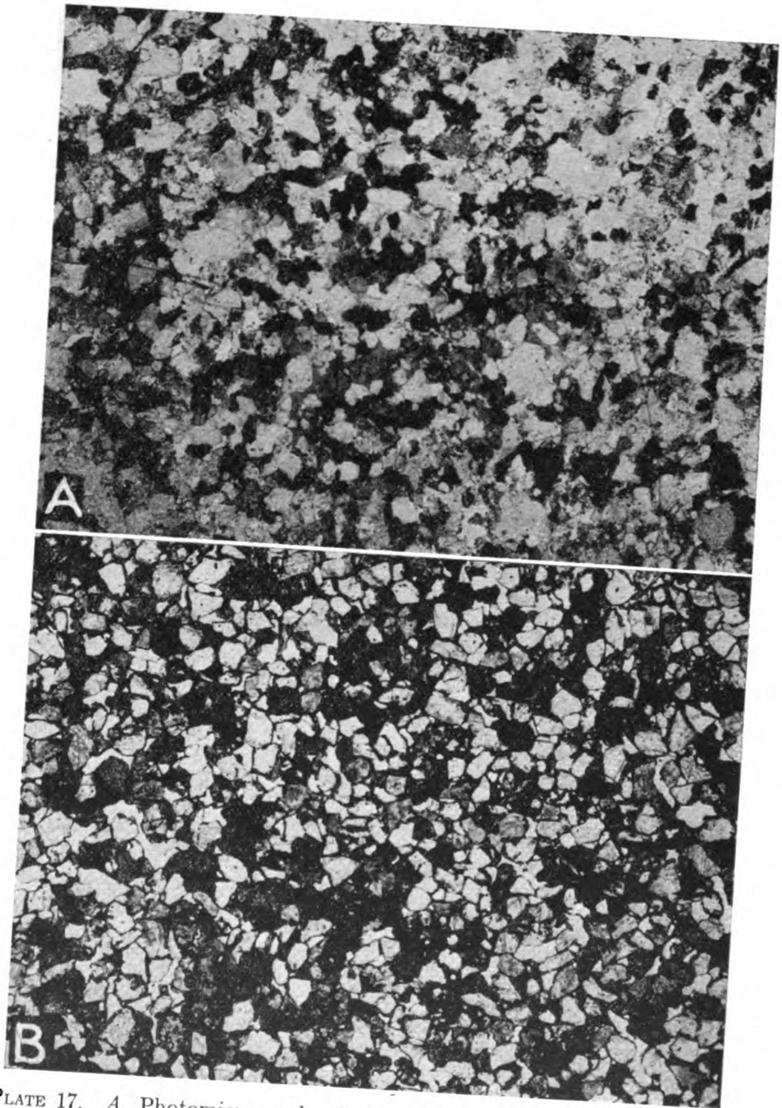

PLATE 17. *A*, Photomicrograph of thin section of shoestring sand from a depth of 1,925 feet in Carter Oil Co.'s Ellis No. 4 well in sec. 27, T. 23 S., R. 11 E. Magnified seventeen times natural scale. *B*, Photomicrograph of thin section of producing sand from a depth of 3,268 feet in Barnsdall Oil Co.'s Johnson 1-A well in the SE¼, sec. 20, T. 33 S., R. 3 E., Rainbow Bend oil field. Magnified seventeen times natural scale.

Different Methods of Forming Sand Bodies

The origin of the shoestring sand deposits of Kansas in Pennsylvanian time are determinable only from the features of the sand bodies and the associated rocks that are revealed by the records of drill holes and a few samples of the sand. These features include extent, size, shape and distribution of the bodies, character, composition and distribution of the sand grains; types of cross bedding; and a few other facts. The method of origin of these ancient sand bodies might be revealed by comparison of their features with those of modern sand deposits.

The shoestring sand deposits necessarily represent some type of very narrow elongated bodies. Only filled stream valleys and some type of shore feature, such as offshore bars or other types of bars, appear to fill this requirement. It is true that some glacial deposits, such as kames or moraines, somewhat resemble in general shape and distribution that of offshore bars or stream channel deposits, but can be distinguished from them by the type of material of which they are composed and by evidences of glacial sediments in adjacent strata[114]; no evidence of glacial deposits is recorded in wells anywhere in the region, and none is apparent where the strata crop out in the southeastern part of Kansas and the western part of Missouri, and in Oklahoma. A glacial origin is accordingly dismissed from further consideration.

The shallow near-shore waters of our present marine water bodies and some of the large fresh-water lakes are bordered by narrow bodies of sand elongated parallel with the shore, but lying a short distance basinward. These are known as offshore bars, or barrier beaches. According to students[115] of shore processes, these bars are formed by the following method. Briefly, as large storm waves approach shore, and therefore approach a shallowing bottom, the lower part of the wave brushes and scours the bottom, carrying forward the sediments that lie there. The forward movement of the wave is retarded, however, by the friction of its lower part with the sea bottom; the upper part of the wave continues its rapid movement forward; the water appears to pile up, and then the wave structure collapses and drops its load of sediment—the collapsing wave is known as a breaker—the forward movement ceases and the water

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114. Gilbert, G. K., gives additional comparisons in, The topographic features of lake shores: U. S. Geol. Survey Fifth Ann. Rept., p. 121, 1885.

115. Johnson, D. W., Shore processes and shore line development: New York, John Wiley & Sons, pp. 365-367, 1919.
Gilbert, G. K., The topographic features of lake shores: U. S. Geol. Survey Fifth Ann. Rept., pp. 87-90, 1885.
Shaler, N. S., Beaches and tidal marshes: Nat'l Geogr. Mon., pp. 151-152, 1896.

returns seaward down the slope, forming a current known as the undertow. This returning current carries with it much of the finer sediment that was carried forward by the wave and dropped at the point of collapse. The action of the larger waves excavates a marine cliff in the sea bottom at the line of breakers and deposits debris on the bench just above the cliff, which in many parts of the coast is a mile or more from shore. Continued excavation and deposition builds a ridge of debris on the ocean bottom parallel with, but some distance removed from, the shore. In time the ridge is built above the water level and it appears as a series of small islands of sand, called offshore bars, aligned parallel with the shore. The water body that lies between the newly formed island chain and the land is called a lagoon. Between the islands, waterways, known as tidal inlets, connect the lagoon with the open sea.

The waves that beat against the offshore bars rarely strike perpendicularly; most of them, generated by the wind, strike at an angle, and the current as it returns seaward is deflected along the bar and therefore sets up a current known as the longshore current, which runs parallel with the trend of the bars. The incoming waves erode material from the seaward slope of the bars and it is transported along the face of the bars by the longshore current, filling in the low places and lengthening the bars. Gradually the islands are connected and the number of tidal inlets is reduced. The closing of inlets concentrates the flow of the tidal waters in the few inlets that remain open, and thereby increases the speed of the currents through them. These currents form deeply excavated channels. There is a constant conflict between the attempt of the longshore current to fill the inlets with sediment and the tidal currents to keep them open.

Bars that are very similar to those described above, and for our purposes here need not be separated from them, spring from the mainland, which is exposed to the direct attack of the waves, and are classified as spits. Examples are Sandy Hook, north of Long Branch, N. J., and the bars on the north tip of Cape Cod, described by Davis.[116] There the material for the building of the spits is derived from the mainland by the direct attack of the waves and is transported along shore by the longshore currents.

Offshore bars are commonly characterized by their narrow elongated lenslike form; in cross section they have relatively plane-like lower surfaces and convex upper surfaces; the individual lenses may

116. Davis, W. M., Geographical Essays, Edited by D. W. Johnson, pp. 707-712, 1909.

be arranged *en échelon.* They should be enclosed within strata that exhibit uniform bedding, which is characteristic of sediments deposited in still bodies of water. The sand in offshore bars should be in part irregularly cross-bedded, due to deposition by conflicting currents and waves. The sand grains in offshore bars are characteristically well sorted and largely devoid of silt and clay. Offshore bars are transitory structures and are probably preserved only rarely.

Streams, because of their strong currents during flood periods, are more likely to deposit a more heterogeneous mass of material than that which is spread by ocean waves and currents; the stream deposit may be characterized by lenses of coarse and fine sediments, commonly cross-bedded; the slopes of the cross-bedded layers are steep and tend to slope in one direction.[117] If the stream deposits merely fill the stream channel the resulting sandstone will be a cast of the stream valley; its areal distribution will form a narrow, elongated, continuous, somewhat meandering pattern, and it will have a valley shape in cross section—that is, the base of the sand body will be convex downward. The Verden channel sandstone[118] in Oklahoma, the Warrensburg and Moberly channel sandstones[119] and the Graydon channel sandstone[120] in Missouri, and the Red Rock channel sandstone[121] and others in Iowa and the shoestring sands in Kansas[122] have been interpreted as originating in this manner.

Streams that rise in highlands commonly have steep gradients and carry large quantities of sediment during flood periods; as they approach the plains the gradients diminish somewhat abruptly, which checks the velocities of flow; the streams are unable to transport the sediments farther and so they are dropped. These sediments fill the main stream channels; then, the streams split into

117. Barrel, Joseph, Criteria for the recognition of ancient delta deposits: Geol. Soc. America Bull., vol. 23, p. 432, 1912.

118. Reed, R. D., and Meland, Norman: The Verden sandstone: Jour. Geology, vol. 32, pp. 150-167, 1924.

119. Winslow, Arthur, The coal beds of Lafayette county: Missouri Geol. Survey Bull. 1, p. 18, 1890.
——— Coal deposits of Missouri: Missouri Geol. Survey Vol. 1, pp. 24-25, 35-37, 1891.
——— Report on Higginsville sheet: Missouri Geol. Survey Vol. 9, pp. 45-54, 1896.
Marbut, C. F., Geology of the Clinton, Lexington, Richmond, and Huntsville quadrangles: Missouri Geol. Survey Vol. 12, pt. 2, pp. 123, 210, 270-272, 275-276, 331-332, 1898.
Hinds, Henry, The coal deposits of Missouri: Missouri Bur. Geology and Mines Vol. 11, 2d ser., pp. 6, 262, 310, 312, 351, 356-358, 1912.
——— and Greene, F. C., The stratigraphy of the Pennsylvanian series in Missouri: Missouri Bur. Geology and Mines, vol. 13, 2d ser., pp. 91-106, 1915.

120. Shepard, E. M., Geology of Lawrence County, Missouri: Missouri Geol. Survey, Vol. 12, pp. 127-139, 1898.

121. Miller, B. L., Geology of Marion County: Iowa Geol. Survey Bull., vol. 11, pp. 153-161, 1901. Williams, I. A., Geology of Jasper County: Iowa Geol. Survey Bull., vol. 15, pp. 316-321, 1905. Bain, H. F., Geology of Appanoose County: Iowa Geol. Survey Bull., vol. 5, pp. 394-398, 1896.

122. Cadman, W. K., The Golden lanes of Greenwood County: Am. Assoc. Petroleum Geologists Bull. Vol. 11, pp. 1151-1172; 1927.

numerous parts called distributaries that spread the sediments fanwise outside the old main channel; the resulting deposit is known as an alluvial fan. If the process continues long enough, fans of several streams may coalesce to form a sheetlike deposit. This type of deposit is forming today bordering many of the mountain ranges in the western semiarid parts of the United States. An example of sediments originating in this manner is furnished by the sand and gravel beds of Tertiary age that cap the High Plains of western Kansas, Nebraska, Oklahoma, eastern Colorado, western Texas, and eastern New Mexico; these deposits on the High Plains are believed[123] to have been formed by sediment-laden streams that flowed eastward from the Rocky Mountains and dropped and distributed the sediments on the plains, where the velocities and the transporting power of the streams were reduced. The deposits on the High Plains are characterized by extreme ranges in size of grains, lack of sorting, steep cross bedding, and discontinuous lenses of boulders, gravel, sand and silt.

The accumulation of delta deposits composed of sand and silt, such as those now being built by the Mississippi river into the Gulf of Mexico, the Nile river into the Mediterranean Sea, and other rivers, constitute important deposition on a large scale. No doubt this process was an important one during ancient geologic time. Barrell[124] has described the characteristics of sediments formed in this manner, but they will not be reviewed here, because the extreme length of the shoestring sand deposits in contrast with their narrow widths is sufficient in itself to eliminate the possibility of their being ancient deltas. For the same reason widespread or sheet sand deposits that may have been formed by coalescing beach deposits of a receding sea or large lake need not be considered at length.

