THE OIL AND GAS RESOURCES OF ANDERSON COUNTY, KANSAS

by

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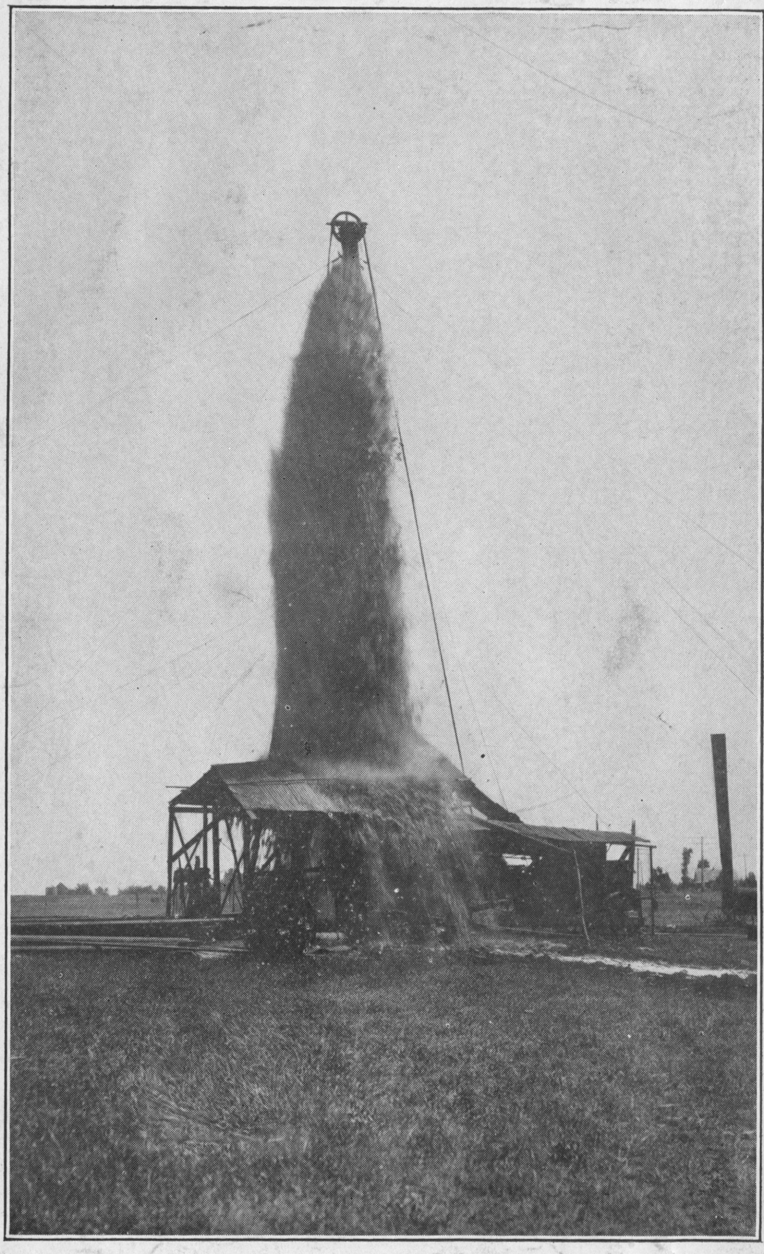
ILLUSTRATIONS.



An Anderson County oil well being shot. Gooch-Denton Petroleum Company's No. 4 Benjamin, Garnett shoestring.

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Introduction.

General statement.

This report on the oil and gas resources of Anderson County, Kansas was prepared from data secured by the writer while engaged in professional geologic work in that county. It is presented to give other geologists and the general public detailed information on some of the shallow oil and gas fields of eastern Kansas, particularly those of the well-known "shoestring" type. These shallow fields are of only slight economic importance as compared with other fields of the Midcontinent region. For this reason and because of the lack of dependency that can be placed on the application in this area of the methods commonly employed for discovering oil and gas, they have received only passing notice from the geologic profession. The same problems of oil accumulation as in Anderson County occur in other parts of the Midcontinent oil fields. However, in these latter places, these problems frequently are not recognized or treated in the proper light due to their minor occurrence and due to the popularity of the anticlinal theory of oil accumulation which is successfully supported in these places by the more general occurrence of the factors necessary for its use. This theory is weakened greatly when applied in regions where the sands have irregular distribution, as in the district covered by this report. The writer hopes that the information presented here will aid in pointing out that in some places sand deposition must be given as weighty consideration as "structure" during a search for oil and gas. Wider recognition of this proposition should lead to a more successful application of geologic methods in certain areas which now are explored or developed with "structure" as the predominating essential condition in mind.

Acknowledgments.

Acknowledgments are made to the many people whose combined contributions of advice and information are represented in this work. Mr. Edgar W. Owen, with whom the writer was associated for two years in the field, is due special credit for reviewing the manuscript and contributing many constructive suggestions and criticisms. Dr. John L. Rich, consulting geologist of Ottawa, Kansas, very kindly furnished helpful ideas induced by his long experience in the "shoestring" fields. Dr. R. C. Moore, head of the department of geology at the University of Kansas and Dr. Kenneth K. Landes, instructor in charge and adviser during the preparation of this thesis, gave valuable assistance in keeping with their positions. The discussions and data furnished by other geologists with whom the writer came in contact served to enlarge his own knowledge of the area treated upon and to make a better written presentation of it than he would have been able to do otherwise.

The writer wishes to thank the State Geological Survey of Kansas for the recognition given this work by including it among its publications, as Part VII of Bulletin 6. This fact accounts for the figures and plates being prints from etchings and halftones rather than ordinary blue prints.

Location and Culture.

Anderson County is in the middle-eastern part of Kansas, approximately 25 miles from the Missouri state line. The county is made up of 576 sections, which form a block 24 miles square.

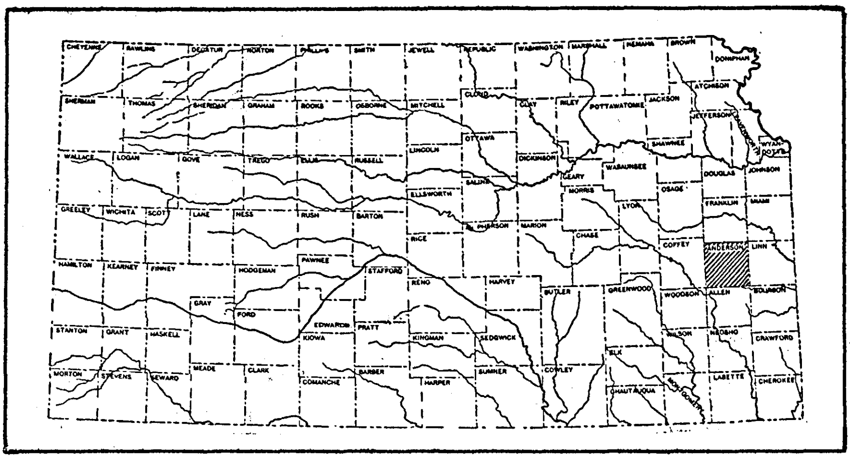


Fig. 1. Index map of Kansas showing location of Anderson County.

Anderson County is devoted primarily to agriculture and stock-raising. The important crops are native hay, corn, wheat, and oats. Pastures and hay meadows comprise large areas of the rougher uplands.

The three principal towns, Garnett, Colony, and Greeley, are within the narrow belt of oil and gas producing territory which extends northeast-southwest through the county. Garnett, the county seat, has a population of about 2500. It is typical of an agricultural rather than an oil district. Colony, in and near which there formerly was large gas production, is a village of about 1000 inhabitants in the southern part of the county. Greeley, another small village, is 10 miles northeast of Garnett.

The Southern Kansas branch of the Atchison, Topeka and Santa Fe Railway extends north-south through the county. The Kansas City-Little Rock line and two minor branches of the Missouri Pacific traverse the county from east to west. The main line of the Missouri, Kansas, and Texas system crosses the southeastern corner.

The highways follow the section lines except where unusual topographic features force them from their direct courses. Clay roads, the predominating type, are kept well-graded and in general good condition when the weather is favorable, but they become uninviting to traffic during the rainy seasons. A few of the main roads have been improved with chert gravel and are readily passable during all seasons.

Topography and Drainage.

Anderson County lies in an area of rather deeply-dissected plains. The chief topographic features are east-facing escarpments and broad intervening slopes. The escarpments are capped by the Iola and Plattsburg-Stanton limestones and hard sandstone members of the Lawrence shale. With many deviations they follow the strike of the rocks. The scarps can be traced for long distances in some parts of the county but in other parts they are covered by clay and gravel and merge into rolling, featureless hills. Less prominent rolling hills are characteristic of the areas underlain by shale. Outliers of resistant beds are numerous. Where the major streams have cut through the hard beds, the valley walls are bluffs 100 to 150 feet high. In the large valleys the streams have developed flood plains and flow in meandering courses across them.

The elevation ranges from 1200 feet at points in the eastern part of the county to 850 feet in the valley of Pottawatomie Creek in the northern part. The average elevation is about 1050 feet.

Pottawatomie Creek is the major stream. It and numerous tributaries which drain the northern two-thirds of the county flow eastward and northeastward and leave the county near the northeastern corner. South Pottawatomie rises two miles east of Welda, flows northward 4 miles, then turns northeast and flows past Garnett to finally enter the main stream a mile northwest of Greeley. Cedar Creek has its source southwest of Welda, flows northeastward, and enters Pottawatomie Creek three miles north of Garnett. The southern part of the county is drained by streams flowing southward and southwestward. All except the larger streams are dry during the summer months.

History of Oil and Gas Development.

The first well put down for oil or gas was drilled about 1885 on the John Neville farm in the SW. $\frac{1}{4}$ sec. 6, T. 20 S., R. 20 E. This well is reported to have had a good showing of oil, but it was not completed as a commercial well because gas was being prospected for at the time. Another of the very early wells was drilled on the Henry Doering farm in the SE. $\frac{1}{4}$ sec. 19, T. 20 S., R. 20 E. It encountered only a small flow of gas and was abandoned at about 500 feet. Only a few scattered wells were put down during the next several years.

The first activity of importance took place after the discovery of gas a mile southeast of Garnett in 1904. Mr. Fred Ball was the operator who opened this field. He sold his interests to the Garnett Gas Company which in turn was taken over by the Garnett Light & Fuel Company. Each of these operators supplied gas to the city of Garnett. As the wells near town became exhausted, prospecting was carried northeastward down the valley of South Pottawatomie Creek. Both oil and gas were found in a narrow, discontinuous belt from Garnett to Greeley. The most recent development in the belt is the gas field discovered one and a half miles south of Greeley in 1923.

The southern part of Anderson County remained unexplored until the summer of 1921. At that time the first gas well was drilled in the Colony gas field. An extensive drilling campaign resulted from this discovery. Within 18 months an unbroken strip of oil and gas producing territory, 12 miles long, was opened from Colony to a point near Mont Ida. In September 1921 the first well of the Garnett oil shoestring came in. This narrow field has been extended westward to a point where the sand contains neither oil, nor gas, nor water. The last but most important field in Anderson County is the Bush City shoestring. The discovery well was brought in during March, 1923. Three and a holf years were occupied in drilling up this trend, which proved to be a rich shoestring extending 14 miles through the county. A few small gas pools were opened up while the major part of the development was taking place.

Many wildcat wells were drilled from 1921 to 1927, the majority of them within four or five miles of the present productive territory. About 2467 wells have been drilled in the county to date (January 1, 1927), of which 816, or 33 per cent, are dry holes; 518, or 21 per cent, are gas wells or abandoned gas wells; and 1133, or 46 per cent, are oil wells or abandoned oil wells.*

*These figures include the wells on the production map accompanying this report (Pl. IX). Shallow gas wells at Greeley and all the the townlot wells at Colony could not be shown. A few of the oldest wells may not be represented, but almost every one drilled during the last five years is accounted for. The percentage data may be considered to be very nearly correct.

STRATIGRAPHY

ROCKS EXPOSED.

The rocks exposed in Anderson County consist chiefly of alternating beds of shale, limestone, and sandstone. They belong to the middle part of the Pennsylvanian system with the exception of deposits of Quaternary age in the stream valleys and some surface gravels of Tertiary (?) age.

Because the regional dip is toward the northwest, the formations crop out in bands having a general northeast-southwest direction. Successively younger beds appear as the county is crossed in the direction of the dip. Escarpments of the limestones extend up the sides of the valleys, enclosing wedge-shaped outcrops of the underlying shales. Surface gravels and geologically recent deposits of clay and sand locally hide the rocks. These combined features furnish many irregularities to the areal geology.

Quaternary system.

Recent series.

Unconsolidated clay, sand, and gravel, laid down during the Recent epoch as slope wash or deposits on the flood plains or beds of streams, are the only representatives of the Quaternary system in Anderson County.

Tertiary (?) system.

Surface gravels, composed chiefly of chert pebbles, form a mantle 0 to 20 feet thick over large areas in southeastern Kansas. Although their position has not been mapped in detail they appear to lie in irregular, broken bands several miles wide. Those in Anderson County are confined almost entirely to the hilltops and ridges. The poor assortment and wide variation in size of the pebbles are striking features. The pebbles are round, subangular, or flat, and most of the angular and flat fragments have rounded edges. Shallow, smooth depressions help make the pieces of gravel irregular in shape. The color is predominantly brown, but the individual fragments may range from clear, white quartz to dark, amber-colored chert. From a position several feet from the face of a pit, one may detect faint traces of bedding in places. The bedding planes cannot be traced far before they merge into unassorted gravel. The beds--more nearly lenses--are made up of pebbles of nearly the same size intermixed with quartz sand ranging from very fine grains to those a quarter of an inch in diameter. Clay occurs in varying amounts. The correct proportion of this clay and sand makes a satisfactory binder when the gravel is used for roads.

The following size analyses from various pits in the county were furnished by Mr. F. T. Bonebrake, County Engineer:

Size analyses of chert gravels in Anderson County, Kansas.

SIZE OPENING		LOCATION				
PASSED	RETAINED ON	SW.¼ 22-20-20	SE.¼ 1-21-19	SW.¼ 12-21-19	SW.¼ 1-22-19	NE.¼ 12-23-18[a]
INCHES						
2	1½	3.3	—	2.2	—	5.0
1½	1	11.0	11.2	14.3	10.4	7.7
1	¾	14.2	12.9	17.3	19.5	8.2
¾	½	22.2	18.7	24.9	25.4	15.6
½	¼	18.8	18.1	18.8	14.9	17.3
¼	—	30.5	39.1	22.5	29.5	46.1
TOTAL PERCENT		100.0	100.0	100.0	99.7	99.9
SILT AND CLAY-LOSS BY WASHING		15.0	20.8	8.5	3.6	10.0[b]

[a] 12-23-18 section-township-range
[b] average

Fossil imprints indicate that the gravel was derived from chert of upper Pennsylvanian or lower Permian age. Limestones of these ages, that contain an abundance of chert, crop out in several counties farther west. In some areas, notably the Flint Hills of Greenwood County, sharp-edged fragments of chert or "flint" have been left after the weathering of their parent limestones.

The rounded edges of the pebbles in the Anderson County gravels seem to justify the conclusion that they have received water transportation, although further rounding may have resulted from solution after the gravel was brought into place. The poor assortment might be accounted for by considerable vertical slump during a long period of weathering.

The age of the rivers that may have spread this material over the southeastern part of the state is uncertain. Later streams, in carving the surface of the land, have cut across the bands of gravel and left remnants of them only in the higher places. Much of the Tertiary of western Kansas is made up of gravels or gravelly sands that are apparently river deposits. The chert gravels of Anderson County may have been distributed by rivers of the same age. They are tentatively assigned to the Tertiary.

Pennsylvanian system.

The Pennsylvanian system is represented among the exposed rocks by most of the Douglas formation, all the Lansing formation, and the upper part of the Kansas City formation.

Douglas formation.

The Douglas formation is made up chiefly of shale and sandstone with an uppermost member consisting of three limestone beds separated by shales, and another limestone member, thin and non-persistent, about a third of the way up from the bottom of the formation. Most of the formation, represented by a thickness of about 300 feet, crop out in the county. Only the lowest bed of its important limestone member crosses the county line, so nearly all the rocks at the surface are shales and sandstones. The Douglas occupies a wide band in the wetern third of the county, the topography of which is flat on the eastern side and made up of sandstone-capped hills on the western side. Comparatively little information is available concerning the formation because most of it is made up of soft, poorly exposed shale and because only about 2 per cent of the wells have been drilled within its outcrop.

Oread limestone member.--The lowest of the three limestone beds of the Oread member forms a high escarpment in the vicinity of Amiot. It is a buff thin-bedded crystalline limestone about 5 feet thick that weathers into small rounded blocks. Among the many fossils, Foraminifera of the genus Fusulina are the most abundant.

Lawrence shale member.--An abundance of arenaceous material, chiefly sandy shale, characterized this member. Sandstones in the Lawrence cap the rolling hills in the western part of the county, holding up the scarps as do the limestone caps in the eastern part, but not as effectively. A thin coal seam is reported to occur in this unit in the vicinity of Westphalia. A few thin limestones are recorded in the log of the only well in the county which was started above the Lawrence. This log shows 193 (?) feet of the member.

Iatan limestone member.--No positive identification of this limestone has been made by the writer. In other localities outside of Anderson County it is thin and rarely forms a prominent outcrop. It is probable that the Iatan is thin in Anderson County and for that reason is not

Geological divisions of Anderson County, and their relation to other rock formations of Kansas.

- Quaternary system.
  - Recent series.
    - Alluvium. (includes sand, gravel and clay deposits along streams in Anderson County.)
  - Pleistocene series.
    - Glacial deposits. (northeastern Kansas)
- Tertiary system. (western Kansas.) (Surface gravels in Anderson County?)
- Cretaceous system. (western and north-central Kansas).
- Comanchean system. (south-central Kansas).
- Permian system. (central Kansas).
- Pennsylvanian system. (eastern Kansas).
  - Missouri group.
    - Wabaunsee formation.
      - Eight limestone and shale members.
    - Shawnee formation.
      - Nine limestone and shale members.
    - Douglas formation.
      - Oread limestone member.
      - Lawrence shale member.
      - Iatan limestone member.
      - Weston shale member.
    - Lansing formation.
      - Stanton limestone member.
      - Vilas shale member.
      - Plattsburg limestone member.
      - Lane shale member.
    - Kansas City formation.
      - Iola limestone member.
      - Chanute shale member.
      - Drum limestone member.
      - Cherryvale shale member.
      - Winterset limestone member.
      - Galesburg shale member.
      - Bethany Falls limestone member
      - Ladore shale member.
      - Hertha limestone member.
  - Des Moines group.
    - Marmaton formation.
      - La Cygne shale member.
      - Lenapah limestone member.
      - Nowata shale member.
      - Altamont limestone member.
      - Bandera shale member.
      - Pawnee limestone member.
      - Labette shale member.
      - Fort Scott limestone member.
    - Cherokee shale.
      - Undifferentiated.
- Mississippian system.
- Devonian and Silurian systems?
- Ordovician system.
- Cambrian system.
- Pre-Cambrian rocks.

Exposed in Anderson County. (Douglas formation through Winterset limestone member)

Not exposed in Kansas. (Devonian and Silurian systems? through Pre-Cambrian rocks) well exposed. Near Westphalia are two yellowish-weathering finely crystalline fossiliferous limestones separated by 3 to 10 feet of shale. Perhaps these beds represent the Iatan member of the Douglas formation.

Weston shale member.--The Weston crops out along the eastern side of the wide shale area between the Oread limestone escarpment and the escarpment of the uppermost limestones in the formation beneath the Douglas. It consists of blue and gray clayey shales containing very little sand. This lack of arenaceous material distinguishes it from the Lawrence shales. The Weston is estimated to be 90 to 100 feet thick.

Lansing formation.

The entire thickness of the Lansing formation, totaling 190 to 260 feet, is exposed and its outcrops occupy a wide band extending northeast-southwest across the central part of the county. About a fourth of the formation, lying near the top, is calcareous. The remainder is made up essentially of shale or sandy shale, a few irregular lentils of sandstone, and local thin limestones.

Stanton limestone member.--The Stanton is made inconspicuous by its occurrence a short distance above the thicker and more massive Plattsburg limestone. The member is 2 to 20 feet thick at the surface but attains greater thickness in the southern and western parts of the county where 35 to 50 feet of it have been logged. The Stanton is thin-bedded, dense, and light gray to white, and weathers into small, thin smooth white to yellowish slabs. Locally it is made up of two limestone divisions, an upper white crystalline bed and a lower dense dark gray bed that is given a porphyritic appearance by protruding crystals of calcite. The two beds are separated by 2 to 4 feet of shale. Where the Stanton is thin, only the upper white bed is present.

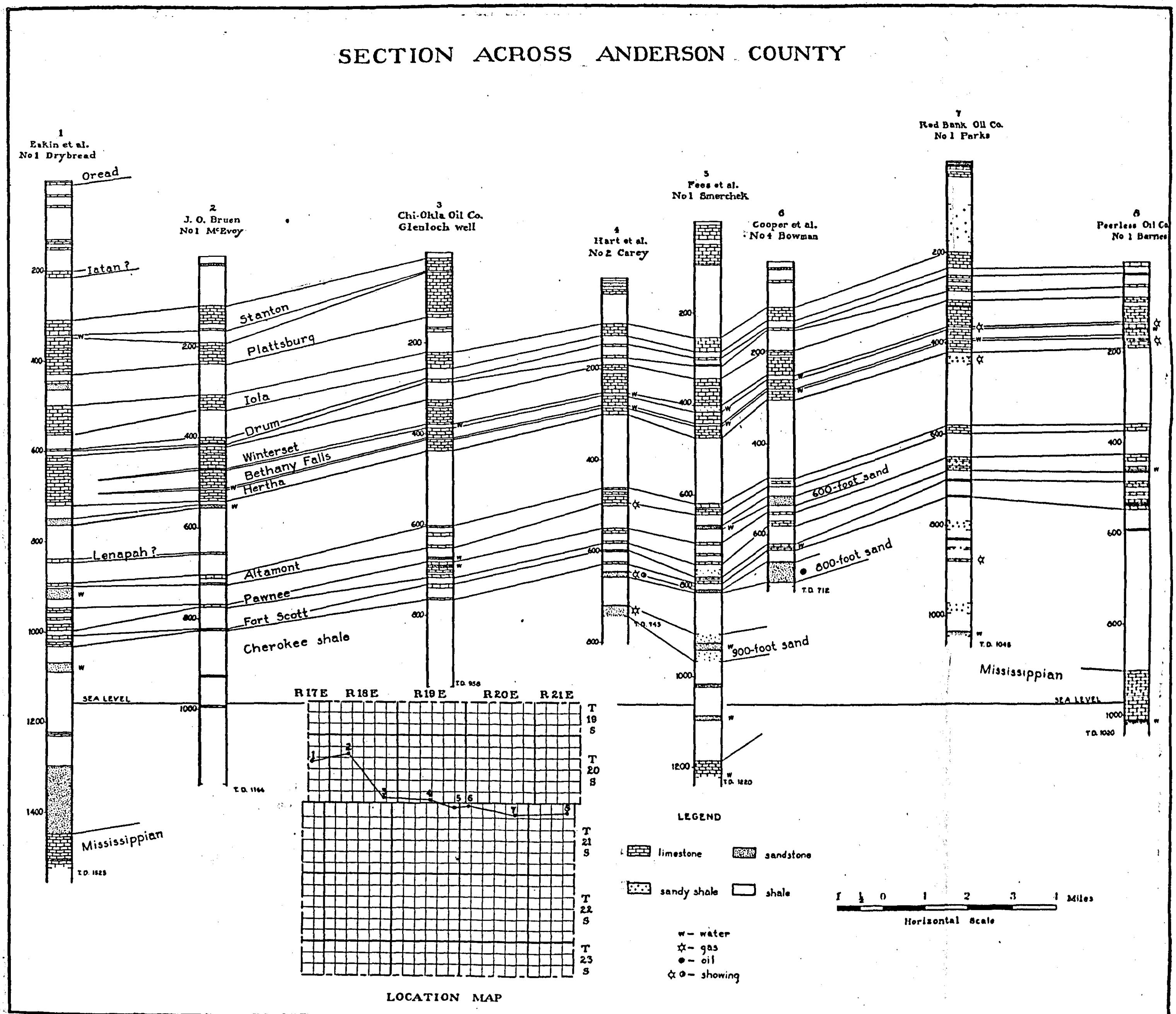

SECTION ACROSS ANDERSON COUNTY
1
Eakin et al.
No 1 Drybread
2
J. O. Bruen
No 1 McEvoy
3
Chi-Okla Oil Co.
Glenloch well
4
Hart et al.
No 2 Carey
5
Fees et al.
No 1 Smerchek
6
Cooper et al.
No 4 Bowman
7
Red Bank Oil Co.
No 1 Parks
8
Peerless Oil Co.
No 1 Barnes
Oread
Iatan ?
Stanton
Plattsburg
Iola
Drum
Winterset
Bethany Falls
Hertha
Lenapah ?
Altamont
Pawnee
Fort Scott
Cherokee shale
600-foot sand
800-foot sand
900-foot sand
Mississippian
SEA LEVEL
R17E
R18E
R19E
R20E
R21E
T 19 S
T 20 S
T 21 S
T 22 S
T 23 S
LOCATION MAP
LEGEND
limestone
sandstone
sandy shale
shale
w - water
gas
oil
showing
Miles
Horizontal Scale

Plate I.

Vilas shale member.--This shale member of the Lansing is much thinner in Anderson County than in its type locality in Wilson County. Its most striking feature is the very abrupt and inconsistent manner in which it thickens and thins, but there is no evidence to show that this condition is due to other than uneven deposition. The thinnest occurrence is in the NE. ¼ sec. 1, T. 21 S., R. 19 E., where 1 foot of shale includes all the member. The greatest thickness is reported from the Colony gas field where 40 feet was logged in several wells. In T. 21 S., R. 20 E. and T. 22 S., R. 20 E. it varies between 9 and 27 feet. No single measurement can be applied over more than a small area. The member is greenish or bluish gray. It is sandy in places and contains some thin lenses of brown sandstone.

Plattsburg limestone member.--This limestone, with the Stanton, from which it is separated by the thin Vilas shale, forms a steep, double escarpment that is continuous for many miles. The escarpment is especially high and prominent along the valleys near Garnett and in the northeastern part of the County. The rolling hills west of Bush City and those in the vicinity of Welda and Colony are capped by these limestones.

The Plattsburg has a variety of lithologic characters which are revealed under the influence of weathering. The sides of its steep escarpments are covered with yellowish-brown fragments scattered several feet below the base of the outcrop. On gentle hillside slopes the limestone occurs as large, smooth, white to dark gray partly-buried slabs. On flat surfaces it commonly weathers into irregular, pitted blocks 2 or 3 inches to 4 feet square. A considerable resemblance exists between the Plattsburg limestone in these latter exposures and the Iola limestone. However, the weathered fragments of the former are smaller and are more easily hidden by vegetation.

Beds of greenish-gray shale, from 1 to 3 feet thick, separate some of the limestone strata. These breaks are not regular in thickness or lateral extent. A common feature is a basal bed of dense limestone 6 inches to 3 feet thick. This bed weathers into brownish-yellow blocks that are used for building stones. In places it is separated from the main member by 1 to 3 feet of greenish-gray shale. Locally, thin chert beds are interbedded with the limestone. The brown chert fragments are mingled with the limestone fragments in the outcrops.

One of the best vertical exposures is in the quarry two miles north of Garnett and just east of the main road to Ottawa. This unweathored 20-foot exposure is made up of massive beds. A majority of them are fine-grained but some are coarse-grained and contain gnarly veins of crystalline calcite. The limestone is grayish-white and sparsely fossiliferous at this place. A thin stratum of gray shale between two of the beds has uneven wavy contacts such as might be made by a current or waves.

The thickness of the member, where observed by the writer, ranges from 8 to 46 feet. It is thinnest in T. 20 S., R. 21 E. and in a general area within a radius of five miles of Greeley. The maximum thickness is in the eastern half of sec. 9, T. 21 S., R. 19 E. According to well records this ~~mmximum~~ thickness observed on the surface is exceeded in the southwestern part of the county, where, in wells at Colony, 60 feet of Plattsburg has been reported. However, it happens frequently that the hard, calcareous sandstone a few feet below the top of the Lane shale, which underlies the Plattsburg member, is logged as a part of the Plattsburg. For this reason the thickness shown in logs may be above the true figure.

This limestone contains many fossils, most of which are well preserved.

Lane shale member.--The Lane consists of gray and greenish-gray shale and sandy shale, lenticular sandstones, and some irregular lenses of limestone. It is 65 to 175 feet thick. The maximum thickness is about a mile north of Garnett in the eastern part of T. 20 S., R. 19 E. and the western part of the adjoining township on the east. From this area it thins toward the east, north, and west. The following table gives the variation in thickness as shown by well records.

