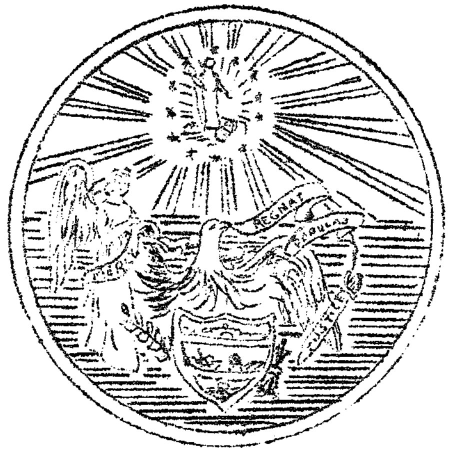
STATE OF ARKANSAS

ARKANSAS GEOLOGICAL SURVEY

GEORGE C. BRANNER
STATE GEOLOGIST

# INFORMATION CIRCULAR 5



# DISCOVERY OF ROCK SALT IN DEEP WELL IN UNION COUNTY

BY

H.W. BELL

STATE OF ARKANSAS
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# DISCOVERY OF ROCK SALT DEPOSIT IN DEEP WELL IN UNION COUNTY, ARKANSAS

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H. W. Bell

LITTLE ROCK
1933

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ARKANSAS GEOLOGICAL SURVEY

Little Rock, Arkansas

June 22, 1933

Hon. J. Marion Futrell
Governor, State of Arkansas,
Little Rock, Arkansas.

Sir:

I have the honor to submit herewith Information Circular 5, "Discovery of Rock Salt Deposit in Deep Well in Union County, Arkansas," by H. W. Bell, Assistant Vice President of the Lion Oil Refining Company. This test, which was the Lion Oil Refining Company's Hays A-9 well, was located in the central portion of the East Smackover field, Union County, Arkansas, and encountered 1,295 feet of rock salt from a depth of 5,960 to 7,255 feet. The presence of this salt has been a matter of great interest to geologists and those engaged in the business of oil production in Arkansas. This report sets forth the details of the discovery and discusses its significance.

Respectfully submitted;

State Geologist

## ABSTRACT

The Lion Oil Refining Company's Hays A-9 well, which was drilled to a depth of 7,255 feet in the SW.¼ NE.¼ sec. 4, T. 16 S., R. 15 W., Union County, Arkansas, is the deepest well which has been drilled in Gulf Coastal Arkansas. It was located on the highest structural point in the Graves sand in the East Smackover field and was drilled for the purpose of determining the character of the deep formations in that field. The greatest depth to which any well had previously been drilled in the field was 4,570 feet.

The test penetrated what is believed to be the Lower Marine formation of the Trinity group of the Lower Cretaceous series and encountered rock salt at 5,960 feet. Drilling continued in the salt to 7,255 feet, penetrating a total thickness of 1,295 feet of salt. Operations were discontinued on April 12, 1932, due to the sticking of the drill stem.

Of the various hypotheses advanced to account for the salt, that which assumes that the salt occurs as a stratified deposit of earlier age than the Trinity group of beds appears to be the most tenable.

Mechanical procedure in drilling the well involved the use of eight lines, carrying an estimated maximum weight of 100,000 pounds. The net horizontal migration of the bottom of the hole at 5,164 feet was 321 feet, and the greatest inclination was 20 degrees at about 5,000 feet.

## INTRODUCTION

This paper describes the results of the drilling of a test well (the Lion Oil Refining Company's Hays A-9) in the Smackover field, Union County, Arkansas, to a depth of 7,255 feet. The test is of particular interest because of the geologic information obtained in carrying the well 2,685 feet deeper than the deepest well which had previously been drilled in the field.

The project was supported principally by the Lion Oil Refining Company 1/ and the drilling was done under the direction of that company. The writer represented the company in the field, acting under the supervision of T. H. Barton, President, and M. E. Wilson, Vice President in charge of production.

## ACKNOWLEDGMENTS

The writer wishes to express his appreciation to George C. Branner, State Geologist, for aid in organizing and editing this report; to W. C. Spooner, Roy T. Hazzard,

1/ While the Lion Oil Refining Company bore the major expense of operation, the following firms made substantial contributions: Gulf Refining Company, Arkansas-Louisiana Pipe Line Company, Root Refining Company, Oil City Iron Works of Shreveport, El Dorado Foundry and Machine Company, Vickers Machine Shop, Ohio Oil Company, Phillips Petroleum Company, El Dorado Lumber Company, Sam Dorfman, and a committee of the El Dorado Chamber of Commerce composed of Messrs. Ike Felsenthal, G. W. James, P. R. Mattocks, J. D. Trimble, and James Dugan.

and C. L. Moody for commenting on the report; and to F. X. Bostick, E. B. Hutson, A. R. Mornhinveg, R. D. Norton, S. H. Rook, and N. L. Thomas for examining the cores and cuttings from the well and reporting upon them.

## PRODUCING HORIZONS IN THE SMACKOVER FIELD

The Smackover oil field was discovered on July 31, 1922, with the discovery of oil in the V. K. F. Drilling Company's Richardson No. 1 well, in sec. 29, T. 15 S., R. 15 W., following a gas blow-out which had occurred on the previous April 14th in the Oil Operators' Trust Murphy No. 1 well, in sec. 8, T. 16S., R. 15 W. Both of these discoveries were made in the Nacatoch sand, which is the uppermost producing horizon in the field.

The field covers some 53 sections of land in Union and Ouachita counties. Six different sands produce oil or gas but the Nacatoch, or uppermost sand, is the only one which is productive over the entire field. The other sands, listed in the order of the size of their productive areas, are the "2,600-foot," the Graves, the Meakin, the Primm, and the Woodbine.

The Nacatoch sand has proved to be productive from a depth of about 1,770 to 1,900 feet below sea level. The underlying producing sands are not exactly parallel to the Nacatoch, or to each other. The top of the Primm (gas) sand occurs about 320 feet below the top of the Nacatoch and about 180 feet below the lowest sand of the Nacatoch producing sands. The top of the Meakin sand lies about 360 feet below the top of the Nacatoch; the Graves about 460 feet; the "2,600-foot" about 700 feet; and the Woodbine about 800 feet.