Sands that have accumulated as a result of transportation by the wind are known as aeolian deposits. They are numerous and some beds are very thick. Such sands are in general comparatively widespread; the sand grains are sorted as to size and type of material, and are commonly well-rounded and frosted; cross-bedding is a prominent feature and characteristically the slopes of the bedded layers are in many directions, which produces an intricate pattern, though exceptions have been reported; the cross-bedded layers are sharply truncated at the top, but approach the horizontal layers

123. Johnson, W. D., The High Plains and their utilization: U. S. Geol. Survey Twenty-first Ann. Rep., pt. 4, 1901.

124. Barrell, Joseph, Criteria for the recognition of ancient delta deposits: Geol. Soc. America Bull., vol. 23, pp. 377-446, 1912.

below by long sweeping curves. The Navajo sandstone of Arizona and Utah, described and photographed by Gregory,[125] is an example of a thick deposit of aeolian sand.

Although each of these types has several features or combinations of features that are commonly characteristic of the type, it is rare that in any formation all the features are distinct. Moreover, the features that are typical of certain types of deposits are commonly associated with features that characteristically belong to other types, because it is probable that most deposits of sand have passed through more than one cycle of erosion and deposition and have therefore acquired the characteristic features of more than one environment. Sand is commonly derived from the erosion of beds of sand or sandstone; accordingly, physical characters shown by the sand grains of a given sandstone did not originate necessarily at the time of deposition of the deposit in which they now occur, but may represent features acquired at a much earlier time. Berkey[126] has shown that the St. Peter sandstone, of Ordovician age, which is so widely and evenly spread over the Mississippi Valley region, including parts of Kansas, was derived from older sandstone beds that had already passed through a long complicated sedimentary history, the effects of which had imparted certain characters, such as rounded and frosted surfaces, to the grains of sand early in Cambrian time, which have persisted throughout the later history. According to Dake,[127] at least four sandstones, including the Gunter, Roubidoux, parts of the Jefferson City, and the St. Peter, in Missouri and adjacent areas, ranging in age from Cambrian through Ordovician, are indistinguishable because they are each composed of rounded grains of quartz derived from the same sources.

If a sheet-sand deposit formed by any one of the above-described processes, at some later time became the land surface, and so was subjected to the agencies of erosion, much of it might be removed, leaving only irregular patches to be buried and preserved by later sediments. These remnants might somewhat resemble in plan the elongated sand bodies, such as filled stream channel or offshore bars. The shoestring sand bodies might be conceived as representing remnants of narrow interstream areas; and the areas between the sand trends might be conceived as representing old valleys, but an

125. Gregory, H. E., Geology of the Navajo country: U. S. Geol. Survey Prof. Paper 93, pp. 58-59, 1917.

126. Berkey, C. P., Paleogeography of Saint Peter time: Geol. Soc. America Bull., vol. 17, pp. 229-250, 1906.

127. Dake, C. L., The problem of the St. Peter sandstone: Missouri School of Mines and Met. Bull., vol. 6, No. 1, pp. 182, 184, 1921.

arrangement of the valleys necessary to produce the sharp angles at the junction of the Sallyards and Quincy trends, in Tps. 22 and 23 S., R. 11 E., necessitates an unreasonable conception.

Hundreds of wells drilled in the Greenwood and Butler counties region have established beyond a doubt that the oil-producing sand actually occurs in elongated lenses and is for the most part absent in the areas adjacent to the lens-shaped bodies. Also, the sand is not present as a sheet sand throughout the region, nor in any appreciable part of the region. All except two (offshore bars and stream channel fillings) of the depositional methods described above produce deposits of more or less widespread extent and can therefore be dismissed from further consideration.

Filled Stream Channels or Offshore Bars

The filling of stream channels and the deposition of offshore bars produce elongated, narrow deposits. In order to determine which of these two methods is responsible for the origin of the shoestring sands, the following features have been considered: The marine or nonmarine character of the sediments; the composition, character, and sizes of the material that makes up the sand; the shapes in cross section of the sand lenses; and the areal distribution of the sand lenses, their arrangement as a whole, and the arrangement of individual lenses with respect to adjacent lenses.

Marine or Nonmarine Sediments.—Deposits formed by the filling of stream channels, known as channel sands, imply a continental environment for the sediments, although it is conceivable that stream channels might be filled with marine deposits; offshore bars most commonly are formed on the margins of oceans and seas, though they may occur on the borders of large bodies of fresh water. Modern offshore bars are most abundant in marine water bodies. Few specific data that bear on the marine or nonmarine character of the shoestring sands are available, and so tentative conclusions must be drawn from but few specific facts and from contributory data of a general nature.

It is known that the lower part of the Cherokee shale consists of uniformly bedded gray and dark gray to black shale with some thin beds of limestone and locally coal beds in southeastern Kansas and northeastern Oklahoma; its uniformity is interrupted by sand lenses, such as the shoestring sands of Greenwood and Butler counties, but the beds of shale adjacent to the sand lenses appear to be uniformly bedded. The ingredients of the sand bodies are fairly uniform in composition and size of grain. These features indicate deposition of much of the sediments in a still body of water of considerable lateral dimensions where waves were effective in distributing the sediments uniformly over the bottom.

Marine fossils have been collected on the outcrop from strata closely associated with coal beds of continental origin in the Cherokee shale near Pittsburg, Kan.[128] Several limestones in the Cherokee shale, some of which occur in contact with or separated from the sandstones by a shale bed only a few feet thick, contain many fossils which are revealed by exposures of these beds in southeastern Kansas and northeastern Oklahoma. Recent microscopic studies of core samples and well cuttings by Constance Leatherock[129] show that limestones in the Cherokee shale contain marine fossils throughout most of Osage and Kay counties, Oklahoma.

Though hundreds of sets of drill cuttings from the shoestring sands and a relatively few sets from the horizon of the sands in localities where the sands are absent have been examined microscopically by petroleum geologists, fossils from these beds have been reported in but few localities. Tarr[130] reported finding a fusulinid in sandy shale 100 feet above the base of the Cherokee shale at the horizon of the shoestring sand in drill cuttings from a dry hole, the No. 1 Levi Higginbottom, in the center of the south line of the SW¼ sec. 29, T. 31 S., R. 6 E., south of the Eastman oil field in Cowley county. Casing had been set 30 feet above the depth at which the fossil was found and so it is safe to conclude that the specimen could not have come from a shallower depth.

Buchanan[131] reported the occurence of marine Pennsylvanian fossils from the Marland Oil Co.'s No. 1 Thiessen well drilled in the SW¼ SE¼ SE¼ of sec. 22, T. 34 S., R. 2 E., in the Padgett oil field. D. C. Nufer[132] states that the log of the above-mentioned well records sand at depths 3,445 to 3,455 and dark-gray shale from 3,455 to 3,468, overlying the "Mississippi lime." The fossils mentioned by Buchanan were recovered while drilling in the shale. He identified two ostracodes as *Healdia* sp., and one specimen of *Chonetes mesolobus*. The *Chonetes* specimen was found in a fairly large fragment

128. Jewett, J. M., personal communication.

129. Bass, N. W., Kennedy, L. E., Dillard, W. R., and Leatherock, Constance, Subsurface geology of Osage county, Oklahoma: U. S. Geol. Survey Press Report 105368, p. 7, January, 1936.

130. Tarr, R. S., The red beds near the base of the Cherokee shales: Am. Assoc. Petroleum Geologists Bull., vol. 9, pp. 350-351, 1925. Location of well given by personal communication.

131. Buchanan, G. S., Early Pennsylvanian "Red Beds" in the Mid-Continent region: Am. Assoc. Petroleum Geologists Bull., vol. 9, p. 814, 1925.

132. Nufer, D. C., personal communication.

of shale that may have caved from the beds above the sand, according to Buchanan.[133] This well is so far removed from the shoestring sand region described here that positive correlation of the strata containing the fossils cannot be made with any specific part of the Cherokee shale of the Butler-Greenwood county region. It, together with other fossils found, shows only that marine conditions prevailed in at least a part of the time during which the lower part of the Cherokee shale was being deposited in this general region.

A few occurences of marine fossils were seen in the drill cuttings examined for this report. Several fragments of crinoid stems and other fossils were found in coarse sand in the Mathews and Rex, Lewis No. 1 well drilled in the northwest corner SE¼ sec. 8, T. 24 S., R. 12 E., southeast of the Landon oil field in the Quincy trend; these fossil fragments were somewhat worn. A small brachiopod spine was found in well cuttings from sand at a depth of 2,710 to 2,718 feet in the Seymour No. 1 well, in sec. 6, T. 27 S., R. 8 E., in the Lucas oil field in the Sallyards trend. A marine brachiopod[134] was found in sand in drill cutings from 2,465 to 2,470 feet in Marolyn Oil Co.'s Harsh No. 1 well, in the northeast corner SW¼ sec. 33, T. 23 S., R. 8 E. A fusulinid,[135] *Productus* spines, and other fossil fragments were found at depths of 2,406 to 2,412 feet, in cuttings of limestone and shale, believed to be in the upper part of the Cherokee shale, in the Jones-Black No. 1 well in the NE¼ NW¼ NE¼ sec. 31, T. 23 S., R. 6 E. This well is very near the Nemaha granite ridge; it is on the southeast flank of the well-known Burns dome,[136] and is 17 miles west of the Scott oil field of the Teeter trend. Only about 80 feet of strata are believed to belong in the Cherokee shale here; therefore, the marine strata in this locality probably are younger than the shoestring sand beds.

Fragments of fossils were noted by Constance Leatherock[137] in drill samples from shale beds in the Bartlesville and Burbank sands in half a dozen or more localities in Osage county, Oklahoma. Several petroleum geologists have stated to me recently that they remembered seeing fossils in the Cherokee shale in well cuttings from the Greenwood-Butler county region, but were unable to recall the localities of the occurrences.

133. Buchanan, G. S., personal communication.

134. Identified by G. H. Girty, U. S. Geological Survey.

135. Identified by Betty Kellett, Amerada Petroleum Corp., Wichita, Kan.

136. For location of Burns dome see Thomas, C. R., Flank production of the Nemaha Mountains: Am. Assoc. Petroleum Geologists Bull., vol. 11, No. 9, figs. 2, 3, pp. 923 and 925, 1927.

137. Bass, N. W., Kennedy, L. E., Dillard, W. R., and Leatherock, Constance, Subsurface geology of Osage county, Oklahoma: U. S. Geol. Survey Press Report 105368, p. 7, January, 1936.

Samples from wells that fail to find sand at the shoestring sand horizon are given only meager examination by local geologists, because, if no sand is present, the well is a dry hole insofar as the main objective is concerned, and there is little to be gained from devoting much time to studying the Cherokee shale in dry holes. This fact may account in part for the relatively few instances in which fossils have been reported from these beds. Moreover, Kindle[138] has shown that fossils may be absent in marine beds or parts of a series of beds, which fact does not establish them as being nonmarine.

These data indicate that the Cherokee shale represents interbedded continental and marine beds; that the shoestring sand bodies are closely associated with beds that are marine; and that the sand is known to contain marine fossils at a few localities. It is, of course, conceivable that the marine fossils found in the sand might not represent organisms that lived at the time and place of the sand deposition, because they could have been eroded from a marine formation and redeposited in the sand. However, it appears more reasonable to conclude that the fossils indicate that the sand was deposited in a marine environment.

Composition, Character, and Size of the Sand Grains.—Stream-laid deposits commonly are composed of a fairly large variety of substances; the material is poorly sorted and much of it is not rounded. However, transportation over long distances tends to wear off the edges and corners of the sand grains, so that the resulting deposit may not show the characteristic angularity of grains. Stream currents are subjected to extremes in carrying capacity seasonally and during flood and drought periods. A stream does most of its work during floods. Its habit is to scour out deep holes in parts of its bed and pile up the debris in other parts. Consequently, the resulting deposits vary abruptly in composition and size of grain, vertically and laterally.

The Warrensburg, Moberly, Graydon and other channel sandstones of Pennsylvanian age in Missouri have been interpreted by Winslow,[139] Marbut,[140] Hinds and Grenne,[141] and Shepard[142] as

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138. Kindle, E. M., Cross-bedding and absence of fossils considered as criteria of continental deposits: Am. Jour. Sci., vol. 32, pp. 227-228, 1911.

139. Winslow, Arthur, Coal deposits, Missouri Geol. Survey Bull. 1, p. 18, 1890. Missouri Geol. Survey Vol. 1, pp. 24-25, 35, 37, 1891, and Vol. 9, pp. 45-54, 1896.

140. Marbut, C. F., Geological description of the Calhoun sheet: Missouri Geol. Survey, vol. 12, pt. 2, pp. 158-159, 1898.