Variations in thickness of the Lane shale in Anderson County, Kansas.

Locality	Thickness in feet.
Between Garnett and Bush City	160
Between Bush City, Kincaid, and Lone Elm	140
Between Welda and Colony	110
Near Northcott	100
Near Westphalia	100
Near Harris	70
Near Glenloch	130
Near Central City	90
Near Greeley	65

Nine miles east of Garnett, in secs. 33 and 34, T. 20 S., R. 21 E., both the upper and lower contacts of the Lane may be observed. At this point the thickness is 110 feet.

The best partial section of the Lane member is in the SE. ¼ sec. 33, T. 20 S., R. 20 E., in a bluff formed by the east bank of South Pottawatomie Creek. The section is as follows:

Partial section of the Lane shale in Anderson County, Kansas.
(in descending order.)

	Feet.
1. Grayish, impure fossiliferous limestone which weathers brown.	1

	Feet.
2. Massively bedded, fine-grained calcareous sandstone, resistant to weathering. Some shale breaks 4 inches to 1 foot thick, not persistent laterally. Upper sides of sandstone beds ripple-marked. Reddish-brown blotches on exposed surfaces.	12
3. Very thin-bedded gray sandstone. Splits along bedding planes with exposure of abundance of tiny flakes of mica. Contains plant remains.	4
4. Greenish-gray, sandy shale which weathers readily. In places has flow structure.	20
5. Bluish-gray, poorly bedded, sandy shale. Contains thin beds of calcareous sandstone which form ledges in softer shale.	29
6. Poorly exposed, very sandy gray shale.	47
	113

The following section was measured four and half miles north of Garnett in the NE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 1, T. 20 S., R. 19 E:

Average section of upper part of the Lane shale in Anderson County, Kansas. (in descending order.)

	Feet.
Base of Plattsburg limestone	...
1. Greenish-gray sandy shale.	17
2. Very calcareous sandstone. Upper part massive and fossiliferous. Some thin shale beds in lower part.	6
3. Brown sandstone and gray sandy shale.	2
4. Gray sandy shale.	2
5. Brown sandstone.	1
6. Gray thin-bedded shales.	3
	31

The calcareous sandstone in the above section is generally present at approximately the same horizon over most of Anderson County.

An exceptional feature of the Lane is a large lenticular body of limestone which occupies the middle of the formation in the southwestern quarter of T. 21 S., R. 19 E., in the southeastern part of T. 21 S., R. 18 E., and the northern two-thirds of T. 22 S., R. 19 E. This stray limestone is thickest in secs. 31, 32, and 33, T. 21 S., R. 19 E., where it is 50 feet. One or two shale breaks are in it in this locality. It is described in some of the well records as gray and hard.

Kansas City formation.

The Kansas City formation is represented among the exposed rocks by the Iola limestone, Chanute shale, Drum limestone, Cherryvale shale, and Winterset limestone. The thickness of the exposed section is 125 feet.

Iola limestone member.--The Iola forms the rocky walls of long, narrow, shallow valleys, the slopes of which are covered profusely with irregular limestone fragments. Thin irregular crystalline grayish-white beds predominate, but a few massive beds 1 to 2 feet thick are locally present. Fossils occur sparingly. The Iola maintains a rather uniform thickness of 25 to 35 feet throughout the area of its outcrop in the eastern and southeastern parts of the county. This limestone is better known in Anderson County as a subsurface formation because the line of its outcrop is east of the section in which most of the wells have been drilled.

Chanute shale member.--The Chanute member is a grayish shale which contains local sandy shales and calcareous sandstones. Very thin seams of impure coal and beds of shale containing plant fossils suggest the continental origin of at least part of the member. The thickness of the

Chanute is 10 to 60 feet.

Drum limestone member.--The chief characteristics of this limestone, its numerous and abrupt changes in thickness and composition, are maintained in this county. In one locality the Drum is a single, medium-grained gray fossiliferous limestone, 8 to 10 inch thick. The exposed surface of the bed is light yellow. It breaks off, where undermined by the weathering of the underlying soft shale, into slabs 1 to 4 feet wide and 2 to 8 feet long. The surfaces of the slabs are made irregular by smooth-faced pits and numerous fossil fragments, including shells of brachipods, bryozoans, and crinoid stems. It is probable that the Drum is impure sandy limestone in some plaees. The member varies in thickness from a few inches to 10 feet. If all the strata between and including two thin limestones as shown in well logs are considered to be the Drum, then it is as much as 35 feet thick at its maximum. However, in such cases it is likely that the upper bed is the Drum limestone and the lower bed a calcareous sandstone or sandy limestone member of the Cherryvale shale.

Cherryvale shale member.--The Cherryvale is a light greenish-gray soft clayey shale that is rarely exposed. A few iron-stained bands on weathered vertical exposures indicate that the amount of iron-oxide varies in the different strata. The member is 20 to 35 feet thick.

Winterset limestone member.--This is the oldest formation exposed in Anderson County. It crops out in a few places along the eastern boundary. The Winterset is made up of thin, irregular beds of hard, dense, gray limestone. Weathering has tinged some of the exposed fragments a faint yellow. Fossils are plentiful and chert nodules may be found in the uppermost beds. A massive bench of irregularly-bedded limestone about

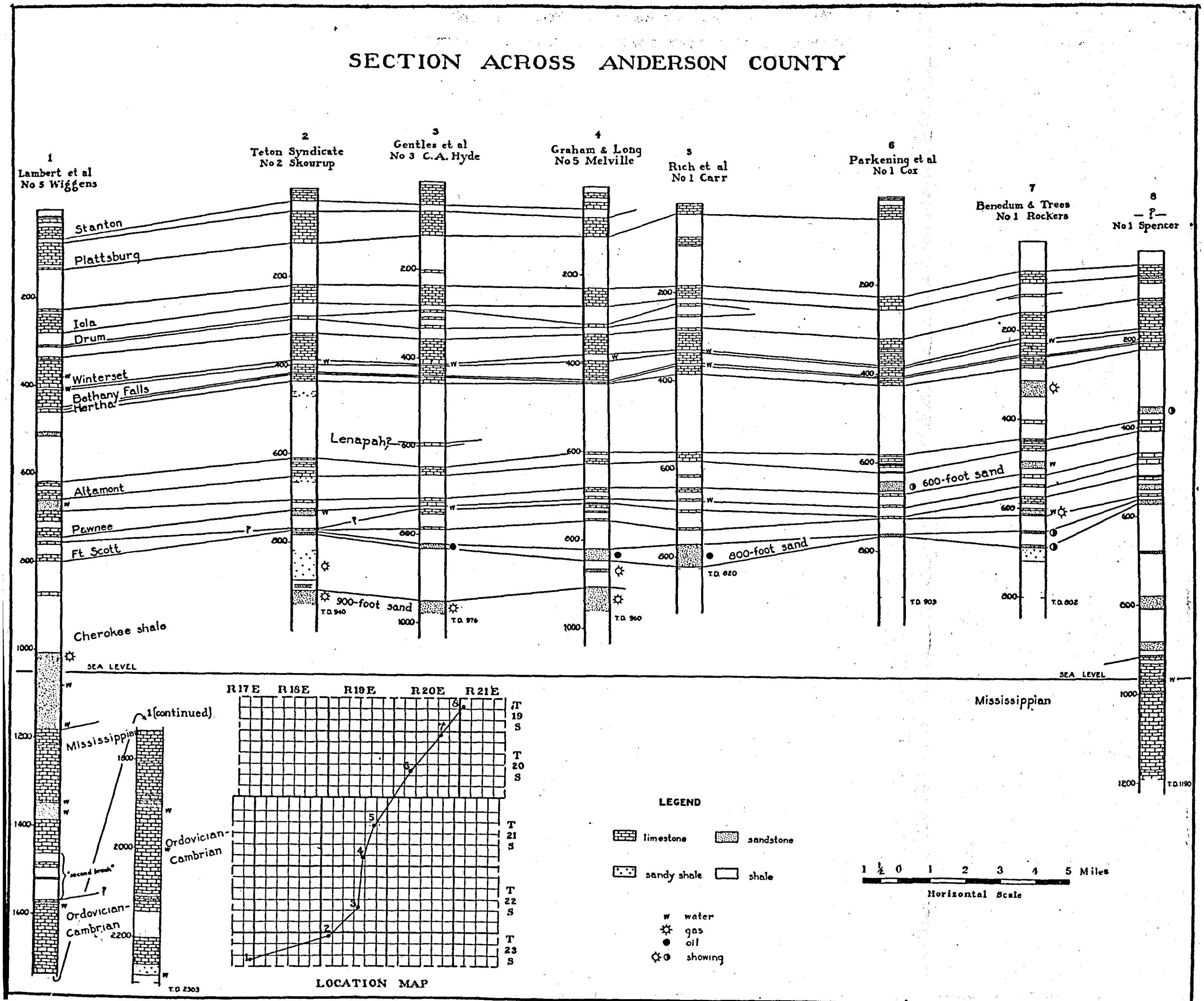

SECTION ACROSS ANDERSON COUNTY
1 Lambert et al No 5 Wiggens
2 Teton Syndicate No 2 Skourup
3 Gentles et al No 3 C.A. Hyde
4 Graham & Long No 5 Melville
5 Rich et al No 1 Carr
6 Parkening et al No 1 Cox
7 Benedum & Trees No 1 Rockers
8 ? No 1 Spencer
Stanton
Plattsburg
Iola
Drum
Winterset
Bethany Falls
Hertha
Lenapah?
Altamont
Pawnee
Ft Scott
Cherokee shale
600-foot sand
800-foot sand
900-foot sand
SEA LEVEL
Mississippian
Ordovician-Cambrian
1 (continued)
"second break"
LOCATION MAP
R17E R18E R19E R20E R21E
T 19 S
T 20 S
T 21 S
T 22 S
T 23 S
LEGEND
limestone
sandstone
sandy shale
shale
w water
gas
oil
showing
1 ½ 0 1 2 3 4 5 Miles
Horizontal Scale

Plate II.

20 feet from the top crops out more prominently than the rest of the member. Large pitted blocks have broken from this bench. The reddish-brown soil immediately above the Winterset is mixed with angular fragments of chert. The thickness ranges from 30 to 40 feet.

ROCKS NOT EXPOSED.

The unexposed rocks of Anderson County range from those of Pennsylvanian age to the oldest rocks known, the Pre-Cambrian. By correlating the formations from other areas, particularly from Oklahoma where the older rocks have been given detailed study, it has become known that some of the major divisions of geologic time are not represented among the unexposed rocks of this district. However, those present, besides the Pennsylvanian and Pre-Cambrian rocks, are parts of at least three systems--the Mississippian, Ordovician, and Cambrian.

Pennsylvanian system.

The buried Pennsylvanian formations continue without a break beneath those described under ROCKS EXPOSED. They comprise part of the Kansas City formation, all the Marmaton formation, and the Cherokee shale. The several members of each of these units are listed in the table on page 11. Because these formations are not available for detailed study, only the major features of each formation, treated as a whole, will be mentioned.

Kansas City formation.

The entire Kansas City formation has a very constant thickness of 200 to 225 feet in Anderson County, of which 60 to 70 per cent are limestones. The uppermost member, the Iola limestone, which, as previously noted, dips beneath the surface in the southeastern part of the county, is the best known of all the unexposed rocks. Because of its uniform occurrence, constant thickness, and easily distinguishable position in the stratigraphic column, it is always recognized by drillers. Sands or water horizons are frequently identified by their position in reference to the top of the Iola limestone.

The lower part of the formation is made up of three massive limestones separated by black, carbonaceous shales, 5 to 15 feet thick. This lower group has a thickness of 100 to 125 feet and, because of the predominance of limestone, is commonly referred to as the "big lime". It includes the following members: Winterset limestone, Galesburg shale, Bethany Falls limestone, Ladore shale, and Hertha limestone. The two shale members of this series are water-bearing.

Marmaton formation.

The Marmaton is made up of alternating limestones and shales, and comprises members from the La Cygne shale to the Fort Scott limestone, inclusive. The thickness varies between 300 and 375 feet. On the basis of lithologic character the Marmaton may be divided into two parts, an upper part consisting of 150 to 175 feet of shale generally free of both sandstone and limestone, and a lower part, 150 to 200 feet thick, containing thin, persistent limestones separated by shales. The large body of shale comprising the upper part of the formation, the "big shale" of drillers and operators, is made up of the La Cygne and Nowata members. The Lenapah limestone, which normally separates them, is absent over most of Anderson County, but it may be represented by a thin limestone recorded in the logs of a few scattered wells. A thin sandstone or sandy shale that is occasionally found in the Nowata shale is at the same horizon as the Peru-Wayside sand of Montgomery and Chautauqua Counties.[7*] In places

*The superior numbers indicate references in the bibliography, p. 109.

a nonpersistent sandstone occurs in the shale (Bandera) beneath the uppermost limestone (Altamont) of the lower part of the Marmaton. This sandstone, referred to as the "600-foot" sand, corresponds to the Weiser sand of southeastern Kansas.[1]

Cherokee shale.

The Cherokee shale in Anderson County is composed of 350 to 450 feet of undifferentiated shale in which are included sandstones of irregular character and extent. Dark blue, dark gray, and black shales predominate, but some light blue, light gray, and white strata are present. Pyrite is a common constituent of some of the beds. Their lithologic character varies considerably, both laterally and vertically. Sandstones and sandy shales are replaced by pure clay shales within short distances.

Most of the sand bodies occur at two horizons in the upper part of the formation, but many lenses of sand and sandy shale are scattered throughout its extent. The larger sand lenses are 80 to 150 feet below the top. Other sand bodies, which have the characteristics of shallow water and river channel deposits, occur 20 to 50 feet below the top. If the origin of the latter is correctly interpreted, the latter part of Cherokee time must have been marked by the emergence*and erosion

*This emergence is not believed by the writer to be of sufficient importance to place the top of the Cherokee formation at the channel horizon, as has been suggested. Probably the Cherokee sea was rather shallow in eastern Kansas as evidenced by shallow-water sand deposits and deposits of coal. Locally the sea withdrew for short periods, during which natural drainage systmes developed. The Anderson County channel deposits are believed to have been formed during one of these periods. Similar channel deposits in Allen and Neosho Counties are 200 feet below the top of the Cherokee. This shows that like conditions took place earlier in Cherokee time. In answer to the suggestion that the channel deposits of the two areas were laid down at the same time and represent a single widespread condition, it is pointed out that it is not justifiable to correlate as the same, deposits only 50 miles apart, separated by such a wide vertical range in a formation having the same thickness at each place.

of the newly formed shales. The thickness of the formation does not vary regularly in any direction. This is due probably to: (1) the shales having been laid down on an unevenly eroded Mississippian floor, (2) the unconformities in the upper part of the formation, (3) the several natural causes for the uneven distribution of muds during deposition.

Mississippian system.

The chief component of the Mississippian rocks is 275 to 325 feet of very hard, crystalline limestone, with characteristic white or light gray color, that is referred to by the operators and drillers as the "Mississippi lime". The top of this limestone ranges in depth from about 900 feet in the southeastern part of the county to 1400 feet in the northwestern part, as effected by the dip and topography. Large amounts of chert occur, especially in the upper part. A very irregular zone of sand or sandy limestone, 0 to 50 feet in thickness, normally is present 5 to 40 feet below the top of the formation. This zone is widely distributed over eastern Kansas and northeastern Oklahoma and is popularly called the "first break" in the "Mississippi lime". The rocks of Mississippian age in Anderson County are a continuation of those which crop out in the extreme southeastern corner of the state. They form the Boone limestone which is believed to belong to the Warsaw division.[2]

Mississippian (?) system.

A short stratigraphic unit composed chiefly of shale which underlies the thick Mississippian limestone in eastern Kansas is called the "second break" in the "Mississippi lime". The upper part of the unit in Anderson County consists of 30 to 40 feet of blue shale underlain by 10 feet of brownish-gray limestone. In view of the fact that a locally occuring deposit below these strata has been classified as of Mississippian age, it appears that the limestone and blue shale are also of that age.*

Forty feet of black shale make up the lower part of the "second break" in the southwestern part of the county. A part of this shale may be represented at the same horizon in the remainder of the county, but it has not been identified, due to the lack of samples and proper descriptions in the logs. This black shale has been correlated tentatively with the Chattanooga of Oklahoma and Missouri, which is considered now to be of lower Mississippian age rather than of Devonian age.[3]

Ordovician and Cambrian systems.

A thick series of limestones and dolomitic limestones with a few intercalated beds of shale are the representatives of the Ordovician and Cambrian systems in eastern Kansas. Only a general idea is had of the character or thickness of these strata beneath Anderson County because no well has completely penetrated them. The deepest one of which a record has been obtained was drilled into them 1125 feet. A well at Iola, 10 miles south of Anderson County, was drilled through 2200 feet of them without reaching the basement igneous rocks. The top of the Ordovician-Cambrian series is nearly flat and probably is a nearly base-leveled land surface that has been made porous by weathering. It invariably holds water in this part of Kansas. However, it is worthy of mention that small oil and gas pools occur in this zone in southeastern Kansas, where many more deep tests have been drilled than in Anderson County. Deep wells in Wilson and Woodson Counties have shown that 25 to 125 feet of arkosic sandstone is between the Cambrian limestones and the granitic

*Samples of this limestone and shale submitted to the geological department of the Atlantic Oil Producing Company, Tulsa, Okla. were identified as of Kinderhook age.

rocks of Pre-Cambrian age. This sandstone may be expected to continue across Anderson County.

Pre-Cambrian rocks.

The oldest rocks beneath the surface comprise the "basement complex" on which all the later formations have been deposited. These basal rocks have not been reached by the drill in this county and probably lie at a depth below 3000 feet. Where they have been encountered in adjoining counties they consist mainly of schists and granites. Rocks of the same type, and very likely of about the same age, crop out in the mountain ranges which border the Midcontinent region. Some of these ranges are the Arbuckle and Wichita Mountains of Oklahoma, the Rocky Mountains of Colorado and adjoining states, and the Black Hills of South Dakota.

STRUCTURE

Regional Structure.

The regional structure of eastern Kansas was developed in post-Paleozoic time. It resulted from an uplift which had its center in the Ozark region of southwestern Missouri. The strata were tilted in such a manner that they now dip northwestward at the rate of 15 to 20 feet per mile. The great number of variations from the general dip include most of the common structural forms, such as anticlines, synclines, domes, and terraces.

Local Structure.

The structure of the formations was determined by obtaining the elevations of the surface beds at many scattered points or by finding the elevation of some readily-recognized bed penetrated by drilling, the elevation of the wells having previously been secured. The horizon used most often for the study of the subsurface structure is the top of the Iola limestone. The Iola is a very easily-recognized formation of uniform occurrence, and nearly all the wells were started above it.

Typical structures in the county which at present have no production on them, and structures which are productive only because of the coincidental occurrence of oil or gas under portions of them will be described here. The others will be described in the discussion of the fields in which they are located.

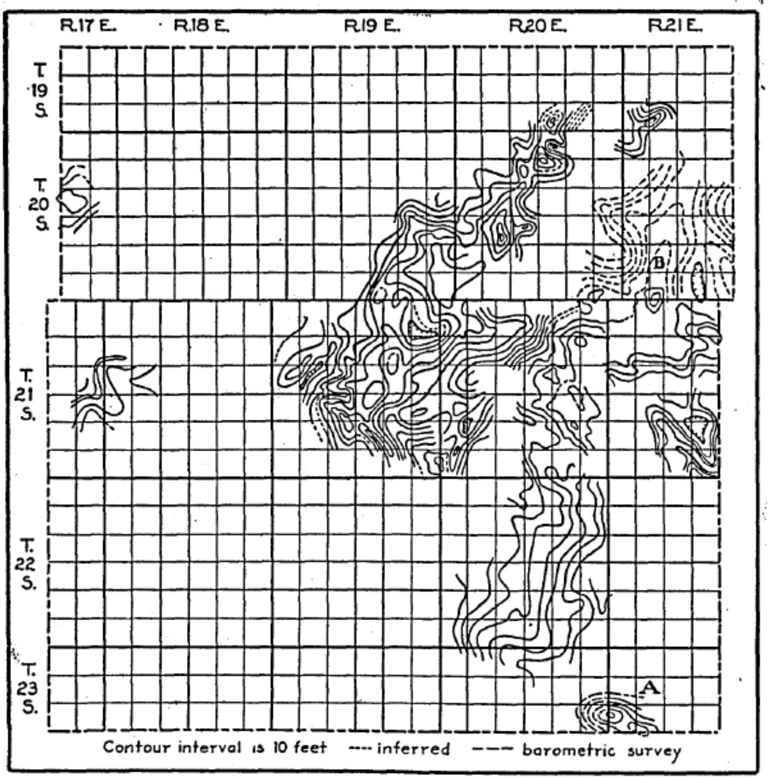


Fig. 2. Surface structural map of Anderson County. Contours are drawn chiefly on the Iola and Plattsburg limestones. "A" is believed to be a structure caused by folding; "B", a structure caused by thinning of a shale member beneath the limestone used for datum. The regional dip is toward the northwest.

An anticline in the southwestern part of T. 20 S., R. 21 E. is the largest in the county. Its major axis extends from the southwest corner of sec. 16, T. 20 S., R. 21 E. to the middle of sec. 5, T. 21 S., R. 21 E., a distance of three and a half miles. The southern end of the structure terminates in a dome with a closure of 20 feet. A structural nose which projects northwestward from this anticline covers parts of secs. 18 and 19, T. 20 S., R. 21 E. and secs. 13 and 24, T. 20 S., R. 20 E. The Bush City shoestring field touches the southeastern flank of this structure in the NW. ¼ sec. 4, T. 21 S., R. 21 E. A very narrow gas pool has been opened in the SW. ¼ sec. 16, T. 20 S., R. 21 E. and vicinity. Another narrow shoestring of gas wells, about three-fourths of a mile long, extends from the NE. ¼ NE. ¼ sec. 5, T. 21 S., R. 21 E. to the middle of sec. 32, T. 20 S., R. 21 E., It parallels and is slightly east of the major axis of the dome described as terminating the large anticline on the south. Numerous dry holes have been drilled on this anticline. With the exception of those in the productive areas mentioned, few of them found more than 5 to 10 feet of sand. A dry hole in the SW. ¼ SE. ¼ sec. 13, T. 20 S., R. 20 E. had a showing of heavy oil in sand from 755 to 766 feet. Two dry holes that reached the Mississippian limestone are reported to have had only 5 feet of sand, and that was immediately on top of the "lime".

Along the west flank of the productive area between Garnett and Greeley is a series of small domes and anticlines separated by basins and synclines. The largest anticline, which has a closure of 30 feet, is in secs. 17, 20, and 29, T. 20 S., R. 20 E., a mile northeast of Garnett. The major axis extends north-south. Two dry holes have been drilled near the top and two on the south flank. The hole in the

NW. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 20 encountered sand from 642 to 663 feet that held a small amount of oil. More sand was logged from 760 to 765 feet.

A structure with closure of about 20 feet lies just west of Garnett in secs. 24, 25, 35, and 36, T. 20 S., R. 19 E. Its flanks dip gently from the apex in the N. $\frac{1}{2}$ sec. 36. Several dry holes have tested the structure.

An almost circular dome about a mile in diameter and with a closure of 20 to 30 feet has its apex in the northeast corner of sec. 11, R. 21 S., R. 20 E. A dry hole in the southwest corner of sec. 2 was drilled to 1045 feet and found only a few feet of "dry" sand.

Two and a half miles south of Kincaid and on the southern edge of the county is a very pronounced structure known as the Mildred dome. Its axis is oriented about N. 65° W. The steep-dipping flanks form a closure of at least 30 feet. Among the four dry holes on the dome is one in the southwest corner of the NW. $\frac{1}{4}$ sec. 18, T. 23 S., R. 21 E. that was drilled to the "second break" in the "Mississippi lime". The hole filled with sulphur water at 1232 feet. The three other wells had showing of heavy oil in the cherty zone on top of the Mississippian limestone.

Origin of the local structure.

The origin of the minor structural features of Anderson County must be attributed to agencies which cause structures that are irregular in size and shape, which have no regular arrangement, and whose axes extend in no single general direction. The following agencies have been considered: (1) direct lateral compression, (2) uneven compaction, (3) uneven deposition, (4) folding influenced by sand bodies,

(5) folding caused by readjustments in the deep, competent rocks.

Direct lateral compression.--Until recently, the theory of direct lateral compression was a favorite for explaining the origin of folds in sedimentary strata. Now, however, it has come to be realized that lateral stresses are not transmitted long distances through relatively thin vertical sections of incompetent beds, such as thin limestones and shales. The competent beds of Anderson County are considered to include those below the Pennsylvanian formations. The rocks older than the Pennsylvanian are massive limestones and dolomites which rest upon a basement of very dense, hard crystallines. The Pennsylvanian strata are chiefly shales, separated by thin limestones, which, in their separate state, are mere shells in a general incompetent mass.

In examining the possibility of the formation of Anderson County folds by direct lateral compression, points of origin of the forces necessary to create them must be sought. The logical places to look for these forces are in the areas of disturbance nearest this district. These are found in the Ozark Mountains of southeastern Missouri and the Ouachita, Arbuckle, and Wichita Mountains of Arkansas and Oklahoma. The Ozark region was not the seat of sufficient force to wrinkle the rocks far from its borders.[4] Sharp folding occurs in the competent beds about the Ouachita-Arbuckle-Wichita group of uplifts, but these folds die out in a comparatively short distance. The folds of central and northern Oklahoma and south-central Kansas are smaller, have different shapes, and have different orientation than those which might be caused by lateral pressure exerted directly from the mountainous regions. Anderson County is at least 200 miles from any of the areas of disturbance mentioned. It may be stated with certainty that incompetent beds would not be thrown into compressional folds at this distance by forces of the size shown to have been in operation. If the deep competent beds had been thrown into compressional folds, the surface strata should conform with them, because they rest like a blanket on the firmer crystallines and are subject to all changes in elevation that appear in the latter.

Uneven compaction.--Practically all sedimentary deposits undergo compaction after they are laid down. Many writers have discussed this subject on both its theoretical and practical sides. The latest and one of the best discussions, and one based on laboratory experiments, is by Hedberg,[5] who shows by quantitative studies that the amount of compaction of shale is related closely to the weight of overburden. Compaction, chiefly of muds, is most likely to show its effects over uneven land surfaces or over isolated sand bodies. According to evidence already accumulated from various sources, shales and their interbedded strata dip over old topography in conformity with the slopes of the buried surface, but at a lesser rate. The dips are from the high points, or hills, where the blanket of sediments is thinner and where total consolidation is less, toward the lower points, or valleys, where there is relatively more consolidation of the thicker sediments.

When the practical worker attempts to test this theory, he generally finds that its strength depends mostly on these conditions: (1) the amount and sharpness of relief of the buried surface, (2) the thickness of overlying sediments (No doubt, these sediments should preferably be strata which at one time were deeply buried, but now, because of erosion, are now the small remaining portion of a once thick series), (3) a factor that is not directly associated with geology, but one to which the practical geologist is forced to give due recognition--the accuracy of well records.

For obvious reasons it can be understood why it is desireable that there be a relatively thin cover of sediments over the buried topography. The chief reason is that the effects of differential compaction become less apparent as the upward interval increases. Since the weight of overburden is an important cause of the amount of compaction, a condition favorable to the expected results of this process would provide for a remaining relatively thin cover of argillaceous sediments which had undergone the limit of gravitational compaction.

When a thick cover of sediments is involved, there can be less expectation of finding dips that resulted from compaction, not only because these dips must necessarily become more gentle away from the buried surface, but also because the factor of time is brought in. As time goes on, the likelihood of the dips remaining essentially as formed or reaching their extreme inclination would be lessened due to the increasing opportunities for the introduction of other geologic processes, such as the uneven deposition of sediments, the creation of unconformities, the deposition of sediments that varied laterally in character, and true folding, which, taken collectively, are as common (and generally more pronounced in their effects) as the process under consideration.

The examination of this theory depends largely on subsurface studies which in turn are dependent on well records. The laymen who make these records invariably lack the personal interest in such duties that would insure accurate data. This circumstance is a tremendous handicap to the investigator and retards greatly the examination of the problem at hand, as well as many other problems.

The irregular surface of the Mississippian limestone is very attractive for the application of the theory of gravitational compaction to explain some of the structural features of eastern Kansas. Wells drilled to the "lime" show that the Mississippian floor beneath Anderson County has a gentle relief, like that of a land surface in the cycle of old age. The presence of sharp ridges, fault scarps, or steep-sided valleys is not suggested. It is believed that the relief amounts to no more than 125 feet. At one place a dip of 90 feet in a mile occurs, which is very much above the average in the county. The cross section in Plate III includes an area where the greatest amount of relief has been found. No conclusive evidence of reflection of the Mississippian erosional surface in the upper strata is furnished by this section. The writer thinkd that differential settling over the uneven surface of the Mississippian limestone is responsible for only a few of the surface dips in this area, and that it has produced only those dips of a gentle type that would not be likely to attract attention.

