PETROLEUM AND NATURAL GAS.

THE MENIFEE GAS FIELD AND THE RAGLAND OIL FIELD, KENTUCKY.[1]

By M. J. MUNN.

INTRODUCTION.

HISTORY.

Menifee gas field.—Gas was discovered in the Menifee field in March, 1904, in a well of the New Domain Oil & Gas Co. on the E. and J. Mynhier farm, about 4 miles S. 25° W. of Rothwell, Menifee County, Ky. The gas was found at a depth of 452 to 478 feet in the "Corniferous" limestone (Boyle limestone of Foerste) just below the black Ohio (Chattanooga) shale. This well developed a closed pressure of about 79 pounds to the square inch and an initial daily capacity of 460,000 cubic feet. The total number of wells drilled in the field up to June 1, 1911, was 115. These range from less than 350 feet to about 800 feet in depth, to the top of the gas-bearing limestone. The majority of the wells are between 400 and 600 feet deep, the difference in depth being due largely to the unevenness of the surface of the country. Of these wells, 90 were gas wells and 25 dry holes. On June 1, 1911, only three of the gas wells had been abandoned. The greatest daily production of the field is not known, but on June 1, 1912, it was reported by the Central Kentucky Gas Co. to be approximately 25,000,000 cubic feet, the gas having a closed pressure of about 60 pounds to the square inch. The field as outlined at that time was about 8½ miles long and 4½ miles wide in maximum dimensions, the total area covered being about 24 square miles. Only small "shows" of oil have been reported from a few of the wells in this field.

Ragland oil field.—This field is about 15 miles northeast of the Menifee gas field. It was discovered October 15, 1900, by a well on the Wooley heirs' property in the extreme southeastern part of Bath County, about three-fourths of a mile southwest of Cave Run station on the Licking River Railroad. This well produced at the start about 30 barrels of oil a day from the "Corniferous" limestone, which lies just below the black Ohio (Chattanooga) shale, at a depth of 381 to 395 feet. This field was largely developed between 1900 and 1904, though more or less drilling has been done since that time. Up to

[1] Surveyed with the cooperation of the Kentucky Geological Survey.

October, 1909, about 200 wells had been drilled in and around the field, of which probably 135 were oil producers. In the valley of Licking River, which crosses the field, the distance from the surface to the top of the "Corniferous" limestone ranges from 320 to about 375 feet. On the adjacent hills the maximum depth to this bed is over 800 feet. The largest daily production of a single well in this field is reported to have been between 200 and 240 barrels. All the other wells ranged from 1 to probably 30 barrels a day at their best. A number of the wells have been abandoned within the last three years, and there are many others which pay little more than the cost of operating them.

A relatively small area in the eastern part of the field has furnished light flows of gas from several wells. This, together with small quantities of gas from oil wells, has been largely utilized in gas engines for pumping the oil wells.

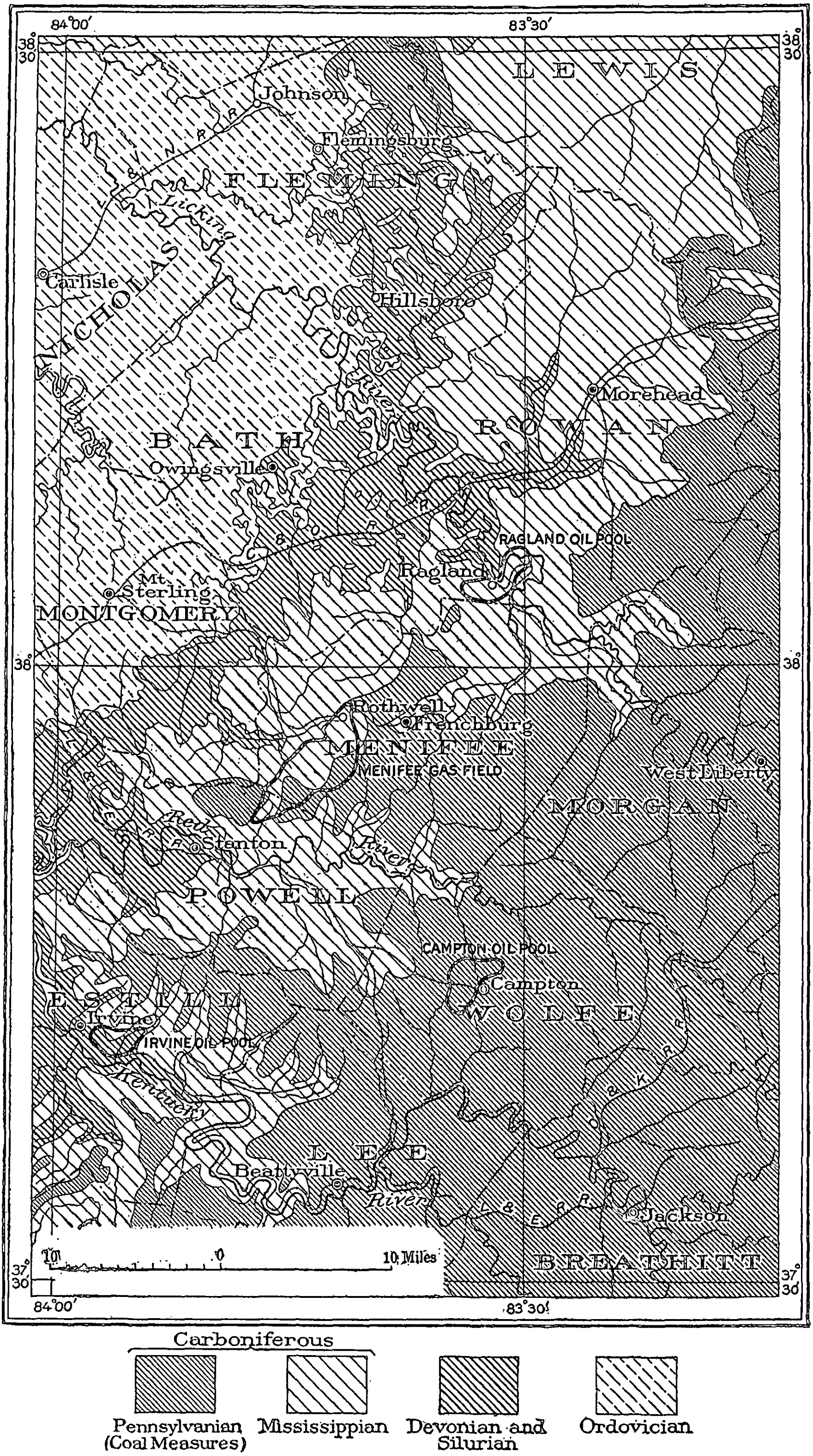
FIELD WORK.

Geologic investigations in the Menifee and Ragland fields, on which this report is based, were reconnaissance in nature, being part of a broader study of the oil and gas of the southern half of the Appalachian region, on which a report is being prepared. One day was spent in the Ragland field in October, 1909, and about four days in October, 1911. At this time three days were occupied in a general examination of the Menifee field. In this field the writer was assisted by W. B. Paynter, of Lawrenceburg, Ky., and his rodman, who spent three weeks during October and November, 1911, in running spirit-level lines to wells.

As the principal object of this work was to determine approximately the dip of the oil and gas bearing bed, practically all of the time available was spent in running spirit-level lines to the mouths of the wells, to determine their relative altitudes, and in copying logs of wells. No pretense was made of collecting all the geologic data available, especially those relative to the age and character of the outcropping rocks.

ACKNOWLEDGMENTS.