141. Hinds, Henry, and Greene, F. C., The stratigraphy of the Pennsylvanian series in Missouri: Missouri Bur. Geology and Mines, vol. 13, 2d ser., pp. 95-96, 1915.

142. Shepard, E. M., Geology of Lawrence county, Missouri: Missouri Geol. Survey, vol. 12, pp. 127-139, 1898.

stream-laid deposits. The Verden channel sandstone of southwestern Oklahoma has been interpreted as a filled stream channel by Reed and Meland,[143] and, as reported by them, consists of angular fragments of red and white chert 3 to 4 millimeters in diameter, spherical, frosted grains of colorless quartz, some angular pebbles of gray and reddish shale, and fossils, the whole bound together with limy cement. The description given by these authors indicates that the Verden sandstone does not closely resemble the channel sands of Missouri or the shoestring sands of Kansas.

Comparisons were made between samples from the Warrensburg and other channel sandstones of Missouri and the shoestring sands of Kansas. A photomicrograph of the Warrensburg sandstone is shown on Plate 16, *A*. The channel sandstones of Missouri do not differ markedly in composition from samples of the shoestring sands of Kansas. Quartz is the chief constituent of each. Fragments of coal are fairly abundant in the Missouri sands and were not identified in the Kansas sands, but fine fragments of black carbonaceous material which were not specifically identified, but might be coal or asphalt, are fairly abundant. Taken as a whole, there is probably a greater variety of material, such as limestone, shale, feldspar and mica in abundance in the Missouri channel sands than in the Kansas shoestring sands, but all these substances occur in small amounts in the Kansas sands also.

The sands from Missouri differ in grain size, angularity of grains, and degree of sorting of grains, from the Kansas sands. The shoestring sand in all the fields in the Teeter and Sallyards trends and much of the sand of the Lamont trend and the northwestern part of the Quincy trend is composed largely of fine and very fine sand, which is finer than the sand in the Warrensburg and Moberly channel sandstones of Missouri. The sand in the Atyeo oil field of Tps. 21 and 22 S., Rs. 9 and 10 E., and that in most of the fields extending from the Edwards Extension field in T. 23 S., R. 11 E., southeastward in the Quincy trend into western Woodson county is composed of medium and coarse sand, which is coarser than much of the sand from Missouri.

The sand grains in the channel sandstones of Missouri are distinctly more angular than those in the shoestring sand. The sand grains in the shoestring bodies between the Edwards Extension oil field in T. 23 S., R. 11 E., and the west-central part of T. 25 S., R. 14 E., in the Quincy trend, and that of the Atyeo oil field in Tps.

143. Reed, R. D., and Meland, Norman, The Verden sandstone: Jour. Geology, vol. 32, pp. 157-167, 1924.

21 and 22 S., Rs. 9 and 10 E., which are composed largely of medium and coarse sand, are subrounded and rounded (shown on pl. 15, *A*) and so present a decided contrast in shape with the angular grains of the Missouri sand (shown on pl. 16, *A*). Comparison of thin sections of the shoestring sands with thin sections of the Warrensburg and Moberly, Mo., sandstones reveal that the grains in the shoestring sand are distinctly more uniform in size than those in the Missouri sandstones.

Chunk samples of Missouri channel sandstone from the Warrensburg and Miami quarries have crudely banded, cross-bedded layers of coaly sand and sand relatively free from coal fragments; the beds blend together and are not sharply defined. Chunks and core samples of Kansas shoestring sands show finely laminated layers of micaceous sandy shale, black carbonaceous shale, and sandstone comparatively free from mica and carbonaceous material; the boundaries between the laminae are sharply defined. Such sharp segregation of material of different specific gravity is more commonly accomplished by waves and currents in large bodies of water than by stream currents, which tend to dump the sediments in more or less of an unsorted mass.

Exposures of the Warrensburg channel sandstone near Warrensburg and at many other localities, and exposures of the Moberly channel sandstone show thick zones in the sandstone body with steeply cross-bedded layers. Reed and Meland[144] state that the Verden channel sandstone of southwestern Oklahoma is cross-bedded at angles of 17 to 20 degrees in all exposures that occur intermittently through a distance of 30 miles. Steeply inclined cross-bedding is common in stream-laid sediments, but occurs in sediments deposited by other agencies also. The few chunks and cores of the Kansas shoestring sands observed did not have this type of cross-bedding; so few samples were available, however, that little importance can be attached to the absence of these features in them. The bedding is practically horizontal in most of the core samples from the sand of the Madison and the Edwards Extension fields that were seen. Cross-bedding is common in the Bluejacket sandstone, which is probably equivalent to a part of the Bartlesville sand,[145] at many exposures of it seen in northeastern Oklahoma and southeastern Kansas, but the type of cross-bedding is not like that

144. Reed, R. D., and Meland, Norman, The Verden sandstone: Jour. Geology, vol. 32, pp. 157-167, 1924.

145. Snider, L. C., Petroleum and gas in Oklahoma, p. 46, 1913.

seen in stream-laid sediments. The cross-bedding planes have maximum slopes of 15 to 20 degrees and flatten by broad, sweeping curves into slopes of one degree or less. In cross section the cross-bedded layers form long, sweeping wedges, tapering toward the lower ends. There is no uniformity in the direction of the cross-bedding. Parallel bedding, having slopes of less than one degree, was seen in many exposures extending for 25 to 50 feet or more along the faces of ledges. The sand in the cross-bedded layers is composed of well sorted, fine and very fine quartz grains, containing less than 10 percent clay and silt. The sand is remarkably uniform in composition and physical character throughout the total thickness of the sandstone, which is as much as 70 feet in some localities. The cross-bedding in the Bluejacket sandstone is similar to that in modern beach deposits and dissimilar to that of river deposits.

Shapes in Cross Section.—Because stream channel and offshore bar deposits differ markedly in their shapes in cross section, it is believed that the shapes of cross sections of the shoestring sand bodies indicate which of these types of deposits is represented by them. When a stream channel is filled with sediment it imparts to the resulting deposit a valley-shaped base, and the deposit is more widespread in the upper part than in the lower part. An offshore bar is quite different from this in cross section. It is built on a comparatively plane base that slopes slightly basinward, and its top forms a low arch; the lower part of the deposit is more widespread than the upper part.

Scores of cross sections of the shoestring sand lenses based on well records, in part supplemented by cuttings, were made across the oil fields in the area in Greenwood county that was studied in detail, and others were made for the Haverhill oil field in southern Butler county and the Atyeo oil field in Lyon county, outside the area detailed. A few of these are reproduced in figure 3.

In most of the cross sections the base of the sand body approaches a plane surface; the sand body is widest at the base; it is thickest in the middle, and its upper surface is convex upward. The cross sections show also the very significant fact that the bases of the sand bodies of the Teeter and Sallyards trends when deposited had low slopes to the southeast and that the sand bodies of the Lamont and Quincy trends sloped to the southwest.

Subsurface contour maps, drawn on the top of the shoestring sands, show the upper surfaces of the sand bodies of all the fields to be convex upward; such a map of the entire region would show

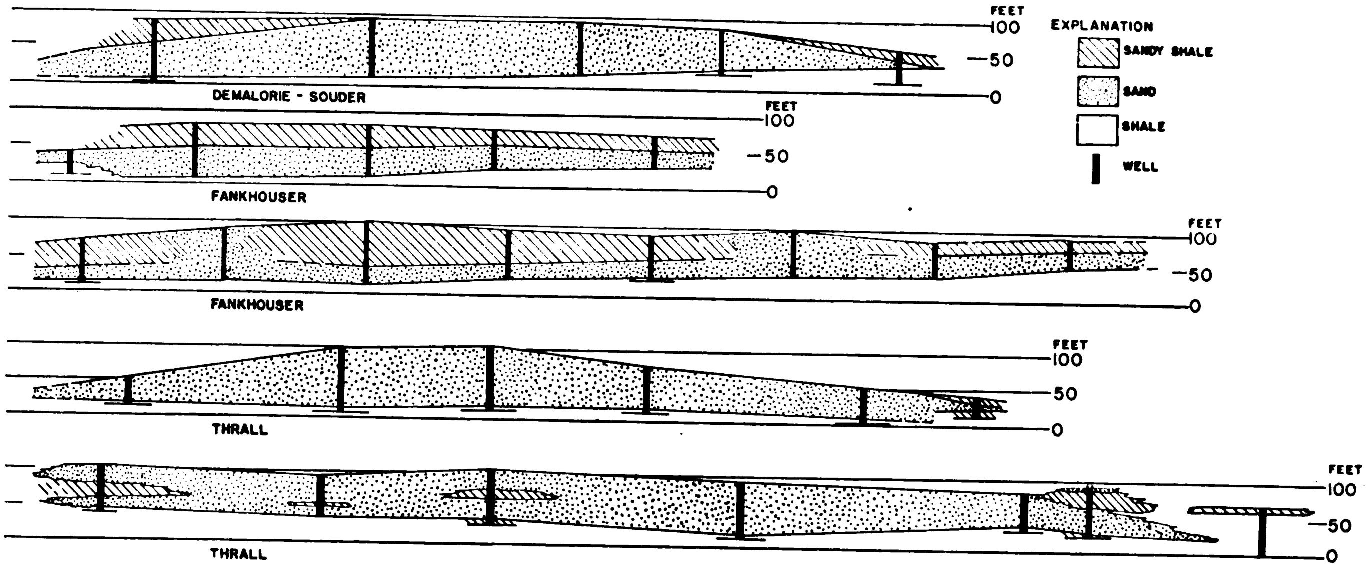


FIGURE 3. *C*ross sections of several sand bodies. The DeMalorie-Souder oil field cross section extends from the SE cor. NE¼ NE¼ sec. 11 to the SW cor. NE¼ SW¼ sec. 1, T. 22 S., R. 10 E. The upper of the two Fankhouser oil field cross sections extends from the NE cor. SW¼ NW¼ sec. 4, to the NE cor. of the SW¼ NE¼ sec. 4, T. 22 S., R. 12 E. The lower Fankhouser section extends from the NE cor. SE¼ sec. 5, to the NW cor. NE¼ SE¼ sec. 4, T. 22 S., R. 12 E. The upper of the two Thrall oil field cross sections extends from the SE cor. of the SW¼ sec. 29, to the SE cor. of the NE¼ of sec. 32, T. 23 S., R. 10 E. The lower of the two Thrall sections extends from the SE cor. sec. 30 to the NW¼ SE¼ sec. 32, T. 23 S., R. 10 E.

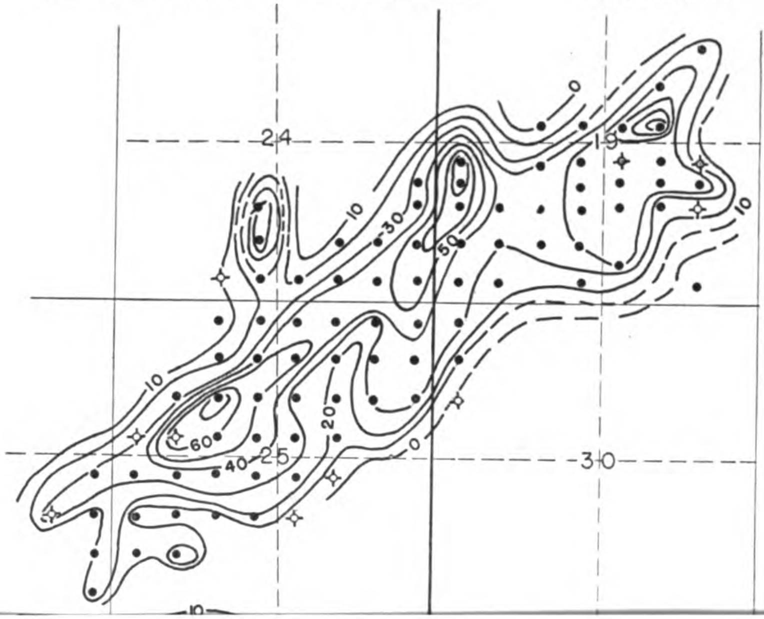
elongated ridges formed by the sand trends. This is illustrated by the map of the Scott oil field of the Teeter trend. It is noteworthy that the map indicates that the sand is lower on the southeast side of this field than on the northwest side, and if the regional dip of the strata, which is to the west, is removed, the eastern margin of the sand lens is seen to be even lower. This fact is additional evidence that the surface upon which the sand lens rests had an original eastward slope.

Block diagrams, on which the sand bodies are shown in perspective, have been prepared for each of several of the oil fields. The diagrams (pls. 10 to 14) show the sand to occur in lens-shaped bodies with convex upper surfaces and plane bases that had initial dips of low angles. The widest parts of the lenses are made by the lowermost part of the sand.