The occurrence of different kinds of deposits at the same stratigraphic horizon may cause dips when consolidation has taken place. Because sand consolidates less than shale, the upper surface of a sand body would undergo less vertical subsidence than the surface of an equal thickness of shale on the sides. The shale would dip away from the sand and the strata above would be inclined by the same settling process. Mindful of this settling, geologists have undertaken to determine favorable places to drill in regions of scattered sand deposits by making surveys of the surface rocks. Their primary purpose in such cases is not to find places structurally favorable for the <u>accumulation</u> of oil or gas--in the general sense of the word--but to discover sand bodies--reservoirs in

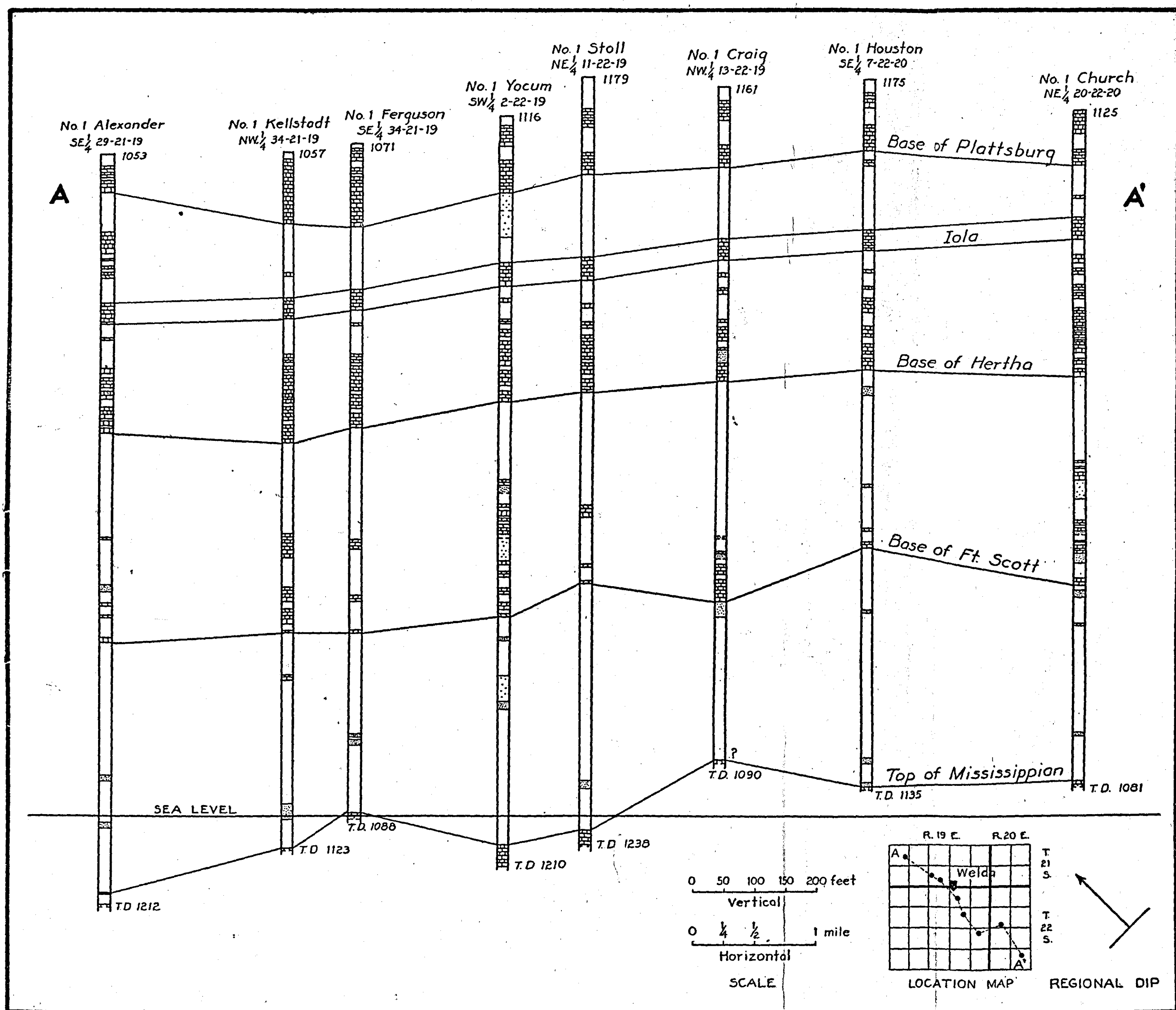


Plate III. A section to show the lack of effect of compaction over the Mississippian rocks on the attitude of the Pennsylvanian sediments. The section also demonstrates the inaccuracy of the part of the logs which includes the Marmaton formation.

in which commercial deposits of petroleum or natural gas commonly collect.

The quality of the sand in Anderson County is a drawback to the uneven compaction theory as used to discover or trace sand bodies. The sand is very fine-grained. Portions of it are so fine as to be silty. Lenses of shales are included in many places. These characteristics induce compaction more nearly equal to that of clean shale than a clean, coarse-grained quartz-sand and, therefore, would tend to lessen the relief in the overlying sediments. The structure which supports this theory best is the anticline northwest of Welda occupied by the Polkinghorn gas field. This fold, for which the sand body may be responsible, is long and narrow, occurs directly over the sand, and its major axis parallels the trend of the sand. However, a somewhat similar structure, only a short distance east of the productive one and having the same orientation, has no sand under it. Moreover, the latter fades into normal dip where the sand is near its maximum thickness.

Folding influenced by sand bodies.--The belief that sand bodies influence folding is an outgrowth of the differential settling theory. It is argued that the beds of shale at the sides of the sand body have an inclination away from it caused by differential settling between the sand and shale. With this initial inclination as an aid, horizontal forces would cause folding to take place over the foreign body in the shale. The horizontal forces called upon by this theory are supplied by movements in the competent basement-rocks. Thin or very narrow sand deposits, such as beach or shallow water sands or channel fillings, probably would not influence the conversion of lateral stresses into vertical ones. Sandbars, which have greater thickness in proportion to their width than the other kinds of sand deposits, might exercise an influence. Strong objections to this theory are that (1) the dips of the strata on the sides of the sand would not be steep enough to invite folding, (2) no horizontal forces would be in effect at the horizon of the sand deposits, but only in the deeper rocks--the deeper folding would be in control and the upper beds would be bent without regard for the type of sediments they contained.

Uneven deposition.--Uneven deposition is considered by the writer to be an important cause of some of the abnormal dips in Anderson County. Both the shale and limestone members of the Lansing formation very considerably in thickness and some of the other Pennsylvanian rocks change in thickness, though not as radically as those of the Lansing. No unconformities are noticeable in the surface formations. (See descriptions of members of the Lansing formation, pp. 12-17.)

The uneven deposition of shale may be caused by: (1) varying distances from the source of supply, (2) variations in the rate of supply of the sediments, (3) variations in the velocity of the transporting agent, (4) the unloading of material into a common area from more than one direction, (5) irregular distribution of the sediments by currents and waves.

When sediments are brought into a quiet sea at a constant rate by a single stream, a lenticular deposit is formed which thins radially from its thickest portion near the shore. When the amount of material is decreased, the size of the deposit is decreased, probably most noticeably in the vertical dimension. When the velocity of the transporting agent is slowed up, the limits to which the material is carried are drawn in. If more than one transporting agent brings material to a place of deposition, the shape of the deposited loads has additional irregularities due to the interfingering or overlapping of sediments. Currents probably play an important role in the final disposition of muds by taking the loads dropped

by the

by the rivers and carrying them long distances to redistribute them. The sediment is scoured from some postions of the ocean floor and dropped at other points where the currents are checked or deflected. The result of all these conditions is a formation of uneven thickness.

When a limestone is laid down on a gently sloping surface, such as that of a layer of mud, the limestone conforms itself to the relief of the mud, because it is deposited in the manner of a precipitate. After consolidation, the limestone has an inclination resembling that caused by folding. In many places in Anderson County the Plattsburg limestone and Stanton limestone have dips that are traceable to changes in thickness of the Lane and Vilas shales. Such dips, when opposed to the regional dip, form "pseudo-structures". They are depositional features rather than true structural features and hold no significance in the search for oil and gas pools.

One broad anticline in the county has 50 feet of reverse dip as mapped on the base of the Plattsburg limestone but at least 40 feet of this dip may be accounted for by the thinning of the Lane shales from 150 to 110 feet.

Folding caused by readjustments in the deep, competent rocks.--Some of the structures may have been formed as the result of readjustments in the deep, competent rocks. It has been observed that the more prominent ones, those with relatively steeper dips, have about the same orientation--N. 30°-45° W. In Oklahoma there are systems of folds and faults arranged *en echelon*. Merritt and McDonald[4] have explained the origin of these as the result of rotational stresses transmitted to the overlying incompetent rocks by shearing in the crystallines, giving rise to compressional anticlines and tension faults. It seems doubtful whether the same thrusts that caused the warpings and faults in Oklahoma were responsible for those in this part of Kansas. The scattered folds here that may be segregated into systems are fewer and have more variations in shape than the Oklahoma folds. Faults are very scarse and of inconsequential displacement. However, the fact that the folds decrease in sharpness and numbers and the faults become less numerous as they are followed northward, lends a faint suggestion that the same thrusting effect, originating somewhere in the southern Oklahoma region, was in play.

Moore[6] has concluded that the "granite ridge" of central Kansas was formed by up-faulting in Pre-Mississippian time, probably in the early part of the Paleozoic era. If movements of such magnitude were in play, their effect in the way of smaller movements can be expected to have reached as far east as the Anderson County area, 75 miles away. Movements along the lines of weakness created in earlier geologic time were renewed in later Paleozoic time, and perhaps in other eras.

The writer is not prepared to say whether these deep-seated disturbances were of the "stress and strain" type that account for the Oklahoma folds, or were faults that fade into folds in the softer rocks near the surface. It is concluded, however, that some such deep-seated regional forces were involved in forming the true folds of this district.

Few data are available on the attitude of the deep rocks in eastern Kansas because only one well in several hundred has been drilled below the Mississippian limestone. A better understanding of conditions in the older rocks might furnish an interpretation of how the structures were formed.

In summary, the abnormal dips of the strata in Anderson County are believed to have been caused chiefly by thickening and thinning of the Pennsylvanian sediments, especially the members of the Lansing formation, and by readjustments in the deep, competent rocks. Differential settling over the Mississippian floor may be responsible for some of the very gentle dips. The writer recognizes the plausibility of the uneven compaction theory but has not found sufficient evidence to convince him that the reflection of subsurface features in this district can be traced upward as far as the formations now exposed.

ACCUMULATION OF OIL AND GAS.

General conditions.

Oil and gas fields in areas of sheet sands have a close relationship to the structure of the rocks. Where the sand contains water, the oil and gas are on top of the water in the highest places in the reservoir. They become concentrated in the traps formed by the flattening or reversal of the dip of the rocks. Anticlines, domes, noses, and terraces are the most favorable types of structure on which to drill. Oil may settle into synclines or basins where no water occupies the porous stratem. Where the reservoir is partially water-filled, the oil rests on the surface of the water where it reaches up the flanks of the structure. This theory of the arrangement of gas, oil, and water, according to density, is known as the anticlinal, or structural theory. It is one of the basic principles which guides the petroleum geologist in his searches.

Not all wildcat wells located on structures are successful. The failures can be accounted for by the absnece of one or more of the conditions whose collective effects are necessary to insure the successful application of the structural theory. Some of the reasons test wells are dry are: (1) the oil may never have been formed in the area being explored, (2) the absence of a suitable reservoir rock, (3) the lack of an impervious roof over the sand, such as a water-wet shale or a limestone, (4) the lack of sufficient pore space to allow the gas, oil, and water to undergo gravitational separation, (5) the presence of avenues of escape for the oil, furnished by faults, or by exposure of the oil sand by erosion, (6) the surface structure is not a true reflection of the structure of the rocks in which the oil is expected, (7) drilling may not have been carried to a sufficient depth, (8) heat furnished by igneous intrusions or the metamorphic action induded by sharp folding may have destroyed the oil, (9) the structure may have been flushed free of its oil by circulating water.

Conditions in Anderson County.

The structural theory of accumulation has only limited application in Anderson County because: (1) the sand have very scattered distribution, (2) the principal oil-bearing sand does not contain water, (3) the structure of the surface rocks is not always an indication of the structure below the surface.

The theory may be used with more confidence when dealing with the possible producing horizons in or below the Mississippian limestone. Conditions there warrant its application because the sands in these lower horizons are quite widespread and contain water. As yet, they have not been found productive in this county but sufficient tests have not been drilled in areas having the proper structural conditions to throw light on their possibilities.

The chief feature of the sands of this district, their scattered distribution, is made more noticeable by the presence of trends of sand only a few hundred feet in width but several miles in length, and by many small disconnected bodies of sand. All the sands, except the main oil sand, contain salt water where they do not hold oil or gas. In every case the gas has migrated to the points where the reservoir rock has the highest elevation. In one place a body of one of the shallow gas sands extends over an anticline. On top of the structure the sand is occupied by gas--down the sides by salt water. (See Fig. 8). The same relationship occurs on a shoestring of gas wells near Garnett. Gas has been found in this sand where it crosses a dome.

In a narrow trend of a deeper sand that yields gas in a continuous belt from Colony to a point near Mont Ida production is cut off on each end by salt water. A major relationship between the sand and the regional dip has caused this separation of gas and water. The conditions may be illustrated as follows:* If a hollow glass tube were bent into the form of an arch and filled with gas and water, were sealed, and laid on a flat surface, there would be a slight separation of the contents, controlled by the diameter of the tube. If the surface on which the tube rested were tilted so that the convex side of the arch became the highest part, an appreciable difference in elevation would result between the ends and the middle of the reservoir. The gas would collect at the top of the arch or "anticline" so formed. The gas-producing area between Colony and Mont Ida is represented by the arch and the parts of the sand body which contain water by the ends of the tube. (See Fig. 10). Recent development indicates that the same body of sand swings up the dip toward the northeast and again becomes high enough to be gas-bearing in an area a mile long.

The accumulation of gas may be controlled by the shape of a body of sand. This condition apparently holds true in a small gas pool in

*Credit for the recognition of such relationships between shoestring sand bodies and the regional dip is due John L. Rich.

secs. 16, 17, 20, and 21, T. 20 S., R. 21 E. In this pool a narrow north-south group of gas wells produces from a bar-shaped ridge of sand. The top of the ridge is wide enough to allow for but one row of wells. Those drilled down the flanks of the ridge found it thinner, broken with shale, and water-bearing. In Figure 3 contour lines on different horizons show the attitude of the beds. One plat indicates the distance of the top of the sand below the Fort Scott limestone and shows that the sand has an "anticlinal" form caused by lensing. The convex top of the reservoir rock serves the same purpose as a folded sheet sand, but it has the distinct disadvantage to the geologist and producer of not being reflected at the surface.

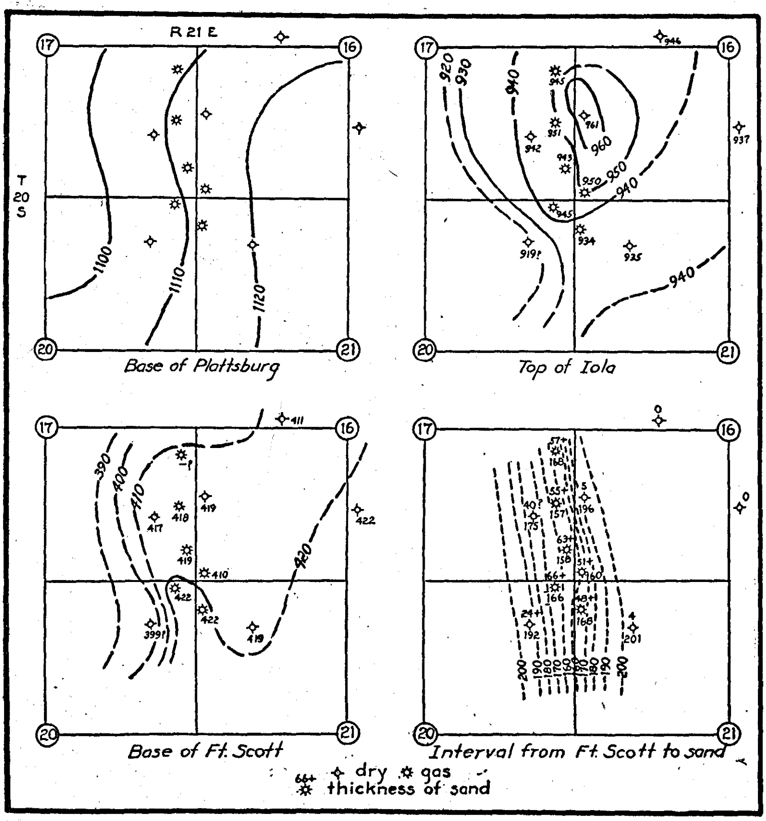


Fig. 3. Structural contours on different horizons above a narrow bar-shaped body of sand. Poorly recorded well logs account for some of the oddities of structure. The structure of the Ft. Scott limestone suggests that later westward tilting increased the "compaction dip" above the down-dip flank of the sand body and decreased it above the up-dip flank.

The chief oil sand contains no water and the limits of the sand define the limits of a field. Exceptions to this statement are found where apparently neither gas, nor oil, nor water are present. The manner in which the relative elevation and cleanness of this sand control the distribution of the oil and gas will be demonstrated in the discussion of the different fields. So far as the writer has been able to ascertain, surface structure has no significance in respect to the occurrence of this oil sand.

OIL AND GAS SANDS.

The oil and gas sands of Anderson County are characterized by their limited extent. They are not sheet sands which were deposited uniformly over a wide area but are long, narrow bodies or small restricted patches of sand buried in the shales. The long, narrow trends are called "shoe-strings" because their length is so much greater than their width. In many instances the stratigraphic horizon of any of these sands may be detected by the presence of sandy shale.

The chief productive sands have been named in accordance with the depth at which they are found. They are the 300-, 600-, 800-, and 900-foot sands. The application of the depths at which they occur as the names of the sands is inaccurate because their depth is varied by the dip, by changes in thickness of the formations, and by the topography. Other sands, which are oil-bearing in other parts of Kansas, but which have not yet furnished commercial production in this area, are below those that have received the most development to date.

<u>300-foot sand.</u>--Shallow, stray sands at about this depth are irregularly distributed in the northeastern part of the county. Sands at different stratigraphic horizons, but approximately at the same depth, are inaccur-

ately referred to as the same sand. The one encountered most commonly is a gas sand near the top of the La Cygne shale, which furnishes wells of about one-quarter million feet initial volume. Its maximum thickness is 35 feet. Generally, the shallow gas has commercial value only when produced in conjunction with the gas from the deeper wells with greater volume.

Another sand, in the Nowata shale, has produced heavy oil in a few wells. These sands have very little commercial importance.

600-foot sand.--The 600-foot sand locally serves as a reservoir for gas. Deposits of this sand are chiefly straight, narrow bodies with convex tops. In many scattered wells throughout the county the sand contains only water. Its maximum reported thickness is 60 feet. This sand was deposited at about the stratigraphic middle of the Bandera s shale and is correlated with the Weiser sand of southern Kansas.

800-foot sand.--The 800-foot sand, often referred to as the "shoestring" sand, produces most of the oil and some of the gas in Anderson County. It is very limited in extent and its thickness is equally variable. This sand occurs in two phases: (1) as long, narrow, sharply-defined bodies with flat tops but convex bottoms, 800 to 1400 feet wide, 0 to 60 feet thick, and several miles long, (2) as irregular patches covering 40 to 400 acres and 0 to 30 feet thick. Both types of sand bodies are 20 to 50 feet below the top of the Cherokee shale and occupy approximately the same stratigraphic horizon as the Squirrel sand of Oklahoma.[7] The Squirrel sand is equivalent to the Prue sand.[7] The sand is brown, fine-grained, and micaceous, and is very impure locally because of included laminae of silty shale. Anderson County probably represents about the outward limit of sand deposition during the time this particular stratigraphic horizon was being laid down.

900-foot sand.--The 900-foot sand furnishes practically all the gas of the county. Operators frequently call it the Colony sand because the first major development in it took place on town lots at Colony. The largest body of this sand has been traced through a gently-winding course for 16 miles in the central part of the county. This trend, 75 to 100 feet below the top of the Cherokee shale, attains a maximum thickness of 140 feet and maximum width of about one-half mile. Lenses of shale are included and it grades into sandy shale and broken sand both laterally and vertically. In the eastern part of the county are other straight, lenticular bodies of sand with a general north-south direction that are correlated with the Colony horizon. They are 150 to 180 feet below the top of the Cherokee formation and are thinner, narrower, and more sharply defined than the large Colony sand body. Most of them are 500 to 1000 feet wide and 0 to 50 feet thick. They yield gas wells having 1 to 8 million feet initial open flow. All the sand at the 900-foot level is fine-grained, gray, and micaceous, and varies over a wide range in purity, according to the amount of shale it contains.

Some people refer to the Colony sand as the Bartlesville, a name applied freely to sands in the Cherokee shale, even to scattered deposits a long distance from the type locality of the Bartlesville. Although the 900-foot sand of Anderson County was laid down at or near the true Bartlesville horizon, it has not been determined definitely of that age.

Stray sand.--On the southeastern edge of the Colony gas field a well which found only sandy shale at the 900-foot level was deepened to 1000 feet where a flow of about one-half million feet of gas was obtained from a stray sand. The daily production and pressure declined very slowly, probably because only one well was drawing gas from the reservoir.

In scattered areas throughout the county this deep stray sand has been discovered, but with the exception of the Colony well, which is high structurally, all other holes have found only salt water. It is very likely that it will be productive elsewhere under the proper structural conditions.

Burgess sand.--A remarkably thick sand lies on top of the Mississippian limestone in the extreme western part of the county. Several dry holes south of Northcott and between Northcott and Westphalia have penetrated 100 to 180 feet of it. A dry hole three and a half miles west of Harris had 150 feet. These widespread occurrences indicate that this sand may extend the entire length of the western side of the county. A few gas wells about two miles south of Northcott produce from the upper 10 to 15 feet of the deposit. Water is under the gas. Showings of oil have been reported in two or three dry holes. Perhaps gas or oil will be found in the upper part in places where the sand is relatively high due to uneven deposition or folding.

Top of the "Mississippi lime".--In that southeastern part of the county set off by a line between Lone Elm and Selma the top of the "Mississippi lime" is composed of a cherty, rotten zone that is very porous. This zone may be the result of weathering before the advance of the Cherokee sea. Almost every well which has been drilled through this zone has found a showing of gas or low-gravity oil. As yet, not enough oil has been found in any well to make it a commercial producer. The amount of the showings is apparently more dependent on the porosity of the limestone than on its structure.

"First break".--Any change of formation which includes shale, sandstone, or sandy limestone between 5 to 75 feet below the top of the Mississippian limestone is referred to as the "first break". Where the break is sandstone or sandy limestone, it invariably contains salt water. No production has been secured from it in the county, and so far as the writer knows, no showings have been credited to it.

"Siliceous lime".--The widespread "siliceous lime" of the Midcontinent region underlies Anderson County at a depth of 300 to 350 feet below the top of the Mississippian limestone. This porous zone is the truncated Arbuckle limestone of Ordovician age. It is the only one of the "second break" or "Wilcox" sand series common to Oklahoma that has been found in this area. One of the nine wells drilled to this deep horizon is reported to have had a showing of oil; the others encountered great quantities of sulphur water.

SUGGESTED ORIGIN OF THE SAND BODIES

The sands of Anderson County represent individual units of deposition that can be outlined and studied separately. Where it has considerable thickness, the sand is concentrated into forms that resemble bars, shallow water or beach deposits, or the fillings of channels. Cross sections of the oil sand can be secured with a fair degree of accuracy from the logs of wells 300 feet apart that are drilled through the sand into the underlying shale. Sections of the 900-foot gas sand cannot be outlined as definitely because the wells are farther apart and, to avoid encountering water, drilling is stopped before the sand has been completely penetrated.

Bars.--The deposits that resemble bars are long and narrow, straight or gently curved. The underside is practically flat or partly convex downward and the top is convex or nearly flat. The sand thins gradually to the edges. In places the total thickness is replaced by sandy shale before all traces of the deposit disappear into the surrounding shale. Fingers of sand 10 to 25 feet thick project 500 to 2000 feet from one or both sides of some of the bodies. There appears to be no way to distinguish between the landward and seaward sides, probably because data are not available to outline the bodies in detail. The unexpected shapes of some "bars" which have little resemblance to familiar types may be traceable to marine erosion, migration during deposition, and possibly to inaccurate descriptions and measurements in well records. However, it is likely that their shape is truly variable and that ideal forms are the exception.

The general processes by which bars are formed are so well known that the writer does not consider it necessary to describe them here.[e]

Bar deposits are represented among all three of the main sand horizons of the county.

<u>Shallow water or beach deposits</u>.--The sand bodies which are believed to have been laid down in rather shallow water, perhaps on the floor of an embayment, are quite uniform in thickness. Their upper and lower sides are clean cut, but they grade laterally into sandy shale. They are irregular in outline and the majority of them are oblong. In many places several small patches of sand at the same horizon are separated by barren zones of shale. The patches have no systematic arrangement among themselves but taken as a whole may form a distinct trend. The slight irregularities in the thickness may be due to deposition on an uneven sea floor or to work of currents or waves. The sandless areas may indicate the former presence of islands. If these sands were ever above the strand line, as beach sands, the wind may have shifted them about. It seems likely that these sand bodies were laid down along the edge of a low land occupied partly by swamps. Coal is found in places near the

the same horizon as the sand.

Channel fillings.--The channel-shaped deposits, which may be several miles in length but only a few hundred feet in width, are the most extraordinary of all the sand bodies. Such deposits in this district are gently curved, but maintain the same general direction for six to eight miles. The minimum amplitude of any of the curves is two miles. Their cross sections have considerable variation in shape but the cross-sectional area remains about the same. Where the channel is narrow, it is relatively deeper. The sections are not always symmetrical but the deepest part swings from side to side. The top of the sand is nearly flat in most instances, but places exist where a shallow, channel-shaped depression has been carved, probably the final work of the current of the stream. In contrast to the depressions are convex portions projecting above the average level. They have the appearance of bars such as are commonly thrown up at the bends of streams. In some places sand or sandy shale is spread out in a thin layer a quarter to half a mile wide in the horizon of the top, or slightly above the top, of the main channel deposit. Developments to date have not shown that these isolated patches are everywhere connected with the main body of sand. Dry holes that had no sand have been drilled between the thin deposits and the main body, but it is reasonable to expect that somewhere they are connected by narrow necks of sand that represent temporary cut-offs of the stream. The isolated deposits locally furnish small wells with oil of lower gravity than that in the nearby shoestring.

The channel filling varies in quality but everywhere remains in the class of fine-grained sand. The best is fine, sugary sand containing very little foreign material. Most of it has much silt and a large percentage of mica in the form of tiny flakes. Thin streaks of silty shale show that the material is cross-bedded.

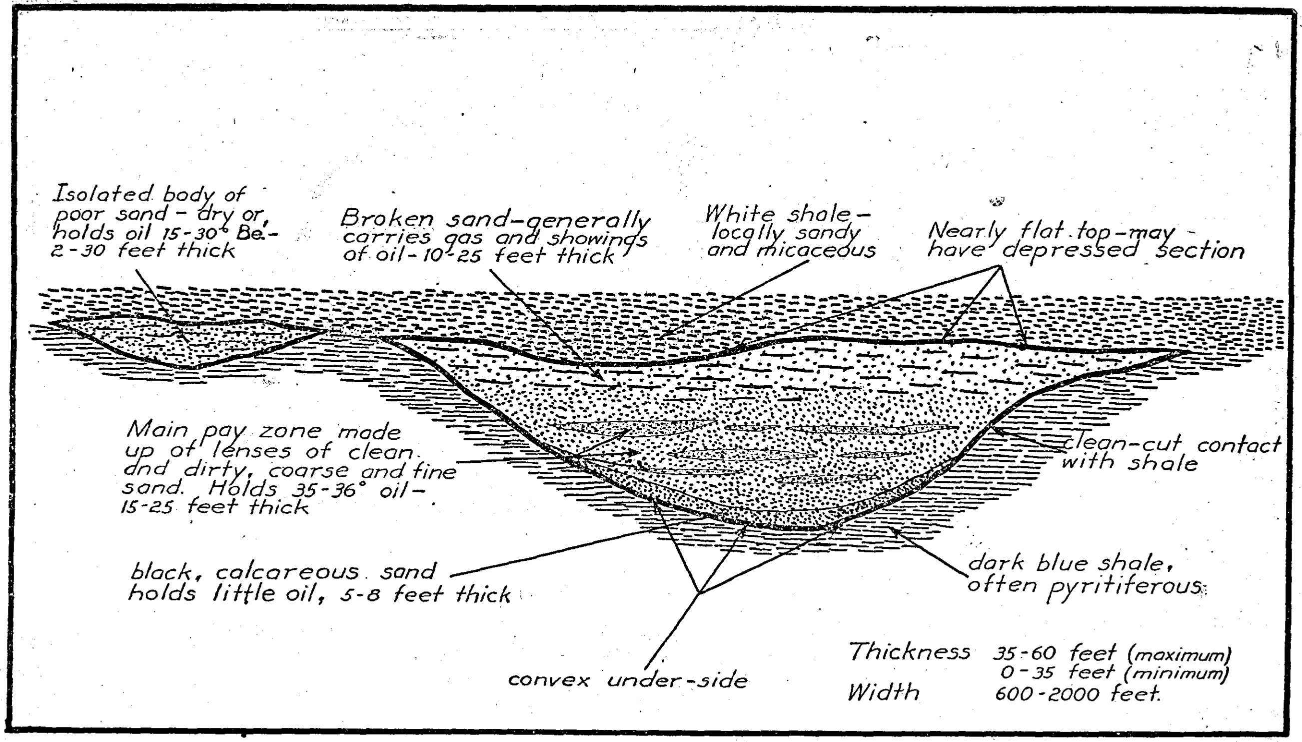


Fig. 4. Typical cross section of a channel filling. The small body at the side is a local feature. (Not drawn to scale.)