In the eastern part of the field the highest structural point of the Nacatoch sand is near the eastern edge of sec. 8, T. 16 S., R. 15 W. The highest point of the Meakin sand is about three-fourths of a mile northeast of the Nacatoch sand high point, or in sec. 9, T. 16 S., R. 15 W., and the highest point of the Graves sand is about three-fourths of a mile farther on in the same direction, or in sec. 4, T. 16 S., R. 15 W. (See fig. 1.)

## DEEP TESTS NEAR THE HAYS A-9

Nineteen wells have been drilled in the immediate vicinity of the Hays A-9 to varying depths below the Woodbine sand. The deepest test was J. E. Crosbie's Berry No. 12 well, in sec. 33, T. 15 S., R. 15 W., which was drilled to 4,570 feet and logged some oil and gas showings. This location is about one mile north of the Hays A-9. The next deepest test was E. M. Jones' Murphy No. 9 well, in sec. 17, T. 16 S., R. 15 W., which was drilled to 4,380 feet. Neither the Crosbie well nor the Jones well is considered by the writer to have been adequate tests of all of the formations penetrated. It appears that the best indication of oil and gas below the Woodbine sand was in the Southern Crude Oil Purchasing Company's Graves No. 10 test at a depth of 3,608 feet, in sec. 3, T. 16 S., R. 15 W., nearly a mile east of the Hays A-9. This well might have made a producer if the top water had been successfully excluded. Other deep tests logged showings of oil and gas at apparently unrelated depths.

All of the showings mentioned above were in what is known as the "red beds" of Upper and Lower Cretaceous age. These beds, which are probably of shallow water, marine origin, consist mostly of clays and sands stained red by oxide of iron. The individual beds are characteristically lenticular. Local porous zones occur in the formations which are not necessarily confined to individual beds. Uniform conditions of porosity and composition persist only short distances both vertically and horizontally. Therefore, as in the Rainbow City field nearby, the finding of oil in the "red beds" at a certain depth at one location does not guarantee that oil will be found in the same horizon as little as 300 feet distant.

Of the producing sands below the Nacatoch, the logging of the Graves sand has been the most reliable and therefore offers the best basis for correlation. Being the deepest of the three major producing sands, it was considered the most dependable for indicating structure in the underlying beds which were to be explored. As it was desirable that the deep test be drilled at the highest structural point in the field, the Lion Oil Refining Company's Hays A-9 was located close to the high point of the Graves sand, in the SW.$\frac{1}{4}$ NE.$\frac{1}{4}$ of sec. 4, T. 16 S., R. 15 W., on the south bank of Smackover Creek, in Union County.

The structure of the Graves sand, the positions of the structurally high points of the Nacatoch and Meakin sands in the East Smackover field, and the locations of the wells drilled below a depth of 2,900 feet, are shown in Figure 1, and corresponding data are set forth in Table 1.

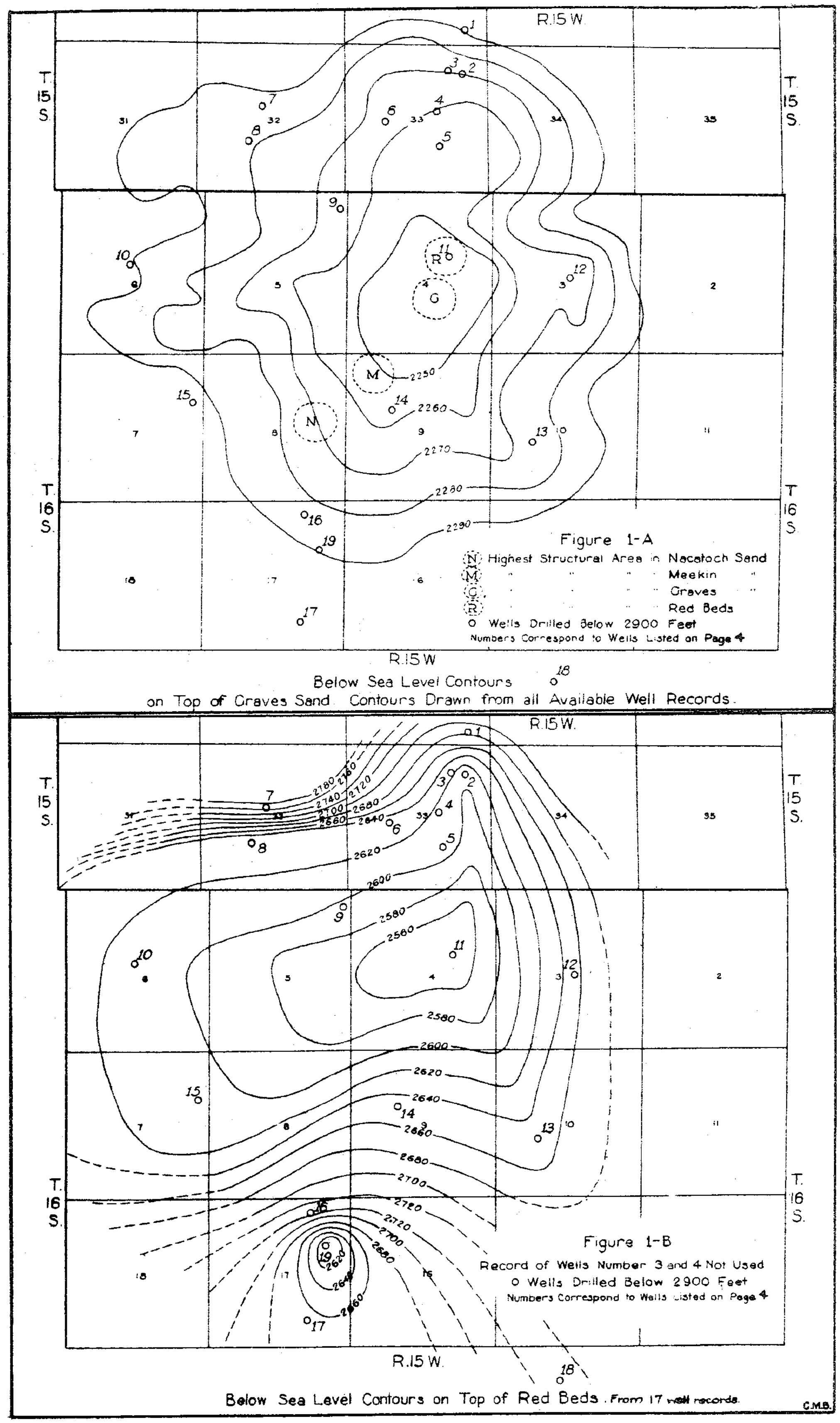
R.15 W.
T. 15 S.
T. 16 S.
2250
2260
2270
2280
2290
Figure 1-A
(N) Highest Structural Area in Nacatoch Sand
(M) " " " " Meekin "
(G) " " " " Graves "
(R) " " " " Red Beds
O Wells Drilled Below 2900 Feet
Numbers Correspond to Wells Listed on Page 4
R.15 W.
Below Sea Level Contours
on Top of Graves Sand. Contours Drawn from all Available Well Records.
R.15 W.
T. 15 S.
T. 16 S.
2560
2580
2600
2620
2640
2660
2680
2700
2720
Figure 1-B
Record of Wells Number 3 and 4 Not Used
O Wells Drilled Below 2900 Feet
Numbers Correspond to Wells Listed on Page 4
R.15 W.
Below Sea Level Contours on Top of Red Beds. From 17 well records.
C.M.B.

