R. I. 3456 JULY 1939

UNITED STATES
DEPARTMENT OF THE INTERIOR
HAROLD L. ICKES, SECRETARY

BUREAU OF MINES
JOHN W. FINCH, DIRECTOR

REPORT OF INVESTIGATIONS

RESERVOIR CHARACTERISTICS OF THE EUNICE OIL FIELD, LEA COUNTY, N. MEX.

BY

C. C. ANDERSON, H. H. HINSON, AND H. J. SCHROEDER

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By C. C. Anderson[2], H. H. Hinson[3], and H. J. Schroeder[4]

CONTENTS

ILLUSTRATIONS

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[1] The Bureau of Mines will welcome reprinting of this paper provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Report of Investigations 3456."

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INTRODUCTION

The Eunice field is one of a group in southeastern New Mexico producing oil and gas from so-called limestone-type reservoirs in which the productive strata are dolomite or dolomitic limestone. Ordinarily, wells in reservoirs of this type show wide differences in their productive characteristics, indicating erratic variations in porosity and permeability. Often there is a large difference in total footage of actual "pay" penetrated in neighboring wells and the vertical distribution of the "pay" within the productive strata varies. In the Eunice field there are few easily recognizable geologic markers to indicate true structural conditions of the oil-productive section, due to horizontal and vertical gradation in chemical compositions and lithologic characteristics of the strata. Geologic markers are found some distance above the oil-producing zones in this field and consequently they indicate only the general structure. Furthermore, no direct relation has been found between the general structure and the accumulation of oil within the reservoir.

Many problems in well-completion and production practice have been met in the Eunice field because of erratic variations in porosity, permeability, in vertical distribution of "pays," and the apparent departure from ordinarily accepted relations of oil accumulation to structure. A detailed study of the position and characteristics of the oil- and gas-producing zones aids production procedure. The methods employed in studying the Eunice field, discussed in this paper, may be applicable to other limestone-type reservoirs.

ACKNOWLEDGMENTS

This report was prepared under the general supervision of R. A. Cattell, chief engineer, Petroleum and Natural Gas Division, Bureau of Mines, Washington, D. C., and C. W. Seibel, supervising engineer, Bureau of Mines Helium Plant, Amarillo, Tex.

The writers wish to express their appreciation for the hearty cooperation of the oil companies and individuals operating in the Eunice field who so generously furnished field data and other information. Special acknowledgment for helpful assistance is given to C. G. Staley and his staff of the Proration Office, Hobbs, N. Mex. The writers thank D. B. Taliaferro, Jr. of the Bureau's Petroleum Experiment Station at Bartlesville, Okla., for determining the porosities and permeabilities of the core specimens referred to in this report.

Grateful acknowledgment is given to the engineers and geologists of the operating companies in the Eunice field and associates of the writers in the Bureau of Mines for many constructive criticisms and review of this report.

HISTORY OF DEVELOPMENT

The Eunice field is in Lea County, New Mexico, approximately 15 miles southwest of Hobbs and 7 miles northwest of Eunice. (See fig. 1.) Most of the field lies in T. 21 S., R. 36 E.; the rest is in the three adjoining townships to the north and west. (See fig. 2.)

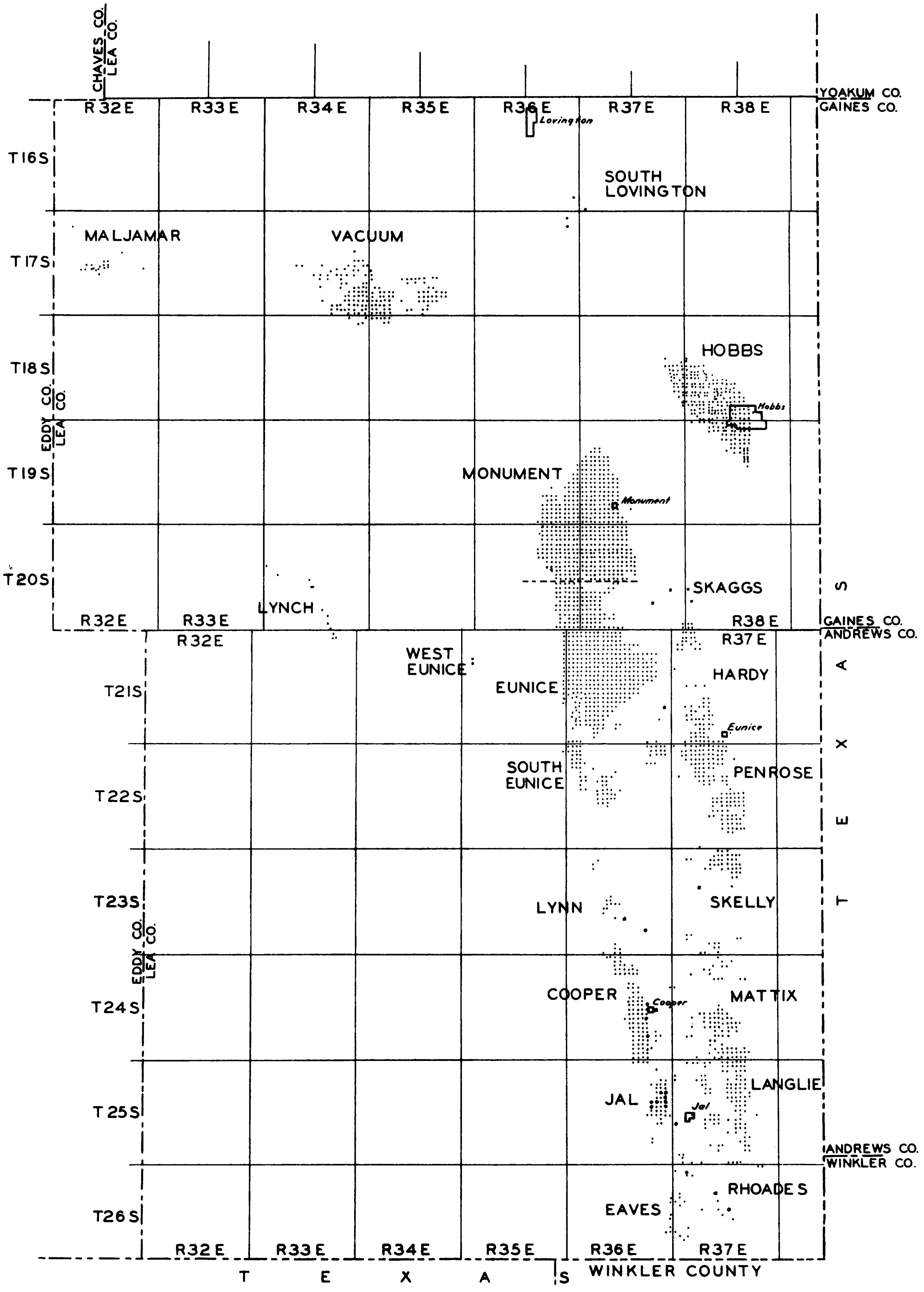

Figure 1.—Oil fields of central and southern Lea County, New Mexico.

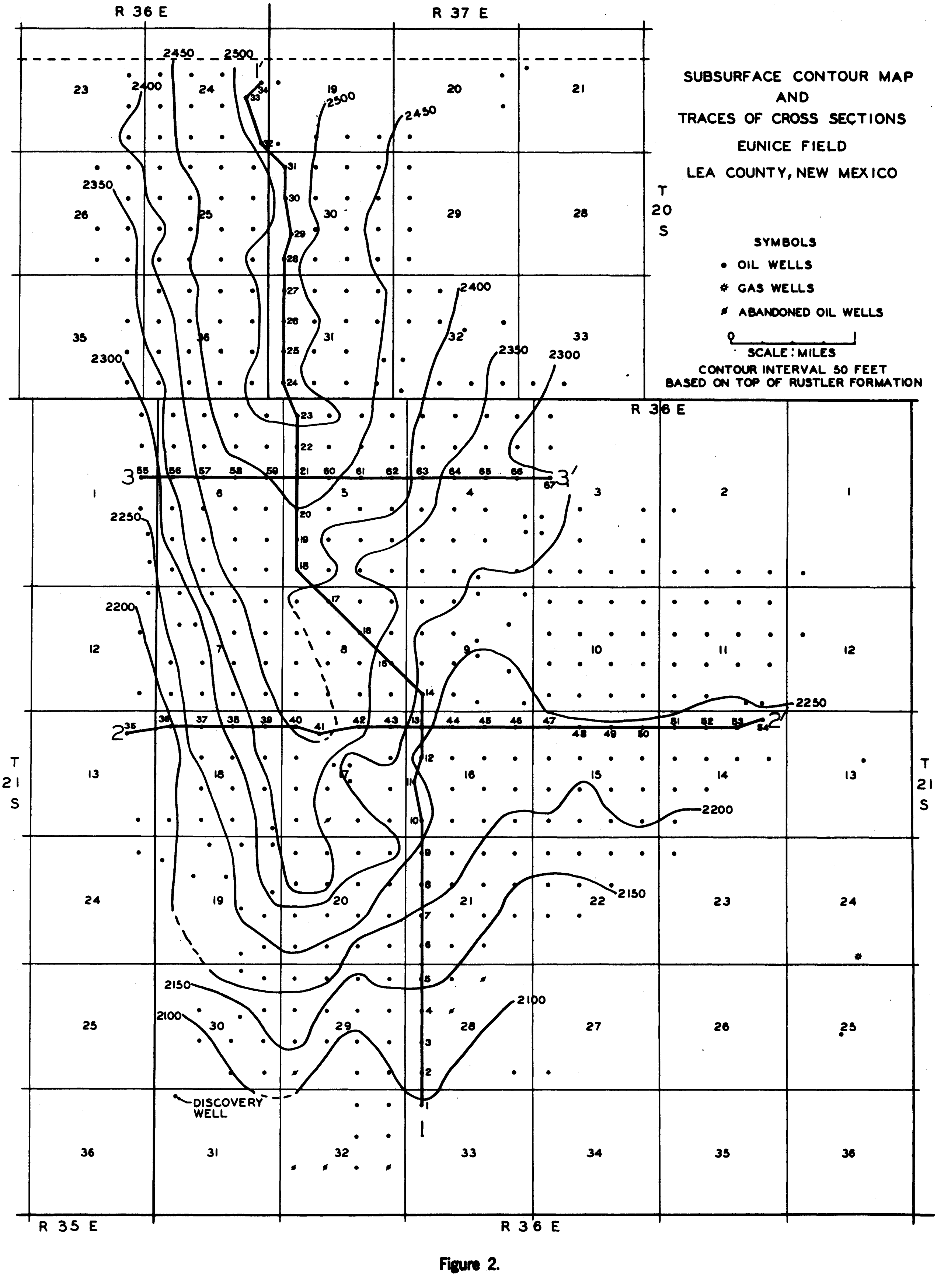
SUBSURFACE CONTOUR MAP
AND
TRACES OF CROSS SECTIONS
EUNICE FIELD
LEA COUNTY, NEW MEXICO
SYMBOLS
● OIL WELLS
☼ GAS WELLS
ø ABANDONED OIL WELLS
0 1
SCALE: MILES
CONTOUR INTERVAL 50 FEET
BASED ON TOP OF RUSTLER FORMATION
R 36 E
R 37 E
R 35 E
R 36 E
T 20 S
T 21 S
T 21 S
2500
2450
2400
2350
2300
2250
2200
2150
2100
1
1'
2
2'
3
3'
DISCOVERY WELL

Figure 2.