The process by which the channels that were carved in the soft Cherokee shales were later filled to the top with sand seemingly cannot be explained by ordinary stream deposition. Present-day streams whose channels are nearly filled with sand flow in sharply meandering courses. The buried channels of Anderson County are only gently curved. It is suggested that the history of the filling process which did not induce meandering is about as follows: Sluggish streams that carried mostly mud emptied into a shallow embayment of the Cherokee sea whose low, marshy shore was several miles east of the Anderson County area. The sea bottom was a smooth marine floor that sloped very gently, providing shallow water several miles from shore. After uplift of the region, the sea began to retreat slowly, and as it retreated, the streams advanced their mouths and thus lengthened their courses on the lower end. Perhaps an increased gradient helped them cut rather straight channels, 40 to 50 feet deep, in the soft freshly-exposed sea bottom over which they made new paths to the sea. Their steep gradient and entrenched channels prevented meandering. Sand, a product to be expected in a rejuvenated stream, was carried by these streams. Some of the sand came to rest on the channel bottoms; some was transported into the sea and was drifted along the shore by currents, finally to come to rest as beach sands and low bars. When subsidence of the land took place and the sea started to regain its former boundaries, it advanced first up the river channels. The sand which the rivers were carrying was dropped when it reached the quieter, deeper water and was added to that which already partly filled the channels. As the edge of the sea continued to advance, the sand-clogged part of the channels was pushed up-stream. Probably a stage of tidal ebb and flow during the silting-up of the channels is responsible for the intricate lamination of mud with fine-grained sand. The surplus sand, beyond that needed to level-up the filling, was spread out on the sea floor along the sides. This took place mostly at the western ends of the stream courses. Finally the entire area was submerged more deeply and a blanket of mud was deposited over the long strings of sand before any form of subaqueous erosion could distrub them.

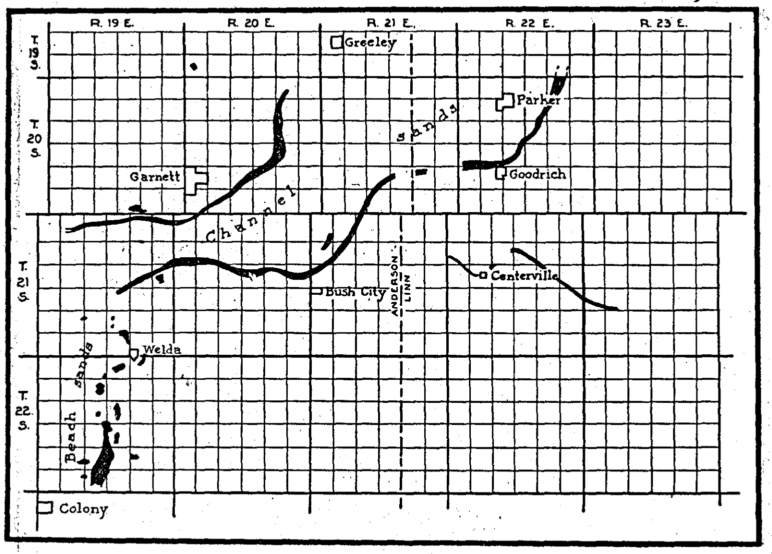


Fig. 5. Deposits of the 800-foot, or shoestring, sand in the Anderson-Linn County district. The two types of sand bodies at the same horizon form an interesting combination.

The theory thus outlined provides for an ordinary drainage system made up of trunk streams and branches that were generally confined to single channels but locally may have sent part of their waters down small, natural depressions near the established courses to form temporary out-offs. The comparatively straight channels already traced out do not suggest to the writer the existence of a braided stream pattern. The ground plan of the "system" of channel deposits in Anderson and Linn Counties (Fig. 5) indicates westward drainage. As yet, none of these branches has been joined by drilling, but the outlook seems good for this to happen. In the older and more thoroughly developed Humboldt-

Chanute district of Allen and Neosho Counties, shoestring trends join each other like stream branches.

The idea that these channel deposits are the fillings of delta distributaries does not appear acceptable, bedause the sand is confined to one horizon. The remains of a delta shold contain much sandy shale and many fragments of channel fillings that were made by several distributaries continually changing their courses to the sea. A delta results from a building-up process and occupies a considerable stratigraphic interval composed of a large proportion of arenaceous material.

PLATE IV

EXPLANATION

Section.

A-A'---Channel type in the old Pottawatomie Valley trend.
800-foot sand.

B-B'---Channel type in the Garnett shoestring with very sharply defined edges. The dry hole on the north side, with no sand, is only 225 feet from a producer with about 40 feet of sand. The base of the white-shale cover denotes the horizon of the top of the channel.
800-foot sand.

C-C'---Another section in the narrowest part of the Garnett shoestring. The productive area is only 600 feet wide.
800-foot sand.

D-D'---A wider, shallower section in the Garnett shoestring. The lower thin wedge may not be connected to the main body. In this part of the trend a thin sheet of sand is spread out several hundred feet in the horizon of the top of the channel.
800-foot sand.

E-E'---From a part of the Garnett field where the sand holds large amounts of gas because of being higher structurally.
800-foot sand.

F-F'---A channel section near the west end of the Bush City trend. The depressed section and flat section of the top are features. The two end wells, which had showings of oil, were drilled several years before the trend was discovered four miles farther west.
800-foot sand.

G-G'---The south edge of the Bush City channel, showing thin sand extending from top of body. The two middle wells are another example of a dry hole and good oil well 300 feet apart.
800-foot sand.

H-H'---This section in the Bush City field has more irregularities than common but is sharply defined on the edges.
800-foot sand.

I-I'---The dry hole on the right might have been avoided by plotting the section of the sand outlined by earlier wells. The distinct rise in the bottom of the channel would have served as a warning of the nearness of the edge of the trend.
800-foot sand.

Section.

J-J'---A bar-shaped deposit in the Polkinghorn gas field. Perhaps some of the convexity is caused by settling. The body was disclosed by wells drilled to a deeper sand.
600-foot sand.

K-K'---Oil sand with bar-like outline from small pool north of Welda. The bottom of the deposit is sharply defined but the upper part grades into broken sand and sandy shale. This is appart of the shallow water or beach deposits of the south-central part of the county.that extend at right angles to the channels. (See Fig. 5).
800-foot sand.

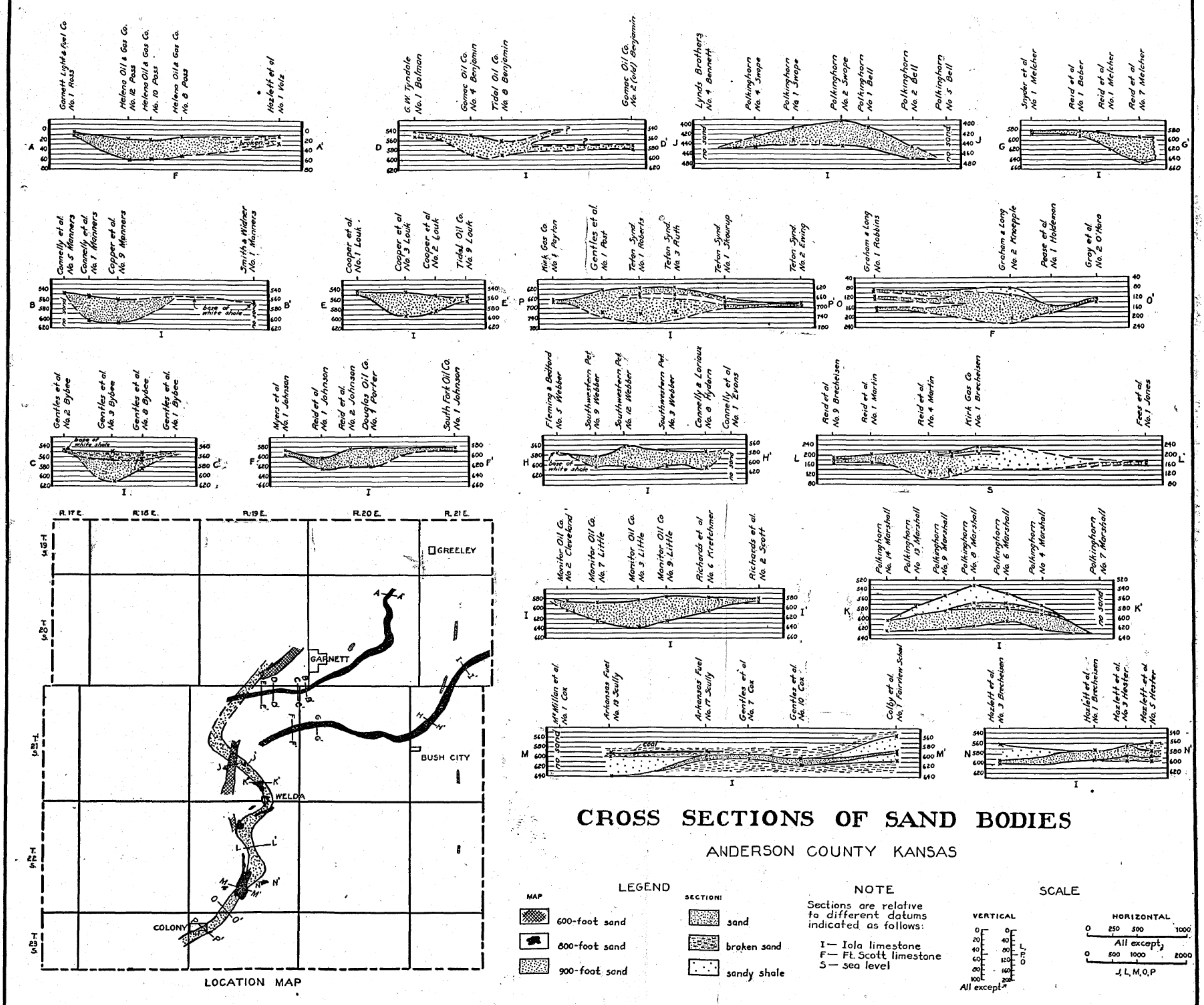
L-L'---Section from the Colony-Welda gas trend. This section, and sections O-O' and P-P', have features that furnish contradictory theories of the origin of the sand body. (See discussion of origin under Colony gas field.) However, the sand body is believed to be a near-shore deposit of the beach-bar type. Attention is called to the lateral gradation into sandy shale on the east side.
900-foot sand.

M-M'---A thin flat beach deposit from the Colony oil field. This is one of the widest of the restricted patches of sand in the Colony-Welda district. The clean-cut top and bottom and laterally gradation into sandy shale should be noted. The coal may be interpreted as indicating that the sand was laid down along a low swampy land.
800-foot sand.

N-N'---A short section of beach (?) sand in the Colony oil field.
800-foot sand.

O-O'---The fingers of sand projecting several hundred feet from the main body feature this section from the Colony-Welda trend. The upward slant of the sand on the east side may be traceable to deposition on a sloping beach.
900-foot sand.

P-P'---This section from the townsite of Colony shows the shale break that separates the "first gas" from the "big gas". The sand body was penetrated over 100 feet in some of the wells. The abrupt thinning of the west side is noteworthy.
900-foot sand.



CROSS SECTIONS OF SAND BODIES
ANDERSON COUNTY KANSAS
LEGEND
MAP
600-foot sand
800-foot sand
900-foot sand
SECTION:
sand
broken sand
sandy shale
NOTE
Sections are relative to different datums indicated as follows:
I— Iola limestone
F— Ft. Scott limestone
S— sea level
SCALE
VERTICAL
All except L, O, P
HORIZONTAL
All except J, L, M, O, P
LOCATION MAP
R. 17 E.
R. 18 E.
R. 19 E.
R. 20 E.
R. 21 E.
T. 19 S.
T. 20 S.
T. 21 S.
T. 22 S.
T. 23 S.
GREELEY
GARNETT
BUSH CITY
WELDA
COLONY
Garnett Light & Fuel Co. No. 1 Ross
Helena Oil & Gas Co. No. 12 Poss
Helena Oil & Gas Co. No. 10 Poss
Helena Oil & Gas Co. No. 8 Poss
Hazlett et al No. 1 Volz
G.W. Tyndale No. 1 Bolman
Gomac Oil Co. No. 4 Benjamin
Tidal Oil Co. No. 8 Benjamin
Gomac Oil Co. No. 2 (old) Benjamin
Lynds Brothers No. 4 Bennett
Polkinghorn No. 4 Swope
Polkinghorn No. 1 Swope
Polkinghorn No. 2 Swope
Polkinghorn No. 1 Bell
Polkinghorn No. 2 Bell
Polkinghorn No. 5 Bell
Snyder et al No. 1 Melcher
Reid et al No. 1 Bober
Reid et al No. 1 Melcher
Reid et al No. 7 Melcher
Connelly et al. No. 5 Manners
Connelly et al. No. 1 Manners
Copper et al. No. 9 Manners
Smith & Widner No. 1 Manners
Cooper et al. No. 1 Louk
Cooper et al No. 3 Louk
Cooper et al No. 2 Louk
Tidal Oil Co. No. 9 Louk
Kirk Gas Co. No. 1 Payton
Gentles et al. No. 1 Post
Teton Synd. No. 1 Roberts
Teton Synd. No. 3 Ruth
Teton Synd. No. 1 Skourup
Teton Synd. No. 2 Ewing
Graham & Long No. 1 Robbins
Graham & Long No. 2 Knoepple
Pease et al. No. 1 Holdeman
Gray et al. No. 2 O'Hara
Gentles et al No. 2 Bybee
Gentles et al No. 3 Bybee
Gentles et al No. 8 Bybee
Gentles et al. No. 1 Bybee
Myers et al No. 1 Johnson
Reid et al No. 1 Johnson
Reid et al. No. 2 Johnson
Douglas Oil Co. No. 1 Porter
South Fork Oil Co. No. 1 Johnson
Fleming & Bedford No. 5 Webber
Southwestern Pet. No. 9 Webber
Southwestern Pet. No. 12 Webber
Southwestern Pet. No. 3 Webber
Connelly & Lorioux No. 8 Hydorn
Connelly et al No. 1 Evans
Reid et al No. 9 Brecheisen
Reid et al. No. 1 Martin
Reid et al. No. 4 Martin
Kirk Gas Co. No. 1 Brecheisen
Fees et al. No. 1 Jones
Monitor Oil Co. No. 2 Cleveland
Monitor Oil Co. No. 7 Little
Monitor Oil Co. No. 3 Little
Monitor Oil Co. No. 9 Little
Richards et al No. 6 Kretchmer
Richards et al. No. 2 Scott
Polkinghorn No. 14 Marshall
Polkinghorn No. 13 Marshall
Polkinghorn No. 9 Marshall
Polkinghorn No. 8 Marshall
Polkinghorn No. 6 Marshall
Polkinghorn No. 4 Marshall
Polkinghorn No. 7 Marshall
McMillan et al. No. 1 Cox
Arkansas Fuel No. 13 Scully
Arkansas Fuel No. 17 Scully
Gentles et al No. 7 Cox
Gentles et al. No. 10 Cox
Colby et al. No. 1 Fairview School
Hazlett et al. No. 3 Brecheisen
Hazlett et al. No. 1 Brecheisen
Hazlett et al. No. 3 Hester
Hazlett et al No. 5 Hester
no sand
base of white shale
broken
coal

Plate IV

THE OIL AND GAS FIELDS.

Anderson County has gained the reputation of being one of the outstanding shoestring districts of eastern Kansas. The three main producing areas are of the distinctive shoestring type.

In the early part of 1927 the average daily production of the oil wells was about 3 barrels.

Annual oil production of Anderson County, Kansas, 1923-1926, inclusive.*

Year.	Production in barrels.
1923	391,741
1924	630,406
1925	824,039
1926	1,168,382

Average daily production by months for 1926.

Month	Production in barrels.
January	3,202
February	3,245
March	3,180
April	3,314
May	3,353
June	3,364
July	3,211
August	3,093
September	3,011
October	3,200
November	3,001
December	3,010

During the development of the Colony, Welda, and Polkinghorn fields the county lead all others in the state in gas production. By 1927 the open flow volume had dwindled to a few million feet per day and many of the wells had been abandoned.

*These production figures were taken from the Oil and Gas Journal.

Pottawatomie Valley Field.

Location.--The Pottawatomie Valley field is the productive territory that occupies the valley of South Pottawatomie Creek from Greeley to the narrow oil field south of Garnett. It is made up of many small groups of wells that form a trend half a mile to one and a half miles wide and eight miles long. Most of it is in T. 20 S., R. 20 E., through which it extends in a northeast course.

Development.--This territory is the oldest in the county in the order of development. The first wells were drilled in 1904 and 1905 on the Myers, Bowen, and West farms, a mile southeast of Garnett. The development was gradually extended down the valley of South Pottawatomie during the next 12 years. The small market for gas, the small size of the few oil wells, and the poor quality of the oil gave little inducement for drilling. Interest was temporarily awakened in the fall of 1917 by several oil wells in sec. 11, T. 20 S., R. 20 E. which had an initial capacity of 75 to 200 barrels. The discovery of larger and richer fields in the county since 1921 has relieved the Pottawatomie Valley of its attraction. Most of the wells are now abandoned.

Surface structure.--The surface structure cannot be determined for a large part of the belt because the wells are on an alluvium-covered valley floor. Furthermore, only a small amount of field work has been done in this old field and for that reason not much detailed information is available concerning the structure. Approximations of structural conditions have been made from surveys of the Plattsburg limestone along the sides of the valley. A shallow, broad syncline near the common township corner about one mile south of Greeley extends northwest-southeast. A narrow syncline, 30 feet deep, lies northeast-southwest in secs. 31 and 32,

T. 19 S., R. 21 E. The structural map of the county (Fig. 2) shows how the rocks are warped adjacent to the trend.

<u>Subsurface structure</u>.--The study of the structure below the surface, like that of many old fields, has been handicapped because many of the well logs are not available and some of those at hand are noticeably inaccurate. A deep syncline, whose axis lies N. 60° W., occupies the NW. ¼ sec. 11, T. 20 S., R. 20 E. The small group of gas wells in sec. 32, T. 20 S., R. 20 E. is on a west-plunging nose. Its western end has been outlined from the well logs, but its extent is indefinite.

<u>Sands</u>.--The 600-foot sand, generally only 450 to 500 feet below the valley floor, was encountered in many wells but was absent in others, or represented only by sandy shale. This sand contains water, small quantities of gas and showings of oil. The volume of gas in most cases was not large enough to make commercial wells.

The 800-foot sand, at about 600 feet below the surface, produces the oil and most of the gas between Greeley and Garnett. It is very variable in thickness and quality, but it maintains a continuous trend the entire length of the field. Its average thickness in producers is 35 feet. This sand does not contain water and is completely penetrated when the wells are drilled in. Its cross section indicates that it is a channel filling. (Section A-A', Pl. IV).

The 900-foot sand, only about 700 feet deep in this field, is a water-bearing sand that contains gas locally. The group of wells in the S. ½ sec. 21 and the NW. ¼ sec. 28, T. 20 S., R. 20 E. and the small field one and a half miles south of Greeley obtain gas from this sand. The abandoned wells on the Enlow farm in the SE. ¼ SE. ¼ sec. 32, T. 20 S., R. 20 E. produced from the 900-foot sand.

<u>Relation of accumulation to structure</u>.--Most of the gas in the 800-foot sand was found where the sand is arched over anticlines, and the oil was in the synclines or basins. As examples of this condition are the following pools: The gas wells in the W. $\frac{1}{2}$ sec. 32, T. 20 S., R. 20 E. are near the top of a west plunging anticline. The oil pool in secs. 2 and 11 is in a syncline.

Migration of the gas may be stopped where the sand pinches out. The gas wells in sec. 21 are flanked on the west by a dome whose crest is 40 feet higher structurally than the wells. The gas has crept up the side of the structure to the edge of the sand.

<u>Production</u>.--The average initial volume of the gas wells in the 600-foot sand was $\frac{3}{4}$ million cubic feet per day. The largest wells had a capacity of about 3 million feet. The rock pressure of the first wells was 240 pounds per square inch but the pressure of those drilled 10 or more years later was only 80 to 90 pounds. A few of the wells had remarkably long lives. In 1907 the Garnett Gas Company's Folz No. 3 in the SE. $\frac{1}{4}$ sec. 28, T. 20 S., R. 20 E. came in with an initial volume of 1 million cubic feet and rock pressure of 240 pounds. Fifteen years later the well tested 20,000 cubic feet volume and 15 pounds rock pressure. It was still on the line in the spring of 1924. The same company's No. 1 Henning, in sec. 14, was drilled in 1905 and produced until 1920.

In general, the wells which obtained gas from the deep sand were shorter-lived than those in the 800-foot sand, but their initial volume was slightly greater. The record well of the Pottawatomie Valley district was drilled in the SW. $\frac{1}{4}$ sec. 11. Its initial volume was 7 million cubic feet, but it was drilled too deep and its productivity was lessened by the early entrance of water.

For a few years the group of gas wells in the S. $\frac{1}{2}$ sec. 21 and the NW. $\frac{1}{4}$ sec. 28 furnished a large part of the gas supply of Garnett, which uses about 75 million cubic feet per year. The initial volume of these wells was $\frac{3}{4}$ to 1 million feet each.

Except those in one or two small pools, the oil wells are of negligible importance. The initial production of most of them was 5 to 10 barrels and they soon fell to half a barrel or less. The wells on the Patton farm in sec. 22 settled to 1/3 barrel each after starting at 4 or 5 barrels. The Fraker wells in sec. 14 started at 15 to 20 barrels but lasted only a year. The richest producing area is the Poss pool in the N. $\frac{1}{2}$ NW. $\frac{1}{4}$ sec. 11, T. 20 S., R. 20 E. The wells came in at 75 to 200 barrels. On one lease, 9 wells produced 57,000 barrels in $4\frac{1}{2}$ years, at the end of which time their average daily yield was 2 barrels per well. After 9 years, they produced only 1/3 barrel each per day.

Garnett Shoestring.

Location.--The Garnett shoestring is the long, narrow strip of productive territory which begins one mile southeast of Garnett in sec. 31, T. 20 S., R. 20 E. and extends in a smooth, winding course as far as the west edge of sec. 2, T. 21 S., R. 19 E. This field is an extension of the old Pottawatomie Valley trend. The sand body is continuous, but it was not traced westward until 15 years after the wells near its eastern end had been drilled.

Development.--The discovery well of the new trend was drilled by H. C. Cooper and associates on the N. L. Bowman farm in the S. $\frac{1}{2}$ SE. $\frac{1}{4}$ sec. 31, T. 20 S., R. 20 E., in September, 1921. The gravity of the oil from this new producer was 36 degrees Baume', which was 6 to 7 degrees lighter than any oil produced in the county previously. The first few wells proved that the oil occurred in a very narrow trend that was sharply defined on the edges. The operators who held leases in advance of the field drilled many holes which found no sand. Gentles and others drilled four dry holes on the Smerchek farm in sec. 1 before they located the shoestring. Three failures were the experience of Bees and others on the same farm. Sixteen dry holes in sec. 1 reflect the diligent search for the oil sand. The following incident demonstrates how some of these caused a greater loss than the prâce of the holes alone: The first hole on the Bybee farm was located in the southeast corner NE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 1.* This test proved dry and the rig was moved 1150 feet north, where another failure resulted. When the second well came in dry, one of the royalty owners sold his holdings. The next test, 450 feet south of the second dry hole, came in as a 150 barrel well having 47 feet of sand. The two dry holes formed a "gate" through which the shoestring passed.

Production was extended as far as the middle of sec. 2 without much difficulty. Most of the drilling up to this point was completed by June, 1924. About 20 holes have been put down within a distance of four miles west of sec. 2. The shoestring sand was found in most of them, but, with a few exceptions, it was barren. A small group of wells in the W. $\frac{1}{2}$ sec. 4, T. 21 S., R. 19 E. produces black oil of about 32 degrees gravity from 10 to 14 feet of sand at the south edge of the sand body.

Structure.--The structure of the area through which the shoestring extends was determined from the logs of the wells by finding the attitude of the Iola limestone. In conjunction with the Iola, the Plattsburg limestone was used. The Plattsburg crops out along the sides of the valley occupied

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*Attention is called to the north row of sections in Township 21 South, which are about a quarter of a mile longer than the normal section.

by the eastern half of the field but crosses the field at several places in the western half.

The strata in sec. 31, T. 20 S., R. 20 E. dip westward at the rate of 60 feet per mile. This westward dip is arrested at the bottom of a syncline. The rocks rise from the syncline to form a dome whose top is in sec. 36, T. 20 S., R. 19 E. The oil sand is at about the same elevation as it bends around the southern edge of this dome to the middle of the NW. $\frac{1}{4}$ sec. 6. From there it swings slightly northward and diagonally descends the southwest dip of the dome mentioned above. The sand reaches the lowest elevation in the NE. $\frac{1}{4}$ sec. 2, on the Zaskey farm. The dip from the east end of the field to here is approximately 80 feet. From the Zaskey farm the sand rises about 10 feet to the middle of the N. $\frac{1}{2}$ sec. 3 and then resumes a westward dip of 50 feet to the east edge of sec. 5.

Relation of accumulation to structure.--The oil and gas have taken up their position according to the elevation of the sand. However, the line between them is not well defined and their separation according to structure is not as complete and distinct as would be expected.