THE DISTRIBUTION OF THE SAND LENSES.—The distribution of the sand lenses presents certain features that appear to be capable of fairly definite interpretation. Meandering courses are common features of stream channels, particularly of those streams that have reached an advanced age and are filling their channels rather than cutting or maintaining a grade. The channel of the Mississippi river, shown on the topographic sheets of the United States Geological Survey, may be used as an illustration (see fig. 4). It is marked by wide meanders throughout its course, except the lowermost part across its delta. Also, the map of an oil pool in the Majkop district in Russia, in which the oil-containing rocks have been interpreted[146] as stream-laid sediments filling a stream channel, is reproduced in figure 4. The author's original map is contoured and shows the definite channel shape of the oil-bearing beds in cross section and the meandering areal pattern formed by the distribution of the sand deposit. The map is based on the records of several hundred wells.

If comparisons are made of the maps of the Mississippi river and the filled stream channel of the Majkop oil district of Russia with maps showing the distribution of the shoestring sand bodies in Kansas, there appears to be much that is dissimilar. The course of the Sallyards or of the Quincy trend in Kansas is too straight to fit even the course of the Mississippi river across its delta. The meandering course of the channel sandstone of the Majkop oil field of Russia and the meandering Mississippi river channel above New Orleans

146. Maksimov, M., Investigation of the interrelation of the horizons producing Majkop light petroleum in conjunction with the genesis of the Majkop arm-like oil pool: The Petroleum Industry, pts. 11 and 12, pp. 813-834, pl. 3, 1929.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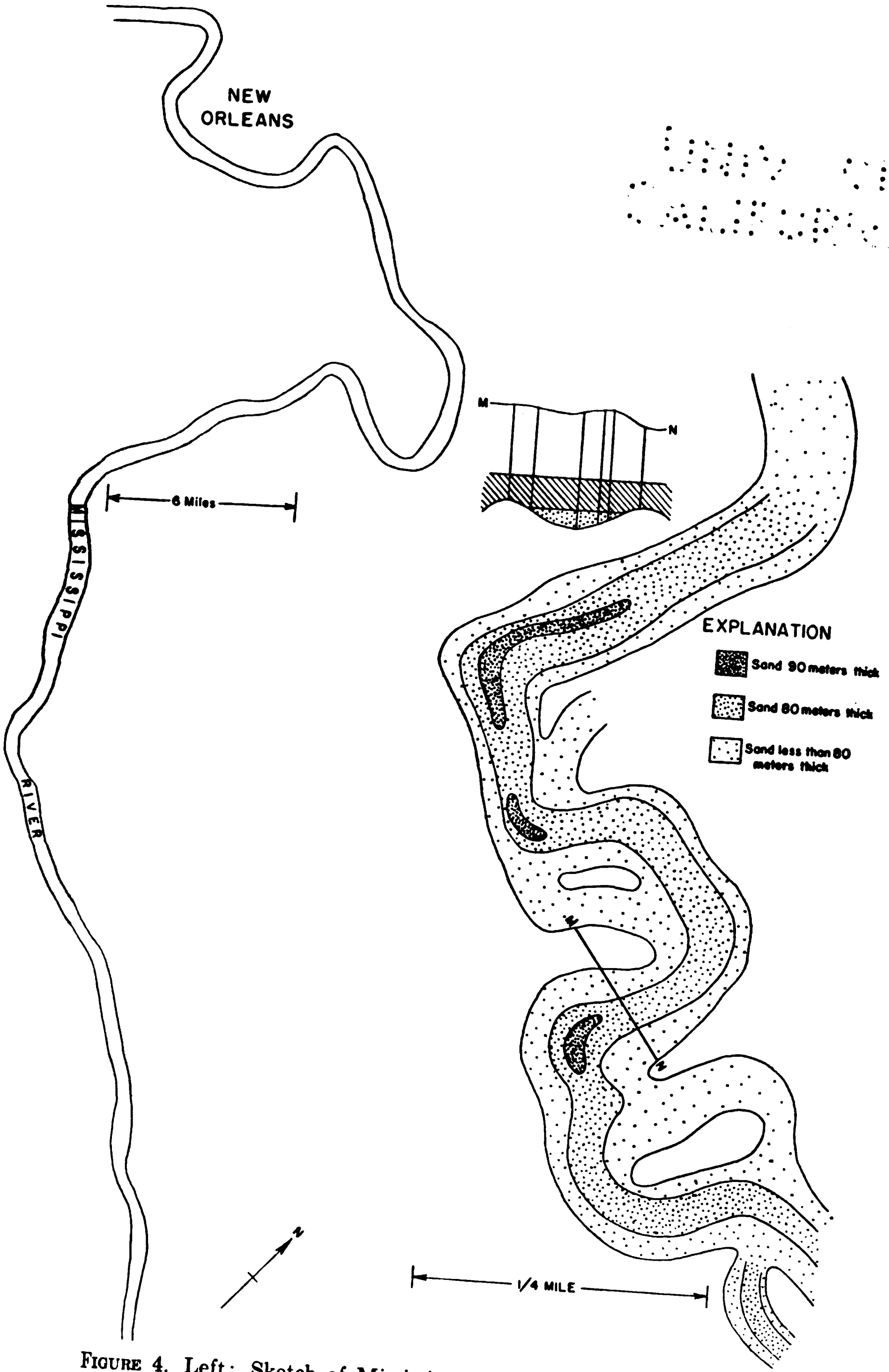

FIGURE 4. Left: Sketch of Mississippi river across its delta. (After U. S. Coast and Geodetic Survey Chart 1271.) Right: Sketch of oil-producing sand in Majkop district, Russia. (Modified after M. Maksimov.)

are in distinct contrast with the course of each of the sand trends of Kansas. The course of the Teeter shoestring trend and that of the Lamont trend could conceivably satisfy the requirements for a stream course, such as the lower part of the Mississippi river.

But if maps of the Kansas trends are compared with the maps of the offshore bars that border parts of our coasts, certain parallelisms are striking. A part of the New Jersey coast, which includes Atlantic City, is shown on Plate 20, copied from the United States Coast and Geodetic Survey Chart 1217. It shows the elongated offshore bars of sand, the marshes which contain numerous thoroughfares of open water and the breaks between the bars, which are called tidal inlets because they connect the ocean and the thoroughfares. On the right half of Plate 20 is a sketch of the Sallyards and Lamont shoestring trends. The sand bodies shown are definitely known from the records of the wells; much of the broad areas adjacent to the sand bodies is known, also from wells, to contain no sand of any appreciable thickness and purity; the other features, such as the marshes, ocean, thoroughfares, and shore lines, are hypothetical. Nearly all the areas shown as tidal inlets are known from the records of wells to contain no thick sand beds; they are narrow barren areas, between thick bodies of sand of the main oil fields.

Several features in the offshore bar system along the Atlantic coast are duplicated in the Kansas shoestring trends. Offshore bars are built[147] largely by storm waves, but are extended by additions of sediment at their ends transported by longshore currents. The growing end of each bar tends to be offset seaward with respect to its neighbor. This offset feature is exhibited on most all parts of the Atlantic coast, but is particularly well-developed along the south shore of Long Island, shown in figure 5, where there is a westerly longshore current; the western ends of the bars are building westward. The tidal inlets between the bars are kept clean of sediments by the swift currents set up by the outgoing tides.

The sand bodies of the Teeter and Sallyards shoestring trends have the offset relationship of adjacent sand bodies remarkably well-developed. The offsets are accentuated if lines are drawn lengthwise down the middle of each sand body and projected somewhat beyond the boundaries of the ends. In the Sallyards trend and in the Teeter trend each sand body, with the exception of that of the Wick oil field, is offset westward with respect to its neighboring sand body on the northeast. In the Lamont trend and in part of

147. Shaler, N. S., Beaches and tidal marshes: Nat'l Geographic Soc. Mon., pp. 151-152, 1896.

PLATE 19. Hypothetical sk
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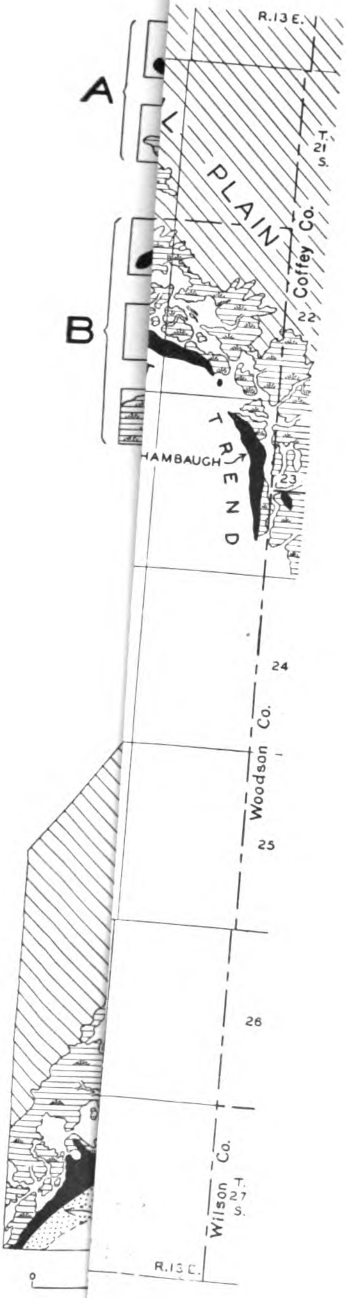

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the Quincy trend each sand body is offset to the northeast with respect to its neighboring sand body on the southeast. The series of small sand bodies in the southeastern part of the Quincy trend fail to show any development of this feature. These offset features are not found in a deposit formed by the filling of a stream channel and, as pointed out by Rich[148] in his description of oil-bearing stream channel sand deposits in the easternmost part of Kansas, a stream channel deposit is a continuous body; it is not broken into segments

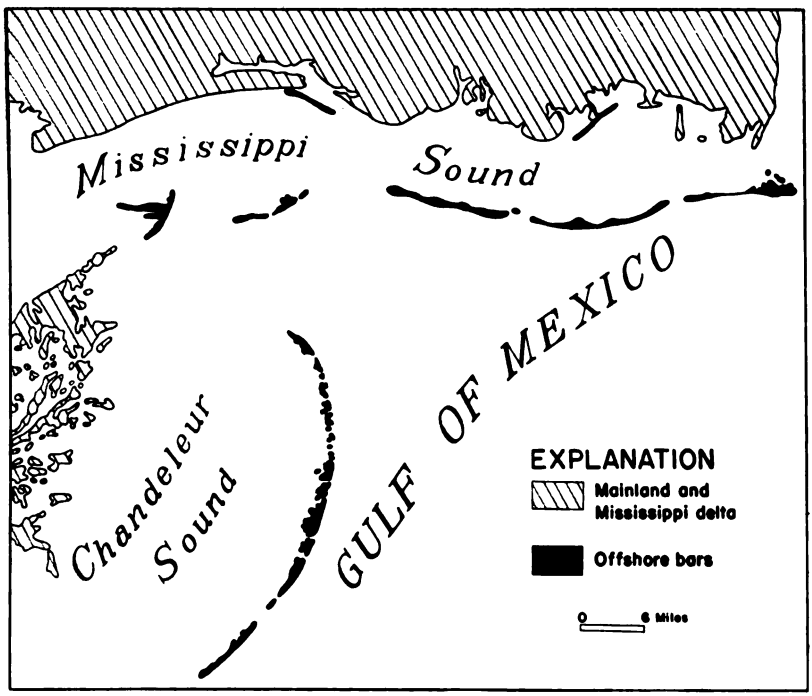

FIGURE 6. Offshore bars on the Mississippi and Louisiana coasts. (After U. S. Coast and Geodetic Survey Chart 1115.)

by narrow areas devoid of sand, such as the gaps between the sand bodies in the trends of Greenwood and Butler counties.

In oral discussions with several geologists, doubt has been voiced that offshore bars would form on both shores of an embayment where they approach at so sharp an angle as that formed by the junction of the Teeter trend with the Quincy trend and the junction of the Sallyards trend with the Lamont trend. A search for a similar arrangement of offshore bars along our modern coasts reveals

148. Rich, J. L., oral communciation.

two localities that resemble the local area. The angle formed by the trend of the offshore bars bordering Long Island and that of those bordering the New Jersey coast approaches a right angle, which is yet considerably greater than the angle of the shoestring sand trends. Also, the angle formed by the offshore bars bordering the southern coast of Mississippi and those on the eastern border of the Mississippi delta closely resembles the angle formed by the junction of the shoestring sand trends. A sketch of the offshore bars at this locality is shown in figure 6.