FIGURE 1

Table 1. - Information concerning wells drilled below 2,900 feet in east Smackover field, used in construction of Figure 1-A

| Map index No. | Company | Lease | Well No. | S.T.R. | Elev. (ft.) | Depth to top of Red Beds | Control to top of Red Beds | Total depth (ft.) | Date of completion |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Simms Oil Co | Hildebrand | 11 | 28-15-15 | 173 | 2856 | -2683 | 3140 | 5-30-29 |
| 2 | Phillips Petr Co | Joyce | 20 | 33-15-15 | 133 | 3744 | -2611 | 3264 | 2-3-29 |
| 3 | Sinclair Oil Co | Berry | 7 | 33-15-15 | 122 | ?a/ | ? | 2934 | 4-28-28 |
| 4 | J E Crosbie | Berry | 12 | 33-15-15 | 96 | 2832 | -2736 | 4570 | 1925 |
| 5 | Gulf Refg Co | Umsted A | 20 | 33-15-15 | 97 | 2709 | -2612 | 3105 | 9-4-26 |
| 6 | Standard Oil Co | Griffin | 9 | 33-15-15 | 99 | 2734 | -2635 | 3167 | ? |
| 7 | Standard Oil Co | Umsted B | 5 | 32-15-15 | 117 | 2893 | -2776 | 3499 | 10-21-25 |
| 8 | Gulf Refg Co | Goodwin | 8 | 32-15-15 | 118 | 2753 | -2635 | 2855 | 8-15-25 |
| 9 | Marine Oil Co | Umsted | 6 | 5-16-15 | 89 | 2685 | -2596 | 3508 | ? |
| 10 | Crawford & Sebastian | James | 10 | 6-16-15 | 97 | 2711 | -2614 | 3233 | 3-5-26 |
| 11 | Lion Oil Refg Co | Hays A | 9 | 4-16-15 | 96 | 2640 | -2544 | 7255 | 4-20-31 |
| 12 | Southern Crude O Pur Co | Graves | 10 | 3-16-15 | 96 | 2751 | -2655 | 3608 | ? |
| 13 | Mazda Oil Co | Lawton | 4 | 10-16-15 | 156 | 2809 | -2653 | 3256 | ? |
| 14 | Lion Oil Refg Co | Murphy H | 3 | 9-16-15 | 151 | 2795 | -2644 | 3450 | 6-28-28 |
| 15 | Lion Oil Refg Co | Murphy A | 10 | 7-16-15 | 138 | 2745 | -2607 | 3038 | ? |
| 16 | Lion Oil Refg Co | Murphy J E M Jones | 9 | 17-16-15 | 213 | 2944 | -2731 | 4380 | 12-12-26 |
| 17 | Humphreys Oil Co | Massey | 1 | 17-16-15 | 199 | 2864 | -2665 | 3505 | ? |
| 18 | Federal Petr Co | Murphy | 4 | 22-16-15 | 140 | 2874 | -2734 | 3052 | ? |
| 19 | Magnolia Petr Co | Wilson | 6 | 17-16-15 | 215 | 2829 | -2614 | 3006 | 9-16-27 |

a/ Used iron oxide in mud.

## FORMATIONS PENETRATED

In drilling the Hays A-9, 96 cores were taken, beginning at 3,308-3,315 feet and extending to 6,938-6,946 feet. A number of wells had been drilled at Smackover as deep as 3,300 feet, so the first core was taken at 3,308 feet where a sand was encountered. The following log shows the formation interpretation of R. D. Norton (see p. 18) and indicates where the cores were taken:

Claiborne formation
20 surface sand
30 sand and shale
31 rock
95 sand with streaks shale
150 gummy shale
180 shale with creek sand

Wilcox formation
250 shale
264 sand
285 gummy shale
350 sandy shale and boulders
360 gumbo
430 shale and sand
432 rock
550 shale with gummy streaks
551 rock
675 shale, boulders and shells
725 sandy shale and shells
850 shale and boulders
900 shale, sand and boulders
901 rock
975 sand and boulders
976 rock
1080 shale and sand

Midway formation
1185 gummy shale
1186 rock
1275 gummy shale with streaks of gumbo
1330 shale and boulders
1520 shale and boulders
1521 shell
1620 shale and boulders
1730 gummy shale