The State Geological Survey of Kentucky cooperated in this work through C. J. Norwood, the director, by supplying funds for the salary and field expenses of W. B. Paynter and his rodman for three weeks in the Menifee gas field, during which time Mr. Paynter made an excellent net of spirit-level lines over the field and secured the approximate altitude above sea level of a large number of wells. The writer is also indebted to Mr. John Tonkin and several other officials of the Central Kentucky Natural Gas Co. for the numbers



SKETCH MAP OF PORTION OF NORTHEASTERN KENTUCKY, SHOWING THE AREAL DISTRIBUTION OF THE ORDOVICIAN, SILURIAN, AND DEVONIAN SYSTEMS AND THE MISSISSIPPIAN AND PENNSYLVANIAN SERIES OF THE CARBONIFEROUS SYSTEM; ALSO THE POSITIONS OF THE CAMPTON, IRVINE, RAGLAND, AND MENIFEE OIL AND GAS FIELDS.

and logs of wells and other valuable data relative to the Menifee gas field. The New Domain Oil & Gas Co. furnished a large number of detailed logs of wells not only in the Menifee and Ragland fields but also throughout most of eastern Kentucky, together with a good sketch map of the Menifee gas field, showing the locations of the wells. The writer is also indebted to Mr. J. H. Fowler, of Salt Lick, Ky., for a sketch map of the Ragland field and records of wells, and to many citizens for assistance and information.

TOPOGRAPHY AND DRAINAGE.

The Menifee gas field and the Ragland oil field are situated in the hilly country bordering the eastern edge of the Blue Grass region of Kentucky. (See Pl. I.) Red River, a tributary of Kentucky River, flows westward along the southern border of Menifee County. Licking River, which forms a part of the northern boundary of this county and also marks the line between Bath County and Rowan County, flows northwestward and enters Ohio River at Cincinnati.

The Ragland field is partly in the valley of Licking River and partly on hills adjacent to it. The Menifee gas field is situated near the heads of Slate, Cane, and Indian creeks. Slate Creek is a tributary of Licking River and flows northwestward from the gas field. Cane and Indian creeks flow southward into Red River. The valleys of these rivers are wide and fairly level for a short distance upstream from the points where they enter the Blue Grass region, but farther up they become narrow and gorgelike between hills which rise from 400 to 600 feet above the river. In the Menifee gas field the drainage is through small rapid streams heading along the watershed between Licking and Red rivers. The altitude of the surface has a vertical range from less than 700 feet above sea level along the rivers to probably as much as 1,500 feet on the highest hills. As a rule the hills are very narrow topped and steep, only a small percentage of the surface of the hill land being tillable. The hills were once covered by a fine forest of oak, pine, poplar, tulip, elm, and chestnut, most of which has long since been cut away, and in its place are dense thickets of small second-growth timber.

GEOLOGY.

STRATIGRAPHY.

GENERAL STATEMENT.

The Menifee gas field and the Ragland oil field are situated on the western edge of the Appalachian bituminous-coal basin and just a few miles east of the line of outcrop of the Ordovician limestones which form the surface of the Blue Grass region.

The Ordovician strata have a general dip toward the southeast at a low angle from the Blue Grass region, at the border of which they pass beneath successively younger rocks of Silurian and Devonian age. These younger rocks are exposed in a narrow belt of hilly country immediately east of the Blue Grass region and are in turn overlain by Carboniferous rocks of the Mississippian and Pennsylvanian series, which form the surface rocks eastward across the Appalachian coal basin. In the western parts of Virginia and Maryland and the eastern part of West Virginia the older Ordovician, Silurian, and Devonian rocks are again brought to the surface in areas where the beds have been subjected to relatively intense folding and faulting.

UNEXPOSED ROCKS.

LOGS OF WELLS IN THE MENIFEE AND RAGLAND FIELDS.

The nature of the rocks not exposed at the surface is shown by the following logs of wells in the Menifee gas field and the Ragland oil field:

Logs of wells in the Menifee gas field.

G. W. Pitts's well No. 1, drilled by New Domain Oil & Gas Co., Mar. 4, 1905, 5 miles S. 5° W. of Rothwell on Spaws Creek.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil and gravel, yellow, loose	10	10
Sandstone, light, medium	33	43
Shale, light, medium	66	109
Limestone, gray, medium	8	117
Shale, blue, soft	13	130
Sandstone, light, hard	9	139
Shale, light, soft	25	164
Lime, blue, hard	56	220
Shale, blue, soft	5	225
Lime, blue, hard	38	263
Shale, blue, soft	27	290
Rock, red, hard	8	298
Shale,[a] light, soft (pocket of gas at 315 feet)	40	338
Shale, black, medium, Ohio (Chattanooga) shale	159	497
Fire clay, white, soft, Ohio (Chattanooga) shale	8	505
Lime, gas, hard ("Corniferous" limestone)	84	589
Salt water at 511 feet.		
Shale, blue, medium	8	597

R. S. Amburgy's well No. 1, drilled by Central Kentucky Natural Gas Co., Apr. 9, 1909.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil, yellow clay	7	7
Shale, blue, hard	28	35
Shale, blue, soft	23	58
Shale, blue, firm	32	90
Shale, blue, soft	8	98
Shale, blue, firm	38	136
Shale, blue, soft	9	145
Shell lime, gray, hard	1	146
Shale, blue, soft	9	155
Shale, blue, firm	45	200
Shale, blue, soft	10	210
Shale, blue, hard	15	225
Shale, blue, firm	61	286
Shale, blue, soft	14	300
Shale, blue, hard	10	310
Shale, blue, soft	14	324
Shale, blue, firm	41	365
Shale, blue, soft	15	380
Shale, blue, firm	35	415
Shale, blue, soft	53	468
Shell lime, gray, hard	2	470
Shale lime, firm	10	480
Shale, black, firm, Ohio (Chattanooga) shale	160	640
Fire clay, gray, soft, Ohio (Chattanooga) shale	10	650
Gas sand, fine, close ("Corniferous" limestone)	18	668
Gas sand, fine, loose ("Corniferous" limestone)	6	674
Shale, blue, firm	2	676

[a] Probably partly Ohio (Chattanooga) shale.

Logs of wells in the Menifee gas field—Continued.

G. W. Pitts's well No. 4, drilled by Central Kentucky Natural Gas Co., Aug. 11, 1909.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil, black, sandy	6	6
Shale, blue, hard	24	30
Shale, blue, firm	9	39
Shale, blue, soft	21	60
Shale, blue, firm	40	100
Shale, blue, hard	12	112
Unclassified	14	126
Lime shell, gray, hard	2	128
Shale, blue, firm	28	156
Shale, blue, soft	10	166
Shale, blue, hard	4	170
Shale, blue, firm	40	210
Shale, blue, soft	21	231
Shale, blue, hard	4	235
Shale, blue, firm	35	270
Lime shell, gray, hard	2	272
Shale, blue, fine	43	315
Shale, blue, soft	15	330
Shale, blue, hard	10	340
Shale, blue, soft	15	355
Shale, blue, fine	45	400
Shale, blue, soft	10	410
Shale, blue, fine	18	428
Lime shell, gray, hard	2	430
Shale,[a] blue, soft	10	440
Shale, black, fine, Ohio (Chattanooga) shale	145	585
Fire clay, soft, Ohio (Chattanooga) shale	10	595
Gas "sand," loose ("Corniferous" limestone)	22	617

J. J. Chambers's well No. 7.

	Thickness.	Depth.
	Feet.	*Feet.*
Unclassified	....	594
Sand ("Corniferous" limestone)	18	612

A. M. and E. E. Buchannan's well No. 1, drilled by New Domain Oil & Gas Co., May 20, 1905, 2½ miles S. 15° E. of Rothwell, on Myers Branch of Indian Creek.