The discovery well was completed on March 8, 1929, by the Marland Oil Co., now the Continental Oil Co., at a depth of 3,992 feet for an initial production of approximately 250 barrels of oil per day. This well, known as the Lockhart B-31 No. 1, is in sec. 31, T. 21 S., R. 36 E. On August 20, 1929, the Continental Oil Co. completed Meyer A-17 No. 1 well in sec. 17, T. 21 S., R. 36 E., approximately 2-1/2 miles northeast of the discovery well. This well was the second producer in the field and flowed at the rate of 1,260 barrels of oil per day.

Owing to lack of pipe-line transportation facilities, the field was developed very slowly, and by the end of 1933 only 11 producing wells had been drilled. Drilling operations increased during the last half of 1934, and by the end of 1935 there were 113 wells in the field. The most active development occurred in 1936, when 191 wells were completed. During 1937, 131 wells were added, and 39 more were drilled in 1938, making a total of 474 oil wells as of January 1, 1939. Nearly all wells were drilled in the center of 40-acre units, and the field has been developed to a density of one well to each of these units. The 474 well units cover an area of approximately 18,960 acres.

Rotary tools were used extensively in drilling the wells in the Eunice field. The general practice was to set three "strings" of casing, namely, a short surface string, an intermediate string, and a production string. The surface casing was set to shut off and protect the fresh-water sands in the Tertiary formations. The usual practice was to set and cement 1,100 to 1,400 feet of intermediate casing, frequently 7-5/8-inch or 9-5/8-inch in size, to protect the hole from red shales, which have a tendency to cave. In some wells the intermediate string of casing was set and cemented at a depth of about 2,500 feet to protect potash-bearing salt strata as well as to exclude caving shales from the hole. The production string was usually 5-1/2 or 7 inches in diameter, depending upon the size of the intermediate string. This casing was set and cemented in the productive zone at a depth of about 3,775 feet. In 430 wells the average elevation of the casing seat of the production string was 174 feet below sea level and the average penetration below the casing seat was 128 feet.

The first million barrels of crude oil was produced by March 1934, or about 5 years after discovery. At that time there were only 11 wells in the field. The cumulative production as of January 1, 1939, was 32,187,000 barrels of oil, an average recovery of 1,698 barrels of oil per acre for the 474 well units. The field has been under production curtailment since active development began, and the greatest daily allowed production was had in May 1937, when an average of 31,936 barrels of oil was produced.

GENERAL DESCRIPTION OF STRATA DRILLED IN THE EUNICE FIELD

The Eunice field is covered by a mantle of sand, soil, and an impure, flaggy limestone commonly called caliche, and the major part of the area is overlain with windblown sand, which in places reaches a depth of 30 feet. Underlying these materials is approximately 200 feet of strata consisting principally of sand, buff to pink in color, with thin shale streaks. The uppermost 50 feet is the more calcareous, and near the top there is usually a deposit of caliche. These beds are considered to be Tertiary in age.

Underlying these strata are 700 to 1,100 feet of red shales and sandstones, which correspond to the portion of the columnar section of the Hobbs field described by DeFord and Wahlstrom[5] as belonging to the Dockum group of Triassic age. This section, except for a basal sandstone member approximately 100 feet thick, consists largely of dense red shales. Beneath this are 100 to 200 feet of sandy red beds, which may correlate with the Post-Rustler Red Beds[6] of Permian age.

The next stratigraphic unit, commonly referred to in the Eunice area as the Rustler formation, consists of about 100 feet of white to gray anhydrite, red shale, sand, and dolomite. In some areas in the field, the basal part of the Rustler formation is interfingered or interbedded with the upper part of the underlying salt, which is potash-bearing in part and attains a thickness of 1,000 to 1,500 feet. Below the salt is a bed of anhydrite 100 to 300 feet thick, which sometimes contains salt, red shale, light-colored dolomite, and sand in the upper part. (See figs. 3, 4, and 5 for generalized geologic section from the Rustler formation to the oil- and gas-producing zones along the cross-section lines 1-1', 2-2', and 3-3', respectively, shown in figure 2.)

Directly beneath this anhydrite are 500 to 800 feet of interbedded buff to brown dolomite and anhydrite with varying amounts of sand and bentonitic shale. In these beds, known as the brown lime section, the interbedded anhydrite decreases with depth and usually disappears at the top of the "sandy-lime" section. The anhydrite and brown-lime sections are thinnest in the southern part of the field and thicken in the northward direction.

The sandy-lime section, as the term is used in this report refers to the fine-grained sandy dolomite or dolomitic sandstone 150 to 300 feet thick that lies immediately under the brown lime. Below this sandy lime is a lighter-colored dolomite, which is white, gray, and buff in color and contains varying amounts of sandy material. The "sandy lime" and the underlying light-colored dolomite probably correlate wholly or in part with the "sandy section" of DeFord and Wahlstrom[7] in the Hobbs field. The principal oil-productive zones in the Eunice field usually are present from a few to 200 feet below the top of the light-colored dolomite.

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[5] DeFord, Ronald K., and Wahlstrom, Edwin A., Hobbs Field, Lea County, New Mexico: Bull. Am. Assoc. Petrol. Geol., vol. 16, 1932, pp. 58-59.

[6] DeFord, Ronald K., and Wahlstrom, Edwin A., Work cited, p. 59.

[7] DeFord, Ronald K., and Wahlstrom, Edwin A., Work cited, pp. 58 and 68-69.

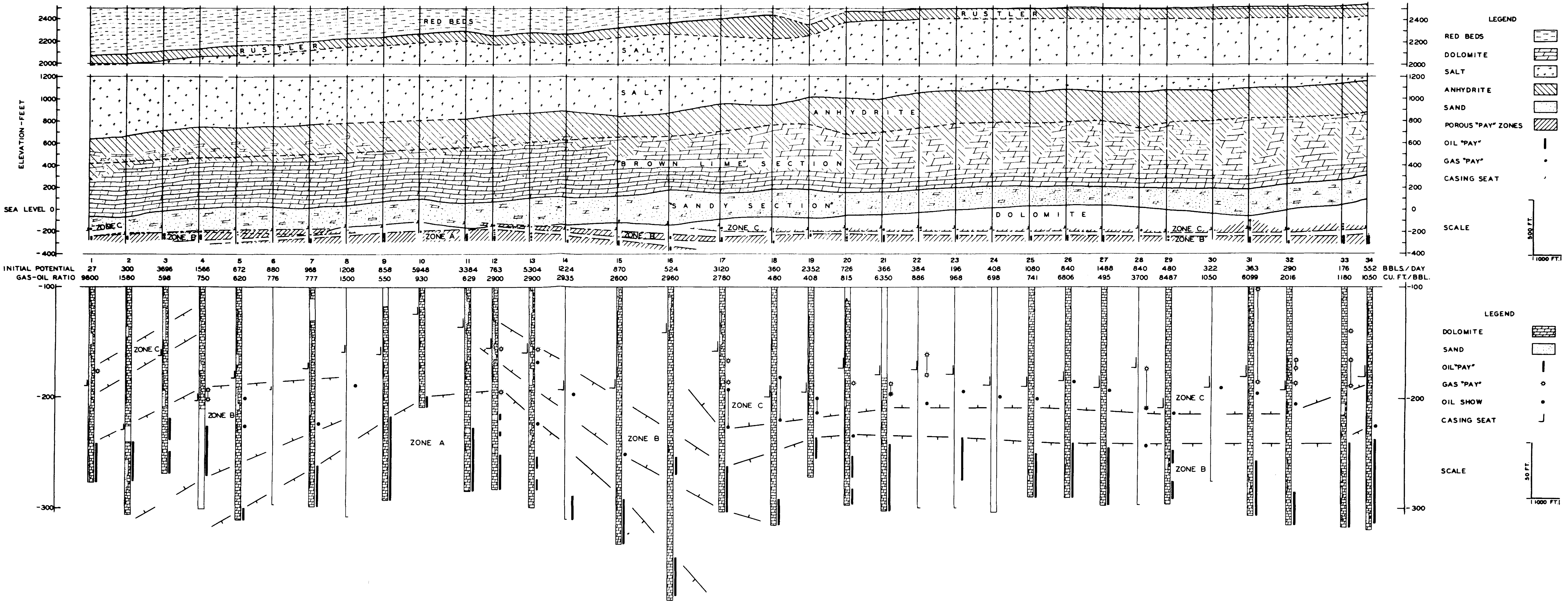


Figure 3.-Cross section 1-1'