Arkadelphia marl
1800 shale with streaks gumbo
1860 gumbo, lime and shale
1900 chalk and shale

Nacatoch sand
1920 sandy lime with streaks of shale
1944 hard lime with streaks of shale
1975 sand, shale and boulders
2000 sandy shale with hard streaks sand
2035 sand and streaks gummy shale
2040 sandy shale
2070 broken lime with gummy streaks

Marlbrook Marl
2100 shale, boulders, shells
2180 gummy chalk and shale
2198 broken chalk
2205 gummy lime
2235 broken sand

Annona chalk
2244 hard sandy lime
2262 lime and shale
2280 lime with gummy streaks
2295 hard sandy lime
2315 gummy lime
2327 gummy shale and boulders
2330 gumbo
2333 hard sandy lime cap

Brownstown Marl (?)
2360 broken sand and rocks
2392 broken sand with streaks lime
2420 lime with streaks sand and shale
2436 lime
2438 sandy lime rock
2441 hard sand rock
2457 shale with streaks sand and lime
2475 gummy shale
2490 shale and sand
2500 shale and shells

Tokio formation (?)
2508 hard sandy lime
2528 shale and shells and hard streaks lime
2540 shale
2560 lignite and sandy shale
2571 gumbo
2575 hard sand
2608 shale with streaks hard sand
2610 hard sand
2630 broken lime
2640 sand

Woodbine formation (?) (non-marine red beds

2650 red shale
2717 red bed and volcanic ash
2733 volcanic ash with hard sandy limy caps
2735 hard lime
2750 volcanic ash with streaks hard sandy lime
2793 red shale with streaks blue shale
2795 hard lime
2830 red shale with streaks lime
2848 shale with streaks pyrite
2865 sandy shale
2877 sand
2900 white sand with hard streaks
2906 hard sand rock
2922 hard sand with streaks pyrite
2932 volcanic ash, streaks pyrite
2953 hard sand with streaks pyrite and hard lime
2980 hard lime with streaks sand and pyrite
2990 hard lime with streaks sand and shale
3002 lime and chalk
3030 gumbo, streaks lime
3055 red shale, shells, streaks sand
3075 gummy shale with streaks lime
3080 hard lime
3100 lime and streaks hard red shale
3120 shale, streaks sand

Washita group (?)

3130 lime, streaks of pyrite
3140 lime and pyrite
3142 gumbo
3155 lime pyrite, red bed and ash
3165 hard lime
3170 red shale with gummy streaks
3190 shale, sand, streaks pyrite
3196 lime, sand and red bed
3201 gumbo
3215 lime, sand and red bed
3245 lime, streaks sand, red bed
3258 lime, sand and gummy shale
3263 hard lime rock
3268 hard sandy lime
3286 lime and sand and streaks pyrite
3300 lime, sand and shale, streaks pyrite
3306 shale and lime
3315 soft (?) sand (core)
3330 broken sand
3340 lime with hard streaks
3342 hard lime cap rock
3349 coarse light gray sand streaks hard blue sandy shale (core)
3360 sandy lime
3372 red shale, streaks pyrite
3378 hard sticky lime
3380 gummy shale
3381 hard broken lime
3388 white sand and blue sandy shale; showing oil, some red bed at bottom (core)
3391 sand and pebbles
3399 shale, lime and streaks chert
3400 hard lime cap
3404 white sand and gummy sand (core)
3408 gummy shale
3415 red gumbo
3420 sticky lime with hard streaks
3421 hard lime cap
3427 sand, showing oil (core)
3433 gummy lime
3448 shale with streaks lime and sand
3455 soft sand with streaks lignite and shale
3460 sand and black shale (core)
3470 shale and streaks of sand
3473 hard red shale
3475 hard lime cap
3481 hard lignite shale on top, sandy shale showing oil and some red and pink shale in bottom (core)
3478 blue shale with streaks of red
3491 red gummy shale
3495 gumbo
3496 hard sand cap
3502 red gummy shale with streaks pink and white gummy shale (cored 2" hard sand)
3508 red shale with streaks blue shale
3514 blue shale with gummy streaks
3522 gummy shale
3523 hard sandy lime
3524 shale
3526 hard sandy lime
3530 hard shale and lignite (core)
3533 red gummy shale with streaks gummy lime
3535 hard sandy lime rock
3538 blue sandy shale)

(core)
3542 sand showing oil)
3545 sand
3547 slick shale
3548 lime cap
3555 sandy shale showing dead oil (core)
3562 red shale and streaks purple blue shale and sand (core)
3564 hard red gumbo
3565 hard sandy lime cap
3570 sand and red bed (core)
3578 hard red shale with streaks gray sandy shale
3593 soft shale with sandy streaks (core 3580-85)
3613 red shale with gummy streaks
3618 hard red sandy shale (core)
3650 blue and red shale with mucky sand streaks
3652 sandy shale
3659 hard blue shale and sandy shale (core)
3675 blue gummy shale
3679 blue shale with streaks red shale
3680 lime cap
3686 salt water sand showing dead oil (trace)
3694 sand
3702 sand
3708 volcanic ash and shale
3720 red shale with streaks ash
3758 red shale white shale with gummy streaks
3760 hard sandy shale
3770 salt water sand (core)
3772 white water sand
3778 salt water sand
3780 hard volcanic ash
3787 shale and ash
3788 sand
3794 hard blue sandy shale (core)
3806 blue shale with gummy streaks
3810 hard blue and red sandy shale
3819 red gumbo (core 3808-14)
3821 blue shale
3836 blue shale with streaks red gumbo
3859 blue shale with streaks of red
3864 sandy shale (core)
3868 shale
3873 salt water sand (core)
3876 red shale and blue sandy shale
3887 red and blue shale
3893 blue shale with streaks of red gumbo
3894 sandy shale
3900 red sandy shale with streaks blue shale (core)
3903 red gumbo
3906 blue and red sandy shale
3911 red gumbo (core)
3918 gray sandy shale (core)
3925 hard water sand (core)
3948 blue shale with streaks red shale
3968 blue shale with streaks red gummy shale
3970 sandy shale
3976 salt water sand, ash and blue sandy shale (core)
3980 salt water sand, ash and blue sandy shale (core)
3996 blue sandy shale, ash and streaks of sand
3998 sand with salt water) (core)
3999 lignitic shale )
4001 oil sand
(S.L. measurement changes depth from 4001 to 4013)
4011-4025 sand with dead oil and salt water (core 4013-17, core 4017-25)
4027 hard blue shale
4029 sand
4033 sandy shale (core)
4054 hard shale
4059 dark brown sand showing dead oil and salt water (core)
4065 soft sand (core)
4070 sand, white
4093 hard shale
4095 sand, white
4096 hard blue sandy shale)
4100 blue sandy shale ) (core)
4101 red sandy shale )
4105 red shale
4106 water sand, hard
4113 hard white water sand with soft streaks (core)
4123 red shale with streaks sand
4127 hard blue sandy shale
4140 soft white sand showing salt water (core 4125-32)
4145 soft water sand
4153 blue shale
4160 blue shale with gummy streaks
4161 hard sand cap
4167 white salt water sand (core)