In the extreme eastern end of the field about half of the sand holds gas and the remainder, oil. The proportion of oil to gas increases toward the west to the point where the sand is lowest. The wells in the deepest part of the syncline in the NE. $\frac{1}{4}$ sec. 2 found the sand almost completely saturated with oil. It is believed that the oil is held back in this low area by the gas that occupies the sand at a higher elevation farther west. A sharp increase in the amount of gas is noted where the shoestring starts its westward rise in the middle of sec. 2. In the Gomac Oil Company's Nichols well No. 2 it was reported at 759 to 800 feet; in

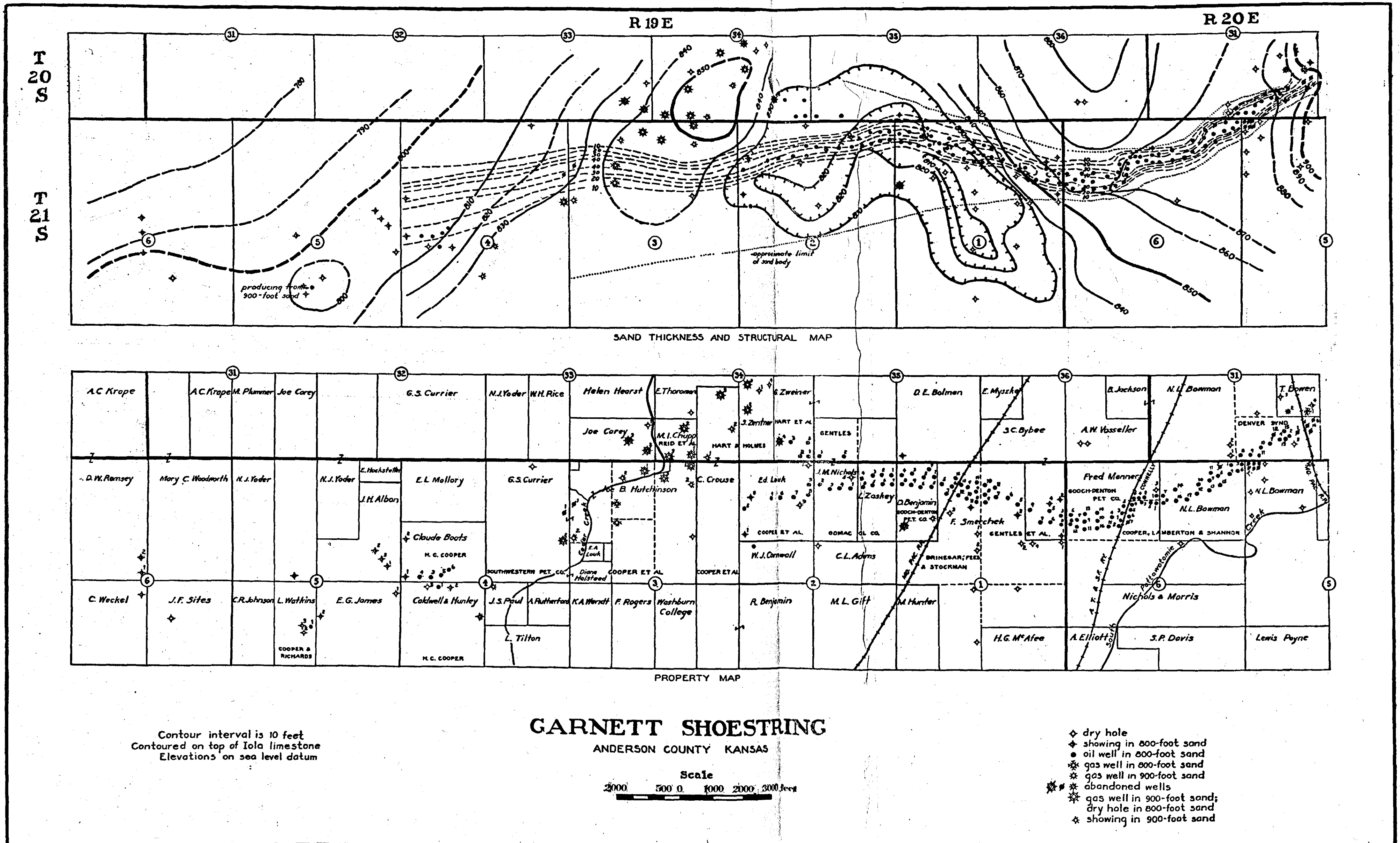
R 19 E
R 20 E
T 20 S
T 21 S
producing from 900-foot sand
approximate limit of sand body
SAND THICKNESS AND STRUCTURAL MAP
A.C. Krope
A.C. Krope
M. Plummer
Joe Corey
G.S. Currier
N.J. Yoder
W.H. Rice
Helen Hearst
E. Thoramen
Joe Corey
M.I. Chupp
REID ET AL
HART & HOLMES
S. Zweiner
S. Zenther
HART ET AL
GENTLES
D.E. Bolmen
E. Myszka
S.C. Bybee
B. Jackson
A.W. Vasseller
N.L. Bowman
T. Bowen
DENVER SYND.
D.W. Ramsey
Mary C. Woodworth
N.J. Yoder
N.J. Yoder
E. Hockstetler
J.H. Albon
E.L. Mallory
G.S. Currier
B. Hutchinson
C. Crouse
Ed. Louk
J.M. Nichols
L. Zaskey
D. Benjamin
GOOCH-DENTON PET. CO.
F. Smetchek
Fred Menner
GOOCH-DENTON PET. CO.
N.L. Bowman
N.L. Bowman
COOPER, LAMBERTON & SHANNON
Claude Boots
H.C. COOPER
SOUTHWESTERN PET. CO.
E.A. Louk
Diana Halstead
COOPER ET AL
COOPER ET AL
COOPER ET AL.
W.J. Cornwall
GOMAC OIL CO.
C.L. Adams
BRINESAR, FEES & STOCKMAN
GENTLES ET AL.
C. Weckel
J.F. Sites
C.R. Johnson
L. Watkins
E.G. James
Caldwell & Hunley
J.S. Paul
A. Rutherford
K.A. Wendt
F. Rogers
Washburn College
R. Benjamin
M.L. Gift
M. Hunter
Nichols & Morris
L. Tilton
COOPER & RICHARDS
H.C. COOPER
H.G. McAfee
A. Elliott
S.P. Davis
Lewis Payne
Cedar Creek
Pottawatomie Creek
South
A. T. & S.F. Ry.
Mo. Pac. Ry.
PROPERTY MAP
GARNETT SHOESTRING
ANDERSON COUNTY KANSAS
Contour interval is 10 feet
Contoured on top of Iola limestone
Elevations on sea level datum
Scale
2000 500 0 1000 2000 3000 feet
dry hole
showing in 800-foot sand
oil well in 800-foot sand
gas well in 800-foot sand
gas well in 900-foot sand
abandoned wells
gas well in 900-foot sand; dry hole in 800-foot sand
showing in 900-foot sand

Plate V

H. C. Cooper's Louk well No. 2, the diagonal southwest offset, at 767 to 799 feet. The elevation of the sand is only 1 foot higher in the latter well. The Nichols well had an initial production of 60 barrels of oil and a good showing of gas; the Louk well about 25 barrels of oil and $\frac{1}{4}$ million feet of gas. The sand appeared to be of about the same quality in each well. The producer 325 feet southeast of Nichols No. 2 made 125 barrels initially. The sand is 8 feet lower.

The top of the sand is 295 feet above sea level in H. C. Cooper's Hutchinson well No. 1, about 1370 feet from the north line and 1470 feet from the west line of sec. 3. This well was drilled into the shoestring sand 33 feet and made 2 million feet of gas with no oil. In Louk well No. 5, an oil well three-quarters of a mile east of the Hutchinson well, the elevation of the sand is 285 feet. In an oil well a quarter of a mile west of the gas well; it is 286 feet. These two oil wells had 20 feet of gas sand capable of producing about $\frac{1}{4}$ million feet on top of 20 feet of oil sand.

From the west side of sec. 3 to the east side of sec. 5 the sand dips 40 feet. In the east half of this distance it probably contains oil of about 32 degrees gravity, but in the remainder it has none except a small quantity on the south side of the NW. $\frac{1}{4}$ sec. 4. Through sec. 5 it lies practically flat and has only a trace of oil.

Sand.--The sand is a channel-shaped deposit about 700 to 1000 feet wide, 20 to 30 feet below the top of the Cherokee shale. Its thickness ranges to a maximum of 55 feet. The wells are completed at a depth of 700 to 850 feet. The extreme width of the of the sand body does not indicate the width of the productive area, because the sand wedges out at the top. It has sufficient thickness at right angles to its trend to allow for the location of two wells, 300 feet apart. Its cross section does not maintain the same shape everywhere. (See sections B-B' to E-E'. Pl.IV). On the east end of the trend it is narrow, clean-cut, and steep-sided. Examples may be cited to show how sharply the bottom of the channel rises to the edge where it is "chopped-off". Cooper's Bowman well No. 1, the second location west of the northeast corner of sec. 6, T. 21 S., R. 20 E., had 44 feet of sand. The dry hole which offsets it on the north, Hafel & Templeton Brothers' No. 1 Bowman, had no sand. It is only 250 feet from the producer. Connelly and associates drilled their No. 3 Manners well 225 feet north of their No. 1 Manners. Well No. 3 had no sand; No. 1 flowed 70 barrels per day during the first week from about 35 feet of sand. On the Bybee farm the shoestring passes between two dry holes 1150 feet apart. Each dry hole had only 5 feet, or less, of sand.

In the west half of sec. 2 the channel is wider and shallow. The top of the sand body begins to spread out at the eastern edge of sec. 1, and the spread increases rather uniformly until its south side is about half a mile wide. Dry holes a quarter of mile south of the trend have found a showing of oil in this thin stratum of sand. On the north side it is represented by a thin widespread deposit covering a large area in T. 20 S., R. 19 E. In the SE. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 34 and the SW. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 35, T. 20 S., R. 19 E. a few wells of about 15 barrels initial production obtain oil from 10 feet of this sand. In this particular area the thin deposit is not connected with the shoestring because dry holes, one with no sand and another with but 2 feet, are between the small pool and the main trend. It is probable that commercial production is available in this locality because the sand pinches out toward the center of a synclinal basin and the oil has drained down to form a pool at the edge

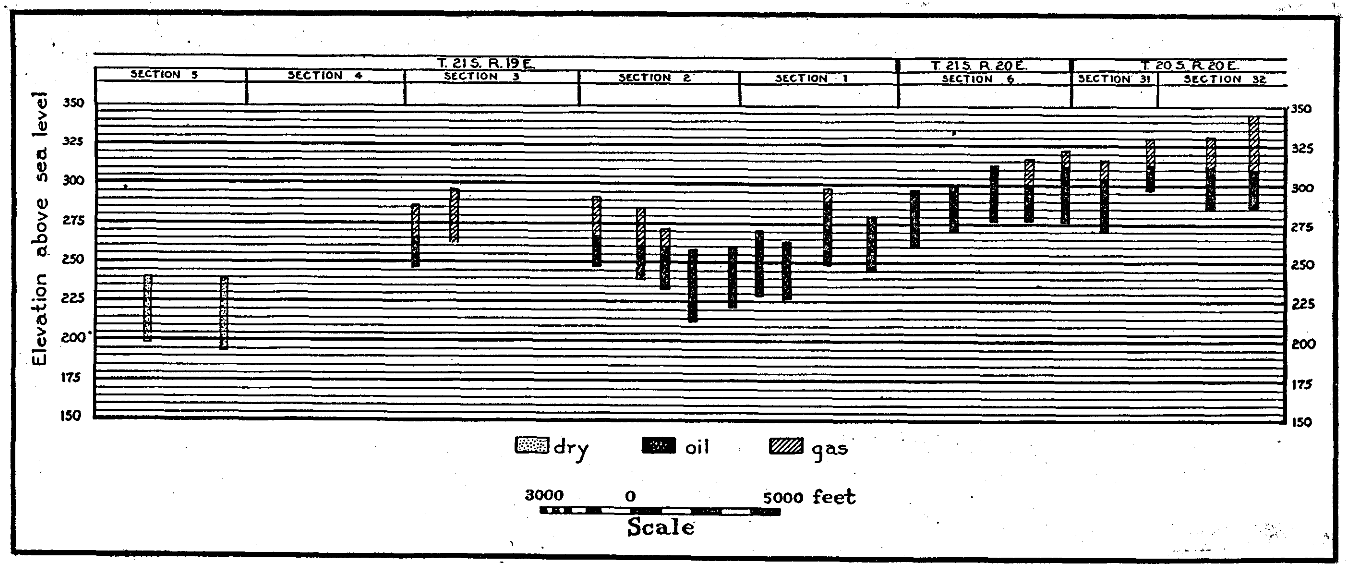

Fig. 6. Profile of the sand in the Garnett shoestring showing the relation of the elevation of the sand to its contents.

of the sand. The oil is 32 degrees gravity, 3 degrees lower than the oil from the shoestring pool nearby.

The sand body has been traced as far as the middle of sec. 5, T. 21 S., R. 19 E. The sand is of good quality and normal thickness in this section but holds only a "rainbow" of oil.

The material which makes up the channel filling is rather clean, fine-grained sand. The portion which contains gas is gray; that which contains oil is stained brown. Locally, a black, coarse sand about 5 feet thick forms the bottom of the deposit. It holds black oil of slightly lower gravity than the dark green oil in the upper part of the sand.

The white shale.--Considerable importance is attached by some people to a white shale, 5 to 20 feet thick, immediately above the shoestring sand in many wells. It is found locally at the same horiaon in the small pools of the Colony-Welda district and in areas where there is no production. On account of its unusually light color, this deposit has attracted attention, and its occurrence above the oil sand has served to give it a significance which it does not warrant. Although somewhat irregular in occurrence, it appears to be a regional rather than a local deposit and if it did not come in the geological section just above the oil sand would probably attract little notice. Its chief value seems to lie in furnishing an indication of where the 800-foot sand may be expected and as a good formation in which to set casing.

Production and decline.--Considered as a whole, the Garnett shoestring field has been the richest in the county. The initial production of the wells averaged about 100 barrels and some made 250 to 300 barrels. A few flowed naturally. At the end of the first year the average well was

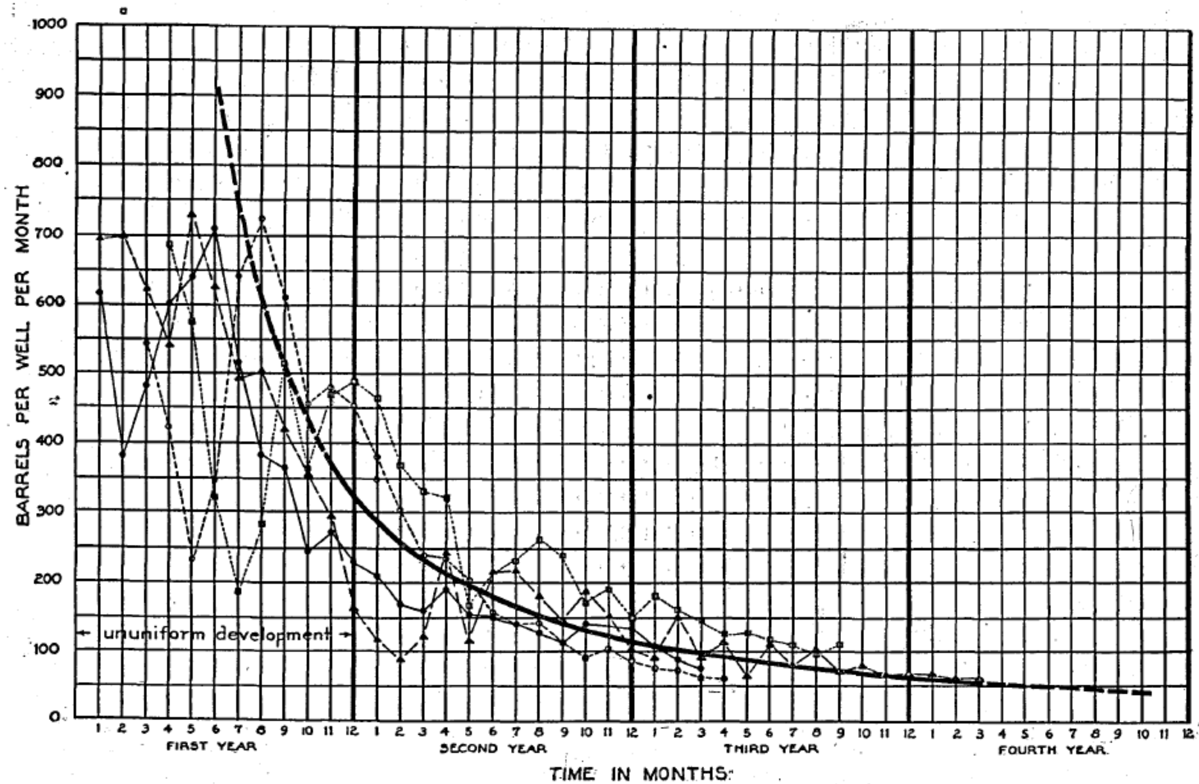

Fig. 7. Production decline curve of the Garnett shoestring.

producing 5 to 6 barrels, at the end of the second year about 3 barrels, and at the end of the third year, $1\frac{1}{2}$ to 2 barrels.

One of the leases for which complete figures are available produced 69,000 barrels in $2\frac{1}{2}$ years, an average of 6,275 barrels per well and 3,285 barrels per acre of productive territory.* At the end of $3\frac{1}{2}$ years this lease would have been furnishing about $1\frac{1}{2}$ barrels per well, but, as the result of the application of compressed air, the yield of each well was about $3\frac{1}{4}$ barrels.

Air recovery.--Favorable results have been secured from the use of air pressure on this shoestring field. At the time this method was adopted, when the wells were 3 to 4 years old, the 95 wells were reported to be producing about 165 barrels. An increase in production was obtained from some of the properties within 3 months. It is reported that after 8 months the increase was 300 per cent in parts of the field and 50 per cent on the entire shoestring. The largest gains took place on the oldest leases.

*Per acre recovery is estimated from the area within the edges of the sand.

Polkinghorn Gas Field.

Location.--This important gas field is 2 miles northwest of Welda. The field covers parts of secs. 21, 22, 26, 27, 28, 34, and 35, T. 21 S., R. 19 E. It bears the name of the lessor who owned most of the productive territory. This field is a continuation of the long trend which winds through T. 22 S., R. 19 E. and has its southern terminus just southwest of Colony. The Polkinghorn field is treated as a separate unit because of its individual history and unique geologic conditions.

Development.--Attention was first directed to this area in May, 1922 by an oil well producing from the 800-foot sand in the NE. ¼ NE. ¼ sec. 29. An attempt to obtain oil in the same sand in the E. ½ NW. ¼ sec. 28 resulted in the discovery of gas in the 600-foot sand. Only a few wells had been completed in this shallow sand before one in the southeast corner of the NE. ¼ SW. ¼ sec. 21 encountered salt water instead of gas. This well was deepened and at 905 feet the Colony gas sand was found. A good market induced the rapid development of this lower sand. About 50 gas wells and 25 dry holeswwere drilled in the district during a period of 2 years, beginning in September, 1922.

Surface structure.*--The surface structure of the field is one of its most interesting features. A narrow anticlinal fold, which broadens toward the northwest, extends from the NW. ¼ sec. 35 to the NE. ¼ sec. 20. At the southeast end, where the anticline is very narrow, its southwest flank dips sharply. The other flank dips into a shallow syncline that separates the main fold from a broad structural nose which swings from the SE. ¼ sec. 26 through the SW. ¼ sec. 23. Another nose, the axis of which extends northeast-southwest, is in sec. 22.

*Surface structure in Figure 18 was mapped by H. E. Crum and E. L. Bradley.

The fold on which the field is located is parallel to a larger and higher structure in secs. 25, 26, and 36, T. 21 S., R. 19 E. and secs. 30 and 31, T. 21 S., R. 20 E. The sand is under only the northwest tip of this larger structure.

Sands.--The three main producing sands are present in the Polking-horn field. The deeper gas sand furnishes the largest part of the production. The 800-foot oil sand ranks second in importance.

The first gas well in the field was completed in the 600-foot sand but later development outlined the productive portion of this sand to include only a small area drained by less than half a dozen wells. This sand occurs in a narrow trend on the west side of the field. It is approximately three-quarters of a mile in width and varies from 0 to 60 feet in thickness. Cross sections have the appearance of a typical bar deposit. (Section J-J', Pl. IV). It is gray, fine-grained, and micaceous and is broken with shale in places. Traces of the same deposit are found as sandy shale in wells scattered throughout the field.

The 800-foot sand produces oil in small, disconnected areas. Most of this sand was discovered in the course of drilling to the gas horizon. The largest group of oil producers is in the S. ½ SE. ¼ sec. 27 and the NE. ¼ sec. 34. A few more wells are in the W. ½ sec. 27. This oil sand is a part of the shallow water or beach deposits common to the Colony-Welda district. A section of the sand body in the SE. ¼ sec. 27 has the shape of a bar. (Section K-K', Pl. IV). In other places it was laid down as thin patches which grade into sandy shale. However, it may be replaced by shale very abruptly. Well No. 4 of D. W. Polkinghorn's in the southeast corner of sec. 27, on the Marshall farm, had 32 feet of sand, but the well 300 feet north had none and it was deepened to the lower gas sand.

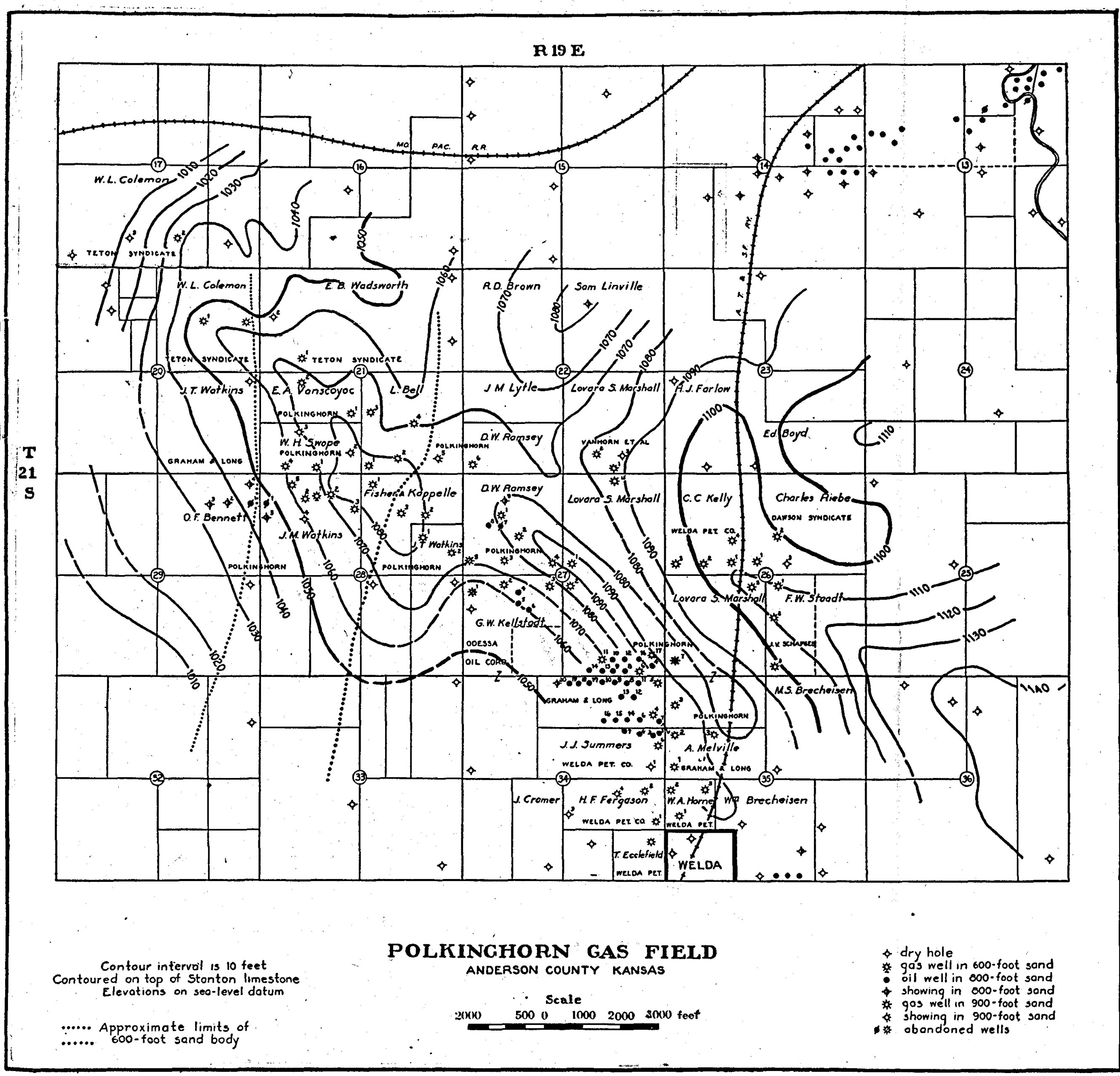

Fig. 8. Structural and property map of the Polkinghorn gas field.

The 900-foot sand gives the Polkinghorn field its importance. In this field it furnished wells with much larger initial volume than the average in the county, except those in the village of Colony. The sand has the same characteristics as in the Colony pool. Shale breaks, 5 to 20 feet thick, occur in the upper part. The "big gas" comes from 20 to 60 feet of sand under the broken section. The maximum thickness of the body exceeds of 100 feet. Its suggested origin is mentioned in the discussion of the Colony field.

Relation of production to structure.--The 600-foot sand extends across the west end of the anticline at almost a right angle to its major axis. (See Fig. 8). On the highest part of the structure a small number of gas wells were developed; down the sides, the sand holds salt water. To illustrate this effect of structure the following wells are mentioned: D. W. Polkinghorn's No. 1 Bell, southwest corner of the SE. $\frac{1}{4}$ sec. 21, was orginally completed as a gas well in the 600-foot sand. This well is 40 feet higher structurally than the dry hole in the northeast corner of the SE. $\frac{1}{4}$ sec. 29 on the Frank Alexander farm, which had only water in the shallow gas sand. Lynds Brothers' well No. 4 J. M. Watkins, southeast corner of the NW. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 28, had a showing of gas in the first 12 feet of this sand but was drilled into water. This well is 20 feet lower on the structure than No. 1 Bell.

Scattered deposits of the 800-foot sand occupy the top and sides of the anticline. The wells on the Marshall and Melville farms in secs. 27 and 34 are on the steep southwest flank. Perhaps the sand is relatively richer here because the oil drained from points higher on the structure. However, it is more reasonable to believe that structure has little effect on the occurrence of oil in these small isolated patches of sand,

and that the amount of oil is accounted for by the nature of the local conditions under which it was made and preserved, and by the cleanness of the sand.

The deep gas sand has a very interesting and apparently close relationship to the structure of the rocks. The axis of the sand body is approximately parallel to the major axis of the fold. The southwest edge of the sand extends parallel to the anticline about 40 feet below the crest. The northeast edge is not well defined but is thought to reach as far as a line passing through the center of sec. 22 and the southeast corner of sec. 23. Thus it passes at a right angle across the contour lines that outline the noses and synclines on that side of the field.

Where the sand is present, the gas is found on those parts of the structure which are generally considered most favorable for its accumulation. The major operator gave careful attention to the structural map of this area during development and confined his locations to the highest parts of the anticline. For this reason, the narrow syncline in the E. ½ sec. 27 and the SW. ¼ sec. 26 was not tested. It is probable that production could have been obtained in it also, because it is no lower structurally than the dome in secs. 21 and 28. Even this policy of locating the wells according to structure was not always successful because three dry holes in sec. 21, on locations as favorable as the average, made less than half a million feet of gas, due, no doubt, to the shaley sand.

It is worthy of note that wells of about the same initial volume are in belts parallel to the trend of the sand body. Probably the sand was sorted into lenticular sections of clean sand and muddy sand while being laid down. The clean sections yield the large wells and the shaley sections furnish wells of small volume, or dry holes.

The maximum thickness of the sand body is maintained where the axis of the structure plunges to the northwest. The holes in the S. ½ sec. 17 had a small amount of gas that was soon drowned out by salt water. These holes are at the edge of the original level of the water in the sand.

Production and decline.--The largest well in the 600-foot sand had an initial volume of 2½ million feet and a rock pressure of 175 pounds per square inch.

The oil wells came in at 25 to 125 barrels. On one of the leases 7 wells produced about 40,000 barrels each, in 30 months. At the end of this time their average daily yield was about 2 barrels.

The gas wells in the deep sand varied greatly in initial production. The largest well, Graham & Long's No. 5 Melville, in the northeast corner of sec. 34, gauged 32 million feet. Two wells in sec. 27 started off at 28 and 30 million feet. Four wells made between 15 and 20 million; 5 between 10 and 15 million; and of the remainder only a few were rated at more than 5 million cubic feet per day. The maximum open flow of the field is estimated to have been 250 million cubic feet. A curve which shows the decline of the open flow of the chief properties is given in Figure 9. The original rock pressure was 280 pounds per square inch. At the end of the first year the pressure had decreased to 175 pounds; at the end of the second year to 95 pounds; and at the end of the third year to 70 pounds. (See Pl. VI).