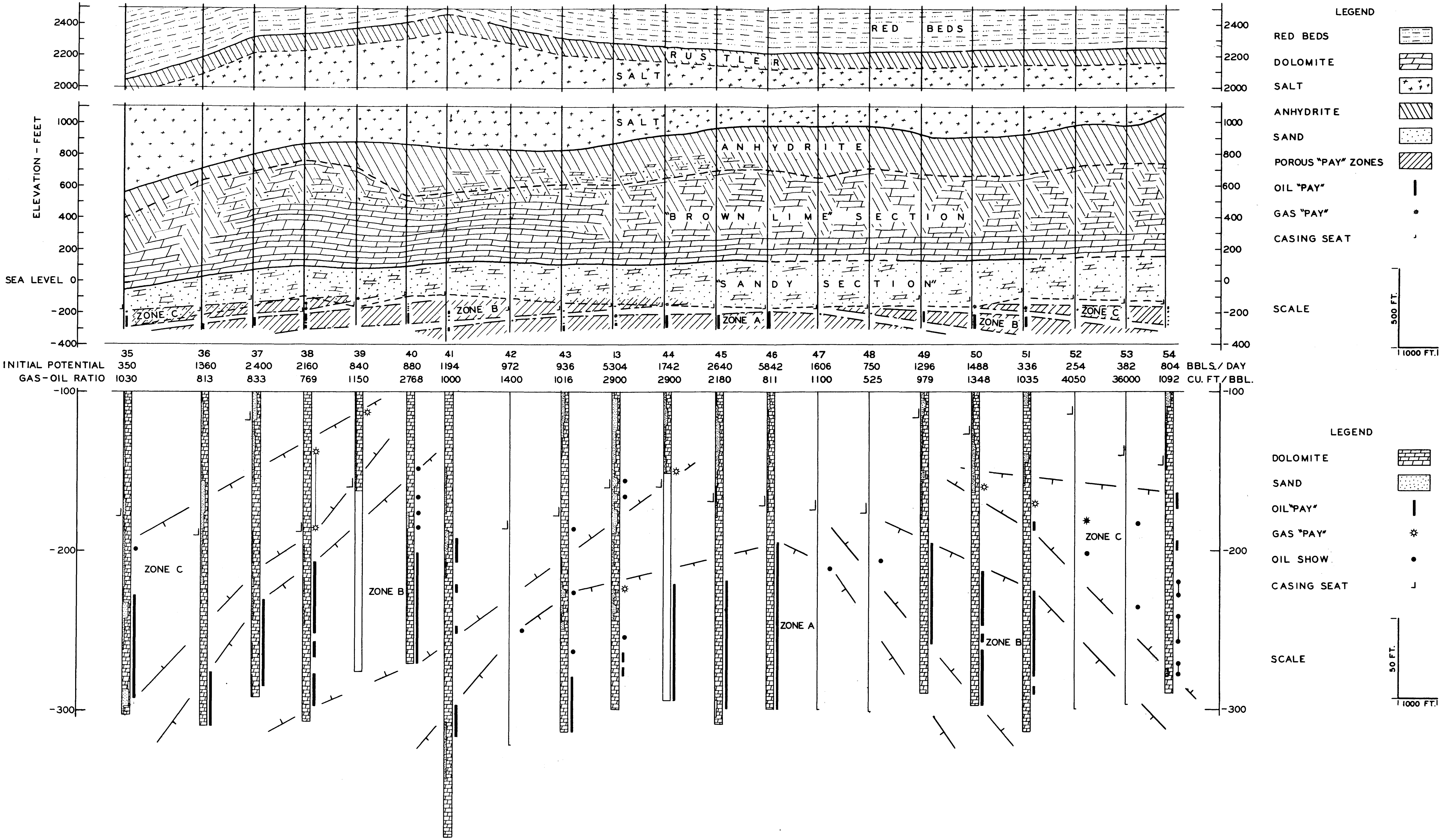
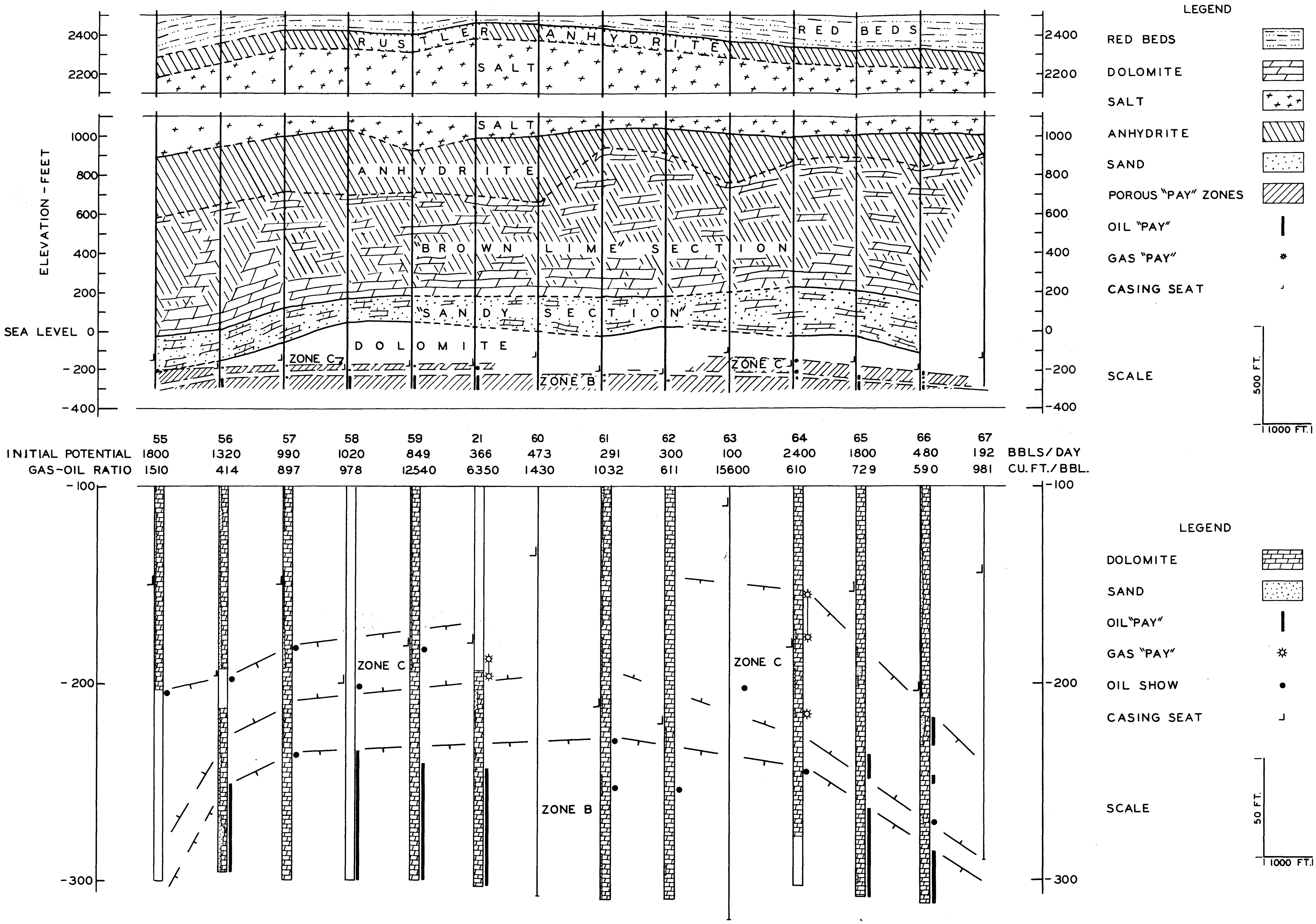


Figure 4.-Cross section 2-2'



	55	56	57	58	59	21	60	61	62	63	64	65	66	67	
INITIAL POTENTIAL	1800	1320	990	1020	849	366	473	291	300	100	2400	1800	480	192	BBLS/DAY
GAS-OIL RATIO	1510	414	897	978	12540	6350	1430	1032	611	15600	610	729	590	981	CU.FT./BBL.

Figure 5.-Cross section 3-3'

GENERAL STRUCTURE

The Eunice field is on the west edge of the Central Basin Platform[8,9] in the Permian Basin of west Texas and southeastern New Mexico. This field is in the northern part of the "structural trend" that includes Hendrick (Winkler County, Texas), Jal, Cooper, Eunice, and Monument oil fields of Lea County, New Mexico. (See fig. 1.)

Based on the configuration of the top of the Rustler formation, which is about 2,500 feet above the oil-producing zones, the structural fold has a relatively steep dip on the west flank and a more gentle slope on the eastern side. (See fig. 2.) The structure rises uniformly from south to north and merges with the Monument anticline. Thus, the Eunice and Monument fields may be considered as one large anticlinal fold, or the Eunice portion may be described as a nose of the Monument structure. The cross sections of the Eunice field, shown on figure 2 and illustrated in figures 3, 4, and 5, which show the strata below the Rustler formation, indicate similar structural conditions. The oil-bearing zones, however, appear to have little relation to the general structure of the overlying beds. In general, the oil-producing section is horizontal, and the oil is found between definite elevations, provided porosity and permeability are developed adequately in the formation between these datum planes.

CROSS SECTIONS OF THE EUNICE RESERVOIR

In a field that produces from a uniform stratum, deposited as a parallel member of a geologic formation, the reservoir often may be defined readily from geologic information. The reservoir of the Eunice field, however, cannot be interpreted so easily because it consists of a series of porous streaks or lenses that, upon casual inspection, are erratic in occurrence and have little or no relation to the attitude of the beds containing them. With enough data, it may be possible to develop an accurate conception of the detailed geologic structure of the reservoir, but, as already mentioned, the oil-producing zones may not coincide with or be directly related to this structure.

In studying the Eunice field, detailed cross sections for each east-west row of wells were constructed from well-completion data and logs that were made from the examinations of cuttings from wells. These cross sections, which have a vertical range of 250 feet (from 100 to 350 feet below sea level), include the known oil-productive zones of the Eunice field. A study of these cross sections suggested the possibility of grouping the various oil and gas "pays" into three major zones, which are separated from each other by dolomitic beds through which there is little or no flow of fluids.

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[8] Carpenter, Charles B., and Hill, H. B., Petroleum Engineering Report, Big Spring Field and Other Fields in West Texas and Southeastern New Mexico: Bureau of Mines Rept. Inv. 3316, November 1936, pp. 16-17.

[9] See Regional Structure Map of West Oklahoma, Texas, and New Mexico: Oil and Gas Jour., vol. 37, No. 21, Oct. 6, 1938, p. 21.

To illustrate graphically the findings of this study, three detailed cross sections, 1-1', 2-2', and 3-3' (the traces of which are shown in fig. 2), are presented in figures 3, 4, and 5, respectively. In these illustrations three major porous and permeable zones have been outlined to conform as nearly as possible to the information obtained from the whole group of cross sections. For convenience in discussing reservoir conditions, the three major porous zones that produce oil and gas are designated, from the bottom upward and from the central portion of the field outward, as zones A, B, and C.

A south-north cross section (1-1', fig. 2) through the central part of the field is shown in figure 3. All three of the major porous zones are indicated in this cross section. It will be seen that the top of zone A is approximately 200 feet below sea level in the southern part of the field, where this zone has a productive width of almost 3 miles. Along 1-1', zone B contains gas in its higher parts and is productive of oil across the field except over the central part of zone A. Zone B thins toward the central portion of the field but does not seem to extend completely across the top of zone A. Zone C is above zone B on the north and south ends of the section. In the southern part of the field, where zone C is relatively thin, it produces gas only; in the northern portion it is productive of oil in the lower part and gas in the upper part. From the available data, the writers have been unable to trace zone C across the top of the structure.