4169 sandy shale
4176 red shale with streaks of white
4181 red shale (core)
4189 sandy shale (blue) showing dead oil and salt water (core)
4192 sandy shale
4204 red shale with streaks of white shale
4212 red gummy shale
4214 sandy shale
4221 blue sandy shale, ash and chert (core)
4233 red shale and blue shale
4235 sand
4239 blue sandy shale with show of dead oil (core)
4246 white water sand (core)
4254 sand
4270 red shale with streaks of blue shale
4275 sandy shale with hard streaks of gray sand (core)
4290 sandy shale with hard streaks sand
4292 sandy shale
4295 hard shale
4298 hard sand cap
4303 hard white sand, bottom showed a little oil (core)
4309 hard sand (core)
4317 hard shale
4318 hard crystallized sand (core)
4320 same
4321 hard crystallized sand
4322 hard crystal gray sand and soft limy sand (core)
4323 hard light gray sand and streaks brown shale (core)
4325 gray sand with streaks brown shale
4331 brown gummy shale
4332 hard sand cap
4336 hard white water sand (core)
4344 hard sand with soft streaks and streaks of hard shale
4357 broken hard sand and red shale and blue shale (core 4347-51)
4364 hard red sandy shale (core)
4395 red shale and blue shale
4402 coarse sand showing oil (core)
4406 sandy shale
4415 red shale
4419 red gummy shale
4420 hard cap rock
4421 hard blue sandy shale
4427 red shale (core)
4445 red shale
4451 hard sandy shale
4455 coarse white sand) (core)
4456 broken blue shale) (core) showing dead oil)
4459 blue shale
4473 shale
4480 salt water sand (core)
4482 blue sandy shale
4498 blue shale
4502 gummy shale
4506 sandy cap, hard) (core)
4510 red sandy shale) (core)
4515 red gummy shale
4535 red shale with streaks blue shale
4545 red shale with gummy streaks
4554 shale
4555 quartzite
4557 quartzite with white shale with thin layer black shale (core)
4558 crystallized sand
4563 water sand with streaks black shale
4571 hard shale
4573 hard sand (core 4573-75)
4581 blue sandy shale
4594 blue shale
4599 hard gray sand ) (core)
4602 mucky sand and shale ) (core)
4610 mucky sandy shale
4620 blue shale
4624 gummy shale
4627 green sand showing dead oil (core)
4644 salt water sand
4656 blue shale with streaks pink shale
4658 hard shale
4660 hard sandy lime) (core 4659-64)
4672 red shale ) (core 4659-64)
4682 red gummy shale
4684 hard gray sand
4688 hard gray water sand with streaks lignite (core)
4699 gummy shale
4700 hard cap rock
4702 sand
4703 hard gray water sand (core)
4711 hard gray sand
4718 red sandy shale
4736 red shale with gummy streaks
4738 sand
4743 hard and soft salt water sand (core)

4751 hard and soft sand
4753 red gummy shale
4761 hard red sand (core)
4792 red shale
4793 hard shale cap
4795 sand
4799 hard gray salt water sand (core)
4812 salt water sand
4825 red shale with streaks of blue
4835 red shale with gummy streaks
4837 hard red shale
4840 hard green sand ) (core)
4842 red shale and sand)
4846 green sand
4856 blue shale with gummy streaks
4858 hard blue sandy shale cap
4860 salt water sand showing dead oil (core)
4865 sand
4866 hard red rock
4874 soft white sandy shale
4878 green sand, blue shale and red shale (core)
4888 red shale
4889 hard sand cap
4890 sand
4893 hard red sand (core)
4909 blue shale
4920 red shale, blue shale and ash
4937 red shale
4940 sandy shale with hard streaks red sand (core)
4948 blue sandy shale
4958 red shale
4962 hard green sand ) (core)
4963 sand showing dead oil)
4964 red shale
4971 red gumbo
4975 white sand with streaks of red (core)
4990 red shale
4996 hard red shale
4999 sand
5003 red sand showing dead oil (core)
5010 red sand and shale
5021 red shale with gummy streaks
5039 red shale
5042 hard red sand (core)
5053 red shale with streaks hard red sand
5065 hard red shale
5081 red shale and red sandy shale
5086 broken chalk and red shale (core)
5095 red shale and streaks broken chalk
5116 red sticky shale and sticky chalk
5118 blue sandy shale
5123 hard red shale with streaks chalk (core)
5128 red shale with streaks sandy chalk
5138 hard red shale and gypsum
5140 hard red sandy shale
5146 hard red shale
5148 sandy limy shale
5150 hard blue sandy shale
5154 hard blue and red shale
5156 hard blue sand
5162 hard blue sandy shale with streaks red shale (core)
5166 red shale with streak of chalk
5194 hard red and blue shale
5206 hard blue and red shale with streaks of blue sandy shale
5220 hard red and blue sandy shale