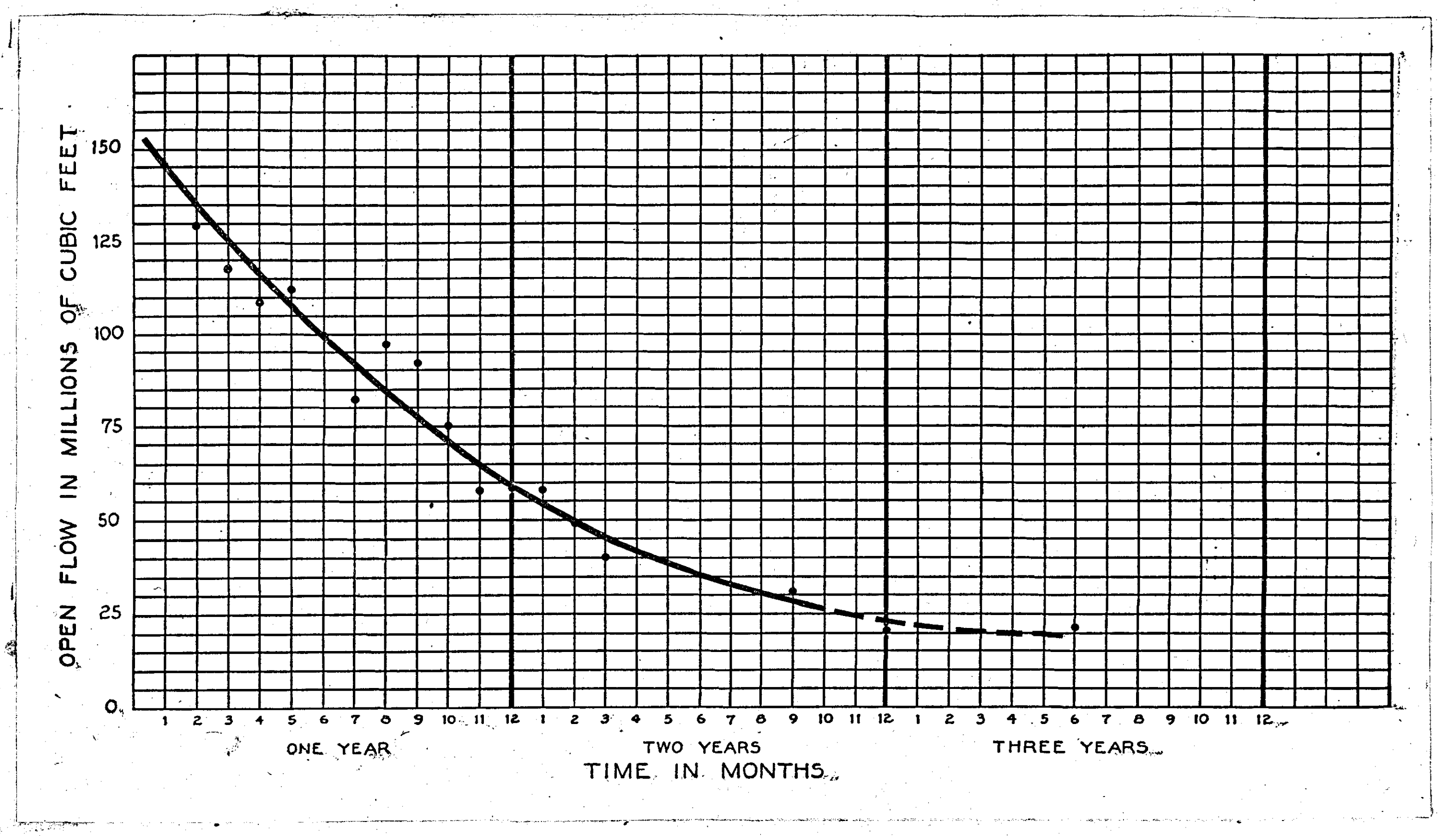

Fig. 9. Open flow decline curve of the chief properties in the Polkinghorn gas field.

Welda Field.

Location.--The Welda field extends half a mile north of Welda to the Polkinghorn gas field and three and a half miles south of Welda to the Colony oil district. It includes the following sections: S. ½ sec. 34 and S. ½ sec. 35, T. 21 S., R. 19 E. and secs. 2,33, 9, 10, 15, and 16, T. 22 S., R. 19 E.

Development.--The productive area has a connected appearance now, but its development did not take place progressively from one end to the other. Scattered semi-wildcat wells were brought in during the period following the discovery of gas at Colony, until the present field was outlined. It forms the connecting link between the important gas and oil fields on each end. The Welda district is left for consideration after the areas on each side, with individual records, have been separated from it. When the territory was being developed, the operators were anxious to secure gas production. In some instances, the 800-foot sand was cased off and drilling continued to the lower sand. Later, development of the oil sand was taken up.

Structure.--The lack of outcrops prevents a satisfactory survey of the surface rocks. The subsurface structure was investigated by use of the Iola limestone. This formation cannot be used in the west half of secs. 10 and 15 because the operator in this area did not keep complete logs of the wells. Many of the other logs are known to be inaccurate. Although a subsurface structural map cannot be relied on for the accuracy of the details, it should show the controlling dips very well.

The general dip over most of the area is toward the northwest. In the NW. ¼ sec. 2, T. 22 S., R. 19 E. is a small dome with a closure of 10 feet. A syncline, 30 feet deep, in sec. 3, plunges westward. The lowest part of this depression is in the NW. $\frac{1}{4}$ SE. $\frac{1}{4}$ of the section. Irregular warping of the strata has taken place in the central part of the E. $\frac{1}{2}$ sec. 9. The 870-foot contour line follows an irregular course in outlining three radiating noses that extend west and southwest. There is evidence of a synclinal basin in the SW. $\frac{1}{4}$ sec. 9. The elevation of the Iola limestone in three wells along the west side of the SE. $\frac{1}{4}$ sec. 15 is slightly over 900 feet; in the dry hole in the SE. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 14, it is 893 feet. These data indicate an east dip, but the location of the axis of the fold is not definite. It is rather hazardous to draw definite conclusions effecting so large an area from the log of the one dry hole. However, the topography tends to indicate that a structure is present here.

Sands.--The 600-foot, 800-foot, and 900-foot sands furnish the production. They occur very near the depths indicated by their names. The shallow sand yields a small amount of gas; the 800-foot sand produces all the oil and part of the gas; and the deep sand produces gas exclusively. Some of the oil sand is present almost everywhere but is productive only in small areas where it attains sufficient thickness and cleanness. About 30 to 45 feet of it occurs in the small group of wells in the north-central part of sec. 2, T. 22 S., R. 19 E. It seems proable that this area will be connected with a like area in the middle of sec. 3, because the gas wells between them had 20 to 30 feet of oil sand at the 800-foot horizon. About 30 wells in sec. 9 have 25 to 45 feet of sand. The sand is replaced by broken sand and sandy shale at the west edge. It is thinner and broken on the east edge in sec. 10, according to the logs of the gas wells drilled to the Colony sand.

The 800-foot sand is believed to be a near-shore shallow-water deposit, the same as in the Colony oil field, which will be described later.

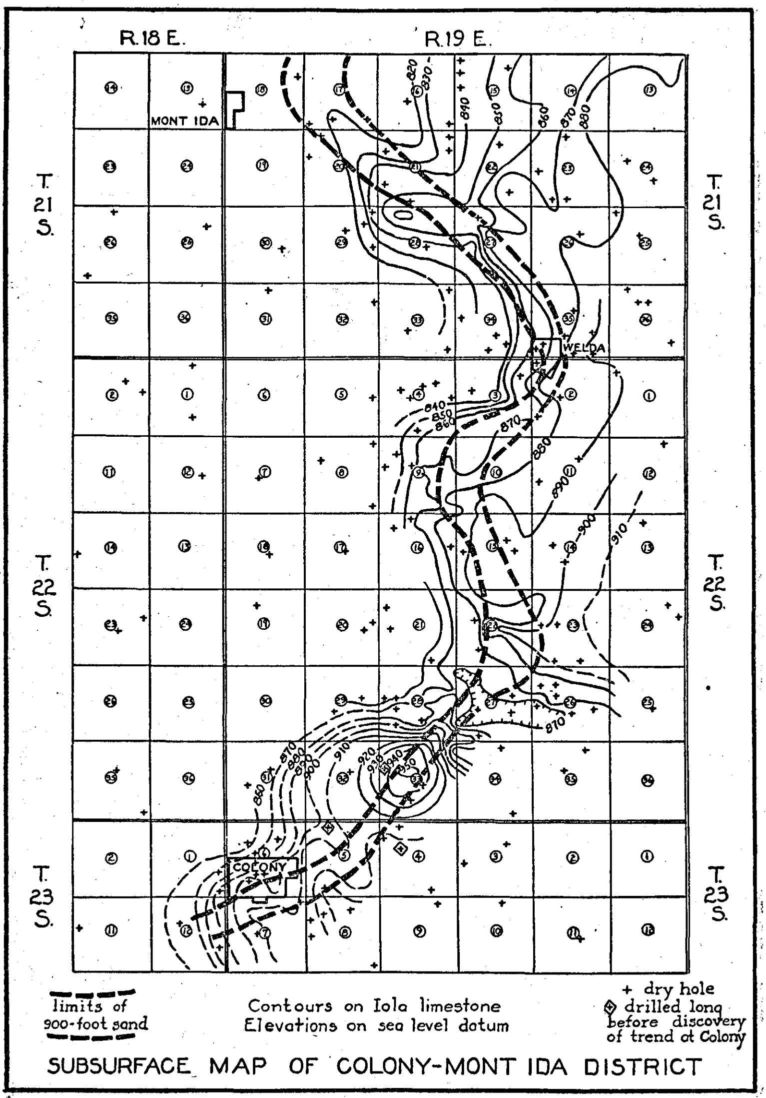

Fig. 10. Subsurface structural map of the Colony-Mont Ida district.

The 900-foot sand is a part of the same sand body found in the Colony and Polkinghorn fields. It maintains the same form but has more broken sand and is not as thick. (See section L-L', Pl. IV).

Production.--The oil wells had an initial production of 5 to 125 barrels. The gas wells had an open flow volume of 1 to 17 million cubic feet and rock pressure of 240 to 285 pounds per square inch.

Colony Oil Field.

Location.--The Colony oil field is 3 miles northeast of Colony. It is made up of disconnected areas in parts of secs. 21, 22, 27, 28, 29, 32, and 33, T. 22 S., R. 19 E.

Development.--Most of the wells were drilled in 1921 and 1922 during the intensive campaign that took place in the southern part of the county during those years.

Structure.--The structure of the surface rocks cannot be determined accurately, because they outcrop in only a few places. The outstanding subsurface feature is the change from north to northwest dip in the central part of the field. The north dip forms one side of a dome that occupies sec. 33, T. 22 S., R. 19 E. An abnormally steep dip of 50 feet in a quarter of a mile is in the S. $\frac{1}{2}$ sec. 28. A long, flat, irregular nose begins in the middle of the SE. $\frac{1}{4}$ sec. 28 and extends into the SE. $\frac{1}{4}$ NE. $\frac{1}{4}$ of the same section. The western end of a steep-sided, narrow syncline, 25 feet deep, is in the northeastern part of sec. 33.

Sand.--The reservoir rock is a brown, fine-grained micaceous sand at a depth of 800 feet. Most of the wells found from 16 to 18 feet of it. The thickest portion, 20 to 25 feet, is in the S. $\frac{1}{2}$ SE. $\frac{1}{4}$ sec. 28 and the NE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 33. The middle of the deposit is rather uniform in thickness and ordinarily does not have a broken upper portion as is common in the shoestring fields. The edges may gradually be replaced by sandy shale, or may pinch out abruptly. On the eastern edge of the small pool near the southwest corner of sec. 28 the sand thins from 20 to 6 feet in 300 feet. A well on the south side of the pool has 7 feet of broken sand on top of 12 feet of "pay". The dry hole in the northeast corner NW. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 28 is credited with 40 feet of sandy shale. The productive area in the SE. $\frac{1}{4}$ sec. 22 is separated from the larger one to the southwest by a dry hole that had no sand.

The oil-bearing rock is considered to be a near-shore deposit. It is made up of thin, disconnected patches which were probably laid down adjacent to a land very near sea level--perhaps within a shallow embayment. Its thin, even cross sections imply that it was not subjected to the disturbing effects of strong wave or current action. (See section M-M' and N-N', Pl. IV).

Relation of accumulation to structure.--Gas is in the sand on the dome in sec. 33. Where the sand is lower, in sec. 28, it is oil-bearing. It contains no water, and oil and gas occur wherever there is sand, regardless of the minor structural features. According to the statement of one operator, the wells located higher structurally had a slightly greater initial production.

Production and decline.--The thinner but more thoroughly saturated sand in this field furnished wells of 50 to 125 barrels initial production. This compares favorably with the production of the wells in the channel sand bodies that are 35 to 50 feet thick but which are made up partly of broken sand. At the end of the first year the average yield per well in the Colony field was 5 barrels; second year, $2\frac{1}{4}$ barrels; third year, $1\frac{1}{4}$ barrels; fourth year, 1 barrel; fifth year, $\frac{1}{2}$ barrel.

The oil is 33 to 34 degrees Baume', and has a dark green color.

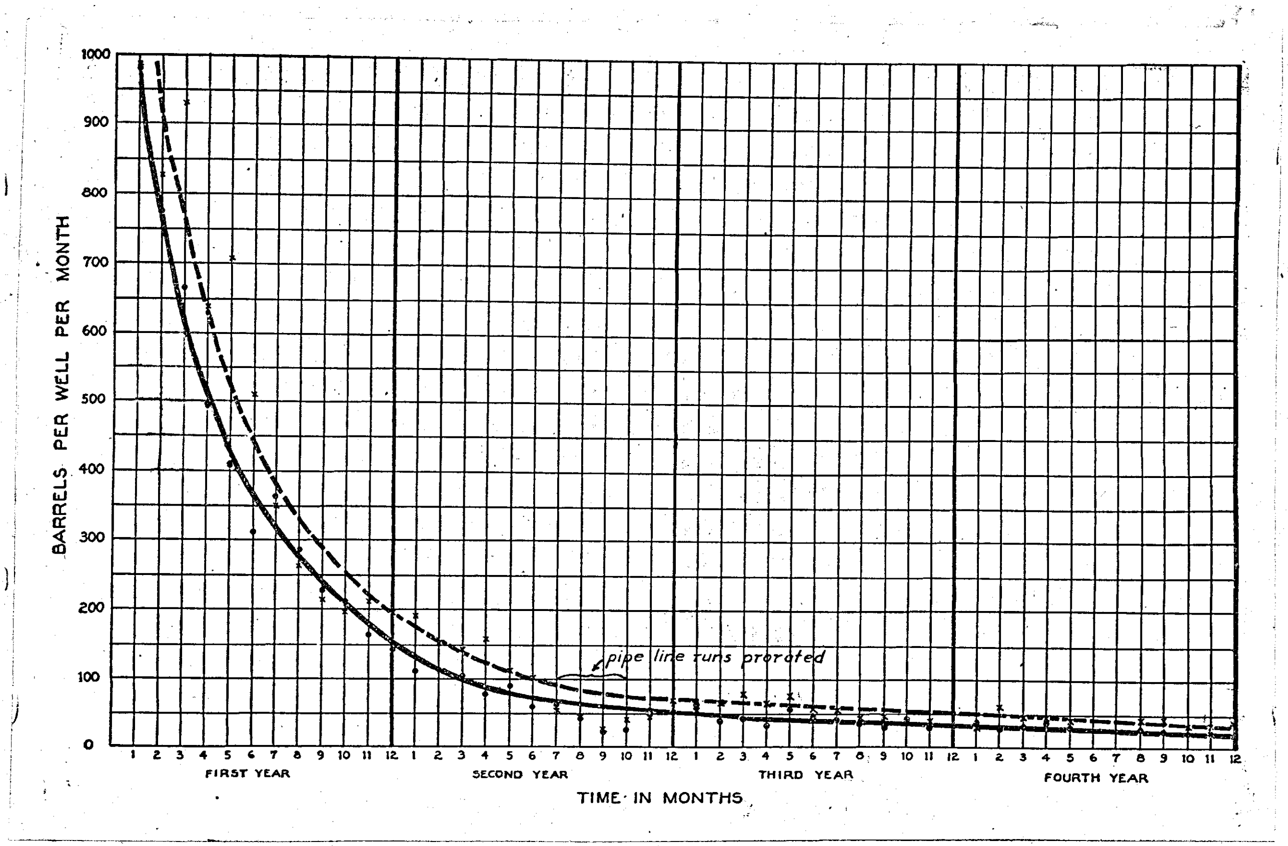

Fig. 11. Production decline curves of leases in the Colony oil field.

Colony Gas Field.

Location.--The Colony gas field extends in a sharply defined northeast-southwest course through the village of Colony and includes half a mile of the gas-producing area on each side. (See Fig. 12)

Development.--The development of the Colony field included a townlot drilling campaign that was attended by the usual financial loss to most of those who participated and a further irreparable loss of a constantly diminishing natural resource. Wonder is often expressed that the village of Colony did not suffer some great disaster when this unrestricted campaign was being carried on. This wasteful drilling took place in spite of the earnest efforts of some of the experienced operators to avoid it. Plans were hurriedly formulated to "pool" the acreage and drill only one well on several blocks. However, the opportunity presented to the unscrupulous to obtain "proven" acreage for purposes of their own, prevented a sane development program from being carried out. Many drilling blocks, each made up of a few city lots, required numerous protective offsets. Feverish drilling contests were conducted by neighboring crews to reach the sand first. Fifteen to twenty portable rigs were running at one time and, on certain days, the air surrounding the village was filled with rock dust and gas blown from the open drill holes. Rigid precautions had to be taken to prevent fires. Frequently, the engines of the drill rigs were operated by gas pressure because steam could not be used when no fires were permitted in the boilers. Housewives temporarily abandoned their homes to escape the danger attendant on wells being completed in their dooryards. Within five months, beginning in July, 1921, the drilling orgy had spent itself and left in its wake 90 gas wells in an area 2000 feet wide and a mile long. On one 40-acre tract were 31 gas wells and 2 dry holes. One well would have been sufficient to drain these 40 acres. The rock pressure of some of the wells was lowered so rapidly that they could not push gas into the gathering line after six weeks of life.*

The most regrettable thing about such useless drilling is the waste of gas--gas that can never be replaced. Probably enough to supply the city of Garnett for 10 years escaped when the wells were being drilled in. Other millions escaped through the avenues always associated with the development of a gas field.

The position of three dry holes northeast of Colony (indicated on Fig. 10 by diamond-shaped enclosures) in respect to the shoestring of gas sand illustrates how the hand of fortune delayed the discovery of the Colony field. The two south wells were put downnin 1908, the other in 1917. In 1921 the gas trend was traced through two sides of the triangle of old wells that are only a mile apart. This is anothereex-ample of how, unknowingly, dry holes are drilled close to oil and gas pools, and also, how dry holes in shoestring territory "condemn" only a small area around them.

<u>Surface structure</u>.--The testing of a large anticlinal nose, on the strength of geological advice, led to the discovery of the gas sand at Colony. The structure extends about N. 45° W. through sec. 8, T. 23 S., R. 19 E. and crosses the northeast edge of Colony. The rocks dip about

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*Some idea of the effectiveness with which the gas can be drained from its reservoir and the uselessness of so many wells may be gained from the development of a 240-acre lease northeast of the village. This lease, made up of the NE. $\frac{1}{4}$ and the E. $\frac{1}{2}$ NW. $\frac{1}{4}$ sec. 5, T. 23 S., R. 19 E., originally had 5 wells on it. All the wells were drilled in the fall of 1921. Their average initial volume was 14 million cubic feet and rock pressure 285 pounds. Five years later, another well was put down near the center of the lease and 1100 feet from the nearest old well, with the hope of replenishing the production. However, the attempt was disappointing because the open flow of the hole was only 65,000 cubic feet and the rock pressure $6\frac{1}{2}$ pounds, the latter the same as in the other wells.

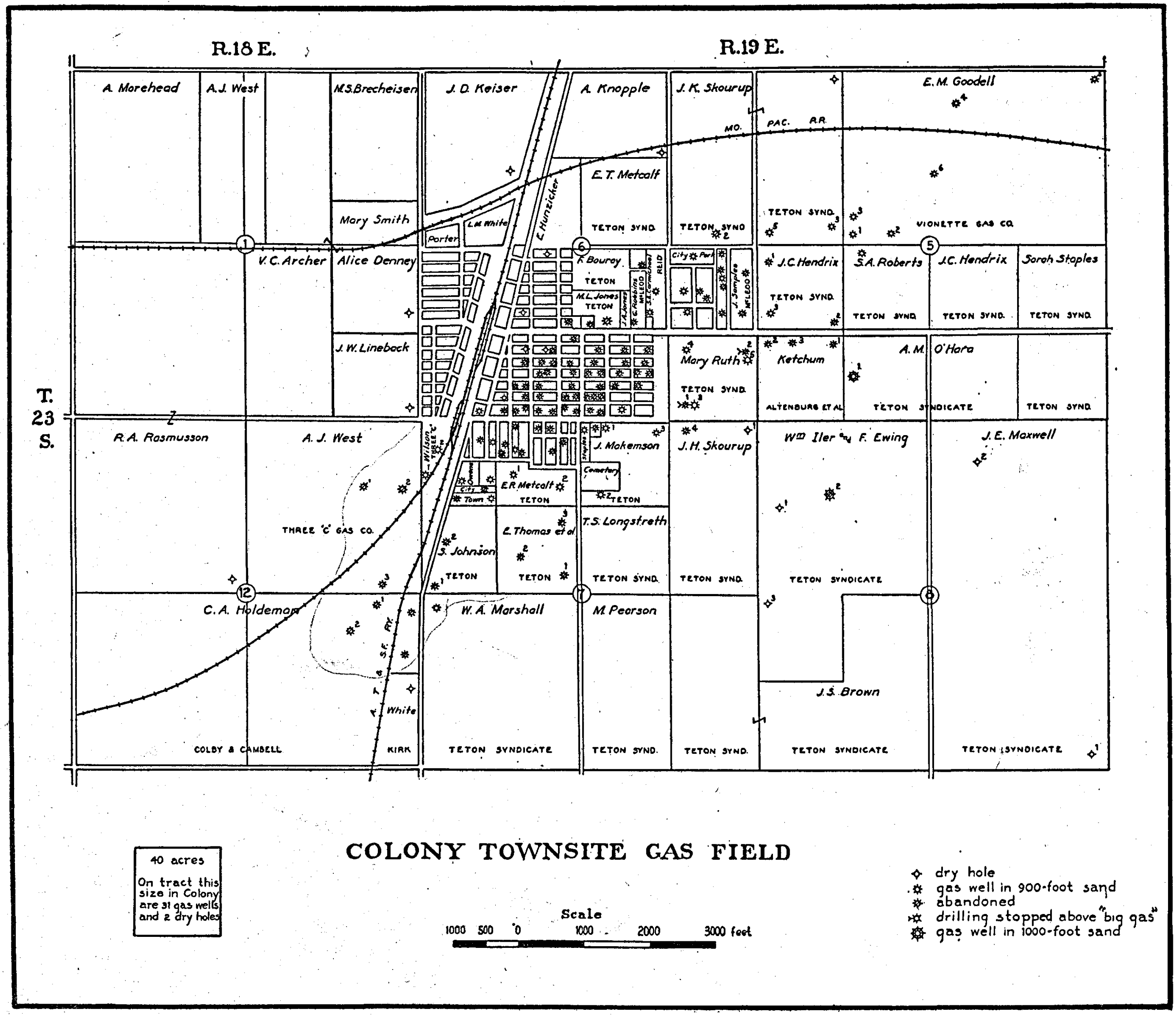

Fig. 12. Property map of the Colony townsite gas field.

50 feet from the top of the structure on the northern side of sec. 8 to the middle of sec. 6, T. 23 S., R. 19 E. The contours which represent the lowest 20 to 25 feet of dip swing southward to include a minor flat nose, or dome, in the N. ½ sec. 7. The north flank of the major structure dips into a parallel syncline whose axis passes through the NE. ¼ sec. 5.

The first well, on the highest part of the nose and in the NW. ¼ sec. 8, found no sand at the Colony horizon. A second test, about half a mile farther northwest, encountered a small flow of gas and was completed after being drilled through the gas sand into shale. Later, it was discovered that the sand penetrated in this first well was only a small portion of a thick body separated by a shale break from a lower portion, 50 to 100 feet thick, that yielded the "big gas".

The majority of operators gave no attention to surface structure in the development of the field. The limits are defined by the extent of the sand body, except on the southwest end, where the sand is lower and is water-bearing.

Subsurface structure.--Contours on the base of the Fort Scott limestone follow the trend of the sand body and define a long, narrow anticline having a west flank that dips sharply at the edge of the sand. Contours on the Altamont limestone and Iola limestone indicate structure essentially like that of the surface rocks. It appears that the dips in the Fort Scott limestone are caused by differential settling over the sand. The higher horizons do not reflect this condition.

Relation of production to structure.--As has been previously pointed out, the pool is only a segment of the 14-mile shoestring of gas sand that winds through the county. It ends about half a mile southwest of Colony where the sand becomes low on the regional structure and contains salt water. The greater accumulation at Colony may be accounted for partly by the anticlinal position of the sand in parts of secs. 5, 6, and 7. It dips off into synclines on each side--the one on the south holding water; the one on the north, smaller quantities of gas. Thus it may be observed that the Colony wells are on an anticlinal "high" that is part of a still larger "anticline" formed by the position of the long sand body on the regional dip.

Sand.--The sand, at the 900-foot horizon and generally referred to as the Colony sand, is included in a body having a maximum thickness of at least 135 feet and having thin wedge-like edges at a uniform distance of approximately 3000 feet apart. It is fine-grained, gray, and micaceous, and covers a considerable range in quality as controlled by varying a amounts of shale or sandy shale. A break of pure shale or sandy shale, occurs commonly in the upper part of the sand body and separated the "first gas", a relatively small amount in 10 to 50 feet of sand or sandy shale, from the "big gas" that comes from 50 to 100 feet of sand.

Outstanding features of the sand body are its great thickness, its abrupt thinning on the sides, and fingers of sand, 5 to 25 feet thick, projecting 500 to 2000 feet from about the middle of the sand body. In places there are at least three of these fingers of sand, separated by a few feet of shale. The top of the sand is slightly convex, or flat, and the bottom is outlined as convex where the lines defining the underside are projected beneath the depths to which the wells penetrated the sand. At Colony, the east side of the sand body decreases in thickness from more than 100 to 10 feet between wells 600 feet apart. On the west side, the decrease is at a lesser rate, or from 100 to 10 feet, in 1500 feet.

The characteristics of the sand body offer conflicting evidence as to its origin. Consideration of its origin here will include all the features observed throughout its extent in the county. (See sections L-L', O-O', and P-P', Pl. IV). Its gently winding course, in which it makes four bends, and its slightly convex underside suggest

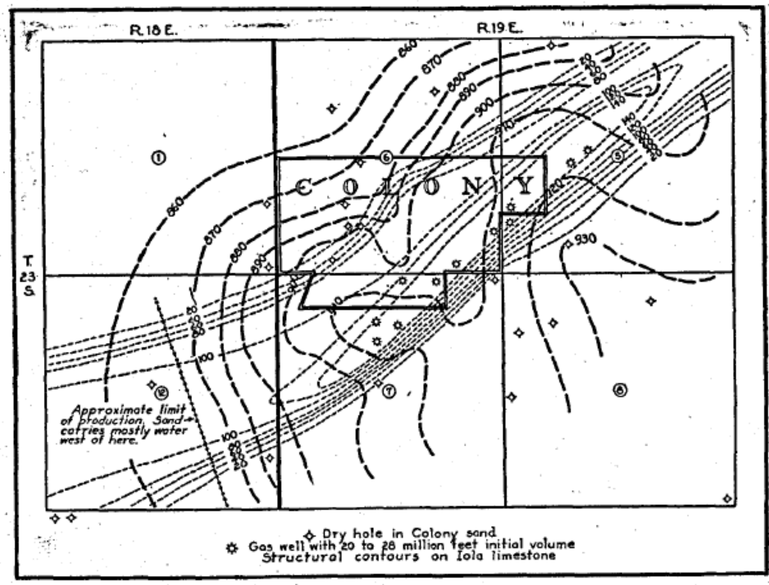

Fig. 13. Sand thickness and structural map of the Colony townsite gas field. The sand thickness contours are assumed from data furnished by dry holes on the edges of the sand, from wells which penetrated 100 feet or more, and from a well in sec. 5, which was drilled through the sand where it is 135 feet thick.

it to be a channel deposit of some kind. Its convex top, thickness, direction, lateral and vertical gradation into sandy shale, the inclusion of lenses of shale, and the variation in thickness along its trend, imply that it is a near-shore bar or beach deposit. The convex underside is not as sharp as in the channel deposits of the 800-foot sand. The average slope of the depressed section is only 1 foot in 25, or 4 per cent, whereas the slope of the underside of the 800-foot channels is often 1 foot in 6, or over 16 per cent. The depression is gentler than is suggested by the sections, plotted at an exaggerated scale. Near-shore bars are often deposited by currents flowing parallel to the shore. Such a current might scour a shallow depression in the sea floor along its course. If the current were given a load of sand, it would fill this depression, and later, the excess sand would be piled up to form the conventionally shaped beach deposit having features that would include a gently convex top, gradation into sandy shale on the sides, and thinning to wedge-like edges. The included lenses of shale indicate times when muddy waters drowned out those bearing sand. Perhaps the fingers of sand resulted from a part of the deposit being pulled out over the ocean floor by the back-drag of the waves. It seems likely that the waves aided in piling up the sand where it is thickest. Most of the stream-channel shoestrings of this district, regardless of their position in the Cherokee shale, have general east-west courses. The direction of the Colony-Welda trend counteracts evidence that it is of the same origin.

Production and decline.--The estimated open flow of the wells at the peak of the development is 900 million cubic feet. The original rock pressure of 285 pounds per square inch declined rapidly because of the many wells that tapped the reservoir. Within one year the pressure was down to 50 pounds, even in wells outside the village and located relatively far apart. The decline of pressure of some of the wells on town lots was plummet-like in rapidity. A curve that shows the decline of one of these wells is shown in Plate VI in connection with the curve for 10 representative wells in the outskirts of the village.

A rather peculiar and interesting situation developed while the drilling progressed at Colony. It was noted that the largest wells, those having an initial open flow of 20 to 28 million cubic feet, were in straight, narrow alignment, 600 to 800 feet from the east edge of the sand body. This line of large wells reached from the southwest corner of the NW. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 7 to the middle of the south line of the SE. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 5. All were drilled 100 feet into the sand. After a few had been drilled, the size of later wells could be predicted very closely from their position in respect to this narrow trend. It seems probable that the cleanness of the thick sand was an important factor in furnishing these large producers.