	Thickness.	Depth.
	Feet.	*Feet.*
Gravel and soil, yellow and soft	4	4
Sandstone, blue, hard	1	5
Sandstone, blue, soft	5	10
Sandstone, blue, hard	3	13
Sandstone, blue, soft	7	20
Sandstone, blue, hard	4	24
Sandstone, blue, soft	7	31
Sandstone, blue, hard	18	49
Sandstone, blue, soft	19	68
Sandstone, blue, hard	9	77
Sandstone, blue, firm	9	86
Sandstone, blue, hard	6	92
Sandstone, blue, soft	1	93
Sandstone, blue, hard	1	94
Sandstone, blue, firm	4	98
Sandstone, blue, soft	18	116
Sandstone, blue, hard	26	142
Sandstone, blue, firm	38	180
Sandstone, blue, soft	39	219
Sandstone, blue, hard	2	221
Sandstone, blue, soft	4	225
Sandstone, blue, hard	1	226
Sandstone, blue, soft	3	229
Sandstone, blue, hard	1	230
Sandstone, blue, soft	16	246
Sandstone, blue, hard	1	247
Sandstone, blue, soft	18	265
Sandstone, blue, hard	10	275
Sandstone, blue, soft	6	281
Lime, brown, hard	2	283
Shale, blue, firm	44	327
Lime, blue, hard	1	328
Shale, blue, firm	60	388
Lime, gray, hard	2	390
Shale,[a] light, firm	8	398
Shale, black, firm, Ohio (Chattanooga) shale	157	555
Shale, light, firm, Ohio (Chattanooga) shale	8	563
Shale, black, firm, Ohio (Chattanooga) shale	½	563½
Gas sand, dark, hard ("Corniferous" limestone)	½	564
Gas sand, gray, open ("Corniferous" limestone)	1	565
Gas sand, dark, hard ("Corniferous" limestone)	1	566
Gas sand, dark, open ("Corniferous" limestone)	16	582

[a] Part of this may be Ohio (Chattanooga) shale.

Logs of wells in the Ragland oil field.

Ewing heirs' well No. 26, drilled by the New Domain Oil & Gas Co., Oct. 31, 1907.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil and gravel, yellow, soft	18	18
Shell, light, hard	1	19
Shale, light, soft	4	23
Shell, light, hard	2	25
Shale, blue, firm	75	100
Shale, blue, soft	15	115
Shale, blue, firm	75	190
Shell, light, hard	2	192
Shale, blue, firm	48	240
Shale, blue, hard and gritty	15	255
Shale, blue, firm	75	330
Shell, light, hard	2	332
Shale, blue, medium	38	370
Shale, blue, soft	50	420
Shell, light, hard	3	423
Shale,[a] blue, soft	19	442
Ohio (Chattanooga) shale:		
Shale, black, medium	19	461
Shale, blue, medium	8	469
Shale, black, medium	161	630
Shale, blue, medium	14	644
Sand, Ragland, dark, hard ("Corniferous" limestone)	55	699
Shale, blue, firm	4	703

Ewing heirs' well No. 27, drilled by the New Domain Oil & Gas Co., Nov. 15, 1907.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil and gravel, yellow, soft	15	15
Shell, light, hard	2	17
Slate, light, medium	9	26
Shell, white, hard	3	29
Sand, dark, hard	9	38
Sand, dark, firm	12	50
Slate, light, medium	20	70
Sand, dark, firm	20	90
Shale, blue, firm	92	182
Rock, light, hard	18	200
Shale, blue, firm	30	230
Shell, light, hard	2	232
Shale, blue, firm	103	335
Shell, light, hard	10	345
Shale, blue, medium	85	430
Shell, light, hard	2	432
Shale, blue, soft	42	474
Shell, light, hard	3	477
Shale,[a] blue, medium	33	510
Ohio (Chattanooga) shale:		
Shale, black, medium	15	525
Shale, blue, medium	17	542
Shale, black, medium	168	710
Shale, blue, medium	14	724
Ragland "sand," dark, hard ("Corniferous" limestone)	55	779

Wooley heirs' well No. 15, drilled by the New Domain Oil & Gas Co., July 1, 1903.

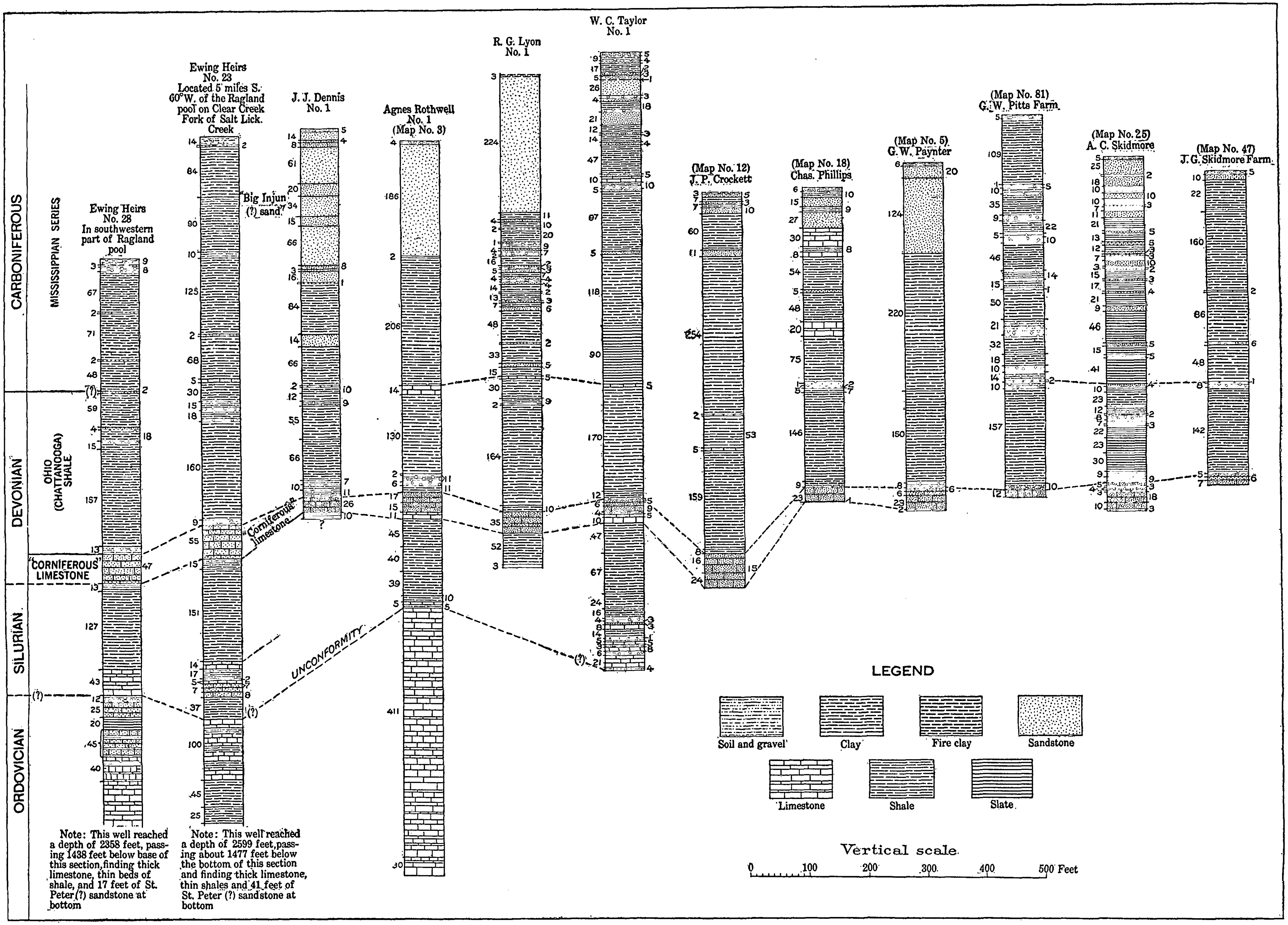
	Thickness.	Depth.
	Feet.	*Feet.*
Slate,[a] white	280	298
Ohio (Chattanooga) shale:		
Shale, white (?)	190	488
Fire clay	10	498
Shale, black	15	513
"Sand" (oil at 517 feet) ("Corniferous" limestone)	22	535

Wooley heirs' well No. 16, drilled July 20, 1903.