Trinity group (marine)

5228 hard limy shale with streaks hard lime
5234 broken lime (core)
5236 broken lime
5239 hard gray limy shale
5240 hard limy shale rock
5241 hard lime
5243 hard lime
5247 hard lime with streaks pyrite
5248 streaks of gray sand
5249 hard lime and chalk showing dead oil (core)
5255 hard lime
5257 sticky lime
5274 hard lime and broken lime
5282 hard lime
5288 lime
5289 sandy lime
5290 chalk (core)
5373 chalk (core 5368-69)
5397 broken chalk and sticky chalk
5494 broken chalk (core 5457-63)
5518 broken chalk with sticky streaks
5531 hard chalky lime
5562 hard chalk and sticky chalk
5590 hard brown lime and hard chalk
5601 hard gray and brown and black lime
5613 hard gray and brown lime

5631 hard and broken lime
5633 sandy lime
5639 sandy lime showing dead oil and salt water (core)
5642 sandy lime
5653 hard lime
5660 hard brown lime
5670 hard lime
5676 broken lime
5678 hard lime
5686 hard brown lime
5687 hard lime
5700 hard brown lime with broken streaks
5706 hard lime
5716 hard brown lime
5731 hard lime
5739 hard lime with streaks broken lime
5741 hard broken lime (core)
5750 hard broken lime
5762 hard lime
5790 broken lime with hard streaks
5794 hard gray lime with streaks black sandy lime showing gas (took two 2-ft. cores)
5810 hard lime
5821 hard gray lime with broken streaks
5835 hard gray lime
5862 hard lime with broken streaks
5865 broken lime
5884 hard gray lime with sticky streaks
5895 broken lime
5898 hard lime with thin layers of sand (core)
5906 hard lime
5918 hard lime with broken streaks
5926 hard brown lime
5929 hard lime with sticky streak
5934 hard lime
5936 red shale
5938 sticky shale
5940 hard lime
5946 hard lime with sticky streaks
5951 hard lime
5966 hard lime and hard shale
5974 soft shale and rock salt (core)

Paleozoic (?)

5988 rock salt
6004 broken salt rock
6020 salt with streaks lime
6024 hard salt
6050 salt (core 6024-31)
6055 broken salt
6071 broken salt with streaks hard salt (core 6071-85)
(core 6094-6104)
(core 6480-6492)
(core 6652-6662)
(core 6698-6706)
(core 6938-6946)
7255 salt

The "red Beds" were reached at 2,640 feet, which was unusually high. This high, occurring in a conformable series, was to be expected if we assume that both the Lower and Upper Cretaceous sediments were vertically uplifted during the formation of the Smackover structure. The "red beds" extended to 5,220 feet, indicating a total thickness of 2,580 feet. The upper part of the "red beds" was devoid of lime, the first lime being noted at 4,660 feet. Although no fossils were found in the "red beds", the following materials were noted, in addition to the usual sand-clay-lime series shown in the log: volcanic tuff, bentonite, glauconite, quartz, quartzite, calcite, hematite, siderite, pyrite, gypsum, asphalt, and oil. The "red beds" grade in age from Upper Cretaceous to Lower Cretaceous. There is no clear-cut boundary between the two series.

A lime-chalk series was penetrated from 5,220 feet to 5,960 feet. This has been usually considered to be the Lower Marine beds of the Trinity formation, which is the lowest portion of the Lower Cretaceous now known in Arkansas. Other than the characteristic materials given in the log, the following were noted in the lime-chalk series: volcanic tuff, lime concretions, oolitic lime, calcite veins, quartz, pyrite, and oil.

Rock salt was encountered at 5,960 feet and persisted to the total drilled depth of 7,255 feet.

The fossil evidence obtained from the 96 cores was meager and insufficient for positive identification of the age of the strata from which they were obtained.

## Paleontological Interpretation

The cores were examined by the following micro-paleontologists: F.X. Bostick, Stanolind Oil & Gas Company; E. B. Hutson, Standard Oil Company; A. R. Mornhinveg, United Gas System; R. D. Norton, The Texas Company; S. H. Rook, Gulf Refining Company; and N. L. Thomas, Pure Oil Company.

F. X. Bostick states: "All the samples examined by me from this test, from 3,308 to 4,001 feet, are non-fossiliferous; therefore, it is impossible to give a definite age to the material furnished us. From the lithologic aspect of this material, however, I am of the opinion that all samples examined are from the Upper Glen Rose Red formation. Cores 62 through 69 are non-fossiliferous. However, it is my opinion all are of Glen Rose in age." This corresponds to a depth range of from 4,702 to 4,893 feet.

E. B. Hutson states: "In the above described cores (shallower than 3,898 feet) no evidence of marine life was present except in the cores at 5,790 feet and at 5,892 feet. In these cores recognizable forms were absent and only a few sections of what may be Miliolidae were noted. The red section down to 5,220 feet doubtless belongs to the Lower Trinity red beds, and the chalk and limestone down to the top of the salt at 5,980 feet may belong to the Lower Marine Trinity. A comparison of this section, however, with the Lower Marine section as encountered in two wells in north Louisiana shows very little similarity. The lithology is entirely different except in the last three cores, which is somewhat similar to certain layers of brown limestone which are present about 300 feet from the top of the section in north Louisiana. No fossils are present to confirm the lithologic similarity and the question must await further information secured from future deep wells drilled in Arkansas." Concerning the core from

5,792 to 5,794 feet, he says: "The presence of Guttalina sp. in this limestone indicates an age younger than the Permian."

A. R. Mornhinveg states that the core 5,156-5,162 feet is probably pre-Glen Rose red.

R. D. Norton gives the following section and notes: "The marine Upper Cretaceous is present from 1,730 to about 2,640 feet. From 2,640 feet to 4,874 feet the section is made up of red beds, red, green and white tuffs, white, hard and soft sands, with practically no calcareous material present. From 4,874 to 5,220 feet, red calcareous tuffs and sands are found. From 5,220 to 5,966 feet, the section is made up of limestones, the lower part of which are believed to be Glen Rose in age.