A west-east cross section (2-2', fig. 2) across the southern part of the field is shown in figure 4. Zone A, the top of which is 200 feet below sea level, has a productive width of about 2-1/2 miles and has a thickness of 100 feet in places. Zone B overlaps zone A on the east and west sides of the field, but the data are not complete enough to indicate whether this zone is continuous over the top of zone A. Zone B, which contains gas in its higher parts, is more irregular in thickness and porosity than zone A. Zone C, which is present on the east and west edges and overlaps zone B, appears to have more erratic variations in porosity and permeability than the lower zones and probably is absent on the upper part of the structure. To substantiate this thought, it will be noted from figure 4 that wells nos. 40, 41, 45, and 49, drilled near the crest of the structure, where zone C would be penetrated at a high elevation if it were present, do not have large gas-oil ratios,[10] although the casing seats are high.

A study of figure 5, a transverse cross section (3-3', fig. 2), reveals that zones B and C are present but zone A is absent in the northern part of the field. On this cross section, zone B is the principal oil-producing pay and zone C overlaps zone B on the east and west sides. Zone C may not be continuous across this part of the field, because well no. 60 in the central part of the cross section with the producing string set high does not have an

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[10] Gas-oil ratios and well potentials as used in this report refer to the original or initial production from wells. Reference to high or excessive initial gas-oil ratios should not be construed to imply that remedial steps have not been taken to operate these wells in accordance with good production practices.

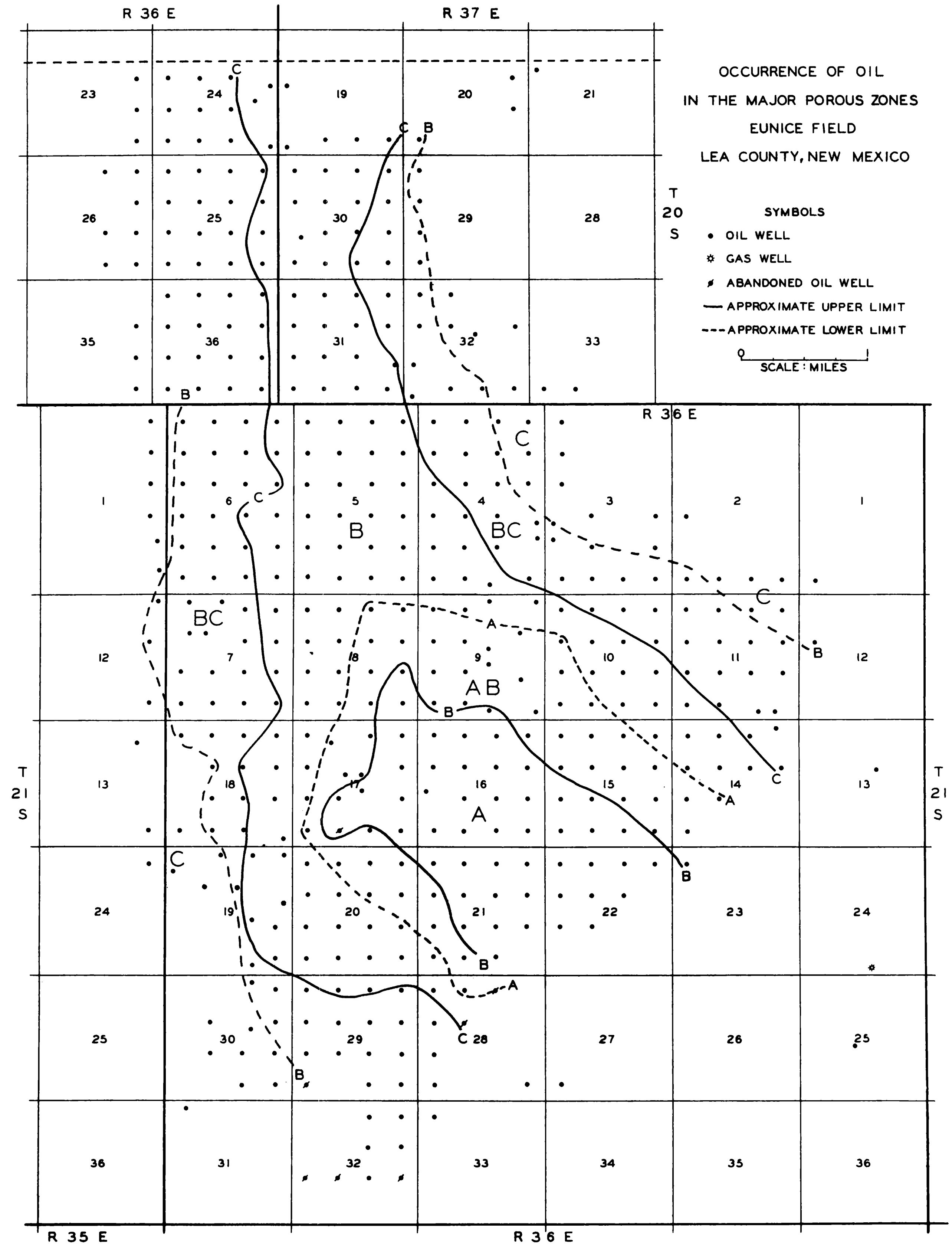

OCCURRENCE OF OIL
IN THE MAJOR POROUS ZONES
EUNICE FIELD
LEA COUNTY, NEW MEXICO
SYMBOLS
• OIL WELL
☼ GAS WELL
ABANDONED OIL WELL
— APPROXIMATE UPPER LIMIT
--- APPROXIMATE LOWER LIMIT
0 1
SCALE : MILES
R 36 E
R 37 E
R 36 E
R 35 E
R 36 E
T 20 S
T 21 S
T 21 S
A
AB
B
BC
BC
C
C
C

Figure 6.

excessive gas-oil ratio. On the other hand, well no. 63, with the casing set high and penetrating the upper part of zone C on the east side of the field, had a high initial gas-oil ratio.

Three partly overlapping zones have been indicated on the cross sections 1-1', 2-2', and 3-3'. In each, the zone consists of a number of small porous pays. The three major zones probably are interconnected, at least to the extent that the reservoir may be assumed to have been in a state of equilibrium prior to drilling, but the channels of communication are not extensive enough to maintain pressure equilibrium among zones under the present production practices. As the permeability between zones is small compared to that within zones, and as the time of producing the field is short compared to that required for accumulation and equilization, the field will react to production according to zonal pattern rather than as a reservoir consisting of continuous and uniformly porous rock.

The relations of the three major porous zones to the detailed geologic structure have not been determined by the writers. If it is assumed that the structure of the upper beds (such as the Rustler formation) is the result of folding, then the attitude of the major porous zones in the oil-producing section may be the result of folding, at least in part. Other factors in addition to folding probably influenced the origin and development of the porous zones and, therefore, they may not lie parallel to the strata that contain them.

AREAL EXTENT OF MAJOR POROUS ZONES

Following the construction of the cross sections of the Eunice field, a map (fig. 6) was prepared to show the areal extent of porous zones A, B, and C. The broken lines on this map indicate the intersection of each zone with a horizontal plane defining the top of the oil-water contact, which is assumed to be at 325 feet below sea level. The solid lines represent the approximate upper limits of oil production from the respective zones. Porous zones continuing inwardly beyond such a solid line are productive of gas. The areas designated by the letters A, B, and C represent the zone or zones from which oil production may be expected.

Apparently these zones are on a structure having an approximate north and south trend. Zone A is productive only in the southeast part of the field. Zone B, overlapping zone A, is productive of oil throughout the central part of the field and dips below the oil-water contact on the edges. Zone C overlaps zone B and is productive of oil only on the edges of the field. Probably zone C overlies zone B in the central and northern parts of the field, but in those areas its pore spaces contain gas only.

COORDINATED STUDY OF WELL PERFORMANCE AND OTHER FIELD DATA

Some of the information disclosed by the cross sections was not adequate to establish the boundaries of the major productive zones. To overcome this difficulty, a coordinated study was made of well performances and other data in relation to the field as a whole. Details concerning this study are discussed in following sections of this paper.

Before equilibrium within a reservoir is disturbed by the drill, the oil in the pore spaces of the structural trap is in equilibrium (for all practical purposes) with water below and gas above. When oil is withdrawn from the reservoir through wells, pressure gradients are set up in the reservoir, and oil, gas, and water move to regions surrounding the wells, where the pressures are lower than elsewhere in the reservoir. As the pressure in the reservoir declines, the gas cap above the oil expands and the water enters the oil-vacated parts of the structure from below. Obviously, the fluids move through the more permeable parts of the reservoir, where they meet with the least resistance to flow. Particularly in limestone-type fields well performance is influenced by the location of the well relative to a porous zone or zones and by the permeability of the zones to flow of fluids through them.

In coordinating the study, it was thought that the position of the porous zones of the Eunice field - a limestone-type reservoir - might be outlined further and many of their producing characteristics determined if enough fundamental engineering data were obtained and analyzed. Well-completion and production data should provide a basis for interpreting reservoir conditions, as such data give information on the position of the reservoir fluids with respect to the wells and the productiveness of these fluids. A study of the oil, gas, and water production of a well also should give an indication of the relation of the well to the porous zones. Accordingly these and other data on "top of oil pay", initial well potentials, gas-oil ratios, and water encroachment were studied to aid in defining the extent of the major porous zones in the Eunice field and to determine some of their physical characteristics.

Study of "Top-Oil-Pay" Data

In the Eunice field, as mentioned previously, the downward dip of one porous zone is covered by the overlap of another. However, in these areas of overlap the productive zones should be found relatively high or low[11/]. (See fig. 7.) If the porosity and permeability were more nearly uniform, the productive zones might be recognized more easily. However, considering the erratic variations in porosity and permeability characteristic of the Eunice reservoir, there are 3 possible conditions affecting the determination of the top of the oil-producing zone or zones in the areas of overlap.

If two zones are present and sufficiently permeable, the top of each can be recognized if adequate well data are recorded. If the upper zone is not permeable enough, it may not be recognized in drilling and only the lower zone will be defined. Thus, the recorded elevation of the top of the productive zone will be relatively low. If the upper zone is permeable enough for recognition and the top of the pay in the lower zone is not detected, the reported elevation of the top of the productive zone will be high. From the above it appears that most of the recorded elevations of the top of the productive zone in an area of overlap will be either high or low, but where the porosity and permeability of the zones are very erratic, medial figures may be obtained.

[11/] The words "high" and "low" are used in this report to convey impressions of relative positions much as they are used in describing hills and valleys, and not as they are used in describing structural conditions.