	Thickness.	Depth.
	Feet.	*Feet.*
Gravel	10	10
Lime, white	298	308
Ohio (Chattanooga) shale:		
Shale, black	207	515
Shale, brown	10	525
Fire clay	5	530
Sand (oil at 533 feet) ("Corniferous" limestone)	....	....
Total depth	....	549

[a] Probably partly Ohio (Chattanooga) shale.

The logs given above were selected from over 170 similar ones obtained from the oil companies operating in these fields. Twelve of these logs have been plotted on a scale of 200 feet to 1 inch and grouped with reference to the top of the black Ohio (Chattanooga) shale, as shown on Plate II. These sections have been arranged on the plate so as to form a line from northeast to southwest across the Ragland and Menifee fields. These sections represent the drillers' identifications of the rocks pierced by the drill, and though in the main correct it is very probable that the drillers have sometimes made errors in classifying the material brought up in the bailer. In studying well sections allowance must be made for these minor errors, and hence often only general correlations can be made.



SECTIONS OF DEEP WELLS IN THE MENIFEE AND RAGLAND FIELDS, KENTUCKY.

Figures at side of sections show thickness of beds in feet. Wells in Menifee field shown in sections are indicated on the map (Pl. IV) by a zigzag line joining the well symbols.

ORDOVICIAN SYSTEM.

The deepest wells drilled in eastern Kentucky of which records are at hand appear to have passed through the entire thickness of the limestones that are exposed at the surface farther west in the Blue Grass region and to have stopped in the St. Peter sandstone, near the base of the Ordovician system. Drillers describe this sandstone as hard, white or gray, containing in a few places slight "shows" of oil and gas and generally an abundance of "Blue Lick" (sulphur) water. Above this sandstone is light and dark limestone in alternating beds having a total thickness of 800 to 1,000 feet, which is overlain by dark or blue shale, with a few thin layers of limestone, occupying a space of less than 200 feet. This shale underlies blue to light-gray limestone from 300 to 500 feet thick, most of which at least appears to be in the Ordovician system. There is a possibility, however, that the upper portion of this limestone is of Silurian age. The formations composing this system can not be differentiated from well-record data.

SILURIAN SYSTEM.

The rocks for probably 30 feet to as much as 200 feet above the great limestone mass described above under the head "Ordovician system" consist principally of thin interbedded limestone and shale. These are overlain by soft red, pink, and light-colored shale from less than 50 to probably 200 feet thick, in which are noted here and there thin beds of limestone.

The Silurian rocks of eastern and southern Kentucky have been studied in great detail by Foerste,[1] who divides them into (1) the Brassfield (Clinton) limestone, at the base, and (2) the Crab Orchard division above, which he further divided into the Indian Fields and Alger formations, consisting largely of soft shale and two or more thin beds of limestone. These divisions of the Silurian can not be definitely recognized in the logs of wells.

DEVONIAN SYSTEM.

"Corniferous" limestone (Boyle limestone of Foerste).—The basal formation of the Devonian system in eastern Kentucky is a limestone ranging from less than a foot to probably 600 feet in thickness, which has been variously called the Devonian limestone, the Boyle limestone,[2] the "Corniferous" limestone, and, incorrectly, by drillers, the Clinton limestone. As it is overlain by a thin but very persistent layer of whitish clay shale, or "fire clay," which is at the base of the black Ohio shale, and in turn overlies soft blue and reddish Silurian shales from 75 feet to probably over 200 feet thick, this limestone is

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[1] Foerste, A. F., The Silurian, Devonian, and Irvine formations of east-central Kentucky: Bull. Kentucky Geol. Survey No. 7, 1906.

[2] Idem, p. 12.

easily recognized by drillers. It is the oil and gas bearing bed in the Ragland, Irvine, and Campton oil fields, and in the gas field of Menifee County. It is called by drillers the Ragland, Irvine, Campton, or Menifee "sand." From the Menifee and Ragland fields this limestone thins toward the south and west and thickens toward the east and north. At Irvine it is not over 20 feet thick and in many places is absent. South of that place it is cut out by an unconformity between it and the Ohio shale above. At Campton it probably has a maximum thickness of 200 feet. Near Hendricks the limestone identified as this formation is about 290 feet thick. On Lick Creek, about 5 miles northwest of Gallup, in Lawrence County, a limestone about 780 feet thick having some red shale not far below and the characteristic black Ohio shale above probably all belongs to this formation. The data on which this correlation is based will be published in full in the general report on oil and gas development in the southern Appalachian region. All the oil and gas of the Menifee and Ragland fields come from thin porous parts of the "Corniferous" limestone. This rock is in only a few places petroliferous throughout its thickness. The oil and gas bearing portion, or "pay streak," as it is called, varies greatly in position and thickness from well to well. It is gray to dark in color, hard and porous, the porosity being due to numerous minute cavities, many of which are microscopic in size. The limestone has, therefore, a true "oil sand" structure, in contrast to many limestones in the southern Appalachian region, which in many places carry small quantities of oil and gas in large crevices without having accumulations of commercial size.

In the Menifee gas field this limestone (gas "sand") in few places exceeds 40 feet in thickness. It averages about 20 feet. It seems to be somewhat thicker along the eastern edge but is fairly uniform in thickness in the remaining portion of the gas-producing area. It appears to be locally absent north and west of the productive area, the change in thickness coming very abruptly in many places. Wells Nos. 45, 51, 67, and 61, along the northern border of the gas field, found no "Corniferous" limestone, its place being occupied by soft blue shale. The thickness of the gas "sand" in adjacent wells is as follows: Well No. 43,[1] 10 feet; No. 66, 12 feet; No. 65, 9 feet; No. 63, 20 feet; No. 60, 10 feet; No. 122, 4 feet; No. 58, 17 feet; No. 62, 16 feet. Along the western edge the following thicknesses of "Corniferous" limestone were found: Well No. 75, 18 feet; No. 74, 10 feet; No. 18, 23 feet; No. 2, 12 feet; No. 120, 13 feet; No. 57, 2 feet; No. 55, 11 feet; No. 119, absent; No. 115, 19 feet; No. 113, 13 feet; No. 111, 9 feet; No. 117, 11 feet; No. 118, 9 feet; No. 101, 18 feet. Along the southeastern side, well No. 44 has 42 feet of gas "sand"; No. 42, 11 feet; No. 90, 26 feet; No. 91, 27 feet; and No. 72, 36 feet.

[1] See small numbers on map.