Tentative Summary

| | Feet |
|---|---|
| Claiborne | 0 - 180 |
| Wilcox | 180 - 1080 |
| Midway | 1080 - 1730 |
| Arkadelphia | 1730 - 1900 |
| Nacatoch | 1900 - 2070 |
| Marlbrook | 2070 - 2235 |
| Annona | 2235 - 2333 |
| Brownstown | 2333 - 2500 |
| Tokio (?) | 2500 - 2640 |
| Woodbine (?) (Non-marine) | 2640 - 3120 |
| Washita (?) (Non-marine) | 3120 - 5220 |
| Trinity (Marine) | 5220 - 5974 |
| Salt | 5974 - 7255" |

S. H. Rook designates Trinity as the age of the strata from 3,308 to 5,794 feet.

N. L. Thomas, referring to cores from 3,308 to 4,893 feet, states: "The upper cores seem to belong to the usual red bed series in this area. There is a skip from 4,336 to 4,858 feet. The lower cores are different. They may belong to the same series, although this cannot be determined without more material. No fossils were noted and all evidence is lithologic. These cores are probably all Cretaceous; there is no evidence that the lowest basement sands have been reached......No fossils were obtained to prove the age of the limestone and marl from 5,248 to 5,463 feet. This series is distinct from the red beds above. There are characters similar to those of the porous Edwards, but there is no proof that the limestone is Comanchean, although this might be expected. It should be noted that typical porous Edwards is not known in east Texas. The limestone is micro-conglomeratic and very porous. If it is capped by impervious beds, it should be a good reservoir like the Edwards limestone of the Fredericksburg of the Comanchean. Cores and samples from further drilling should furnish evidence for determining the formation and I would recommend that both samples and cores be taken."

## CHARACTER OF THE SALT

Some of the core samples of the salt are as clear as glass while others are milky in appearance. Two milky specimens which were analyzed contained diffused anhydrite and the cloudiness is ascribed to its presence. Geologists who are familiar with the salt of the salt domes of the Gulf Coast state that this salt is usually milky, even though the salt is over 99 per dent pure.

The following analyses of salt from the Hays A-9 were made by the United Gas System:

| | Core 5,974-5,980 feet (Per cent) | Core 6,094-6,104 feet (Per cent) |
|---|---|---|
| Silica. . . . . . . . . . . . . | 1.42 | 0.03 |
| Iron and alumina. . . . . . . | 3.52 | 0.10 |
| Calcium carbonate . . . . . . | 0.15 | 0.14 |
| Calcium sulphate. . . . . . . | 0.71 | 3.56 |
| Calcium chloride. . . . . . . | 2.04 | 0.20 |
| Magnesium chloride. . . . . . | 0.08 | 0.04 |
| Sodium chloride . . . . . . . | 92.08 | 95.93 |
| | 100.00 | 100.00 |

Remarks: Core from 5,974-5,980 feet is 4.44 per cent insoluble in hydrochloric acid. The residue consists of 1.42 per cent silica and 3.02 per cent iron and alumina referred to the weight of the core analyzed.

The following analyses of salt water were made by W. M. Carney, of the Lion Oil Refining Company:

| | a/Water sample from 4,400 ft. (Parts per million of water) | b/Water sample from 5,236 ft. (Parts per million of water) |
|---|---|---|
| Loss on ignition. . . . . . . | 5,840 | 5,260 |
| Silica. . . . . . . . . . . . . | 840 | 700 |
| Iron oxide and alumina. . . . | 380 | 260 |
| Magnesium . . . . . . . . . . . | 1,110 | 980 |
| Sodium. . . . . . . . . . . . . | 11,310 | 7,510 |
| Calcium . . . . . . . . . . . . | 10,740 | 7,170 |
| Chlorides . . . . . . . . . . . | 82,500 | 77,200 |
| Sulphur trioxide. . . . . . . | Trace | Trace |
| Undetermined. . . . . . . . . . | - | 4,020 |
| Total solids. | 112,720 | 103,100 |

a/ Total alkalinity (normal) 40 parts per million.
b/ Total alkalinity (normal) 10 parts per million.

The hypothetical combinations for the two water analyses are given below:

| | Water sample from 4,400 ft. | Water sample from 5,236 ft. |
|---|---|---|
| | (Parts per million of water) | |
| Organic and volatile matter | 980 | 690 |
| Silica | 840 | 700 |
| Iron oxide and alumina | 380 | 260 |
| Magnesium carbonate | Trace | Trace |
| Magnesium chloride | 1,720 | 1,430 |
| Magnesium sulfate | Trace | Trace |
| Calcium chloride | 20,100 | 13,600 |
| Sodium chloride | 88,700 | 82,400 |
| Undetermined | - | 4,020 |
| Total solids | 112,720 | 103,100 |

## AGE OF THE SALT

The following are tentative stratigraphic interpretations of the section in the Hays A-9 deep test well, suggested by R. D. Norton and W. C. Spooner 2/:

**Interpretation of R. D. Norton**

| | Depth in feet |
|---|---|
| Tertiary-Eocene | |
| Claiborne formation | 0- 180 |
| Wilcox | 180-1080 |
| Midway | 1080-1730 |
| ---Unconformity | |
| Cretaceous-Gulf Series | |
| Arkadelphia marl | 1730-1900 |
| Nacatoch sand | 1900-2070 |
| Marlbrook marl | 2070-2235 |
| Annona chalk | 2235-2333 |
| Brownstown marl (?) | 2333-2500 |
| Tokio formation (?) | 2500-2640 |
| Woodbine formation (?) (non-Marine red beds) | 2640-3120 |
| ---Unconformity--- | |
| Cretaceous-Comanche Series | |
| Washita group (?) (non-marine red beds) | 3120-5220 |
| Trinity group (marine) | 5220-5974 |
| ---Unconformity (?)--- | |
| Paleozoic (?) | |
| Salt | 5974-7255 |

**Interpretation of W. C. Spooner**

| | Depth in feet |
|---|---|
| Tertiary-Eocene | 0-1860 |
| ---Unconformity--- | |
| Cretaceous-Gulf Series | 1860-2953 |
| ---Unconformity--- | |
| Cretaceous-Comanche Series | |
| Trinity group | |
| Lower Trinity red | 2953-5220 |
| Trinity group (?) | |
| Lower marine | 5220-5974 |
| ---Unconformity--- | |
| Paleozoic-Permian (?) | |
| Salt | 5974-7255+ |

2/ Spooner, W. C., Salt in Smackover field, Union County, Arkansas: Bull. Amer. Assoc. Petrol. Geol., Vol. 16, No. 6 (June, 1932), pp. 601-608.