CONCLUSIONS

In any study such as that of the origin of the Kansas shoestring sands the geologist is hampered by only meager data. The determination of the origin of sediments, particularly sandstones, is difficult, even where the rocks are exposed and can be studied en masse. But the shoestring sands of Kansas are buried 1,500 to 3,000 feet deep, and the few facts collected from wells were limited, in most cases, to the thickness of the sand drilled, the drill cuttings of the sand, and a few chunks and cores of parts of the sand bodies. Conclusions drawn from such data are necessarily somewhat speculative. In this study the available data have been summarized, and comparisons have been made with facts known about most common types of sandstone deposits. Certain features of the Kansas sands can be applied to any one of several types of sandstone deposits; other features appear to fit only one or possibly two types of deposits.

In summary, the following critical features appear to be significant: The narrow elongated shape of the sand bodies; the occurrence of the sand bodies in trends 15 to 50 miles long; their offset arrangement in the trends; the occurence of gaps between sand bodies wherein little or no sand occurs; the shapes in cross section of the sand bodies; the initial dips of the bases of sand bodies; the occurrence of coarse rounded sand in sand bodies in the Quincy trend which resulted probably from wave action on a beach, the occurence of marine fossils in the sand and in limestones in the Cherokee shale and associated with the shoestring sands in southeastern Kansas and northeastern Oklahoma; and the character of the bedding exhibited by cores of sand wherein laminae containing material of different specific gravities are sharply defined. These features have led me to conclude that the shoestring sand bodies were formed as offshore bars bordering the shores of a broad embayment on the western margin of the Cherokee sea, which occupied eastern Kansas and Oklahoma. The evidence indicates that they were deposited in two stages; the Teeter and Quincy trends were deposited first and the Sallyards and Lamont trends were formed at a later time.

A land area in Lyon county and adjacent region.—This interpretation requires the presence of a land area bordering the Quincy and Lamont trends on the northeast. But few facts other than the features of the sand bodies themselves, which suggest that they are offshore bars, indicate the existence of land here. However, data that suggest the presence of a broad positive area in about the position of this suggested land area are obtained from studies of the thickness of the stratigraphic column throughout eastern Kansas. Howell[149] has made extensive studies of the groups of rocks that underlie the "Mississippi lime" in eastern Kansas and has found that a broad area trending northwest-southeast across southern Lyon, northeastern Greenwood, and northern Woodson counties contains a thinner column of sediments than areas to the northeast and to the southwest. The shale unit that immediately underlies the "Mississippi lime" is notably thinner here. A sketch map on Plate 1, representing the thickness of the Cherokee shale in eastern Kansas and northeastern Oklahoma, shows that the formation is thin in a broad area trending slightly south of east through Lyon county, northeastern Greenwood, Woodson, Allen, and Bourbon counties. This area coincides approximately with the area delineated by Howell as containing a thin column of the older rocks. These facts suggest that this part of Kansas stood periodically at a slightly higher elevation than the adjacent regions and so received less sediment.

It is known from the character of the sediments, the fossils that are preserved in them, and the presence of old erosion surfaces, that eastern Kansas was alternately a sea floor receiving deposits and a land area subject to erosion throughout much of geologic time. The relatively thin beds in the Cherokee shale, which contain land plants and coal beds closely associated and interbedded with rocks that contain marine fossils, indicate that during Cherokee time in some parts of Kansas land and sea conditions alternated in relatively rapid succession. If the conclusion that there existed a northwest-southeast trending area in Lyon, Greenwood, and Woodson counties, which stood frequently at a slightly higher elevation than the ad-

149. Howell, J. V., unpublished manuscript and oral communication.

jacent areas, is correct, it necessarily follows that during periods of withdrawal of the sea this area would emerge earlier than the neighboring regions. At such times it would form a low barrier between the basin region of northeastern Kansas and the basin region of southeastern Kansas.

The Teeter-Quincy stage.—During one of the withdrawals of the Cherokee sea it is suggested that it halted for a period of time, with its western shore near the position of the Teeter shoestring trend, extending thence southwestward into Oklahoma, and with its northeastern shore at about the position of the Quincy trend. During this time, which I have designated the Teeter-Quincy stage of the Cherokee sea, a system of offshore bars was slowly built bordering the coast lines (pl. 19). The land bordering the sea is believed to have been an exceedingly low featureless expanse. The area that lay northeast of the Quincy shore probably consisted of expansive marsh flats, because it had but recently been the mud bottom of the sea. The Quincy shore line was of exceedingly simple outline, with almost a straight northwest-southeast trend through northeastern Greenwood county. Likewise the western shore, which bordered the present position of the Teeter trend, lay upon the old sea bottom, and it no doubt was also of simple outline.

It has been pointed out by Gulliver and Johnson[150] that a sea floor has very low relief, because whatever may have been the initial irregularities of the sea bottom the deposition of sediment distributed by waves and currents should have largely filled the depressions, leveled the surface, and obliterated the irregularities. Therefore, when the sea receded and the former sea floor was exposed, the new shore line which rested against the old sea bottom should have been devoid of sharp irregularities; it should tend to have a simple outline with only broad, gentle curves. An offshore bar system built parallel with the shore should likewise have a simple outline. The nearly straight-line courses of the Teeter and Quincy sand trends appear to be in harmony with the conception that they were built along a coast devoid of prominent irregularities.

Shift of the embayment.—Subsequent to the Teeter-Quincy stage the shallow areas near the margins of the Cherokee sea gradually filled with sediment; the lagoons back of the offshore bars silted up; the shore lines were pushed seaward slightly; and the lagoonal marshes encroached upon the offshore bars. Inasmuch as the land

150. Gulliver, F. P., Shoreline topography: Am. Acad. Arts and Sci. Proc., vol. 34, p. 162, 1898-1899. Johnson, D. W., Shore processes and shore-line development, pp. 186-187, New York, John Wiley & Sons, 1919.

bordering the sea was a coastal plain of very low relief, fresh-water swamps likely bordered the salt-water swamps; and as the salt-water lagoons migrated seaward the fresh-water swamps followed, but remained on the inner borders of the swamp lands. A coal bed, reported to be 5 feet thick, overlies the sand body of the Theta oil field in secs. 8 and 17, T. 22 S., R. 10 E., in the Teeter trend, and it, together with the series of sandstone and shale beds associated with it, bear evidence of this sequence of events. The offshore bars of the Teeter trend and those in the northwestern half of the Quincy trend were buried, at least in part, by the encroaching marsh and lagoonal sediments.

After this, or during this silting-up process, the broad embayment of the Cherokee sea that occupied the Greenwood-Butler county region shifted bodily eastward until its shore line stood only a few miles back from the present site of the shoestring sand bodies of the Sallyards and Lamont trends. The mechanics of the crustal deformation that caused this migration are of course not known, but a slight subsidence in the main trough of the Cherokee basin which lay 50 miles to the east (see sketch map on pl. 1), accompanied by a slight elevation in the region of the Nemaha granite ridge which lay about 15 miles to the west, could have accomplished it. The very thick sedimentary column in eastern Kansas indicates that throughout a very long period subsidence occurred along the trough of the Cherokee basin; likewise the thinning[151] of several parts of the entire column of Pennsylvanian sediments overlying the Nemaha granite ridge area indicates periodic or continuous uplift in that region. Therefore, the supposition that some change in level occurred during that part of Cherokee time occupied by the formation of the shoestring sands seems reasonable. Students of shore lines believe that fluctuations of level and changes in the position of shore lines have been very common. In support of this view, Shaler[152] states: "Thus in the geologically brief period since the beginning of the last Glacial Epoch, or as we may fairly term it since the morning of the geologic yesterday, all the eastern coast of North America has swayed up and down in several successive oscillations ranging from a few score to a few hundred feet." Shaler's clear explanation of the shifting of the shore lines that are subjected to changes in level because of crustal movements is believed to be applicable to this Kansas region and so is quoted below.[153]

151. Reeves, John R., El Dorado oil field, Butler county, Kansas. Structure of Typical American Oil Felds, Am. Assoc. Pertoleum Geologists Vol. 2, fig. 3, p. 162, 1929.

152. Shaler, N. S., The geological history of harbors: U. S. Geol. Survey Thirteenth Ann. Rept., pt. 2, pp. 110-114, 1893.

153. Shaler, N. S., op. cit., pp. 112, 189.

FIGURE 7. Sketch of a part of Delaware Bay. (After U. S. Coast and Geodetic Survey Chart 1218.)

"It is easily to be conceived that in . . . a movement of uprising land and downsinking sea floor we necessarily have a neutral or fulcrum point of the motion in the manner indicated by the diagram." (See fig. 8.) "The neutral point, or position of no motion, on a line extending from the interior of the continents to

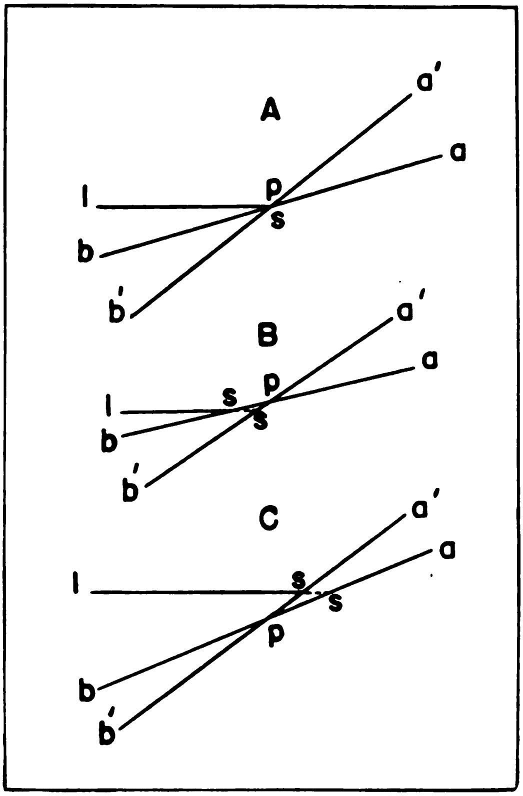

FIGURE 8. Fulcrum point (after Shaler). In A, B and C lines, *ab* represent land before the movement, *a'b'* after the movement; *ss*, position of shore line; *ls*, sea level; *p* pivotal point. A, fulcrum point coincides with position of shore line; B, fulcrum point is on land; C, fulcrum point is seaward. Cut loaned by American Association of Petroleum Geologists.

the areas of the neighboring sea basin, may occupy either of three positions in relation to the shore line. It may be just at the coast (fig. 8, *A*), in which case a good deal of upward and downward movement at either end of the section may take place without any alteration in the position of the shore line, or the pivotal point may be some distance within the land (fig. 8, *B*), in which case the movement may lead to a gain of the sea upon the continent. In the third possible condition the point of no motion may be seaward of the shore (fig. 8, *C*), when, though the nature of the movement may be exactly the same as before, the coast line will rise and the land gain upon the sea."

If, subsequent to the deposition of the offshore bars of the Teeter and Quincy trends, the broad region on the west flank of the Cherokee basin was tilted eastward, the fulcrum point for the movement being east of, or basinward from the west shore, the conditions illustrated in figure 8, *C* must have held. Both shores of the Greenwood county arm of the sea shifted eastward, the western shore migrated seaward and the eastern shore encroached upon the land that lay to the northeast. Because the land areas bordering the Cherokee sea in Kansas were coastal plains only slightly above sea level, and because the water body was probably very shallow, an elevation or depression of only a few feet would shift the shore lines several miles. The shore lines bordering the shoestring sands were shifted only 4 to 10 miles, so that the relative change in elevation that took place is believed to have been very slight. Conditions here may have been similar in some respects to parts of the Texas and Louisiana coast bordering the Gulf of Mexico, which would be inundated 15 or more miles back from the present shore line, if the area were to be depressed 5 feet or less.[154]

The Sallyards-Lamont stage.—After the sea shifted to its new position it again remained stationary for a period of time during which the offshore bars of the Sallyards and Lamont trends were deposited. I have designated this later period the Sallyards-Lamont stage of the Cherokee sea. The new western shore rested on the former sea bottom and so it should have had a simple outline;[155] the new northeastern shore, however, rested upon a former land surface, [156] and so should have had an irregular outline, because a land surface is more irregular than a sea bottom. The offshore bars built along the borders of these newly formed shore lines appear to harmonize with these assumptions. The Sallyards offshore bar system, which bordered the western shore, forms an almost straight-line course for nearly 50 miles, the chief departures being in the form of wide sweeping curves, such as that of the sand body of the Agard oil field in the eastern part of T. 24 S., R. 9 E. In contrast, the arrangement of the sand bodies of the Lamont trend, which bordered

154. Barton, D. C., Surface geology of coastal southeast Texas: Am. Assoc. Petroleum Geologists Bull., vol. 14, p. 1307, fig. 4, 1930.