The fact that this limestone (gas "sand") is absent at five or more places along the northern and western sides of the Menifee gas field suggests strongly that it may be locally absent over most of the area a short distance farther in that direction. Judging from the variations in thickness of the "sand" as given above, the northwestern margin of this limestone may correspond to the dotted line shown on the map.

Ohio (*Chattanooga*) *shale.*—At the base of the Ohio shale, and immediately overlying the "Corniferous" limestone (Boyle limestone of Foerste), is noted in many well logs a thin layer of soft brown or dark shale, which in turn is overlain and locally replaced by a soft blue to whitish clay shale, which drillers frequently note as fire clay. This appears to be the bed described in many reports as overlying the Devonian limestone (Boyle limestone of Foerste) where it is exposed at the surface along the southern and eastern edges of the Blue Grass region. It seems to gradually increase in thickness, as noted in well records, eastward from its outcrop in the vicinity of Irvine, and to be from 100 feet to as much as 200 feet thick in Lawrence County. Above the white clay shale in the Menifee and Ragland fields is 150 or 200 feet of black fissile bituminous shale, in which occur at places thin brown to whitish or blue layers and which has been easily identified by drillers as the Devonian or black shale, wherever it has been penetrated by the drill over thousands of square miles in the Appalachian, Mid-Continent, and Northern Interior oil and gas fields.

In the southern Appalachian region, where this formation is generally represented by from 5 feet to less than 100 feet of black bituminous shale, it has been named the Chattanooga shale, from a typical exposure at Chattanooga, Tenn. In the northern Appalachian region, where the Devonian shale is thousands of feet thick and has several distinct subdivisions, it is known as the Ohio shale group. The region of transition from the northern to the southern phase is northeastern Kentucky.

CARBONIFEROUS SYSTEM.

MISSISSIPPIAN SERIES.

"*Waverly*" *formation.*—Between the Ohio (Chattanooga) shale and the lowest exposed rocks, in the Ragland and Menifee fields, is 200 feet or more of soft bluish shale, in which occur a few thin layers of limestone and sandstone. This shale is equivalent to the "Waverly shale" of Ohio and probably to the Pocono formation of Pennsylvania. The upper part of the "Waverly" formation is exposed for several hundred feet on the hillsides adjacent to the larger valleys and is described below under the head "Exposed rocks."

Attention is called to the thin limestone shown in a number of sections on Plate II, lying from immediately above the Ohio shale to 40 feet above it. Where this limestone does not lie directly upon the Ohio shale the two are separated by a very soft blue shale, and the limestone is similar in these respects to the Beaver Creek "sand" (a limestone) of southern Kentucky, which occurs at the same stratigraphic position. There is no information at hand to show that it has furnished any oil or gas in the Menifee and Ragland fields.

EXPOSED ROCKS.

In the short time at his disposal the writer was unable to make a detailed examination of the rocks exposed, and the following paragraphs give only a general description of the surface rocks:

CARBONIFEROUS SYSTEM.

MISSISSIPPIAN SERIES.

Beneath the Pennsylvanian series are between 550 and 650 feet of limestone, sandstone, and shale belonging to the Mississippian series. Only the upper 250 or 300 feet of these rocks are exposed at the surface.

"Waverly" formation.—The Maxville (?) limestone described below is underlain by sandy shale and thin-bedded sandstone, the latter being in places 200 feet or more in thickness and locally massive. This sandstone, from casual examination, appears to occupy about the stratigraphic position of the "Big Injun sand" of the drillers. Soft blue shale and thin sandstone layers, with possibly thin beds of limestone of the upper portion of the "Waverly" formation, occupy the base of the section of exposed rocks along the deeper valleys.

Maxville (?) limestone.—At or near the top of the Mississippian series is exposed in many places from 50 to 140 feet of limestone, which is probably equivalent to the Maxville limestone, or "Big Lime" of the oil region farther north, and which is probably the same, at least in part, as the Newman limestone of the Richmond folio of the Geologic Atlas of the United States and other reports on neighboring areas to the west.

PENNSYLVANIAN SERIES.

Pottsville formation.—In this district the hills are capped by a few feet to probably 300 feet of massive sandstone interbedded with sandy shale, thin beds of clay and coal, and possibly some limestone, all of which belong in the Pottsville formation.

STRUCTURE.

GENERAL CHARACTER.

One of the principal objects of this paper is to call attention to the structure of the "Corniferous" limestone (Boyle limestone of Foerste), which is the oil-bearing bed in the Menifee and Ragland fields. In these fields the dip of this formation has been determined by running spirit-level lines to many wells and determining their altitude above some local datum plane. This altitude, minus the depth to the top of the "sand," gives the altitude of the "sand" above the assumed datum plane. Variations in the height of the "sand" are shown graphically on the sketch maps of the fields by the larger numbers beside well symbols and by the contour lines, which have a vertical interval of 10 feet and are drawn through points of equal altitude on the top of the "sand."

In the Menifee gas field the datum plane selected is sea level, the spirit-level lines to wells being started from a bench mark of the United States Geological Survey on the top of the rail in front of the railroad station at Rothwell, which has an altitude of approximately 974 feet above sea level. In the Ragland oil field there was no bench mark showing the altitude above lea level, and it was not possible to run a level line to connect the two fields in the time available for the work. Consequently the rail in front of the railroad station at Cave Run was taken as a temporary bench mark, and its altitude assumed to be 600 feet above sea level. All determinations of altitude in the field were based on this datum, which is probably within 50 feet of the correct elevation.

The fact that the rocks of this district have a general dip to the southeast has already been pointed out. The amount of dip can not at this time be more than roughly approximated. In the Menifee gas field the "Corniferous" limestone (gas "sand") has an average elevation of about 400 feet above sea level. The elevation of the same sand in the Campton oil field of Wolfe County averages approximately 150 feet below sea level, showing a general dip of about 550 feet between the center of the Menifee gas field and the center of the Campton oil field, a distance of 15 miles, or approximately 37 feet per mile. These fields occupy similar local structural positions and lie on a line trending about N. 40° W., whereas the maximum dip is probably about S. 45° E., so it is estimated that the average general dip in that direction may be about 40 feet to the mile. It is interesting to note that the rocks also dip northeastward from Rothwell, in the Menifee gas field, to Cave Run, in the Ragland oil field, at the rate of probably about 10 feet to the mile. From the Ragland field almost due south to the Campton oil field, a distance of about 22 miles, the total dip is between 400 feet and 500 feet, or not more than 25 feet per mile.