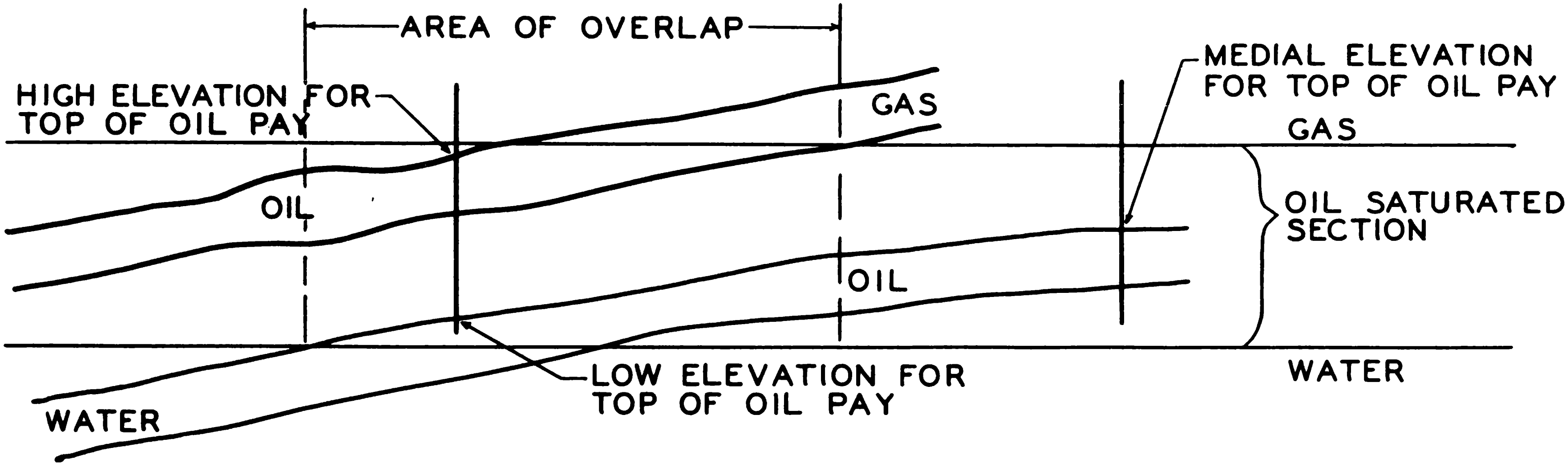
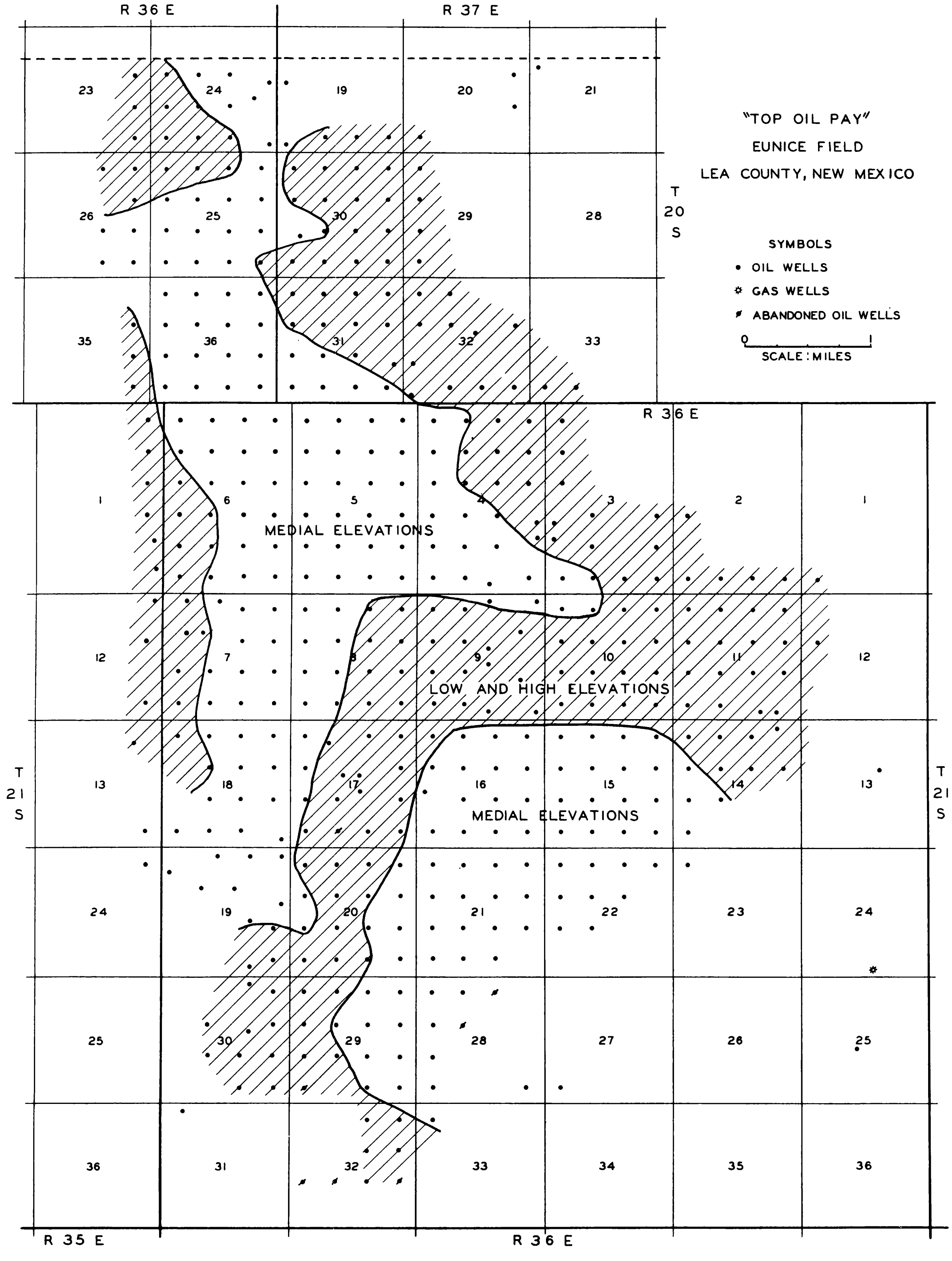


Figure 7.—An idealized section to illustrate overlapping zones.


"TOP OIL PAY"
EUNICE FIELD
LEA COUNTY, NEW MEXICO
SYMBOLS
• OIL WELLS
☼ GAS WELLS
⁄ ABANDONED OIL WELLS
0
1
SCALE: MILES
R 36 E
R 37 E
T 20 S
R 36 E
T 21 S
T 21 S
R 35 E
R 36 E
MEDIAL ELEVATIONS
LOW AND HIGH ELEVATIONS
MEDIAL ELEVATIONS
23
24
19
20
21
26
25
30
29
28
35
36
31
32
33
1
6
5
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3
2
1
12
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35
36

Figure 8.

Following this method of analysis, the Eunice field was divided into two areas based on the conditions of productive-zone overlap; that is, one area in which the top of oil pay was found either high or low and another in which the elevations of the top of oil pay were more uniform and approached a medial figure between the high and low elevations. Figure 8 is a map of the Eunice field divided into these two areas, and table 1 presents data on top of oil pay for the field. The shaded portion of the map shows the areas where low and high elevations for the top of the oil-productive zones occur, and the unshaded portion outlines the medial elevations.

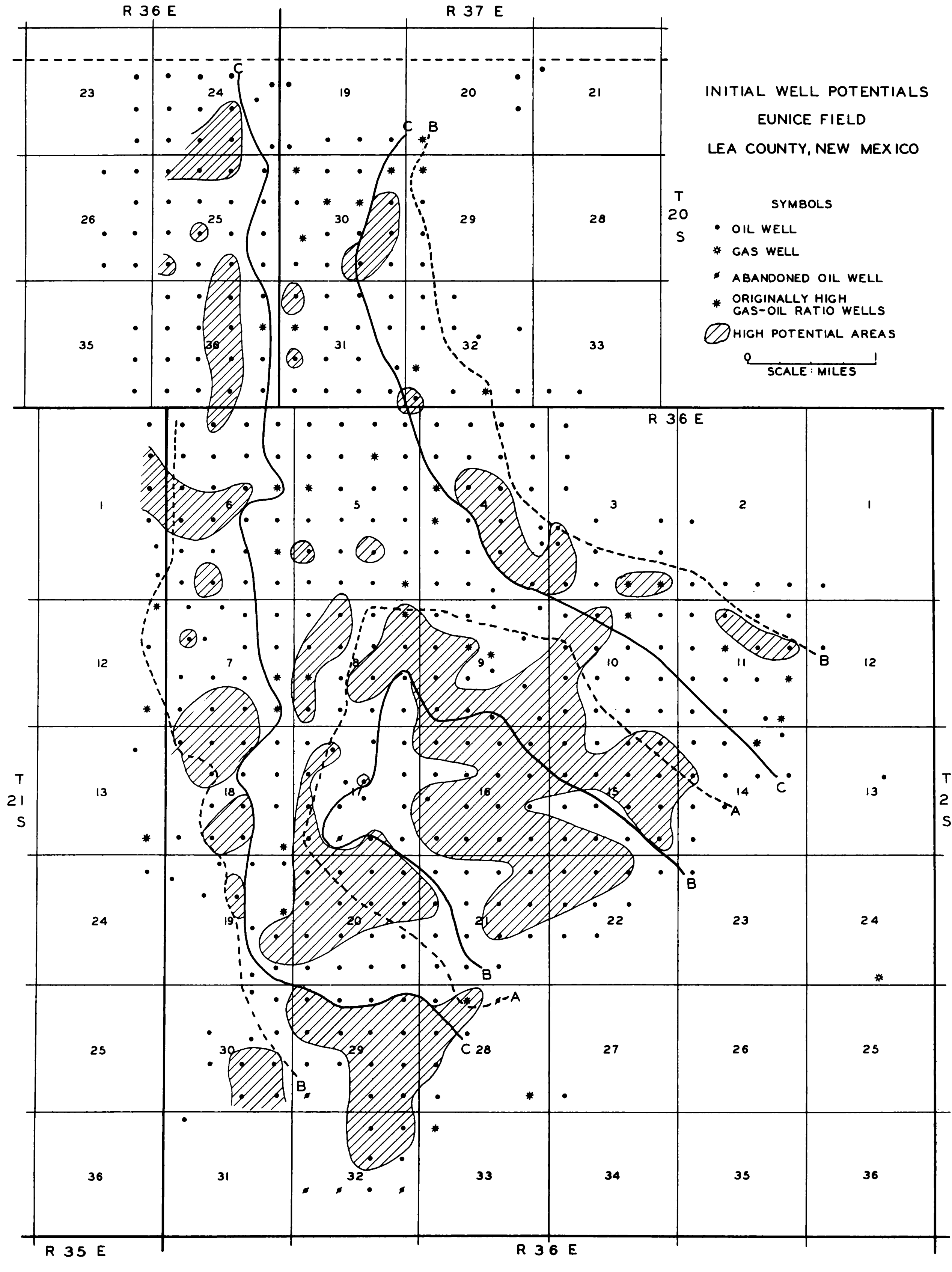
In the development of the top of oil pay map of the Eunice field, the relationship of the occurrence of high, low, and medial elevations for the top of the oil-productive zones in the various wells were noted, and some of these are discussed. As the average elevation of the highest oil production was approximately 225 feet below sea level, the medial elevations were taken to be between 200 and 250 feet below sea level. The high elevations were taken to be above 200 feet and the low below 250 feet below sea level. By this division of high and low deviations, the total number of wells in which elevations of the top of the pay were medial was found to be approximately equal to the sum of the high and low wells. In other words, for half of the wells the elevations were medial and the number of wells in which high and low figures were recorded each made up one-fourth of the total. It was found that in the unshaded area of figure 8, 164 wells had medial elevations, 55 high, and 13 low. Thus, medial elevations in the unshaded area occur 2.4 times as frequently as high and low elevations combined, indicating that top of oil pay elevations in this area are predominantly medial. In the shaded portion of the map, 75 elevations are high, 84 low, and 72 medial. In this shaded area the combined low and high figures occur 2.2 times as often as the medial ones, which indicates that the low-high figures predominate.