155. Johnson, D. W., op. cit., pp. 186-187, 1919.

156. Johnson, D. W., op. cit., pp. 172-186, 272-345, 1919.

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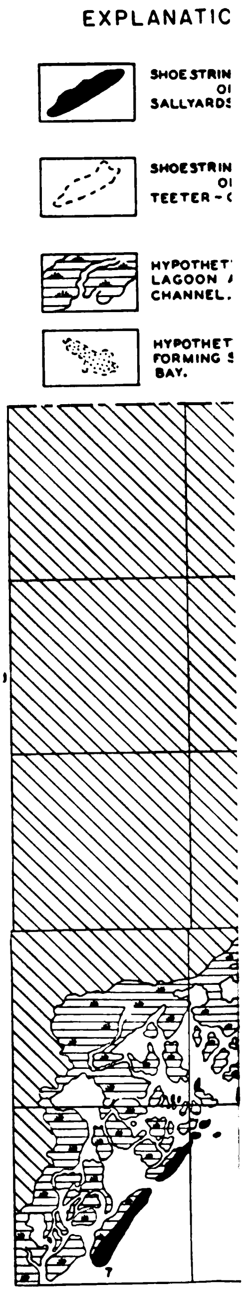

PLATE 21. Hy
Lamont stage of
stages.

the northeastern shore, is the most irregular of any of the shoestring sand trends in the region.

During the Sallyards-Lamont stage the western shore of the sea crossed the northeastern shore line of the earlier Teeter-Quincy stage in the vicinity of the Seeley oil field (pl. 21). It seems probable that the sand body of the Edwards Extension and Seeley fields remained mostly above sea level and projected out into the shallow water as a peninsula. The southeastern extremity of the sand body probably lay below sea level during a part of the Sallyards-Lamont stage. It may be significant that the main part of this large sand body is composed of fine and very fine sand similar to the material in the sand bodies of the Sallyards and Teeter trends, but the southeastern part of the sand body contains an increasing amount of coarse sand. The southeastern part of the Quincy trend must have been far out in the sea, 10 to 15 miles from the new northeast shore and, no doubt, the sand bodies there were below sea level. In this position the waves must have attacked these sand bodies and attempted to destroy them, because they formed irregular promontories on the sea floor. The fine material of the sand bars was readily removed under ordinary weather conditions, but the coarse material no doubt had a tendency to remain, except when subjected to the forces of strong storm waves and currents. Consequently, it does not seem improbable that parts of the old offshore bars that were built here during the Teeter-Quincy stage might have escaped destruction under the new set of conditions. At any rate, it is a fact that numerous sand bodies composed of material that is much coarser than that of most of the large bar-shaped sand bodies in the region have been found by wells in an almost straight line course trending southeastward across the eastern part of Greenwood county. The assumption is that they are remnants of former large offshore bars that were partially destroyed not long after they were built. It is not believed, however, that the abundance of medium and coarse sand in the sand bodies here is due mainly to concentration by the removal of the finer particles subsequent to the formation of the sand bodies. The sand bodies of the Quincy trend were no doubt built originally of much coarser sand than that which forms the greater part of the sand bodies of the other trends.

The sand body of the Atyeo oil field in Tps. 21 and 22 S., Rs. 9 and 10 E., does not appear to fit into this scheme. Its position is outside the trend of the principal systems formed by the other sand bodies; its orientation is at variance with other sand bodies nearby, and it is composed of material that is of much coarser grain than that of the sand bodies near it. As shown on Plate 19, the Atyeo sand body is represented as an elongated bar in a narrow bay, protected from the storm waves of the open sea, but subject to strong tidal currents that must have surged in and out of the bay mouth. Chesapeake Bay, Delaware Bay, and other bays on the Atlantic coast contain numerous sand bars aligned approximately at right angles to the trend of the coast line, but approximately parallel with the trend of the bay, similar to the hyopthetical position shown for the sand body of the Atyeo field. Streams that enter Chesapeake Bay and Delaware Bay are constantly dumping sediment into the bays and the stream and tidal currents sort it and distribute it. Part of the sediment is carried out to sea, but much of it is built into elongated sand bars in the bays, as shown in figure 7, which is a part of the United States Coast and Geodetic Survey chart 1218, showing the Delaware Bay region.

Explanation of certain features of the sand bodies.—If the Seeley-Edwards Extension sand body projected seaward as a narrow peninsula during the Sallyards-Lamont stage, the coast line that lay northwest of it near the present position of the Wick oil field would have been protected from the sweep of southerly winds and so would not have been washed by strong waves. Contrasted with this protected position, the shore at the localities of the Burkett and Thrall sand bodies and elsewhere southward along the Sallyards trend faced a great expanse of open sea where the easterly and southerly winds had a long sweep. These ancient coasts were no doubt similar in many respects to our present coasts, which have well-developed offshore bars bordering the stretches that face the open sea, but few or no bars on the protected parts of the coasts.[157] The facts known about the Greenwood county sand bodies appear to fit the expectations. The sand lenses of the Burkett and Thrall oil fields have typical bar-sharped forms, and they are thick bodies composed almost entirely of sand. The sand body of the Wick field consists of interbedded sand, shale, and sandy shale, and but little could be learned from studies of the well logs about its shape in cross section. The sand body of the Madison field adjacent to the Wick field on the northeast is a thick lens composed almost entirely of sand. Because the locality of the Madison body of sand was removed several miles from the Seeley-Edwards Extension sand body, its shore faced

157. Wilson, A. W. G., Shoreline studies on Lakes Ontario and Erie: Geol. Soc. America Bull., vol. 19, p. 499, 1908.

a broad area of the sea to the east over which the winds were able, no doubt, to generate comparatively large waves.

The main sand body of the Madison oil field trends northeast-southwest through the northeastern part of T. 22 S., R. 11 E., but a narrow prong of oil-bearing sand projects eastward from its south end into secs. 14 and 23, as shown on Plates 1, 11, 20, and 21. Dry holes that found no sand east, south, and southeast of the oil wells fairly well establish the boundaries of the sand body in those directions. The oil well in the NW¼ SE¼ SW¼ sec. 14 found only a thin bed of sand which, with the dry holes farther to the northeast in sec. 14, fairly well defines the east margin of the main sand body and so fixes the north boundary of the eastward trending prong within fairly narrow limits. Considerable speculation has been made concerning the origin of this prong of sand. Examination of coast charts of the Atlantic and Gulf coasts of the United States reveals that features similar to this are fairly common on our modern coasts. They are parts of tidal deltas[158] that are built by the tidal currents as they flow in and out of the tidal inlets between the offshore bars. The inflowing current carries debris into the lagoon and the outgoing current carries sediment seaward. It is only in the narrow part of the inlet where the current is swift that the sediment is freely transported; it is dropped close by where the outgoing current enters the sea and where the incoming current comes in contact with the fairly still water of the lagoon. The greater development is most commonly on the lagoon side, because the waves and longshore currents tend to destroy the delta on the seaward side. If the waves and currents are weak, however, the seaward side may develop prongs of sand projecting seaward on each side of the tidal inlet; such prongs are called spits. Figure 9 shows features bordering offshore bars on the coasts of Alabama and Mississippi that are strikingly similar in plan with the prong on the south end of the sand body of the Madison field.

Recent drilling in secs. 28, 29, 32, and 33, T. 23 S., R. 11 E., south of the Edwards Extension oil field, has shown the presence of a body of sand there, which may be similar in origin to the prong of the Madison body of sand—that is, it may be part of a tidal delta.

Many of the tidal inlets of the offshore bar systems on the Atlantic and Gulf coasts have a double channel separated by a small island of sand; the Hereford inlet near the southeast end of the offshore

158. Johnson, D. W., Shore processes and shore line development, p. 374, New York, John Wiley & Sons, 1919. Davis, W. M., Physical geography, p. 353, 1899.

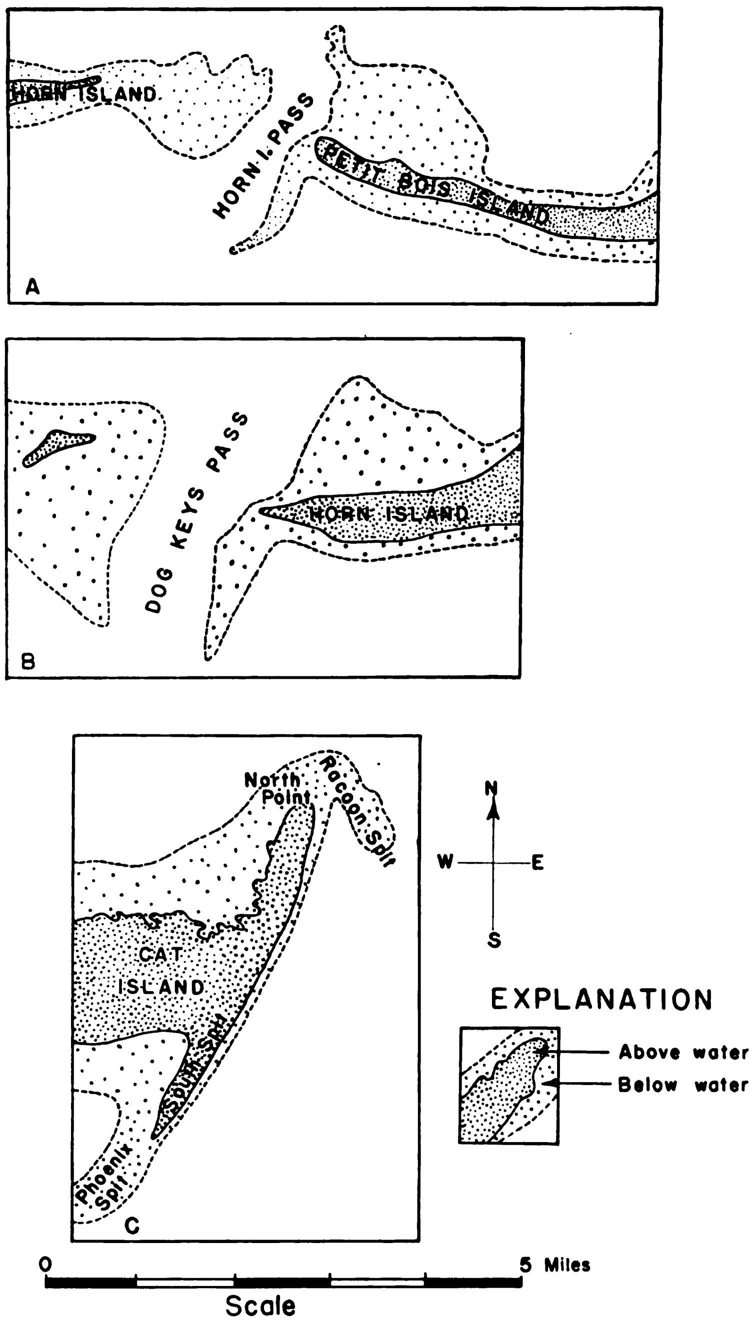

FIGURE 9. *A, B* and *C,* Spits bordering tidal inlets on north coast of Gulf of Mexico. (After U. S. Coast and Geodetic Survey Chart 1267.)

bars bordering the New Jersey coast, shown on Plate 20, illustrates this feature. The small body of sand in sec. 7, T. 23 S., R. 11 E., between the Burkett and Seeley fields, bordered by two narrow areas shown by dry holes to contain no sand, is believed to represent this type of coast feature. The areas containing no sand, of course, represent the old tidal inlet channels, and the sand body represents the island between the channels. The small sand bodies in Tps. 26 and 27 S., R. 8 E., northeast of the Seward field, may be other examples.