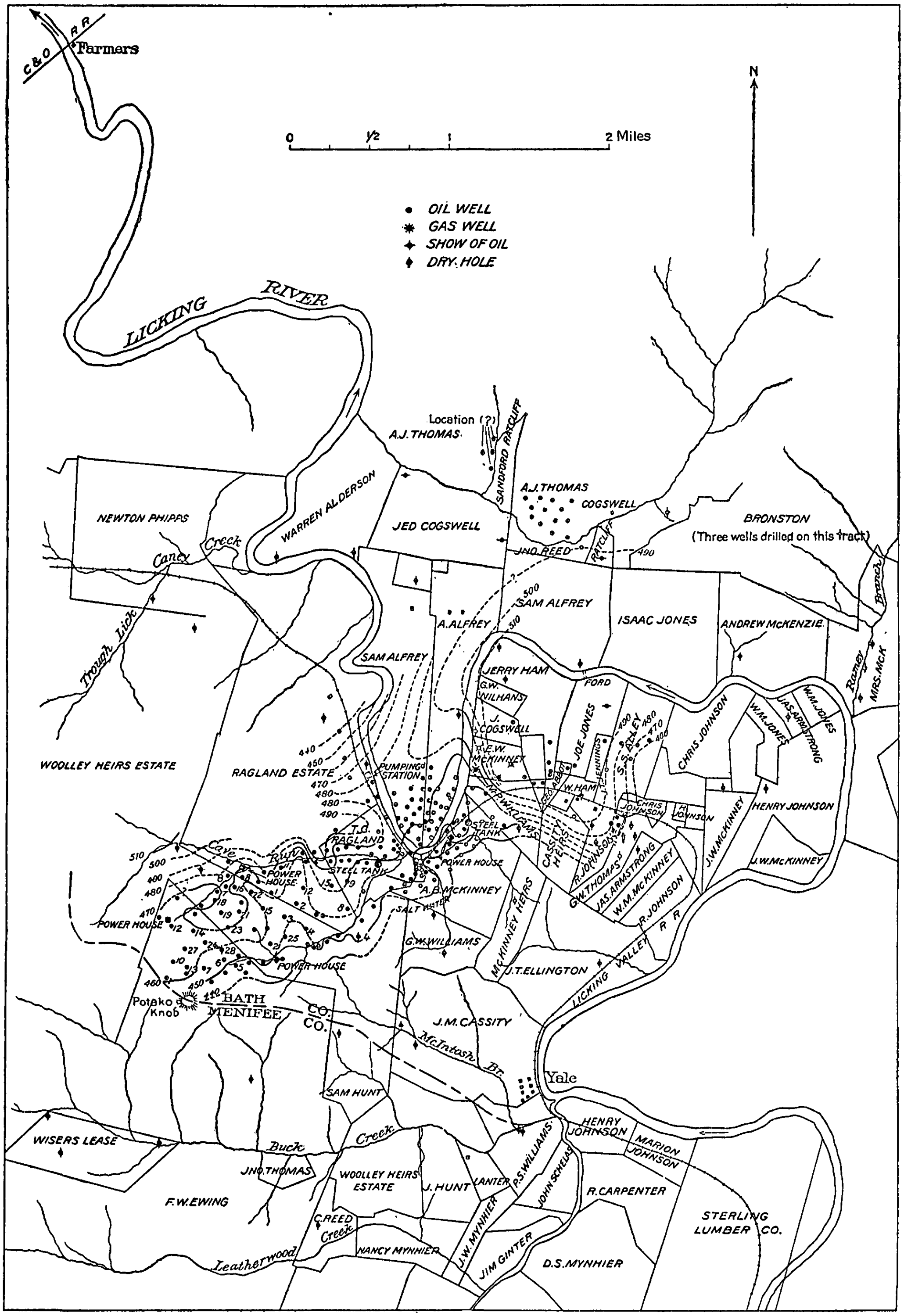
From the Menifee gas field due east to the wells on Toms Run, 5 miles north of Paintsville, in the central part of Johnson County, a distance of approximately 50 miles, the dip of the "Corniferous" limestone is about 1,400 feet, or an average of about 28 feet per mile. From the Menifee gas field southwest to the Irvine field, in Estill

County, a distance of about 21 miles, the limestone appears to show a total rise, based on a rough calculation, of 120 to 160 feet. As the Irvine field is somewhat farther west than the Menifee field, this rise in the limestone is not unexpected, but the fact that the limestone in the latter dips steeply southwest indicates that there is a syncline between these fields in which the limestone is much lower than it is in either field. The same is true of the area between the Menifee gas field and the Campton oil field, Wolfe County. The general dip toward the southeast in the Menifee field, if continued to Campton, would bring this limestone to a depth several hundred feet below that at which it is found. It seems probable that when the structure of this region is mapped in detail it will show a series of broad, shallow folds extending in a general northeast-southwest direction, and each of the anticlines will probably be found to be unsymmetrical, having very broad, low dips on the northwest side of the axis and much steeper dips on the southeast side.

STRUCTURE IN THE RAGLAND OIL FIELD.

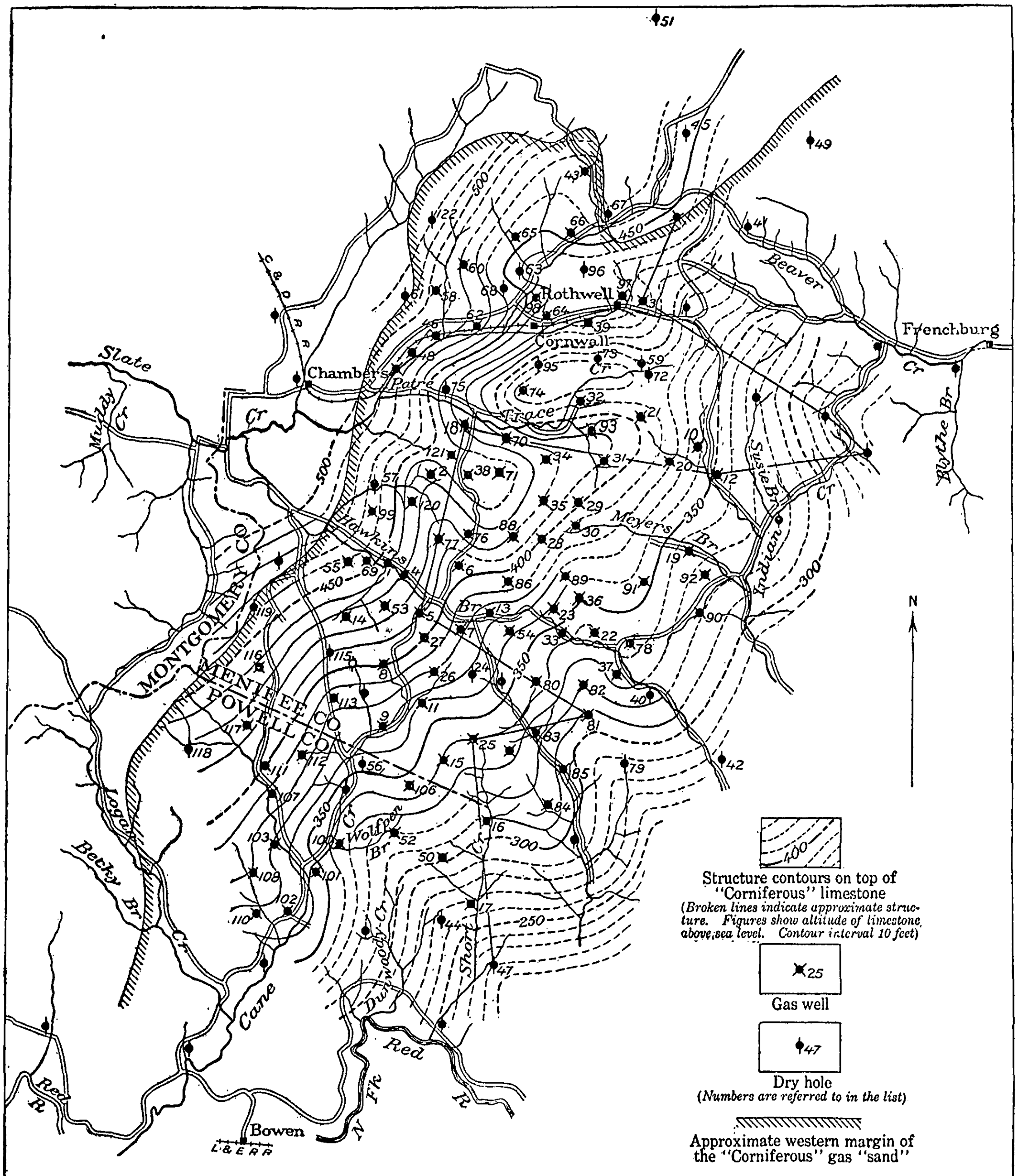
On the map of the Ragland oil field (Pl. III) the elevation of the "Corniferous" limestone ("Ragland oil sand") above the plane assumed to be sea level is not given in detail. It is sufficiently outlined, however, to show the close alignment of this pool with the structure contours. In the southwestern part of the field the lower edge of the oil-bearing part of the limestone lies everywhere at an elevation between 240 and 250 feet above the datum plane, which is estimated to approximate sea level. Likewise it appears that at no place in this field is the limestone oil bearing where it has an elevation of over 300 feet above this plane. In much of the field salt water occupies the lower portion of the limestone where the upper portion is oil bearing. Beyond the southern edge of the field, where the limestone is lowest, it contains nothing but salt water. The structure contours also suggest the existence of a low anticline along the northern border of the field, but the data are too meager to determine it in detail. The line of wells along the railroad north of the T. C. Ragland farm shows a decided dip of the "Corniferous" limestone in that direction and is therefore on the north side of this fold. The altitude of 313 feet for the oil "sand" in the gas well on the E. W. Williams farm may be too great, and the record, having been given from memory, may be in error. Records of most of the wells in this part of the field could not be obtained, and consequently no spirit-level lines were run to these wells.