As indicated by figure 8, the low-high areas are on both the east and west sides, in addition to being in the area crossing the south-central part of the field. As it was exceedingly difficult to determine the top of oil pay accurately in many of the wells, errors may have been introduced into the data, and thus the shaded area of figure 8 should not be assumed to define the boundaries of the overlaps definitely.

TABLE 1. - Top of oil pay data, Eunice field

Zone	Wells with high elevations1/	Wells with low elevations2/	Wells with medial elevations3/	Average,			
				High elevations4/	Low elevations4/	Medial elevations4/	All elevations4/
A	6	7	37	191	260	217	220
A-B overlap	17	14	19	182	272	219	222
B	29	11	70	187	274	221	217
West flank B-C overlap	19	15	24	186	277	220	223
East flank B-C overlap	19	21	15	189	268	228	230
Total B-C overlap	38	36	39	188	272	223	227
West flank C	5	4	17	178	290	214	219
East flank C	4	4	14	176	281	227	228
Total C	9	8	31	177	286	220	223

1/ Above 200 feet below sea level.
2/ Below 250 feet below sea level.
3/ Between 200 and 250 feet below sea level.
4/ Feet below sea level.


INITIAL WELL POTENTIALS
EUNICE FIELD
LEA COUNTY, NEW MEXICO
SYMBOLS
• OIL WELL
✲ GAS WELL
ABANDONED OIL WELL
✱ ORIGINALLY HIGH GAS-OIL RATIO WELLS
▨ HIGH POTENTIAL AREAS
0 1
SCALE: MILES
R 36 E
R 37 E
R 36 E
R 35 E
R 36 E
T 20 S
T 21 S
T 21 S
23
24
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20
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A
A
B
B
B
B
B
C
C
C
C

Figure 9.

Study of Initial Well Potentials

In a field with overlapping productive oil zones it is probable that in the areas of overlap total combined thicknesses of the producing formations will be greater than the maximum thickness of any individual zone, and if the permeability of each zone is uniform throughout, the wells in areas where zones overlap should have relatively large "potentials."[12] The general practice in the Eunice field has been to obtain data on the potential productivity of wells only at the time of their completion. As previously indicated, this field is thought to have more than one major zone porous and permeable enough to be productive of oil and gas, and, therefore, initial potentials of wells in the overlap areas may have been influenced to some extent by the greater productive thickness of pay formations. Time of development, acidization, diameter of well bores, tubing sizes, procedures followed in taking potential tests, and other details were considered by the writers as having an influence on the productivity of the wells in the Eunice field. However, as the present study was to be very general, these factors were considered to be of minor importance.

The following table is a summary by zones of the well-potential study of the Eunice field:

TABLE 2. - Summary of well-potential data by zones

Zone	Number of wells	Total initial well-potential, barrels of oil per day	Average initial well-potential, barrels of oil per well per day
West flank C	23	20,455	889
East flank C	27	8,512	315
Total C	50	28,967	579
West flank B-C overlap	98	107,780	1,100
East flank B-C overlap	54	47,579	881
Total B-C overlap	152	155,359	1,022
B	128	91,138	712
A-B overlap	53	75,329	1,421
A	48	87,502	1,823

On figure 9 the areas of high initial oil potentials in the Eunice field are shaded, those of low potentials are unshaded. The average of the initial potentials was 1,016 barrels of oil per well per day.

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[12] Potential, as used in this report, refers to the volume of oil produced by a well during its initial test. Generally, a well in the Eunice field is tested by producing through the tubing, under steady flow, for 4 hours or longer, the duration of the test depending upon the capacity of the well to produce and on storage facilities. The average hourly rate of production during the test period was multiplied by 24 to obtain the average daily initial well potentials used in this report.

Areas in which the potentials were equal to and greater than 1,016 barrels of oil per well per day were inclosed by a heavy line, thus visually separating the field into areas of low and high potentials. Upon defining these areas, it was found that many of them were on the overlaps of the zones. The outlines of the three major porous zones shown in figure 6 have been superimposed on figure 9 to show the relations mentioned.

On the east and west flanks of the field most of the high-potential areas lie on the overlap of zones C and B. In these parts of the field the irregular occurrence of the high-potential areas indicates that the original potentials were influenced by erratic conditions of pay thickness and permeability as well as the overlapping of the pay zones. In the southeast part of the field, a large number of the high potential wells are in the area of overlap of zone B on zone A. The central and northeast portions of zone A show high potentials, which may indicate that this zone has relatively high productivity. Zone B apparently contains a few irregular areas of high potentials, most of which lie in the southern part of the field.

The wells having initial gas-oil ratios greater than 5,000 cubic feet of gas per barrel of oil are shown by a conventional symbol on the potential map (fig. 9). From the areal distribution of these high gas-oil-ratio wells, it appears that most of the gas from the Eunice field was produced from the upper parts of zones B and C. No high gas-oil-ratio wells were found in the area where production is obtained only from zone A.

Study of Water Encroachment

In a field producing from one uniform zone and acted upon by a water drive, the water encroaches uniformly from the edges if production rates are controlled properly. As the Eunice field has more than one major porous zone, the water should move through each zone according to its relative position with respect to the source of water, the permeability and porosity of the formation, and rate of withdrawal of oil and gas. The appearance of water in any area is influenced locally by the total depth of the wells. In an area subject to water encroachment, the deeper wells produce water first if the bottoms of the well bores are in a porous and permeable formation connected to a source of water. The first general sustained appearance of water in an area may indicate the base of the oil-producing zone.

Using data assembled by the New Mexico Proration Office, a water-encroachment map of the Eunice field (fig. 10) was prepared. The shaded portions of this map indicate areas in which the wells are producing some water. The lines within the shaded areas indicate the water encroachment by years from 1934 to 1937. The lines outlining the three major porous zones shown in figure 6 have been superimposed on this water map to show the relation of water encroachment to the major porous zones A, B, and C. The broken lines A and B in figure 10 indicate the approximate outermost limits of the areas in which the porous zones dip below the water level.

Water was produced first in the southwest part of the Eunice field, probably because that part was drilled first. Water is encroaching on the