Numerous wells near the main sand bodies, but somewhat outside the trend, have found thin beds of sand and a considerable thickness of sandy shale. Many of them have yielded good shows of oil and a very few have produced oil in commercial amount. Wells of this type include: the well in sec. 14, T. 23 S., R. 10 E. (color omitted from pl. 1), half a mile west of the Burkett pool; the well in sec. 22 (color omitted from pl. 1), of the same township, also west of the Burkett pool; the well in the SW¼ SE¼ SE¼ sec. 24, T. 24 S., R. 9 E., east of the Agard pool and surrounded by dry holes, and many others shown on Plate 1. Inspection of charts of our present coastal areas suggests a plausible explanation of these erratic occurrences of sand. Islands of mud and sand occur distributed irregularly through the lagoons between the offshore bars and the land. Water wells drilled on some of these islands along the New Jersey coast are reported to have penetrated sand, muddy sand, and silt.[159] Dredging operations carried on in the lagoonal swamps for opening canals between the thoroughfares are reported to have found the material in some places to be sand in thin layers overlying mud; in others mainly mud or silt, with some sand.[160]

Seaward from the offshore bars the coast charts show low ridges and mounds of sand in many parts of the coast. If the shoestring sand systems represent offshore bar deposits, as seems a logical conclusion, then it should be expected that small, thin sand deposits should occur irregularly distributed through the bodering areas, just as they occur on our present coasts. In most localities the sand possibly has too low porosity to serve as a reservoir for oil, because it contains so large an amount of silt. In some localities a thin bed of fairly clean sand may be oil-bearing. Such deposits are so irregularly distributed on modern coasts that an example filling every conceivable condition with respect to the main sand bodies

159. New Jersey Geol. Survey Ann. Repts.

160. New Jersey Geol. Survey Ann. Rept., p. 43, 1907.

probably could be found on the coast charts. Occurrences of small sand bodies bordering the shoestring sand trends appear to be equally as irregular. The coast charts indicate that fairly large bodies of sand occur in large embayments behind the offshore bars; the irregular shoestring sand bodies in the northeastern part of T. 25 S., R. 8 E., may represent deposits of this type. However, speculation as to the particular type of deposits that the small sand bodies outside the trends represent is about as hazardous as prospecting for them with the drill.

Although the sand recorded in several wells in Lyon county, north of the trends, occurs somewhat above the stratigraphic position of the shoestring sand, the logs of some wells record sand containing water at the horizon of the shoestring sand. Some geologists have interpreted these occurences as representing extensions of the Teeter and Sallyards trends. However, they may represent irregularly distributed deposits of sand that were wind laid or stream laid on the low land that bordered the sea during the Teeter-Quincy and Sallyards-Lamont stages of the Cherokee sea.

Source of the Shoestring Sand Sediments

According to Johnson[161] offshore bars on our modern coasts are built largely by waves which collect material from sediments on the shallow sea bottom. Prior to deposition on the sea floor the sediments no doubt were eroded from the neighboring land and carried to the sea largely by streams. Some of the material of offshore bars commonly is supplied by marine erosion of stretches of the shore that are attacked directly by the waves,[162] but according to Johnson,[163] generally the sediments derived in this manner form a small portion of the total material in the offshore bars.

The most of the bar sediment in many modern bars is of relatively local origin. Colony[164] found that much of the material in the offshore bars that border the Long Island and New Jersey coasts is similar to the rocks that comprise the land sediments of the adjacent regions, which constantly are being eroded and carried onto the shallow sea bottom by the streams. A portion of the sands of the offshore bars migrates slowly along the bars, however, and may

161. Johnson, D. W., Shore processes and shore line development, pp. 365-366, New York, John Wiley & Sons, 1919.

162. Davis, W. M., Geographical Essays, edited by D. W. Johnson, pp. 707-712, 1909.

163. Johnson, D. W., op. cit., pp. 365-366.

164. Colony, R. J., Source of the sands on the south shore of Long Island and on the coast of New Jersey: Jour. Sedimentary Petrology, vol. 2, pp. 150-159, 1932.

finally come to rest far from its source. Martens[165] has shown that grains of feldspar have traveled 400 miles or more southward along the southeastern coast of the United States; and Shaler[166] states that observations from New York to Florida show that beach sands are migrating southward; and again he speaks of "the sand beaches, the debris of which has journeyed great distances from the north."[167]

By analogy it appears probable that the material of the shoestring sand bodies of Greenwood and Butler counties was scoured from the Cherokee sea bottom, near the localities where the sand bodies occur today.

The relative uniformity of the material in the Sallyards, Teeter, and Lamont sand systems indicates that most of the offshore bars of these systems were built from the fine sands concentrated from a sea bottom containing relatively homogeneous material. The pronounced offset relationship of the offshore bars that are developed so uniformly in the Sallyards and Teeter systems strongly indicates that longshore drift of material likely played an important part in the final distribution of the sands. The coarse, well-rounded sand that characterizes the sand bodies for a distance of about 20 miles of the Quincy trend could be accounted for by assuming that a stream which drained parts of the land mass in Lyon, Morris, Geary and adjacent counties entered the Cherokee sea in northeastern Greenwood county; coarse sediment gathered from the land would have been dropped by the stream in a restricted area near the stream's mouth, and later brushed up by the waves and built into offshore bars by the action of waves and longshore currents.

The rounding of the grains of the coarse sand in the Quincy trend could have been accomplished by wave action; it is known that coarse material on modern beaches is generally more rounded than the fine material. It might be argued that the coarse sand was rounded by the wind on the land before it was carried into the sea. Modern coasts are commonly bordered by areas containing sand dunes, and so portions of the Cherokee sea coast were probably bordered by sand dunes. If such were the case, waves and longshore currents which reached the mainland promontories would have cut into the dune sands and distributed the sand along the offshore bars, or streams that crossed a sand dune area would have carried the

165. Martens, J. H. C., Persistence of feldspar in beach sand: Am. Mineralogist, vol. 16, p. 531, 1931.

166. Shaler, N. S., Phenomena of beach and dune sands: Geol. Soc. America Bull., vol. 5, p. 208, 1894..

167. Shaler, N. S., The geological history of harbors: U. S. Geol. Survey Thirteenth Ann. Rept., pt. 2, p. 188, 1893.

dune material into the sea, to be later brushed up by waves onto the bars. However, dune sand[168] is commonly much finer grained than the rounded sand found in the shoestring sand bodies. It appears almost certain, therefore, that the sand grains were rounded by waves rather than by the wind.

The concentration of the coarse material in the sand bodies in part of the Quincy trend may have been accentuated during the second, or Sallyards-Lamont stage, of offshore bar construction, during which time it is believed that these bars stood below the water surface and were undergoing destruction while the offshore bars of the Lamont system were being thrown up near the new shore. The waves that swept across these old bars would have had a tendency to remove the finer material and to concentrate the coarse sand in the deposit that remained.

According to the scheme presented here, after the first offshore bar system was built the sea transgressed northeastward onto the land in northeastern Greenwood county and southeastern Lyon county. Consequently, the offshore bars which were subsequently thrown up bordering this coast might be expected to contain coarse material derived from land promontories that may have reached the sea. The sand bodies of the Sallyards system which were built on the old sea floor might be expected to contain finer sand. It is a fact that the lower part of the sand body of the Shambaugh field in the Lamont trend is reported by oil operators to contain considerable coarse sand that is well rounded; the sand body of the Lamont field contains a higher portion of coarse, well-rounded sand than the sand bodies of the Sallyards and Teeter trends; but the sand body of the Fankhouser field has a lesser portion of coarse, well-rounded sand than those of the other fields in the Lamont trend; it's sand closely resembles the fine sand of the sand bodies in the Sallyards and Teeter trends.

If the sand of the shoestring sand bodies was derived from the Cherokee sea bottom, it must have had its original source in the same localities that supplied the muds of the shale beds that now underlie it. A similarity of composition of the sands in different localities in Greenwood, Butler and Cowley counties, Kansas, and Osage county, Oklahoma,[169] indicates that they had a common source. The heavy minerals isolated from drill cuttings and cores

168. Twenhofel, W. H., Treatise on sedimentation, p. 69. 1932.

169. Bass, N. W., Kennedy, L. E., Dillard, W. R., and Leatherock, Constance, Subsurface geology of Osage county, Oklahoma: U. S. Geol. Survey Press Report 105368, p. 8, January, 1936.

from the shoestring sands in Greenwood county were studied a few years ago by geologists with the Empire Oil & Refining Co.[170] They found like minerals in all the sand trends, which indicates that the sand of all of the shoestring bodies had a common source. Inasmuch as a rather extensive land area probably lay west and northwest of this part of the state in early Cherokee time (sketch map on pl. 1), it doubtless furnished some of the lowermost Cherokee sediments of the western part of the basin, including Greenwood and Butler counties. Material identified by Barwick[171] in well samples of the producing sand of the Atyeo oil field in Tps. 20 and 21 S., Rs. 9 and 10 E., indicates that it was probably derived from Ordovician and Mississippian beds, and the feldspar grains that comprise a small portion of the shoestring sands may have been derived from rocks of the basement complex which were exposed not many miles to the northwest in the Nemaha granite ridge area. The somewhat large portion of feldspar grains in core samples of the sand of the Madison field, which Colony[172] stated occurred in much greater abundance than in the modern offshore bars that border the New Jersey and Long Island coasts may be satisfactorily accounted for: granitic rocks yielding weathered feldspar fragments are believed to have been exposed only a few miles northwest of the old shore lines. It is not surprising that feldspar material reached the coasts in fair abundance; the lack of vigorous wave action, such as the Atlantic coast experiences, would account for the preservation of the feldspar grains. Marine beds in California are reported to contain more than 25 percent feldspar.[173]

A relatively small land mass probably existed on the east side of the Cherokee basin in the region of the present Ozark Mountains of Missouri[174] and shed sediment into the Cherokee basin of Kansas, Missouri and Oklahoma. More remote sources, such as Llanoria, an ancient land mass that lay southeast of Arkansas and, according to Miser,[175] furnished most of the Paleozoic sediments of the Ouachita Mountains and Arkansas Valley region of Arkansas and Oklahoma, probably account for a portion of the Cherokee sediments of

170. Clark, F. T., oral communication.

171. Barwick, J. S., oral communication.

172. Colony, R. J., letter to D. W. Johnson.

173. Reed, R. D., Geology of California: Am. Assoc. Petroleum Geologists, pp. 126-127, 149-150, 243, 1933.

174. Hinds, Henry, and Greene, F. C., The stratigraphy of the Pennsylvanian series in Missouri: Missouri Bur. Geology and Mines, vol. 13, 2d ser., pp. 39-40, 1915.

175. Miser, H. D., Llanoria, the Paleozoic land area in Louisiana and eastern Texas: Am. Jour. Sci., 5th ser., vol. 2, pp. 61-89, 1921. See, also, Moore, R. C., Environment of Pennsylvanian life in North American: Am. Assoc. Petroleum Goelogists Bull., vol. 13, pp. 483-484, 486-487, 1929.

Kansas. It seems likely that in a shallow sea, such as the Cherokee sea is believed to have been, waves and currents distributed the sediments widely. It is probable that some sediment from Ozarkia in Missouri and Llanoria in Louisiana, and perhaps other land areas remotely located, found its way to the western shores of the Kansas part of the Cherokee sea and were mingled with the muds from the nearby lands.

Preservation of the Offshore Bars

As pointed out by Gilbert,[176] shore features are some "of the most perishable of geologic phenomena." Consequently, some unusual combination of favorable conditions would appear to be necessary to permit the preservation of offshore bars. The method of deposition of the shoestring sands proposed that the western margin of the Cherokee basin was elevated subsequent to the deposition of the Teeter and Quincy sand trends. This elevation should have subjected the sand bodies of the Teeter trend to erosion unless they were protected in some manner. The fact that the sand bodies of the Scott, Teeter and Browning oil fields fail to show any erosion features indicates that little or no erosion occurred. The elevation was presumably so slight and so gradual that these earlier offshore bars were actually buried by muds and swamp debris before the sea retreated. The land that bordered the sea is thought to have been an expansive coastal plain and swamp land which stood only a few feet above sea level, where streams were able to accomplish but little erosion. Furthermore, the withdrawal of the sea was not accomplished by deformation alone. The first stage of the seaward migration of the shore was probably brought about by the silting up of the basin margins. The bed of coal, 5 feet thick, that overlies the sand body of the Theta oil pool in T. 22 S., R. 10 E., indicates that the salt-water lagoons were gradually silted up and cut off from the sea, and as the seashore was pushed seaward, fresh-water swamps occupied the old sites of the salt-water marshes.

Incidentally, the coal bed bears evidence of the very long time consumed in the accomplishment of some of the events believed to have taken place in connection with the deposition of the shoestring sands. On the assumption that it required a century to form 1 foot of compressed peat, 3 feet of which were required to form a bed of coal 1 foot thick,[177] the small coal lens above the sand in the Theta

176. Gilbert, G. K., Lake Bonneville: U. S. Geol. Survey Mon. 1, p. 101, 1890.

177. Ashley, G. H., The maximum rate of deposition of coal: Econ. Geology, vol. 2, p. 45, 1907.

oil pool required 1,500 to 2,000 years of plant growth. The time consumed in the accumulation of the vegetation that resulted in this coal lens is but a small part of the period involved in the deposition of the shoestring sand bodies.