On the whole, the structure of the Ragland oil field appears to be that of a small, flat anticline rising toward the west and southwest and trending east-northeast, with the maximum dip probably almost



SKETCH MAP OF THE RAGLAND OIL FIELD, KENTUCKY.

Showing location of wells and structure contours on "Corniferous" limestone (Boyle limestone of Foerste).



Scale, 1/125,000

1 0 1 2 3 Miles

SKETCH MAP OF THE MENIFEE GAS FIELD, KENTUCKY.

Showing location of wells and structure contours. Symbols indicating wells whose sections are given on Plate II are joined by a zigzag line.

due southeast. The structure so far as known is strikingly similar to that of the Campton oil field, where the "Corniferous" limestone is oil bearing in an area in which the top of the limestone is probably between 400 and 500 feet lower than it is in the Ragland pool.

STRUCTURE IN THE MENIFEE GAS FIELD.

The contours and numbers on the sketch map of the Menifee gas field (Pl. IV) have the same meaning as those on the map of the Ragland field described above. The contours show the height of the top of the "Corniferous" limestone (the gas "sand") above the sea. The limestone is gas bearing between the 290-foot contour on the southern side of the field and the 500-foot contour on the northern side, the maximum difference in the height of the top of this bed in the field being somewhat more than 200 feet. These structure contours show a fairly uniform dip of the limestone across the field. Two small secondary synclines trending east-west break the monotony of this southeast dip in the vicinity of Rothwell. North and west of the field the rocks apparently continue to rise at about the average rate.

The gas of the Menifee pool has accumulated in the "Corniferous" limestone, where the porous part of the bed, and in fact probably all of the limestone, begins to pinch out in a northwest direction. The limestone is saturated by salt water around the southeastern and southern edges of the gas-bearing portion, where the limestone is lowest. In this connection it is interesting to note that limestone in the Campton oil field, Wolfe County, contains gas on the north side of the field, where the limestone appears to be highest, and salt water on the south side, where the limestone is lowest. It is also very important to note that the salt water in the Campton pool appears to have no greater head than it has in the same bed in the Menifee gas field, where its altitude is over 500 feet higher. This fact suggests strongly that the salt water in the limestone is under hydraulic (not hydrostatic) pressure, and that the edge of the area saturated by salt water is not marked by a horizontal line in this bed across the region but that the height of the salt water varies greatly from place to place.

GUIDES IN FUTURE PROSPECTING.

The apparently close conformity of the Menifee, Ragland, and Campton pools to local structure may be of great value to oil prospectors, as there are doubtless other areas in the eastern Kentucky coal field having similar structure and similar salt-water pools in the oil-bearing sands.

It is evident that in attempting to locate new pools the prospector should be provided with complete structural maps of the region.

These maps should show not only the axes of all rock folds, both anticlines and synclines, but also the amount and direction of dip at all points, the location of all deep holes drilled in the region, the height of the oil sands in each well above some horizontal datum plane, and the relative amount and head of the water (if any) found in the sands. With these data at hand the prospector should be able to eliminate large areas where the probabilities for getting oil or gas are slight and thus locate his wells in the more favorable areas. In making these selections he should keep in mind certain modifications of the well-known anticlinal theory of oil and gas accumulation that, to the writer, appear to be of such importance as to justify the following statement.

The anticlinal theory accounts for the accumulation of pools of oil and gas at certain favorable places (usually the axes of anticlines) by the difference in weight of gas, oil, and salt water, it being assumed that these three substances were once mixed in some porous rock and that subsequently the gas, oil, and salt water arranged themselves in the folded porous bed according to their respective gravities. It is assumed that the gas, being lightest, collected at the tops of the anticlines, or above the water line in the porous bed, that the oil collected below the gas, and the salt water below the oil. Areas of close, hard sand in the oil-bearing stratum are thought to have offered barriers to the upward movement of the oil and gas, thus forming pools on the lower sides of the barriers. Conversely, where no salt water is present in an oil or gas sand it is assumed that both these substances have drained down the dip through the porous stratum and collected in a pool in the bottom of the syncline or on the upper side of some local barrier of impervious material.

It is evident, therefore, that if an oil prospector follows the anticlinal theory he should drill either in the highest parts of each anticline or, if the water line does not reach the top of a given anticline, at any point where a given oil sand is at the same level as it is in known oil pools. If he finds the sands destitute of water he should look for pools in the synclines.

Though the application of this theory has been very successful in many oil fields, it has not proved satisfactory in accounting for (1) the closed pressure of gas pools (sometimes amounting to 1,500 pounds to the square inch); (2) the presence of oil and gas pools that completely occupy sandstone lenses which are surrounded on all sides by shale and furnish no salt water; (3) the presence of oil and gas under high pressure in porous pay streaks in sandstone of ordinary texture and porosity; (4) the presence in a dry sand of large pools of both oil and gas that do not conform to structure lines but extend across minor anticlines and synclines alike; (5) the fact that pools occur in pay streaks differing greatly in porosity; and (6) difference in the initial closed pressure of gas wells in a given area, together with many other phenomena of a local nature the significance of which can not be discussed at length in this paper.

The fact that the anticlinal theory does not provide logical explanations for the above-named phenomena, which are encountered in all fields by producers, leads the writer to believe that the basic idea on which it is founded—namely, accumulation through difference in gravity of gas, oil, and salt water—is wrong. On the other hand, the writer does not wish to be understood as denying the very evident fact that geologic structure has determined the position of many pools of oil and gas, but he can not believe that the known facts regarding the processes of oil and gas accumulation justify the assumption that difference in weight of oil, gas, and water is the principal factor.