The initial volume of the many wells indicates the vast quantities of gas that were stored by Nature beneath Colony. A resume' of the producers shows that about 11 were rated at 20 to 28 million, 12 from 15 to 20 million, 35 from 10 to 15 million, 26 from 5 to 10 million, and 11 below 5 million. Each of these groups might be enlarged from the 30 unclassified wells. Seventeen dry holes were drilled.

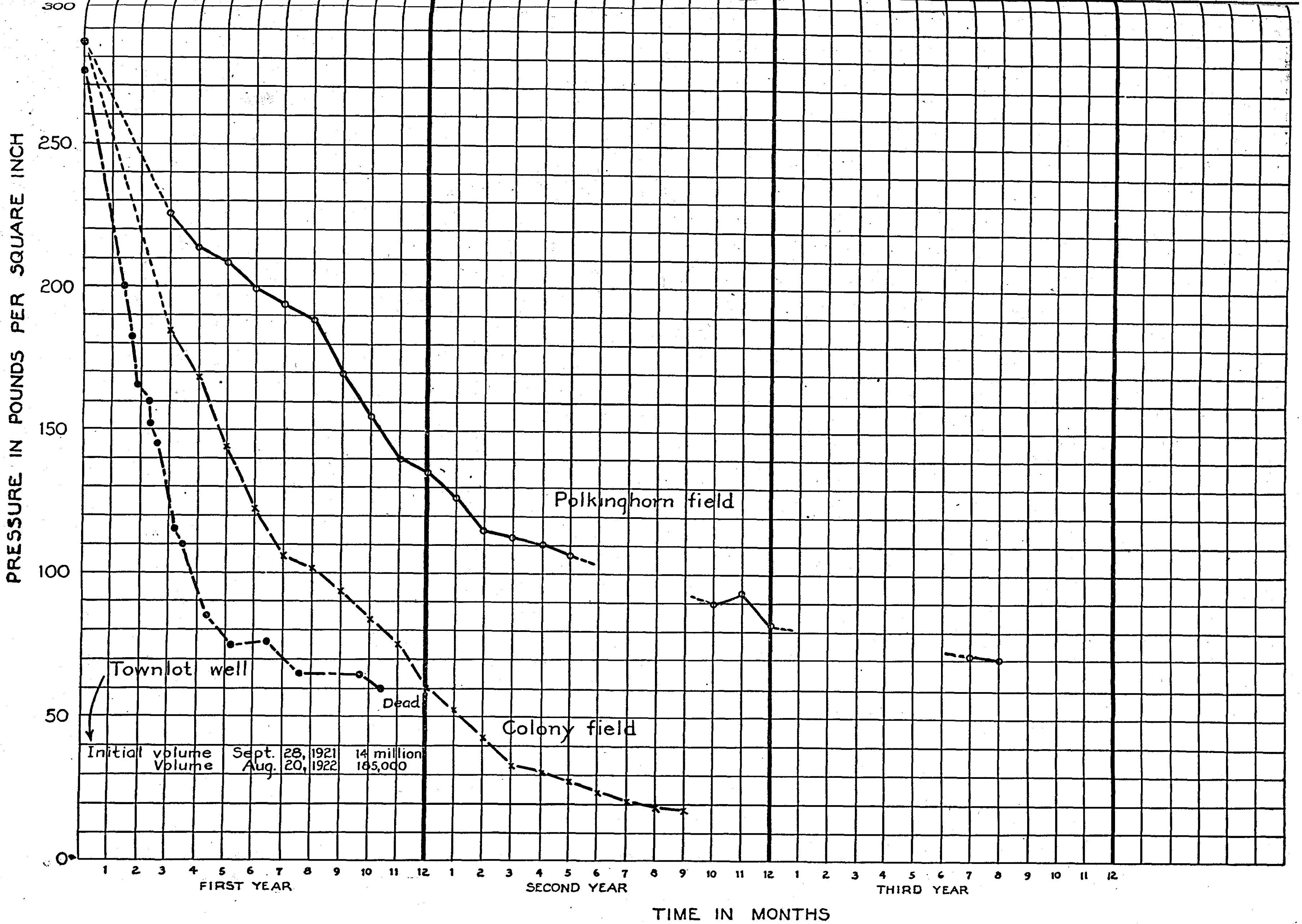

Plate VI Pressure decline curves of the Colony townsite and Polkinghorn gas fields.

Bush City Shoestring.

Location.--The Bush City shoestring is the long trend which has been developed from sec. 14, T. 21 S., R. 19 E. to sec. 27, T. 20 S., R. 21 E. This narrow field, 13 miles in length but averaging only a quarter of a mile in width, follows a gently curved east-west course in 8 miles of its trend on the western end and then turns northeast for 6 miles. It apparently joins the sand body of the older Goodrich shoestring at the eastern edge of the county.

Development.--Approximately 775 oil wells were drilled in this 13 miles of productive territory from March, 1923 to January, 1927, and, in addition, about 100 dry holes resulted from attempts to extend the trend or define its edges. On January 1, 1927 proven locations for about 50 wells remained, so the total number in the field should eventually be about 825.

The discovery well was drilled by A. H. Keys on the Emma J. Ware farm in the southeast corner of the NE. $\frac{1}{4}$ sec. 15, T. 21 S., R. 20 E. This well was located on a large anticline with the purpose of testing the Colony gas sand horizon. Two previous tests on the same structure were failures. When an oil sand was encountered unexpectedly at 800 feet in the third well, it was completed at that depth. Fate seems to have hurried the discovery of the Bush City field, because the successful well was drilled to retain a lease about to expire and on a location seemingly less favorable than many. The next well drilled after the discovery well, the southeast offset, was dry. The initial producer is only 500 feet from the edge of the sand body.

In another instance the discovery of this shoestring was delayed by only a narrow margin. Several dry holes, which had showings of oil, were drilled along the South Fork of Pottawatomie Creek in secs. 12 and 13,

T. 21 S., R. 19 E., three to five years before the first well was brought in four miles west of them. The trend that was subsequently developed passed between two of these old dry holes.

The history of the Bush City field is characterized by a series of spurts of activity controlled by the price of oil and by wildcat wells brought in ahead of proven territory.

<u>Wells which served as extensions to the Bush City field during its development.</u>

Operator	Well	Location	Length of extension in miles	Date
Peerless Oil Co.	No. 1 Crozier	Northwest corner SW. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 18-21-21 [a]	1	March, 1924
J. L. Rich et al.	No. 1 Whetstone	SW. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 13-21-19	4	May, 1924
Douglas Oil Co. and J. L. Rich	No. 1 S. P. Johnson	Southeast corner SW. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 7-21-19	2	June, 1924
Littrell and Polkinghorn	No. 4 Hydorn [b]	Northwest corner SW. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 8-21-21	3/4	April, 1925
Whiteside and Fieldor	No. 1 Badders	Southwest corner NE. $\frac{1}{4}$ sec. 8-21-21	1/2	April, 1925
Denton et al.	No. 1 Rosell	Southwest corner NW. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 4-21-21	1	May, 1925
Denton et al.	No. 1 Jackson	NE. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 32-20-21	1	Oct. 1925
Childs et al.	No. 1 Cleveland	Southeast corner SW. $\frac{1}{4}$ sec. 28-20-21	3/4	Jan. 1926

a 18-21-21 indicates section-township-range.
b This is the first well drilled beyond the bend north of Bush City.

Structure.--The surface rocks along this shoestring have been surveyed carefully, because geologists still cling to the hope that some peculiarities of structure may be found which will prove useful in locating local deposits of sand or tracing such deposits beyond their known limits. The Bush City field passes over a variety of minor structural features.

At the western end of the field, in sec. 14, T. 21 S., R. 19 E., the rocks rise to the east at about the normal rate and then flatten for a distance of one mile across sec. 13. From this rather flat area, or terrace, the normal northwest dip is present for 3½ miles to the middle of sec. 15, T. 21 S., R. 20 E. The base of the Plattsburg limestone is 90 feet higher at that point than at the west end of the field. In the E. ½ sec. 15 and the W. ½ sec. 14, the sand body crosses a dome on the north end of an anticline that occupies the east-central part of T. 21 S., R. 20 E. From the middle of sec. 14, T. 21 S., R. 20 E. to the N. ½ sec. 5, T. 21 S., R. 21 E. no key beds are exposed. Subsurface studies indicate that the sand rises about 45 feet from the west side of sec. 13, T. 21 S., R. 20 E. to the crest of a dome in the NE. ¼ of that section and the NW. ¼ sec. 18, T. 21 S., R. 21 E. A shallow synclinal area in the NW. ¼ NE. ¼ sec. 18 is encountered before the sand again becomes higher in the SW. ¼ sec. 8. In the next 3 miles it has minor fluctuations in elevation that amount to a maximum difference of 35 feet. The sand is highest in the NW. ¼ sec. 8 and the SW. ¼ sec. 5, at 425 to 430 feet above sea level, and lowest in the NW. ¼ sec. 4, at 395 to 405 feet above sea level. At each end of this 3-mile section, and at points between, the sand is about the same elevation, because it follows approximately the strike of the beds. On each side of the line between secs. 27 and 28, T. 20 S., R. 21 E. the sand is relatively low, being 360 to 370 above sea level. From the western edge of sec. 27

it rises about 80 feet to the county line, where it is replaced by sandy shale and broken sand that have only showings of oil and gas.

Sand.--The producing sand is a channel-shaped deposit, 0 to 55 feet thick and 1000 to 2000 feet wide, that occurs 20 to 40 feet below the top of the Cherokee shale. The depth to the sand changes from about 600 feet in the eastern part of the field to about 800 feet in the western part. This difference is accounted for mostly by the regional dip and the topography. The lowest part of the channel is not always midway between the edges and therefore it pinches out more abruptly at some points than others.

The following examples are mentioned to picture how sharply the channel bottom rises. A well with 36 feet of sand in sec. 8, T. 21 S., R. 21 E. is offset on the south by a dry hole that had 10 feet of broken sand. A dry hole that had 6 feet of sand, in sec. 18, T. 21 S., R. 21 E., is 425 feet southeast of a well with 46 feet of sand. A failure with 2 feet of sand, in the NW. ¼ sec. 8, T. 21 S., R. 21 E., is 300 feet west of an oil well that had 44 feet.

Patches of sand, 2 to 30 feet thick, have been discovered outside of the main trend. They contain small quantities of black oil of lower gravity. Two to four feet of shoestring sand that had a showing of oil were logged in three tests in the NW. ¼ sec. 17, T. 21 S., R. 20 E. On the north side of the shoestring, in secs. 6 and 7, T. 21 S., R. 21 E., 12 to 30 feet of sand yield oil of 22 to 30 degrees gravity. This patch of sand is not connected with the main field through the area closest to it, but the ends of the patch may have "leads" into it. Perhaps it represents an abandoned temporary channel of the stream that was responsible for the main unit. A large number of failures a quarter to half a mile from the edge of the shoestring penetrated traces of sandy shale at the

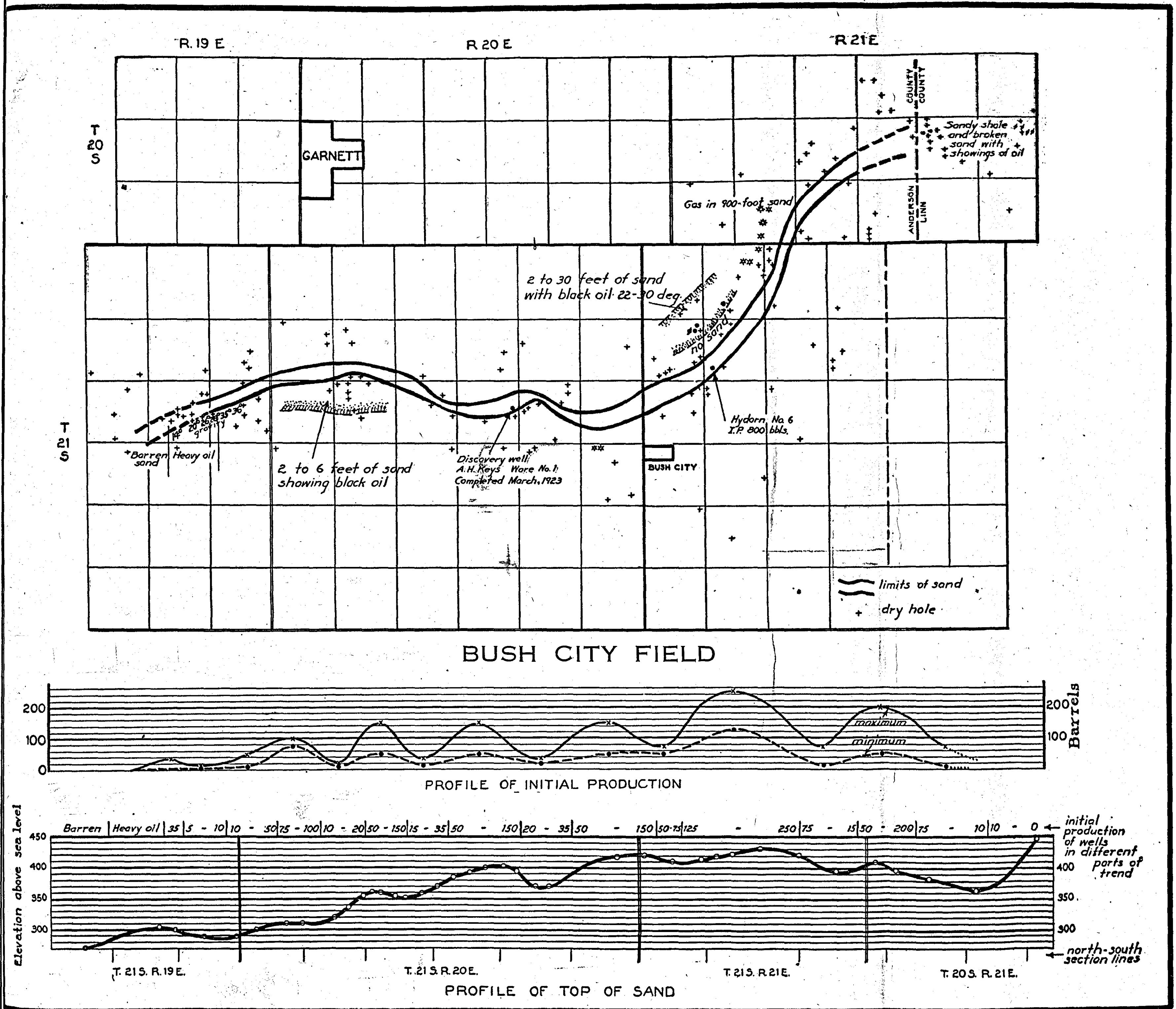
R. 19 E
R 20 E
R 21 E
T 20 S
T 21 S
GARNETT
COUNTY
COUNTY
ANDERSON
LINN
Sandy shale and broken sand with showings of oil
Gas in 900-foot sand
2 to 30 feet of sand with black oil 22-30 deg.
no sand
Hydorn No. 6 I.P. 800 bbls.
Barren sand
Heavy oil
gravity
2 to 6 feet of sand showing black oil
Discovery well A. H. Keys Ware No. 1 Completed March, 1923
BUSH CITY
limits of sand
dry hole
BUSH CITY FIELD
200
100
0
Barrels
maximum
minimum
PROFILE OF INITIAL PRODUCTION
Barren | Heavy oil | 35 | 5 - 10 | 10 - 50 | 75 - 100 | 10 - 20 | 50 - 150 | 15 - 35 | 50 - 150 | 20 - 35 | 50 - 150 | 50-75 | 125 - 250 | 75 - 15 | 50 - 200 | 75 - 10 | 10 - 0
initial production of wells in different parts of trend
Elevation above sea level
450
400
350
300
north-south section lines
T. 21 S. R. 19 E.
T. 21 S. R. 20 E.
T. 21 S. R. 21 E.
T. 20 S. R. 21 E.
PROFILE OF TOP OF SAND

Plate VII

channel horizon.

The channel filling is sandstone that varies over a wide range in quality, according to the amount of shale or sandy shale associated with it. The shale occurs mostly as fine laminae but increases in places to form beds at least 2 feet thick. The sand is divided into alternating layers of fine and coarse material that may be noticed in the drill cuttings. Those of the fine sand are so fine as to appear muddy; those of the coarse sand have a texture like sugar. It is likely that the sand is far more impure than generally assumed, because, by following the general custom of washing the cuttings in a bucket, the finest sand and the mud are eliminated, and the sample left for examination is made up of the cleaner, coarser sand.

Locally, a layer of hard, black, calcareous sand, 5 to 7 feet thick, and like that in the Garnett shoestring, covers the bottom of the channel. This sand is not believed to hold much oil, because no increase can be noticed when it is penetrated. It is not included in the part of the sand that is shot. The main producing zone, or "pay", is above the black sand and occupies about two-thirds of the channel. It is relatively clean sand that bleeds freely in wells of average size, or larger. The remainder is chiefly brownish-gray "broken sand" that holds some gas everywhere, but in varying amounts as governed by the structure. The term "broken sand" is often erroneously applied to clean sand that contains little oil. In some places the quality of the sand is uniform from top to bottom.

Fragments obtained from wells after they have been shot afford a good means of studying the producing rock. A poor cleavage is developed along the thin laminae whose surfaces are covered with flakes of mica. Tiny layers of silt appear as dark bands, and by means of these and the edges of the laminae of mica cross-bedding can be detected. After examining specimens of this fine, silty sand, one concludes that it lacks much of being an ideal reservoir rock.

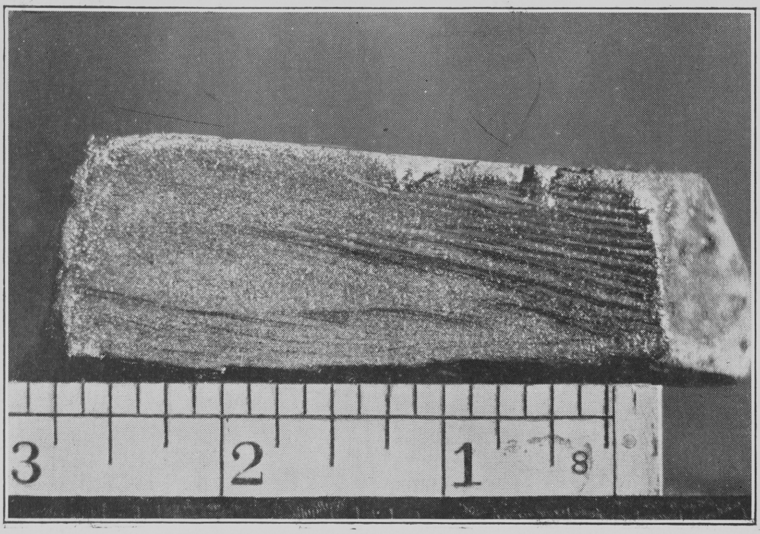

Fig. 14. Fragment of sand from the Bush City shoestring. The fine cross-bedding is shown by flakes of mica that line the bedding planes and separate the clean bands of sand. This channel sand retains a large percentage of its oil because of its fineness and lenticular structure of impure material.

Relation of accumulation to structure.--A noticeable condition in respect to the Bush City field is the variation in the amount of initial production of the wells in different sections. The areas of largest initial yield are structurally highest. This is shown conclusively by a comparison of the profile of the sand and the profile of the estimated initial production in various parts of the trend. (See Pl. VII). Wells in some of the synclines made only 5 to 15 barrels, whereas wells on adjacent anticlines made 50 to 150 barrels the first day. Local synclinal areas that furnished moderately large producers are generally a part of a major high area. Such a condition exists in the NE. 1/4 sec. 18, T. 21 S., R. 21 E., where wells that made 50 to 75 barrels are in a shallow syncline which is a part of a 3-mile anticlinal section that proved to be the most prolific of the entire shoestring. The individual wells within the areas of different productivity vary greatly among themselves. This is evidently caused by differences in the quality of the sand, which is made up of fine and coarse, dirty and clean lenses. The quality of the sand may offset the effect of structure, as demonstrated by the barren broken sand in sec. 26, T. 20 S., R. 21 E., on the western edge of Linn County. This area is higher than any part of the shoestring in Anderson County and would have been expected to furnish large wells had the sand been clean.

Heavy oil.--Conditions somewhat similar to those in the west end of the Garnett shoestring are also present in the west end of the Bush City field. The dark green oil of 35 to 36 degrees gravity is replaced by heavy, black oil before the sand becomes barren. However, the drop in gravity is more abrupt. A well near the west edge of sec. 13, T. 21 S., R. 19 E. produces 34-degree oil; a well 300 feet farther west has 28-degree oil. The oil pumped on the last commercial lease on the trend tests 26 degrees. A stringy, tar-like oil has been found near the middle of sec. 14. Beyond there the sand carries only a stain of oil.

Production and decline.--The extremes in initial production of the wells range from 5 to 800 barrels. It is difficult to estimate the average initial production, but it is placed at approximately 60 barrels. A few wells flowed naturally and most of those of average size flowed by heads for a day to a week after being shot. About 10 per cent started at 20 barrels or less and 10 per cent at more than 150 barrels. The largest well of the field flowed 34 barrels per hour during the first day.

This well was truly a freak because it produced initially 500 barrels more per day than its nearest rival.

A study of the decline of leases which were drilled up rapidly and had a good flush production, furnished by 75- to 150- barrel wells, indicates that the recovery by natural methods after 15 years will be from 4500 to 9000 barrels per well, or 1500 to 3000 barrels per acre.* The average recovery per acre on the best leases can be expected to be about 2500 barrels. The production of a well that made 100 barrels initially is $4\frac{1}{2}$ to $5\frac{1}{2}$ barrels at the end of the first year, 2 to $2\frac{1}{2}$ barrels at the end of the second year, and 1 to $1\frac{3}{4}$ barrels at the end of the third year. After the third year, the production will probably decline very slowly during the next 10 to 12 years until the average daily production is 1/5 to 1/4 barrel per well.

The possibilities of increasing the recovery in the Bush City field by applying air pressure are still unknown. The few air plants that have been installed have not been in operation long enough to furnish definite information as to their worth. Judging from the favorable results secured by the use of air on the older Garnett shoestring, an additional recovery may be allowed for in the Bush City field, although poorer sand conditions there may lessen the success of this method.

*Per acre recovery is estimated from the area included within the edges of the sand.

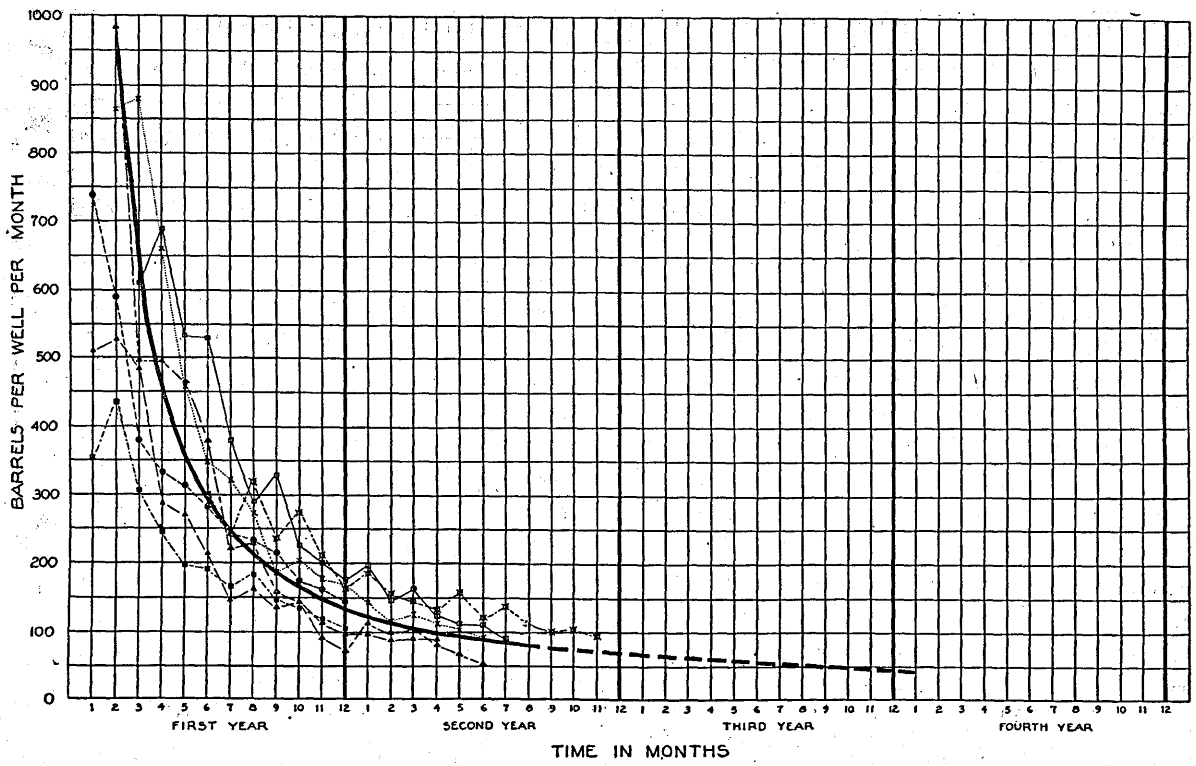

Fig. 12. Production decline curve of the Bush City shoestring.

Other Fields.

A few gas wells, which produce from the 900-foot sand, have been drilled 3 miles west and 1 mile south of Garnett. The largest wells are on the top of a small dome. Dry holes drilled off this dome encountered salt water. The initial daily papacity of the wells varied from 1/10 to $2\frac{1}{2}$ million cubic feet and their rock pressure was 275 pounds per square inch.

A short shoestring oil pool, 3 miles southwest of Colony, trends N. 30° W. The pool is about a mile long but only 700 feet wide. The channel-shaped sand body has a maximum thickness of 30 feet and is 10 to 15 feet below the top of the Cherokee shale. This trend has not been developed fully, because the wells had very small initial production.

A shoestring gas field in sec. 28, T. 21 S., R. 21 E. produces from the Colony sand, which is at a depth of about 700 feet here. The initial open flow averaged about 2 million cubic feet per well. The sand body is sharply defined on the edges, as shown by the dry holes, with 0 to 4 feet of sand, that are offsets to gas wells with 20 to 30 feet. A peculiar feature of this shoestring is that no water occurs in the bottom of the sand where it has been developed to date.

A narrow gas pool in the Colony sand is 7 miles east and $1\frac{1}{2}$ miles north of Garnett. The sand body is on the west flank of an anticline. Seven wells, which average about 2 million feet open flow when drilled in, make up the pool. The 300-foot sand is productive also in this field.

The source of the gas used in Garnett is in a shoestring field 7 miles east of the city. The gas comes from the Colony sand. Eight wells, with initial volumes of 1 to 4 million feet and pressure of 250 pounds, are in a narrow line 1 mile long, trending slightly east of north.

Refineries and Pipe Lines.

No refineries have been built in Anderson County. The oil enters trunk lines that reach refineries in Missouri, Illinois, and Indiana.

The Prairie Oil & Gas Company and the Sinclair Crude Oil Purchasing Company buy the oil from the producers. The former company was the original one in this district and its lines connect most of the leases. The Sinclair company takes oil from a few of the properties in the eastern end of the Bush City field and transports it to Centerville in Linn County, where it enters a trunk line. The main lines of the Prairie Pipe Line Company which are laid through the county consist of one 8-inch and three 12-inch lines. A pump station at Greeley has a capacity of 189,000 barrels per day.

The Kansas Natural Gas Company and the J. B. Kirk Gas & Smelting Company are the chief purchasers of gas. The Kansas Natural has two 16-inch lines which extend north-south. They cross the southern boundary of the county about 2 miles southwest of Colony, extend to Colony, thence along the Santa Fe Railway to Welda, from there to Garnett, and then pass straight north from Garnett across the Anderson-Franklin county line. The gas is raised to the line pressure, about 200 pounds, at a compressor plant at Welda and is transported with the gas from Texas and Oklahoma to Ottawa, Lawrence, Topeka, Greater Kansas City, Saint Joseph, and other towns and cities in that general district.

The J. B. Kirk Gas & Smelting Company supplies gas to a market made up principally of cement plants at Iola and Mildred, and the city of Iola. Its lines take gas from wells in the Colony-Welda district, from the field 3 miles west of Garnett, and from small pools on the eastern side of the county.

Future Possibilities of Anderson County.

The conditions under which the oil and gas occur in Anderson County make an appraisal of its future possibilities rather uncertain. Probably they rest principally in the dands that have already given the most production.

A few scattered deposits of the 300-foot sand that will yield gas may be expected, chiefly in the northeastern quarter of the county where this sand has been found most often.

The 600-foot sand, like the shallow one above it, has little potential worth. Up to this time, only a very small percentage of the gas production has come from it. The short lives of the wells, which had original small volume, make estimates of its future output almost negligible.