There are a number of localities on our modern coasts where old offshore bars are now part of the coastal plain and are bordered on the seaward side by swamps and newer offshore bars; according to Shaler,[178] examples may be seen at many places along the eastern shore of Florida. Shaler[179] described an area on the coast of Massachusetts where an ancient offshore bar lies in the midst of the lagoonal marsh that lies behind a newly formed offshore bar which has been built some distance seaward. Parts of the ancient bar are exposed above the marsh debris, and it forms a disconnected ridge in the midst of the marsh. Shaler's cross section showing the relationship of the old and new offshore bars is reproduced in figure 10.

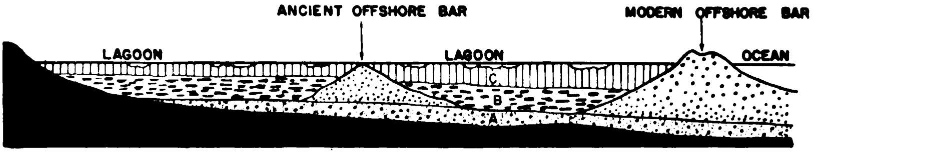

FIGURE 10. Diagrammatic section through Plum Island, Mass. (After N. S. Shaler.) *A,* Sand and gravel; *B,* Eelgrass; *C,* Upper marsh.

In 1935, after preparing this report, I examined an ancient offshore bar that lies landward behind a lagoon and a recently built offshore bar about 11 miles southeast of Wilmington, N. C. A steep-sided canal, which is a part of the intracoastal waterway, has been dredged through the old bar and exposed it in part in cross section. (See U. S. Coast and Geodetic Survey charts 1235 and 425.) The walls of the canal are black, made so by black carbonaceous material that coats the sand grains and partially fills the interstices between the grains. The carbonaceous material was removed from a sample of the sand by heat, and the residue was found to be composed mainly of quartz grains similar to the other beach sand near by.

The few localities cited where offshore bars are being buried and preserved on our modern coasts would appear to establish that under favorable conditions their preservation can be accomplished. The low swampy coastal plain that is believed to have characterized the

178. Shaler, N. S., The geological history of harbors: U. S. Geol. Survey Thirteenth Ann. Rept., p. 187, 1893.

179. Shaler, N. S., Seacoast swamps of the eastern United States: U. S. Geol. Survey Sixth Ann. Rept., p. 382, 1885.

region bordering the Cherokee sea in Kansas appears to have provided conditions that were more favorable for the burial and preservation of shore features than those cited on our modern coasts.

Origin and Accumulation of Oil in the Shoestring Sands

Much has been written concerning the origin and accumulation of oil, and it is beyond the scope of this report to discuss at length the theories advanced or even to cite many references to writings on the subject. Most petroleum geologists are agreed that the preponderance of evidence indicates that oil has evolved by the partial decomposition of plants and animals buried with the sediments, but they differ in their opinions as to whether the oil originated as particles widely disseminated in the sediments, or formed in some abundance in locally restricted areas; wide divergence of opinion exists as to the manner of accumulation, or segregation and concentration of the oil into the reservoir rocks in which it is found today. With essentially the same data at hand, one group of geologists[180] defend the thesis that oil originates elsewhere than at the localities of its present abode and subsequent to its creation has migrated considerable distances through the rocks and has been concentrated locally in porous reservoir beds. The thesis[181] of the other group is, briefly, that the oil found in oil fields originated in the sediments that make up the reservoir rocks or in beds closely associated with them, at or in the very near vicinity of the localities where it is found today. The followers of this school of thought believe that oil has not migrated, except very locally.

The Kansas shoestring sand oil fields may be important "keys" to the correct explanation of the occurrence of oil in at least one type of oil field. The shoestring sands are relatively small lenses of porous beds surrounded by dense, fine-grained shale, which probably forms an effective barrier to fluids that strive to migrate into or out of the porous sand lenses. Chemical analyses of waters from the shoestring sands compared with analyses of water from the "Mississippi lime" 50 to 150 feet below, show marked differences in composition, indicating that there is no communication of liquids in appreciable amounts across the shale beds. Sufficient differences in

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180. Rich, J. L., Moving underground water as a primary cause of the migration and accumulation of oil and gas: Econ. Geology, vol. 16, No. 6, pp. 347-371, 1921; Function of carrier beds in long distance migration of oil: Am. Assoc. Petroleum Geologists Bull., vol. 15, pp. 911-924, 1931; Source and date of accumulation of oil in Granite Ridge pools of Kansas and Oklahoma: idem., vol. 15, pp. 1431-1452, 1931.

181. Clark, F. R., Origin and accumulation of oil. Problems of Petroleum geology. Am. Assoc. Petroleum Geologists, pp. 309-335, 1934.

character of waters[182] from the shoestring sands at localities 25 to 30 miles apart appear to indicate that there is a lack of lateral movement of liquids through the sand lenses, except locally, and certainly indicates a lack of movement from one lens to another. Therefore, the occurrence of oil in the shoestring sand lenses would tend to show that it originated in the sandstone sediments and in the sediments that occur close by, because the few facts available indicate that it has not migrated far through the impermeable shale strata associated with the reservoir beds.

Assuming that the shoestring sands were deposited as offshore bars bordering a sea, the environment in the sites of their deposition should have been favorable for abundant accumulation of probable oil-forming organisms. It is a well-known fact that the lagoons on the landward side of modern offshore bars and the shallow waters on the seaward side contain abundant life. As pointed out by Shaler,[183] the constantly shifting sands and tidal inlets, and the storms that frequently strike the coasts bring about a high mortality of many types of living forms, both animals and plants. The same waves and currents that destroy the life also grind the plant and animal remains on the beaches and bottoms and carry them into shallow waters and the lagoons, where they form a constantly replenished food supply for the abundant life that exists there. The accumulation of sediment goes on here at a fairly rapid rate, insuring quick burial of the abundant remains of the abundant life. Accordingly, insofar as the shoestring sands of Greenwood and Butler counties are concerned, the few data available appear to indicate that the sand bodies were deposited in an environment that was favorable to the occurrence in abundance of plant and animal organisms whose remains might contribute oil to the local sediments. These data indicate that the oil now found in the sand bodies likely originated locally, within a mile or so laterally of its present abode, and within a few feet stratigraphically of the rocks in which it occurs. The data do not indicate that the oil was originally widely disseminated in the Cherokee shale or other formations and later was concentrated in pools by migration laterally through a distance of several miles or vertically through an interval of several hundred feet.

182. Bash, D. A., Empire Oil and Refining Co., oral paper before the Kansas Geological Society, November, 1932.

183. Shaler, N. S., The geological history of harbors. U. S. Geol. Survey 13th. Ann. Rep., Pt. 2, p. 155, 1893.

Possibility of Discovering Additional Shoestring Sand Oil Fields

The oil producer is interested in the interpretation of the origin of the shoestring sand bodies primarily to whatever extent it enables him to discover more oil fields. If studies of the facts revealed by the development of the oil fields indicate the locations of untested areas that are prospectively valuable for oil, they are of very practical worth. Such interpretations are believed to be possible from the study of the shoestring sand oil fields. For instance, it has been shown that buried river channel deposits should exhibit certain characteristics that are in many ways decidedly different from those of coastal features, such as offshore bars. The correct interpretation of the origin of the known sand bodies is accordingly essential to the projection of their trends into undrilled areas, and is particularly important in interpreting the information disclosed by prospect holes that fail to locate a new sand body. A geologist or operator attempting to extend the shoestring sand trends into undeveloped territory will project a circuitous, irregular pattern beyond the known oil fields if he believes that the sands were formed by the filling of stream channels, but will plot approximately straight line projections arranged in an offset pattern if he believes that the sand bodies originated as offshore bars similar to the bars on our modern coasts.

It is reported that more than 75 percent of the present coast lines of the world are fringed with beach sand deposits. On the Atlantic coast, offshore bars form an almost unbroken chain of narrow, elongated islands from the south coast of Long Island to the tip of Florida, and except for a few gaps fringe the coast of the Gulf of Mexico from Florida to beyond the Rio Grande. It takes but little optimism to conclude that offshore bars were formed along the ancient shores of the Cherokee sea for many miles beyond the present known extremities of the shoestring sand trends. It is possible, however, that even though additional offshore bars than those now known were formed, they may not have been preserved.

Shore features are perishable,[184] and it is only under the most favorable set of conditions that they are not destroyed. The physical conditions under which the shoestring sand bodies were buried are perhaps more difficult to reconstruct than those that made possible the deposition of the sand. But it is known that continuous trends of sand bodies throughout a linear distance of more than 50

184. Gilbert, G. K., Lake Bonneville: U. S. Geol. Survey Mon. 1, p. 101, 1890.

miles were preserved. Recent studies of oil-bearing sand bodies in Osage and Kay counties, Oklahoma,[185] 60 to 70 miles south of this area, indicate that they were deposited by a similar method, under like environment, and at about the same time as the shoestring sands of the Butler-Greenwood county region. These facts prove that conditions favorable for the preservation of sand bodies prevailed over a fairly large region in Kansas and Oklahoma and indicate that such environment prevailed elsewhere in the region.

The Sallyards trend has scarcely an interruption throughout its known length of 45 miles, except the few local barren areas between the sand bodies that are believed to represent the former sites of tidal inlets, and so should normally be expected to contain little or no sand. Likewise, the Teeter trend is composed of relatively large, fully developed sand bodies, separated by narrow stretches marking the sites of tidal inlets. The abrupt terminus of the Sallyards trend at the southwest end of the Keighley oil field (sec. 33, T. 27 S., R. 7 E.) and of the Teeter trend at the southwest end of the Scott oil field (sec. 23, T. 23 S., R. 8 E.) appears not to be the natural thing to expect. It is my belief that the Sallyards and Teeter trends will be extended southwestward and the Haverhill trend will be extended southward toward Oklahoma, and it appears probable that they, together with some of the sand bodies in Osage county, Oklahoma, are parts of a continuous shoreline system. There are extensive areas in Cowley county, Kansas, and Kay county, Oklahoma, that lie between the Burbank, Rainbow Bend, Burden and other shoestring sand oil fields that should be thoroughly prospected for sand bodies that likely were deposited there during the Teeter-Quincy and Sallyards-Lamont stages of the Cherokee sea.

Development has shown that the sand bodies in the Quincy and Lamont trends commonly occupy small areas, and so they are difficult to locate. However, the drilling depths are only about 1,500 feet here, and many tests can therefore be made at no great expense. It thus appears reasonable to conclude that additional oil and gas pools in shoestring sand bodies will be found in extensions southeastward from the known Quincy and Lamont sand trends.

The general scheme of a fluctuating inland sea in eastern Kansas which halted, at least twice, sufficiently long to permit shore features, such as offshore bars, to be built, and coal beds of considerable thickness to accumulate in low lands not far removed, suggests that these

185. Bass, N. W., Kennedy, L. E., Dillard, W. R., and Leatherock, Constance, Subsurface geology of Osage county, Oklahoma: U. S. Geol. Survey Press Report 10536, January, 1936.

phenomena were not necessarily limited to two stages; there may have been others. The western shore of the Cherokee sea likely migrated across northern Butler county, between the eastern gentle slope of the Nemaha granite ridge and the Teeter shoestring trend. It is not impossible that at one or more periods the shore remained fixed sufficiently long to permit the waves to throw up a series of offshore bars, which may have been buried by later sediments and preserved. Also, theoretically, one might conjecture further that at the period of formation of the shoestring sands, offshore bars probably formed all along the ancient shores on the west and east sides of the Cherokee sea in Kansas, and that they therefore should be found swinging northward around the old land barrier that extended eastward across Woodson and Allen counties, thence trending northwestward through Franklin and Osage counties, northward through eastern Wabaunsee county, thence northeastward through Shawnee, Jackson and Nemaha counties, possibly into Nebraska.

If I may presume to offer a bit of advice I would like to caution operators to prospect in a projection of an established sand trend; to remember that offshore bars and the developed shoestring sand bodies have an established offset arrangement, and that there are barren gaps between modern offshore bars and between the developed shoestring sand bodies; that the information disclosed by the developed oil fields overwhelmingly indicates that the shoestring sand bodies were deposited as offshore bars and you should therefore expect them to occur in systems or trends that exhibit features strikingly similar to the modern offshore bars on our own Atlantic coast. Features of modern bars are admirably shown by the coast charts of the Atlantic coast between northern New Jersey and southern South Carolina, published by the United States Coast and Geodetic Survey.

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INDEX

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