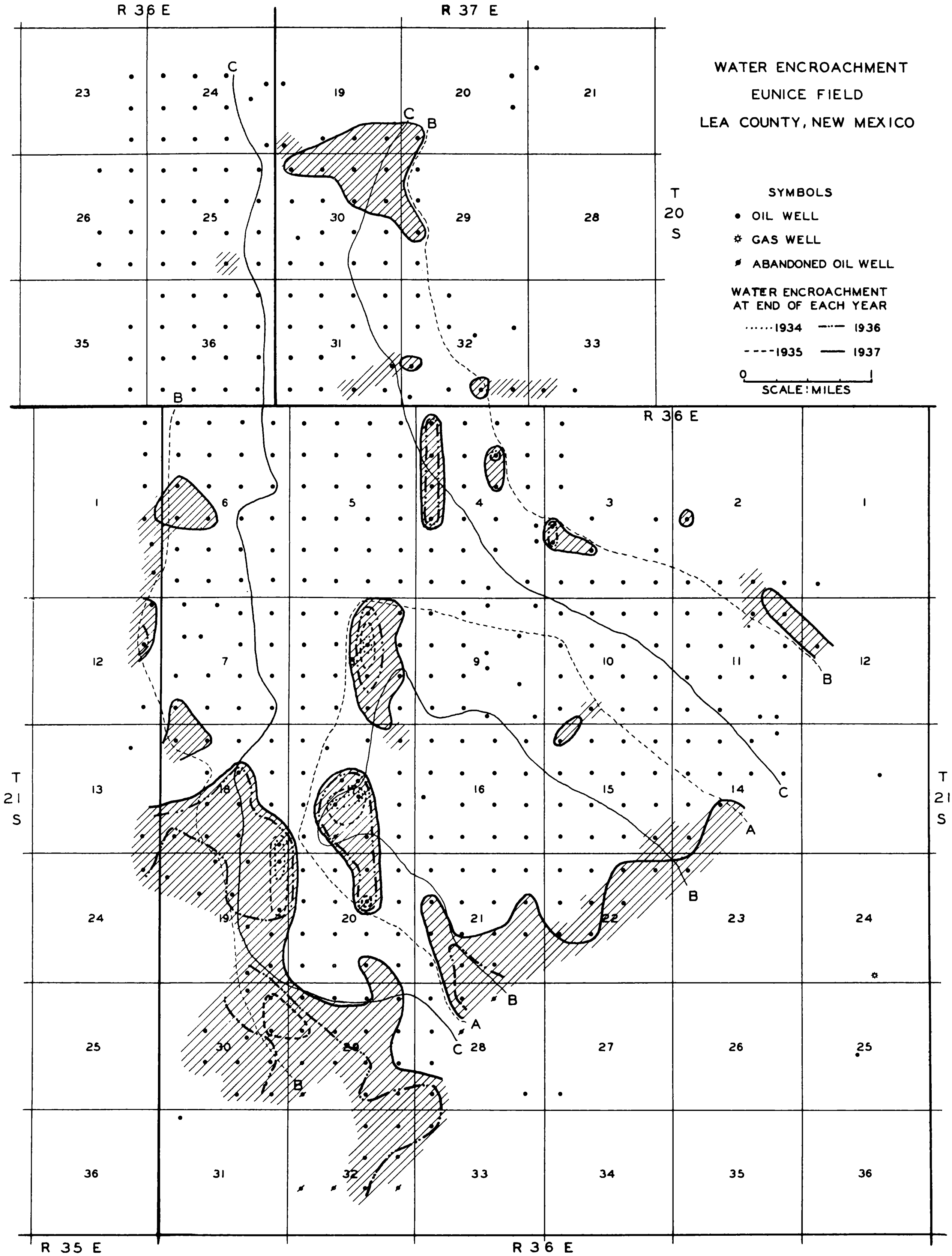WATER ENCROACHMENT
EUNICE FIELD
LEA COUNTY, NEW MEXICO
SYMBOLS
OIL WELL
GAS WELL
ABANDONED OIL WELL
WATER ENCROACHMENT AT END OF EACH YEAR
1934
1935
1936
1937
0
1
SCALE: MILES
R 36 E
R 37 E
R 36 E
R 35 E
R 36 E
T 20 S
T 21 S
T 21 S
A
B
C
23
24
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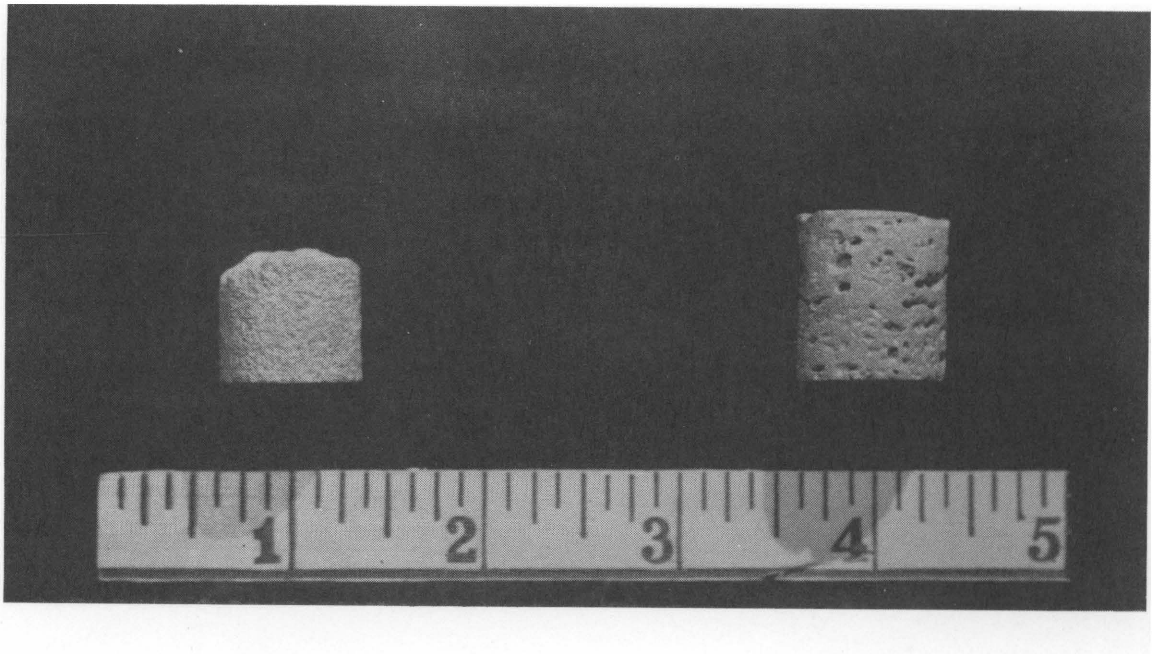
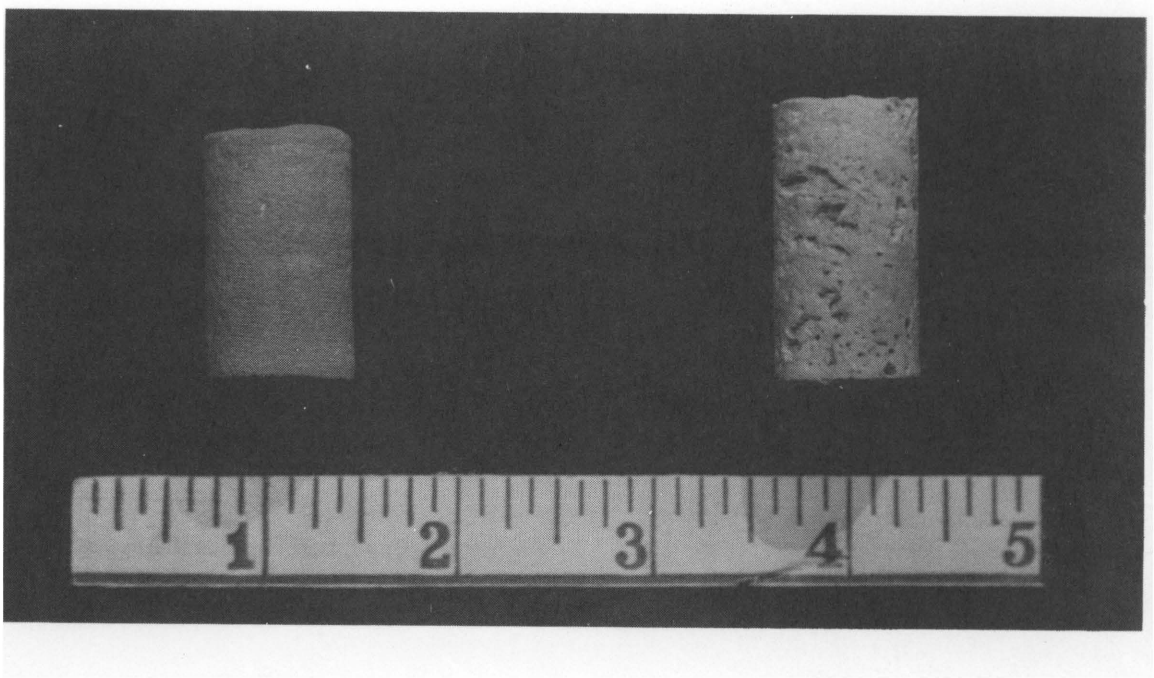
Figure 10.



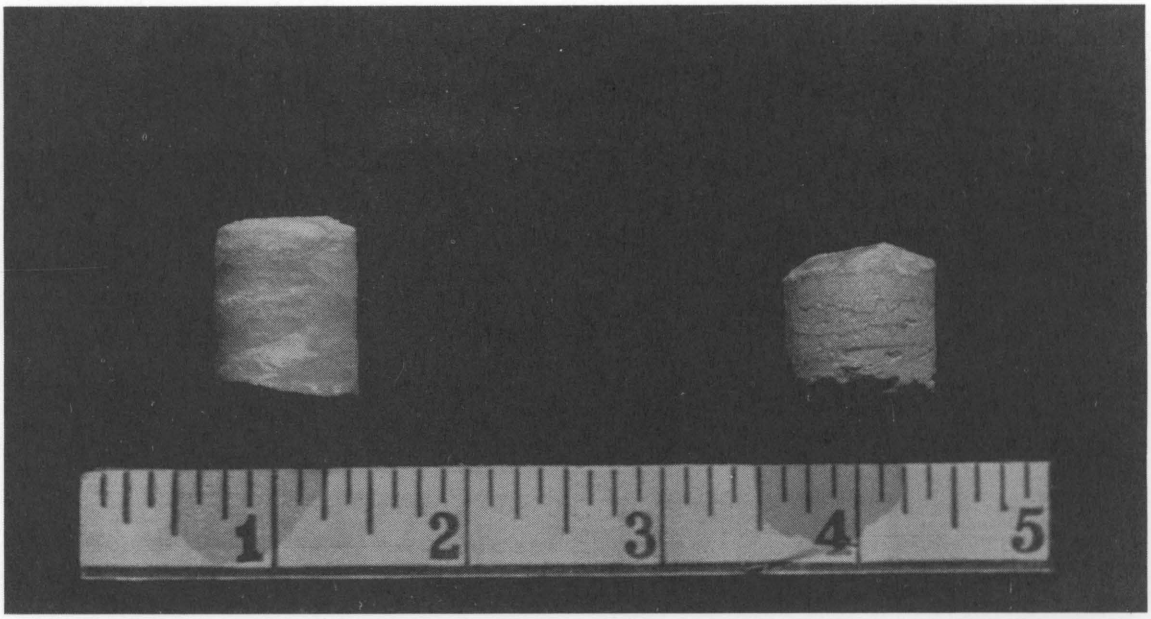
Core 1 Core 2

Figure 11.



Core 3 Core 4

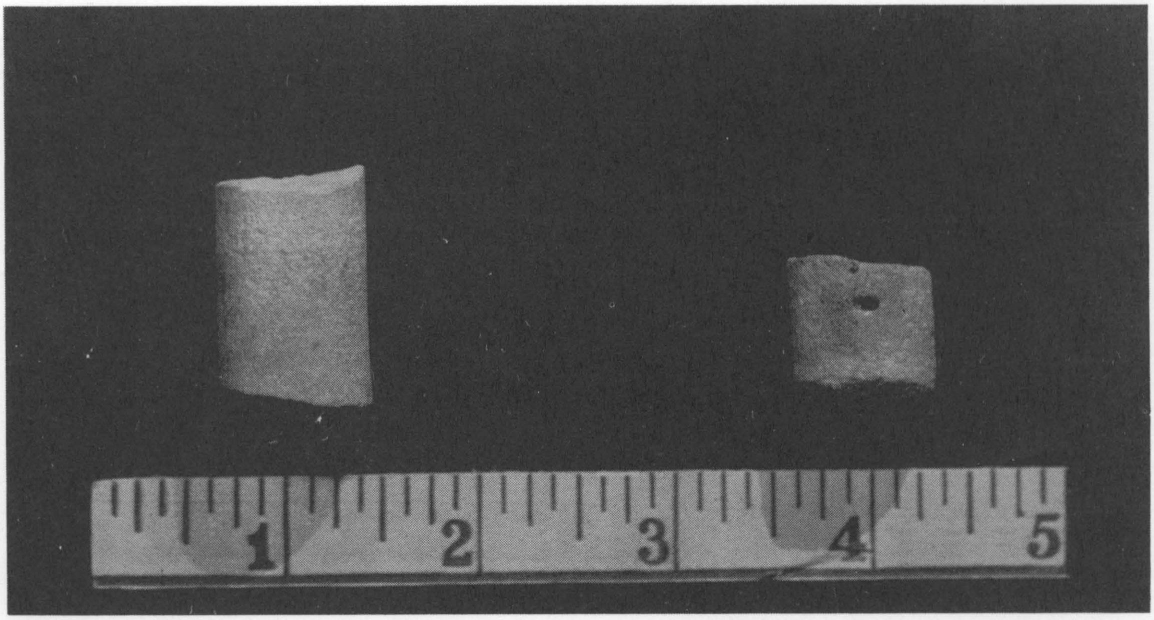
Figure 12.