The two main sands, the 800-foot, or shoestring sand, and the 900-foot, or Colony sand, will probably contribute most of the future production. The part of the county south of the Bush City field offers good prospects for more shoestring fields of the channel type. If these deposits are the fillings of stream channels, it does not appear reasonable to believe that more than one or two of the size of the Bush City field, and two or three narrower ones, are present. Streams a quarter of a mile in width would be expected to be several miles apart. Minor branch deposits may be found, but, as yet, conclusive evidence of their existence has not been brought to light.

More small oil pools should be opened up in the Colony-Welda disdtrict between those already discovered, and also in an area one to two miles wide, paralleling the west side of the trend now outlined. The best prospects are believed to be on the west side, because the sand was laid down as a near-shore or beach deposit, with the sea lying to the west.

It is easy to conceive how scattered sand bodies may have extended some distance off shore. The almost complete lack of sand on the east side of the pools discovered to date makes it appear that the edge of the land bordered closely to the shoreline already traced out, and that east of the line, channel fillings are the only type of deposits to be expected.

Northwest of Garnett and between Glenloch and Scipio many wildcat wells have found good showings of oil in 2 to 50 feet of sand at the 800-foot horizon. Enough oil was found in some wells that other tests were drilled only a location from those that had the showings. Although no pools have been opened to date, the showings lend encouragement to the belief that this part of the county may yet yield commercial production.

It is doubtful whether any larger deposit of the Colony sand than that of the trend extending from Colony through Welda and northward will be found. The best place to expect this sand in large bodies is in the western part of the county where traces of it have been found in some dry holes and where little prospective territory has been eliminated by dry holes. Many more small, narrow fields, such as have been developed near the eastern edge of the county, will probably be opened up, some of them in general alignment with those found to date. Other north-south trends, made up of similar small sand bodies, may occur between this eastern series and the large Colony-Welda sand body. Any gas in the 900-foot sand west of the Colony-Welda shoestring is more likely to be collected only under anticlines or domes, because the sand would be below the water level as established by a line drawn between the two water-bearing ends of the trend.

Considerable drilling has been done in the Harris-Westphalia-Northcott district, chiefly in search for oil or gas in the thick sand immediately above the Mississippian limestone. A very small gas pool near Northcott is the only favorable result of this drilling. A few showings of oil induce a few operators to prospect in the area. Because this sand holds water, tests should be drilled only on structures. The absence of key beds in most of the district prevents selection of the favorable areas. The fact that the sand is only partially filled with water in places must be taken into consideration in locating tests for oil, which would most likely be on the flanks of structures just above the water-level. The gas, however, should occupy the highest points, regardless of the amount of water in the sand.

The weathered zone on top of the Mississippian rocks in the southeastern part of the county locally is capable of producing small amounts of gas and heavy oil. The rapid depletion of the gas, that appears to be in "pockets", and the poor quality of the oil, detract all commercial possibilities from this "sand" as long as the market for these products remains as it is.

The "first break" in the "lime" has furnished no production in this part of Kansas. It is worthy of being tested on structures by wells that have missed the upper sands.

The "second break", represented by the top of the "siliceous lime", might furnish small pools of low gravity oil. The accumulation of oil at this horizon is very sensitive to structural conditions. Oil in this "sand" in Montgomery and Chautauqua Counties has collected in small pools at the top of domes with 20 to 40 feet of closure. The oil is heavy, 22 to 24 degrees Baume', and about the same grade would probably occur in Anderson County. In view of the difficulties of determining the structure below the Mississippian limestone, and the small pools of heavy oil to be expected, it does not appear that there is at present sufficient inducement for prospecting in this zone.

The fine, impure sand of the Anderson County fields probably gives up far less than the average percentage of oil obtained from sand by natural drainage. The large quantities left in the sand should act as an incentive for the application of artificial methods of recovery. These may be depended on to account for a large portion of the future supply. It is likely that air or gas pressure will be applied to most leases before they are abandoned. Mining methods may be adopted in the end.

RELATION BETWEEN ACCUMULATION AND STRUCTURE IN THE OIL SHOESTRINGS

The two main oil shoestring trends in the county show a marked relationship between the accumulation of the oil and gas, and structure. In the Bush City shoestring the largest oil wells, and those which had the most gas with the oil, were on the anticlinal portions of the trend; the smallest oil wells, and those which had very little gas, were in the synclines. An explanation for this exceptional accumulation in the waterless sand is based on the fommer greater saturation of the sand, higher rock pressure afforded by a thicker overburden of sediments, and the character of the reservoir rock. Except for a few variations and additions, the writer is in accord with the theory offered by Rich[9] to explain the present unsaturated condition of some of the shoestring sands. In the case of the Bush City shoestring it is believed that the sand was originally filled with water, a <u>portion</u> of which was replaced by oil and gas. The customary gravitational separation in water-bearing sands took place--the oil and gas gathered in the higher parts of the trend and the water took up its position in the lower parts. It seems necessary to grant that the accumulation of gas and oil in the anticlinal portions of the trend took place while the sand held water--otherwise there would be no inducement for them to segregate in these higher places. Equal volumes of oil and gas were not exchanged for water, because the sand is not saturated now, assuming, of course, that only negligible amounts of the hydrocarbons have escaped since they migrated into the sand. All the oil and gas available for this replacement may have been used before all the water was taken up. It is believed that the water continued to travel into nearby shales to replace that which escaped with gases formed during the metamorphism of the shale, or perhaps into nearby shales of continental origin that were never thoroughly saturated with water.* As the water-bearing portions of the trend became smaller, the gas slowly followed up the water as the latter withdrew. The spread of the gas was facilitated when the rock pressure was lowered by the erosion of the overlying sedimentary column. The gas carried some oil with it to the parts of the trend vacated last by the water--the synclines. However, the very fine-grained, silty sand retarded greatly the spread of the gas so that only small amounts of oil and gas reached the areas where the sand is down-folded. Although no data are available, it might be expected that the sand in the synclines contains more cement, left when the water was slowly reduced in volume and at last completely absorbed. This would also retard the movement of the oil and gas and cause smaller wells.

A different condition may be noticed in the Garnett shoestring. The sand is filled with oil and gas throughout its course, there being no sections of light production as in the Bush City shoestring. It is believed that this is caused by a complete replacement of the former water in the sand with oil and gas. The higher parts of the sand are filled with gas; all the remainder is occupied by oil. (Fig. 6). Even the portion of the trend that crosses the deepest syncline in the county is thoroughly saturated with oil.

It is concluded that the relationship between accumulation and structure in the shoestrings depends on the degree of saturation of the sands with oil and gas and the texture and purity of the sand. It is probable that the oil in an unsaturated coarse-grained sand would drain into the synclines.

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*More detailed discussion of unsaturated shales and their relationship to the "shoestring" oil sand is given under "Absence of water from the oil sand" on pages 96-100.

BARREN SAND AND SAND CONTAINING HEAVY OIL

One of the greatest disappointments to oil operators who are drilling in shoestring territory, where sand deposits are so difficult to find, is the discovery of sand at the oil horizon that either shows no traces of gas, oil, or water, or yields unmarketable oil. Examples of the former are the barren sections at the west ends of the Garnett and Bush City shoestrings; of the latter, scattered patches of sand in the eastern half of the county.

The oil becomes increasingly lower in gravity in the two shoestrings until the barren zone is reached. The more rapid decrease in the Bush City field may be due partly to leakage of the lighter constituents, because two higher, normally non-oil-bearing sands hold a thick, asphaltic residue that is believed to have been deposited from oil and gas that escaped along a fault from the sand below. An unconfirmed report by early residents describes a gas seepage in the vicinity of the heavier-oil section.

The east edge of the barren zone in the Garnett shoestring is only a mile from a point where gas and oil were under pressure of 250 pounds per square inch. A similar condition existed in sec. 33, T. 20 S., R. 20 E., only half a mile from good gas wells in the same sand. One would naturally expect that the oil and gas would spread into the barren sand, the physical appearance of which differs but slightly from that which yields large quantities of oil. Rich[9] has suggested that the barren ends of the shoestrings might be accounted for by the former presence of water that has since withdrawn to the westward. Water-bearing sand has been found at the shoestring horizon on the western side of the county. The sand may be cemented so tightly by mineral matter or muddy sand between the barren and productive sections that the oil and gas cannot migrate. The barren sand is harder and is lighter colored than the oil-bearing sand, being more nearly gray than brown. Some of each type of sand from the Garnett shoestring was tested with acid. A sample from the rich part of the shoestring in sec. 6, T. 21 S., R. 20 E. did not cause any effervescence. A sample from a well on the west side of sec. 3, which had oil of 29 degrees gravity, and another sample from a dry hole in sec. 5, T. 21 S., R. 19 E., which had 40 feet of "dry" sand, both showed some effervescence, thus suggesting a cement of calcium carbonate. Perhaps the character of the shale adjacent to the sand is responsible for the lack of oil and gas, particularly if accumulation is not dependent on long-distanced migration. If the source of the hydrocarbons was in the underlying carbonaceous shales, a barren zone in the sand might reflect a "lean" condition in the shale. The relative richness of source rocks of petroleum is controlled by kind, quality, and conditions for preservation of the organic material buried with them. These factors might change within short distances along a low shore where the source-material itself would exist in varying amounts. Some of the material might escape oxidation and ultimately be a source of oil and gas; some might not be favored with the proper conditions and so might be destroyed. Perhaps the change from sand holding light oil through that containing increasingly heavier oil to the barren sand marks the westward change of the shales into which the channels cut--the change being from rich, carbonaceous shales to leaner, marine shales.

In some cases, shales of continental origin that were never thoroughly saturated with water and held only a little oil may have acted as "blotters" to absorb the water from the sand without returning a noticeable contribution of oil.

Small patches of the 800-foot sand, that hold no oil or only, small amounts of heavy oil are found up the dip from the barren zones in the ends of the shoestrings. Some of these patches are very near the shoestring fields of 35- to 36-degree oil. The heavy oil can perhaps be explained best by the escape of a controlling percentage of the gas associated with the original oil of normal gravity. Assuming that the rate of natural leakage would be the same, and because there would be a relatively greater contact with avenues of escape through the surrounding shales, a small body of oil would be depleted of a relatively larger portion of its lighter constituents than a large pool.

The pore spaces of the so-called barren sands are probably filled with small quantities of natural gas and so would not be vacuums, as the word "barren" might imply.*

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*Suggested to the writer by R. C. Moore.

ABSENCE OF WATER FROM THE OIL SAND

The absence of water from some of the shallow oil and gas sands of eastern Kansas and other parts of the Midcontinent field is a condition strange enough to attract more than passing notice. The lack of water reacts favorably to the operators in that the sand may be entirely penetrated when the wells are completed, and, when the casing is set properly, no trouble is experienced during operation by the invasion of water. A disadvantage may rest in the lack of pressure furnished by edge water in forcing the oil into the drill holes.

The term "dry" of the so-called dry sands has received different interpretations from geologists, some maintaining that the dryness is only apparent because the proportion of water to oil may be too small to be observed, or, in the case of sands that yield neither oil nor water, the interstices of the reservoir rock may be too fine to emit the contents. The latter condition is not related to this discussion which has to do with productive waterless oil sands. There appears to be no room for doubt that the oil sand of Anderson County is free of water-- at least to the extent that free water does not occur within the pore spaces. All the wells are drilled through the sand into the shale below, and none, even those in the synclines, produced water after several years of pumping. The color of the sand is not the light color generally associated with water sands.

It seems necessary to assume that the oil sands were water-bearing at one time, because, even though they were deposited under continental conditions and dried out, they would eventually be subjected to the entrance of some water when later water-borne sediments were laid down over them. Therefore, the problem must be attacked with the idea of accounting for the subsequent elimination of the water, and with the supposition that the effective conditions were peculiar to particular stratigraphic horizons, because water-bearing oil and gas sands are both above and below the non-water-bearing oil sand near the top of the Cherokee shales.

The absence of water from sands has been attributed to:

1. Hydration of minerals.
2. Evaporation due to heat.
3. Compaction.
4. Cementation.
5. Drainage as the result of elevation.
6. Mode of origin.
7. Absorbtion by unsaturated shales.
8. Removal by gases.

Hydration would probably have little effect in the elimination of connate water from the sands, because there are few, if any, minerals in them that would take up water in chemical combination, and further, such a process would more likely have taken place when the sediments were being transported. The mica is clearly clastic material that was transported with the other constituents of the sand, and settled flat with the bedding.

Evaporation by heat due to increased depth would not be expected to take place, because corresponding increases in pressure would tend to prevent the water from reaching its boiling point.

Compaction might eliminate some water by "squeezing" during the early stages of the process, but the degree of saturation would remain the same, or be increased, though some of the pore space were eliminated,

Although cementation might force out some of the water by filling up the pore space, the final effect would be the same as with compaction--the degree of saturation would remain the same. The extreme of such a process would be reached when all the pore space was taken up by the cement.

The situation might be pictured wherein partially-saturated sands would become dry after their water-content had drained down the dip. Difficulties arise in explaining this drainage from lenses of sand surrounded by shale and from a horizon between others that hold water.

Another theory suggests that the lack of water in the sands may be accounted for by the geologic conditions under which the sand and associated shale were laid down. The difference is thought to depend on whether the sediments, while being built up, were frequently exposed to the atmosphere because of their position near the shore or on flood plains, or were deposited in the sea and were never exposed to the atmosphere. Reeves[10] accounts for the absence of water in some oil sands by the supposition that, because of their continental origin, the sands were not originally saturated with water. By experiments he found that water will not thoroughly penetrate ½ meter of fine-grained sand after it has stood under water for several weeks. However, it does not appear reasonable to the writer that the waterless oil sands in this district escaped original thorough saturation. No doubt the shoestring channels were filled with sand under water, and the other kinds of sand bodies have the shape of those laid down in water.

The provision of unsaturated fine argillaceous sediments near the sand might give a working basis to account for the present lack of water in the sands. Perhaps muds deposited on low land near the sea during short periods of inundation would be dried and their pore spaces filled with air after the waters withdrew. The gray to white shale above the oil sand in this district has the appearance of air-dried material. King[11], in discussing the entrance of rainwater into soil, states:

> "where the surface is covered with this finer soil, even a moderate shower is likely to fill up the surface pores so completely as to prevent almost entirely the escape of the soil air, and this at the same time prevents the entrance of water. Under these conditions the little moisture that finds entrance to the soil penetrates so short a distance under the great hindrance of estrangled air that it is quickly returned to the surface by capillarity and lost by surface evaporation."

While it should not be expected that sheet water would be so effectively retarded from entrance into fine air-filled sediments, it seems possible that a thorough saturation would not result in all cases. When water spread over such sediments, probably some of the air would by-pass the water and bubble to the surface; other air might be driven back by the pressure of the water into the finest pore spaces and gradually be replaced by natural gas before the invading water reached it. After the addition of more sediments there would be no way of escape for the gas and it might eventually replace some of the water in the buried sands.

The original water-content of some of the shales may have suffered partial depletion by being absorbed and carried away by gases, principally methane, carbon dioxide, and nitrogen, which are formed during the metamorphism of organic matter.[12] This process might be so effective under some circumstances that the shales would lose all their free water and be dry, except for the films of moisture that might line the pore spaces. If this be true, the generally accepted view that the ground water occupies all the rocks within the zone of fracture must have exceptions additional to those best known, to include not only the waterless oil sands, but also the non-marine shales that were never saturated with water and were dried by escaping gases. Furthermore, in areas where the strata lie nearly flat and where there is little inducement for underground circulation or ingress or surface water, the rocks may be characterized by alternating "dry" and "wet" zones, depending, according to their origin, on whether their original content of water has been retained.

The most plausible reasons for the absence of water from the oil sand, according to the view of the writer, provide: (1) shales sufficiently petroliferous to exchange oil and gas for all the water in the comparatively small bodies of sand imbedded in them, (2) unsaturated shales caused chiefly by the escape of water with gases formed during the metamorphism of the shales--the unsaturated condition would not be one of long duration but rather one which would bring about without delay the repletion of the water-content of the shales by absorbtion of water from the coarser sands.

DISCOVERING AND TRACING SHOESTRING SAND BODIES

The evidence sought in the attempt to discover or trace shoestring sand bodies is divided into surface and subsurface indications. In Anderson County the search for surface evidence is confined to a study of structure, because all other kinds of evidence, such as seepages or bituminous deposits, are lacking. The surface structure has been employed theoretically on the basis of the following propositions:

1. Sand bodies might be reflected by differential settling.
2. Settling might reflect topographic features that favor the deposition of sand.
3. The structure of the surface rocks might conform with the subsurface structure, the former representing a renewal of folding that took place before the sand was laid down. Further, that the synclinal area might be above synclinal valleys that were occupied by streams now represented by channel fillings.

Some of the factors that would effect settling over sand bodies, or their later detection, are: (1) their thickness, (2) width in proportion to thickness, (3) cleanness, (4) weight of greatest overburden, (5) present distance from the surface, (6) influence of other agencies, such as uneven deposition or true folding, (7) type of conditions at the surface on which mapping is dependent, (8) personal equation represented in the geologist.

It should be easily understood how a thick sand body would be reflected more readily than a thin one. In the case of the former, the settling differential between the sand and the surrounding shale would be large, with a resultant large depression of the strata at the sides.

However, a wide, thick sand body, that lenses out very gradually, might not cause dips that would attract attention. More settling should take place adjacent to a body of clean sand than one containing considerable material like that at the same horizon. As previously noted, the amount of compaction of shale has been shown to be related closely to the weight of the overburden.[5] Additional data to take into account the factor of time would be of interest. Do Tertiary and Devonian (or older) shales compressed by equal weights of overburden have the same porosity? The "cavey" nature of Tertiary clays and sands in deep wells in the Gulf Coastal and California oil fields implies that the beds lack much of final compaction. If time is an important factor in the process of compaction, sand bodies in the older formations would be more likely to cause reflective dips than those in younger strata. The depth to which erosion has removed the rocks is vital in disclosing surface evidence of a sand body. The ideal situation would be the removal of a great thickness of relatively old formations to within a short stratigraphic interval of the sand. Counteracting conditions, such as uneven deposition and true folding, may eliminate all effects of differential settling. Few areas are free of such influences, and in the majority of cases, it is probable that upward reflection, if present, would not be represented by symmetrical dips that conform to the shape of the buried topographic features or depositional unit, but by irregular "wrinkles" or "noses", the resultants of all opposing forces. Uneven deposition is compensated for rather peculiarly in many districts by relatively thicker sediments occuring over thin ones, so that the interval between the top and bottom of a thick series is nearly the same over a wide area, even though individual members are lenticular. The disadvantage of formations of uneven thickness lies principally in their unsuitability for mapping.

In many instances the proper allowance cannot be made for depositional dips because no evidences of variations in thickness are noticeable unless both contacts of a formation are exposed, or sufficient reliable well logs are available. As another limitation to the settling theory, the type of conditions at the surface on which mapping is dependent should be considered. Since is is desirable to examine the surface structure in great detail, the key beds should be well exposed, persisent, not too numerous and similar within a short stratigraphic distance, of uniform thickness, and preferably rather thin. Finally, the personal equation, the ability of the geologist to map the structure and interpret its origin, carries an influence.

The main issue concerned with differential settling over sand bodies does not involve its existence, which is readily granted, but its limitations. Ample proof has been found by the writer that settling has caused dips immediately above sand bodies in Anderson County. The position of the thin edges of some of the bodies, even the channel deposits, indicates that depression has taken place proportional to the thickness of the sand and has given a slightly convex surface to a body that originally may have been more nearly flat. In one or two places where the sand has exceptional thickness, it seems to have effected the surface rocks, but in the great majority of cases its effects appear to die out among the unexposed formations.

Closely allied with the differential settling theory in connection with sand bodies is that which postulates the reflection of topographic features favorable to the deposition of sand. These might include sea-cliffs, headlands, or valleys. It is quite generally conceded that such features controlled the location of some of the Burgess sand that was laid down on the Mississippian floor. Since the Burgess carries very little oil or gas in Anderson County, it is not as earnestly sought as the other sands. No data are available to show whether the position of the sand is related in any way to the old Mississippian topography. The most important sands were laid down during local breaks in the deposition of the thick Cherokee shales. The idea that compaction over the Mississippian topography would be pronounced enough to cause features that would control the location of sand deposits in the Cherokee muds does not seem tenable, because the mud floor should have been leveled off by wave action more rapidly than differential settling would create reflections. A further barrier to the use of this theory is the absence of key beds to decipher topography in these shales.

The examination of structure along the shoestring channel fillings has not revealed that they follow synclinal areas. Probably the channel-streams flowed through wide, shallow valleys, independent of the dip of the rocks.

Subsurface evidence of certain kinds has been found to have more worth than surface evidence in the shallow fields of Anderson County. A suggested method by which the trend of sand bodies might be predicted involves contouring on a key bed a short distance above the sand, and warped by differential settling. Swings in the contours would be expected to indicate swings in the trend of the sand. This method is impractical in this district because the limestones in the Marmaton formation (the ones closest to the main sands) consist of many thin beds that seldom receive proper recognition from the drillers. Since some of the errors in measurement are cumulative, and may amount to 10 to 20 feet in all, the data that might have the precise use suggested are untrustworthy. Furthermore, wells ahead of the trend would very likely have traces of the sand, and those would carry more weight than structural data.

Traces of sand at the producing horizon, even sand that does not give showings of oil or gas, are important when areas are being outlined as possible seats of sand deposition. A geologist should be present when wildcat wells are drilled-in to note traces of sand that might not be enough to be shown in the log. The position of sand in depth might be so éffected by topography or dip that it would not be at its usual depth and so be passed by without proper notice by operators who do not keep such éffects in mind.

After the discovery of a new pool, the geologist should learn as soon as possible the type of sand body that has been found. Suggestions are furnished by its regional location but more accurately by its cross section. The most valuable information to use during development of a pool is isobathic contours of the sand. These not only indicate the thickness but outline the ground plan. By projecting the isobathic contours of the channel deposits, the thickness and position of the sand at undrilled locations can be foretold with surprising accuracy. Many dry holes on the edges of the trends can be avoided by paying attention to these sand-thickness maps.

Core-drilling of the important sections of a drill hole would give accurate samples that would allow uniform interpretations by a geologist. Features not disclosed by ordinary drill cuttings would undoubtably be brought to light and lead to valuable conclusions. The opportunities to make such studies would be welcome.

GENERAL CONCLUSIONS

The following conclusions are offered by the writer from his observations of the shoestring oil and gas pools of Anderson County:*

1. Given a sand body filled with gas and water, the gas will collect in the highest part of the sand. Accumulation may be controlled by: (1) folding, (2) uneven deposition, (c) pinching-out up the dip.
2. Thin patches of sand or long narrow channel deposits are not associated with any particular type of surface structure. The idea that the shoestring oil fields follow synclinal areas is not supported by facts. They occur under all types of flexures.
3. Reflection of sand bodies in this district by differential compaction does not appear to have been effective in the surface rocks. Strong evidence of such reflection in a few areas is so outbalanced by contrary evidence in many other areas that application of the settling theory cannot be made with the same degree of confidence as imposed in the structural theory in regions where conditions are favorable to it.
4. The accumulation of oil and gas in the non-water-bearing sand is controlled by the elevation of the sand and its cleanness. Where there is an abundance of gas, the "highs" are occupied by it and the oil is forced to take up its

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*The writer wishes to emphasize that these conclusions are based on studies of one particular area of eastern Kansas--one that represents the extreme in shoestring fields. Judgment cannot be passed on all the shallow fields on the basis of this report, because in a large portion of the eastern part of the state the sands are sufficiently widespread to cause "structure" to be given the usual primary consideration.

position in the synclines. Where there is a small amount of gas, the oil is in greatest amounts in the "highs". The effect of structure may be varied by the purity of the sand.*

5. When exploring for new deposits or extensions of the oil sand, a geologist should grant more importance to indications of sand deposition than to structure. Past experience has shown that it is dangerous to ignore a trace of sand at the significant horizon in preferance to an untried structural theory.
6. When exploring for gas, it is best to drill on structurally high places in line with the defined trend of a sand body. Local structure may be ignored if the position of the sand in respect to the regional dip is anticlinal. However, wells with larger volume may be looked for on the higher portions of a trend.
7. Several noses along the thick body of 900-foot sand between Colony and Mont Ida should be kept in mind while more data are being collected to aid in the discovery of sand bodies. Perhaps future developments will point rather conclusively to the fact that noses, rather than closed structures, are the results of differential settling over sand bodies.

*Conclusion No. 4 reflects a very exceptional condition that probably holds true only locally, where waterless oil sands are very fine-grained. The common condition wherein oil in waterless sands is pooled in synclines is represented in fields only a few miles farther south.

8. Geologic methods must conform to the conditions in the territory in which they are applied. <u>Many disappointments await the geologist who uses the practices with which he is most familiar in areas that lack the fundamental requisites on which those practices depend</u>.

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STATE GEOLOGICAL SURVEY OF KANSAS

PRODUCTION MAP OF ANDERSON COUNTY, KANSAS

RAYMOND C. MOORE
STATE GEOLOGIST

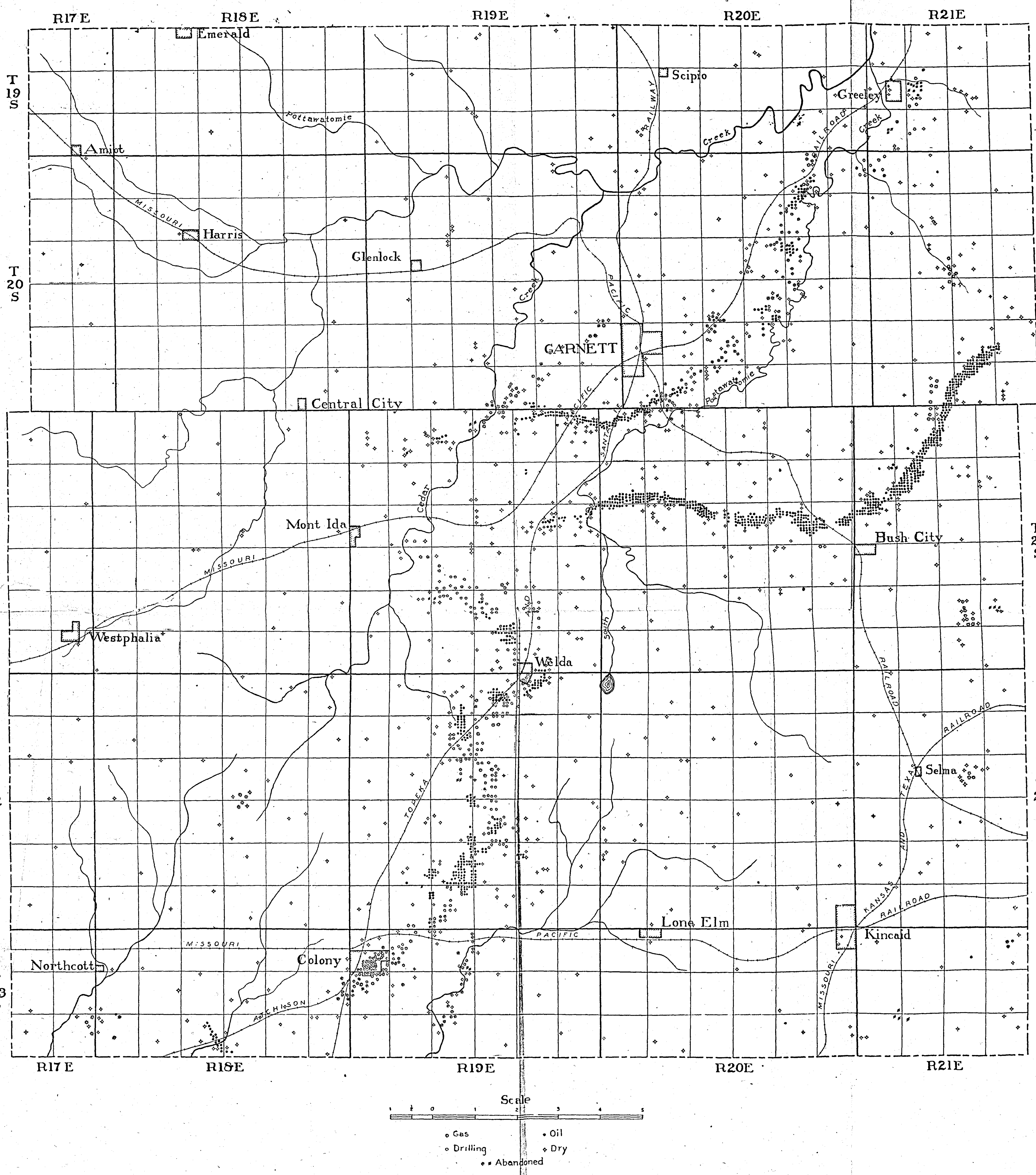

Plate VIII