The phenomena which the writer has observed lead him to believe that the accumulation of oil and gas pools is due to the action of large bodies of water moving under both hydraulic and capillary pressure. If this is the true mode of accumulation, oil and gas pools of commercial size have been formed by invading bodies of water moving along the bedding planes and collecting ahead of them a portion of the oil and gas contained in the porous bed. This oil and gas may have been indigenous to the porous bed or it may have been forced into it from above or below by previous invasions of water traveling more or less vertically from water-bearing beds by capillary pressure aided by hydraulic pressure through the shale or other fine-grained petrologenic rock. Favorable places for accumulation according to this theory are places in the porous bed where there is great variation in the rate of movement of different portions of the edge of the invading body of water, the oil being thereby confined between saturated portions of the oil-bearing bed, which have been filled by water moving in opposite directions. The pitching axes of anticlines, structural domes, monoclines of irregular trend, and points where the porosity of the oil sand changes greatly offer favorable locations for trapping portions of the oil and gas accumulated by the moving water. This theory has been stated in more detail elsewhere[1] and need not be repeated here, attention being called to it simply to make clearer the following suggestions to prospective operators in this region.

The existence of an anticline at a certain location does not necessarily indicate the most desirable place for a test well. It should be kept in mind by the prospector that anticlines have relatively great length in comparison with their breadth, that the axes of folds vary in altitude from place to place, and that each fold has

[1] Munn, M. J., The anticlinal and hydraulic theories of oil and gas accumulation: Econ. Geology, vol. 4, No. 6, October, 1909; Sewickley folio (No. 176), Geol. Atlas U. S., U. S. Geol. Survey, 1911. Munn, M. J., and Shaw, E. W., Foxburg-Clarion folio (No. 178), Geol. Atlas U. S., U. S. Geol. Survey, 1911

what may be termed a critical altitude for each oil sand, at which oil and gas are most likely to accumulate. The critical altitude of an oil sand seems to depend on its content of water, which in turn depends on many important factors, such as the regional distribution of the sand, its character—whether uniformly coarse and open, fine and close, or porous at some places and hard and close at others—the general structure of the oil-bearing rocks, and the source of the water in them and its head. Unfortunately the value of all these factors can not be definitely determined in any region in advance of the drill. Their combined effect, however, is to cause certain portions of each oil sand to be saturated with water under sufficient head to furnish a flow into wells drilled into it, the height to which this water will rise in a well varying from 0 to several hundred and even thousands of feet in different areas. The portion of a given sand most likely to be productive forms a belt of greater or less width along the margin of that part which is saturated with water or in which the water is under a low head. This belt does not occupy a horizontal plane in the sand but, as already stated, varies in height from place to place. Therefore the critical altitude at which pools are most likely to occur on one anticline in a given sand may be and generally is quite different from the critical altitude for the same sand on another anticline some distance away. This is illustrated by the positions of the Menifee gas field and the Campton oil field. Both of these fields are located at the edge of the salt-water area of the "Corniferous" limestone on different anticlines, yet they have a difference in elevation between 400 and 500 feet.

The hydraulic hypothesis of accumulation lends itself readily to the explanation of pools in and around which no water is found in the oil sand, for it is remembered that the water content of a given sand may change materially with the lapse of geologic time. This is due to the modification of the shape of the bed by both upward and downward movements of the earth's crust, the development of local folds in the strata, changes in the size, character, and height of the intake area from which the water is derived, climatic changes, and many other phenomena which are commonplace incidents in the geologic history of every region. It is therefore not safe to assume because a given "sand" shows no water in wells surrounding an oil or gas pool in it that this sand contains no water and that the pool was not accumulated by moving water. Where pools occur in "dry" sands which show no water, it is not safe to go further than to assume that the water in the sand has little or no hydraulic head, and therefore little or no pressure to force it into the wells. The very fact that oil and gas pools do exist under high pressure in porous "sands," many of which have great horizontal extent, justifies the assumption that the rocks above, below, and entirely surrounding the "pay sands" of these pools are impervious to the oil and gas; otherwise the great pressure not only would have dissipated the pool long ago but would have been an ever-present impediment to the accumulation of such pools. It is a well-established fact, however, that the rocks which inclose these "pay sands" contain considerable pore space (ranging from probably 1 per cent up to 6 or 8 per cent of the rock mass). Therefore the only conclusion possible is that the pores of the rocks in contact with "pay sands" of oil and gas pools are temporarily filled with something that renders the rocks impervious to oil or gas under high pressure. The only substance which will universally satisfy this requirement is water, and it is safe to assume that the rocks surrounding oil and gas pools are always saturated with water, and that where no water is obtained from the oil sand in wells surrounding pools the head or pressure of this water is too small to force it through the pores of the rock in appreciable quantities because of the very great resistance due to friction. This pressure may have been many times greater at some other period—sufficient, in fact, to force the water through the rocks and to accumulate the pools ahead of it as described above.

The principal object of this paper, however, is not to discuss the theories of oil and gas accumulation, but to show the close resemblance in local structure of the Menifee, Ragland, and Campton pools. The practical application of the theories given above in the search for new pools in this oil and gas district can best be made only after the positions of the anticlines and synclines have been carefully mapped, the approximate height of the "Corniferous" limestone on the folds shown, and the head of the salt water in this "sand" determined at as many places as possible. However, with the meager data available, the writer suggests that the southern end of the Menifee gas field may be extended westward by a well located on Logan Creek about 3 miles above its junction with Cane Creek. If the "Corniferous" limestone is present and of good character at this location it will probably contain gas. If a test here should prove successful, care should be taken to keep above the 400-foot contour on the "sand" because the salt-water line in this "sand" increases in elevation westward from the Menifee field. The fact that only 7 feet of "sand" was found in well No. 118 need not condemn the country lying between it and the location on Logan Creek mentioned above. Theoretically this end of the field is somewhat more likely to develop oil. The syncline which crosses the triangle between the Menifee gas field and the Irvine and Ragland oil fields is probably unproductive, the "Corniferous" limestone being saturated with water. The Irvine and Campton fields are probably on the same anticline, which may prove to be the westward extension of a fairly definite anticline observed at a number of places in Morgan County. If careful geologic work in this area should show this to be a fact, there is a strong possibility that some of the territory along the axis of this fold between the Irvine and Campton field will furnish small though valuable fields of oil or gas. The possibilities of other oil and gas pools being found in the "Corniferous" limestone of eastern Kentucky will be discussed in the forthcoming reconnaissance report on the southern Appalachian oil and gas fields.

TECHNOLOGIC FEATURES OF THE MENIFEE AND RAGLAND FIELDS.

Gas from the Menifee gas field has been utilized for fuel and lighting in the cities of Mount Sterling, Winchester, and Lexington, a 10-inch pipe line to them having been completed in February, 1906. One well-equipped compressing plant in the gas field having a capacity of 8,000,000 cubic feet per day supplies pressure to this line.

The oil from the Ragland field is pumped to Salt Lick station on the Chesapeake & Ohio Railway, a distance of about 7 miles, and from that place is shipped by rail. In 1907 there was sufficient gas produced in the Ragland field to supply six power plants for pumping. The balance of the pumping was done by steam, using crude oil as fuel.

The wells were drilled with cable tools, some by the use of a derrick and others with drilling machines. The latter method seems to offer some advantages in this shallow territory, where most of the wells reach the "Corniferous" limestone at a depth of less than 600 feet. One of the most serious difficulties in the use of the drilling machine is the character of the country and the roads over which it must be moved from one location to another. In drilling to the "Corniferous" limestone a few feet of 8-inch casing is generally used at the top as a conductor and a short string of 6¼-inch casing set to shut off fresh water, usually at a depth of between 100 and 200 feet, the balance of the well being uncased.

The relatively small cost of test wells in this district is a favorable factor in considering the practicability of attempting to find other profitable pools in it. The minimum number of test wells can also be used to test the district if preceded by careful geologic work. Under such conditions it seems very probable that search for new pools may be profitably conducted regardless of the negative results obtained by test wells that have already been drilled outside of the above-named fields.