Core 5

Core 6

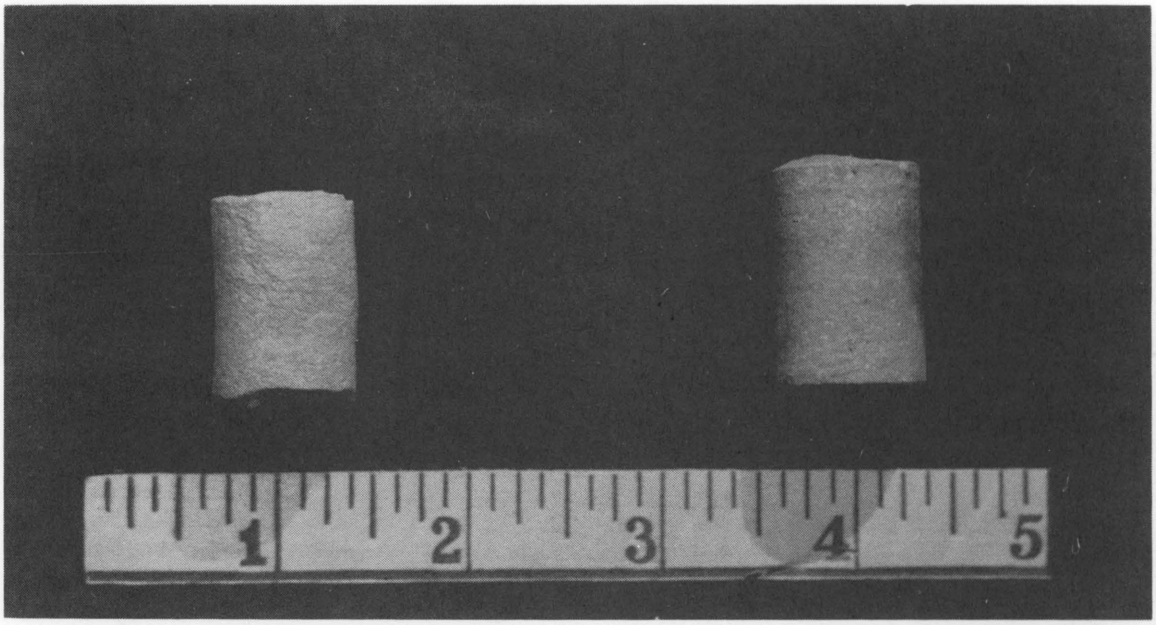
Figure 13.



Core 7

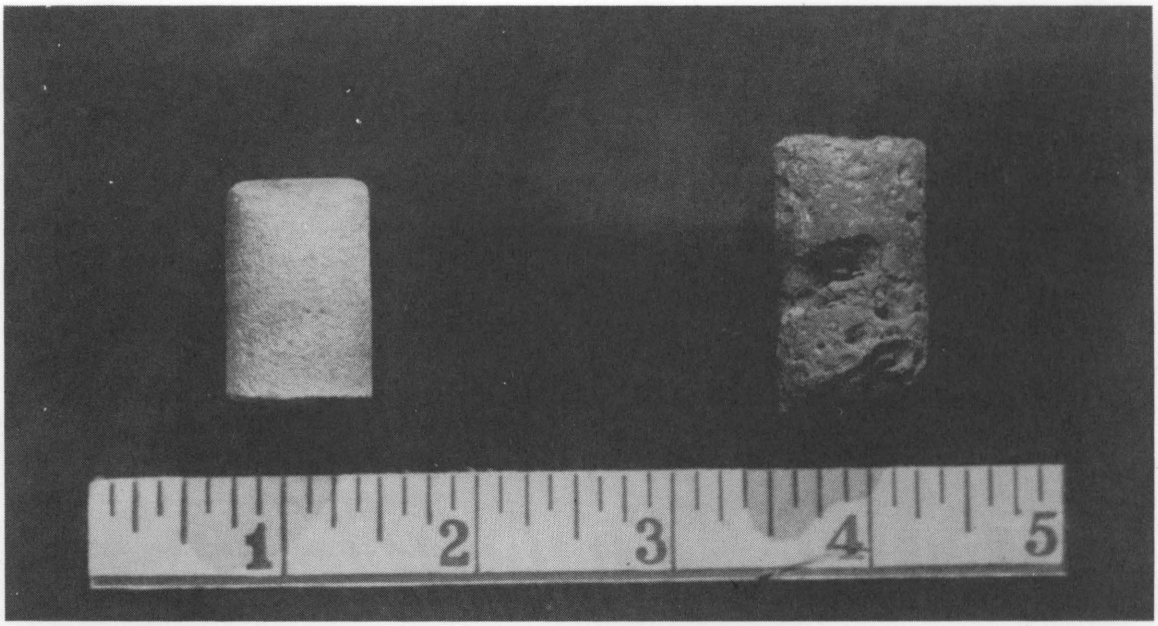
Core 8

Figure 14.



Core 9 Core 10

Figure 15.



Core 11 Core 12

Figure 16.

west, southwest, and southeast edges of the field, but the water drive appears to be most active on the southwest.

It will be noted in figure 10 that water is being produced from a large part of the structurally low portion of zone A. Water is encroaching from the southeast and only recently has made its appearance in the northeastern portion of the zone.

On the west water encroachment is active in zone B but is irregular in zone C. The northwest edge of the field shows no water encroachment, probably because it had not been drilled until recently. On the east side of the field, water has encroached irregularly in zones B and C.

POROSITY AND PERMEABILITY DATA

The erratic character of the porosity and permeability of the major productive zones in the Eunice field has been mentioned. To illustrate some of the porosity and permeability characteristics of the reservoir, six photographs showing 12 core specimens, together with porosity and permeability data, are included in this report (figs. 11-13). These specimens were selected as being representative of the various types of porous materials recovered by coring but were not classified as to major porous zones, as these types may be present in each zone. Generally, in coring limestone or dolomite reservoirs the percentages of core recovery are very small in the prolific parts of the pay section and, therefore, the data presented with the photographs probably are representative only of the harder and less prolific oil-producing portions of the reservoir rock.

The specimens shown were three-fourths inch in diameter and were cut approximately perpendicular to the bedding planes from larger cores taken from wells. These specimens were selected primarily for use in porosity determinations, but information as to vertical permeabilities also was obtained.

Core 1 (porosity 19.7 percent, permeability 218 millidarcys) is a porous oolitic dolomite, at least half of the individual pore spaces of which are filled with cementing material. Although the pores are very small, this core is the most permeable of those shown.

Core 2 (porosity 23.6 percent, permeability 0.48 millidarcy) is dark-gray, flaky, sandy, and oolitic dolomite. The original pores were large and much secondary material had been deposited in them. Even though the pores appear large, the vertical permeability is low.

Core 3 (porosity 23.6 percent, permeability 35.9 millidarcys) is an example of fine-grained dolomitic sandstone. Its porosity is as high as that of any core shown.

Core 4 (porosity 10.9 percent, permeability 0.05 millidarcy) is dense white dolomite with local dark streaks, which dip at about 15° from the horizontal. Most of the original pore space is filled with secondary material.

Core 5 (porosity 8.5 percent, permeability 0.07 millidarcy) consists of gray and light buff-colored dolomitic sand with abundant inclusions of very angular dolomite fragments.

Core 6 (porosity 11.6 percent; no permeability test) contains cream-colored sandy dolomite and banded gray dolomitic sandstone. The pores in the sandstone are very small.

Core 7 (porosity 15.3 percent, permeability 5.84 millidarcys) is an example of oolites embedded in a dense flaky and sandy dolomite. The oolites are about four times as large as the grains of sandy dolomite and show hollow interiors when broken.

Core 8 (porosity 20.9 percent, permeability 18.6 millidarcys) consists of fine-grained, flaky, and partly oolitic dolomite with some very fine, irregularly spaced pores.

Core 9 (porosity 15.4 percent, permeability 0.50 millidarcy) is a uniform-gray dolomitic sandstone. Upon casual inspection, this specimen appears to have little porosity, but the test indicated more than 15 percent.

Core 10 (porosity 11.9 percent, permeability 2.97 millidarcys) is a flaky and microscopically sandy dolomite with a trace of open solution-channel porosity.

Core 11 (porosity 11.2 percent, permeability 1.95 millidarcys) is a very fine-grained, flaky, partly oolitic dolomite.

Core 12 (porosity 19.5 percent, permeability 0.95 millidarcy) is a dark-gray flaky and sandy oolitic dolomite with large pores partly filled with secondary material.

SUMMARY

From an analysis of logs that were made from examinations of cuttings from wells and data concerning well completions, initial well potentials, gas-oil ratios, and water encroachment for the Eunice field, three major porous and permeable zones have been outlined as shown in figure 6. These zones must not be confused with lithologic or geologic units, as they may not be directly related to geologic structure.

Attention is called to the special value of each group of information in outlining the major porous zones of the Eunice field and the general agreement between the sets of data. Each zone in the field was defined by determining its approximate upper and lower limit. The upper limits of the zones were determined by the use of cross sections, elevations of the top of oil pay, initial well potentials, and gas-oil ratios. The lower limits were defined by the use of cross sections, elevations of the top of the oil pays, and water-encroachment data.

The lowest productive zone, A, is in the southeastern part of the field and overlapped by the intermediate zone B. Zone A probably does not extend above the gas-oil contact. Wells producing from zone A had the highest initial potentials in the field, and none had excessively high gas-oil ratios. The water encroachment occurring on the west in the lower part of zone A may be due largely to the fact that this part of the field was drilled first.

Of the three major oil-producing zones, B has the largest areal extent, overlapping zone A in the southern part of the field, extending through the central and northern portions, and being overlapped by zone C on the east and west sides. Zone B probably does not extend entirely across the top of zone A but rises above the gas-oil contact in the area of overlap. The top of zone B also may rise above the gas-oil contact in portions of the central and northern parts of the field. Water is encroaching into zone B more rapidly on the western side of the field than on the eastern flank. The average initial potential for wells in this zone is larger than for those in zone C but smaller than for zone A. In the area of productive overlap of zones A and B, the average initial well potential is larger than for zone B and less than for zone A.

As previously mentioned, zone C, overlapping zone B on the east and west edges of the field, probably is not continuous over the high portions of zone B but is productive of gas in the higher parts of the areas of overlap. The group of wells in the overlap area of zone C on zone B have an average initial potential which is larger than for either of these zones. The wells producing wholly from zone C have the smallest average initial potential of any zone or area of overlap in the Eunice field.

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