Although the fossil and lithologic evidence for correlation is meager and the paleontologists do not entirely agree, the consensus of opinion is that the lime beds above the salt are near the base of the Trinity section. The salt is therefore very probably of pre-Trinity age, but at present there are no data available which make it possible to determine the age with certainty. No salt is known to exist in the Paleozoic rocks where they are exposed in Arkansas, and no salt has been encountered in wells drilled into the Paleozoic rocks in the Gulf Coastal Plain region. So far as is definitely known, the age of the salt may be Lower Cretaceous (Trinity), Jurassic, Triassic, Permian, or older, but it is believed both by the writer and by Spooner 3/ that the most probable age of the salt is Permian. The reason for this conclusion is that the Permian is a notable carrier of salt deposits. Examples of this are the immense deposits of stratified salt in the Permian beds of west Texas, Kansas, and Oklahoma.

The salt and anhydrite beds of the west Texas Permian basin are known to be at least 1,200 feet thick but the percentage or thickness of reasonably pure salt present is problematic. Wells drilled into these beds are equipped with rotary tools and very little coring is done in the saline beds which are above the "Big Lime" producing zone. Considerable thicknesses of anhydrite have been logged, sometimes alternating with salt. In the Hays A-9, at Smackover, no distinct beds of anhydrite have been encountered. A small amount of anhydrite has been found diffused in the salt and in small lumps in it.

## STRUCTURE

The salt can occur (1) as a stratified deposit older than the Trinity beds; (2) as a pre-Trinity dome which was truncated by erosion before the Trinity beds were deposited, or (3) as a dome intruded into, or only slightly above, the base of the Trinity. According to Spooner 4/ the contact between the salt and the Trinity beds can be unconformable either by erosion or intrusion. The following are points in favor of the hypothesis that the salt is either in the form of a stratified deposit or a dome truncated by erosion in pre-Trinity times:

1. Spooner 5/points out that, "The structure of the Smackover field, as determinable in the Cretaceous and Tertiary strata, does not argue for salt intrusion into the Comanche. In fact, the stratigraphic evidence indicates that there was no differential movement during the accumulation of the Comanche strata penetrated by the drill in this area, which contrasts with the Bellevue dome in Louisiana, where the Trinity shows a thinning of several hundred feet as the result of upward movement of the dome during deposition."

2. It may be assumed that the salt is stratified and that the excessive thickness (at least 1,295 feet) may be due to the fact that the bed is steeply inclined. In this case, the drilled depth could be much greater than the thickness of the bed, measured at right angles to its bedding plane. This is essentially the interpretation suggested by Spooner 6/ in which he assumes that the salt was originally deposited as a salt bed of Permian age, which was deformed prior to Trinity time, and is now

3/ Spooner, W. C., Idem.
4/ Spooner, W. C., Op. cit., p. 605
5/ Spooner, W. C., Idem.
6/ Spooner, W. C., Idem.

in the form of a salt anticline which was truncated by pre-Trinity erosion.

3. Much of the salt is clear whereas the rock salt found in salt domes is, for the most part, milky, due possibly to minute fracturing produced during the intrusion of the salt.

4. Dead oil and gas associated with salt water were encountered not far above the salt in the Hays A-9. If the salt were in the form of a dome of post-Trinity age and therefore intruded into the Trinity beds, it would be expected that these beds would be tilted and that the oil, gas, and salt water would be separated by virtue of their different gravities. Inasmuch as these are not separated, the conclusion is that the salt deposit is parallel to the Cretaceous beds and does not affect their structure.

5. It has been pointed out by George C. Branner, State Geologist of Arkansas, that the average southward slope of the Paleozoic floor from the edge of the Gulf Coastal Plain in Clark County is approximately 95 feet per mile, referred to the horizontal. If the elevation of the Hays A-9 is assumed to be 100 feet lower than the edge of the Coastal Plain in Clark County, then the average slope from the top of the salt (5,974 feet) to the edge of the Coastal Plain, referred to the horizontal is 94.6 feet per mile. This checks remarkably well with the average known slope in southern Clark and northern Ouachita counties, and this fact strengthens the belief that the salt is either stratified or is a truncated dome, the surface of which does not project above the Paleozoic basement. The situation described above is illustrated in the cross section in Figure 2.

In favor of the salt dome hypothesis, the following facts are set forth:

1. The dome nearest to the Hays A-9 is at Arcadia, Louisiana, 60 miles south southwest from the well. Other interior salt domes at about the same latitude as the Arcadia dome are as follows:

1. Bistineau, Webster Parish, La.
2. Vacherie, Webster Parish, La.
3. Gibsland, Bienville Parish, La.
4. Kings', Bienville Parish, La.
5. Grand Saline, Van Zandt County, Tex.
6. Steen, Smith County, Tex.
7. Haynesville, Wood County, Tex.
8. East Tyler, Smith County, Tex.
9. Mount Sylvan, Smith County, Tex.

It therefore follows that the Hays A-9 may not be located too far north to have encountered a salt dome.

2. The unpenetrated thickness of the salt (1,295 feet) lends support to the dome hypothesis equally as well as to the stratified or truncated dome hypothesis.

3. The dome-like structure of the Smackover area, contoured on the Graves sand, has an appearance very similar to other dome-like structures known from drilling records to be underlain by salt domes or where the existence of salt domes has been

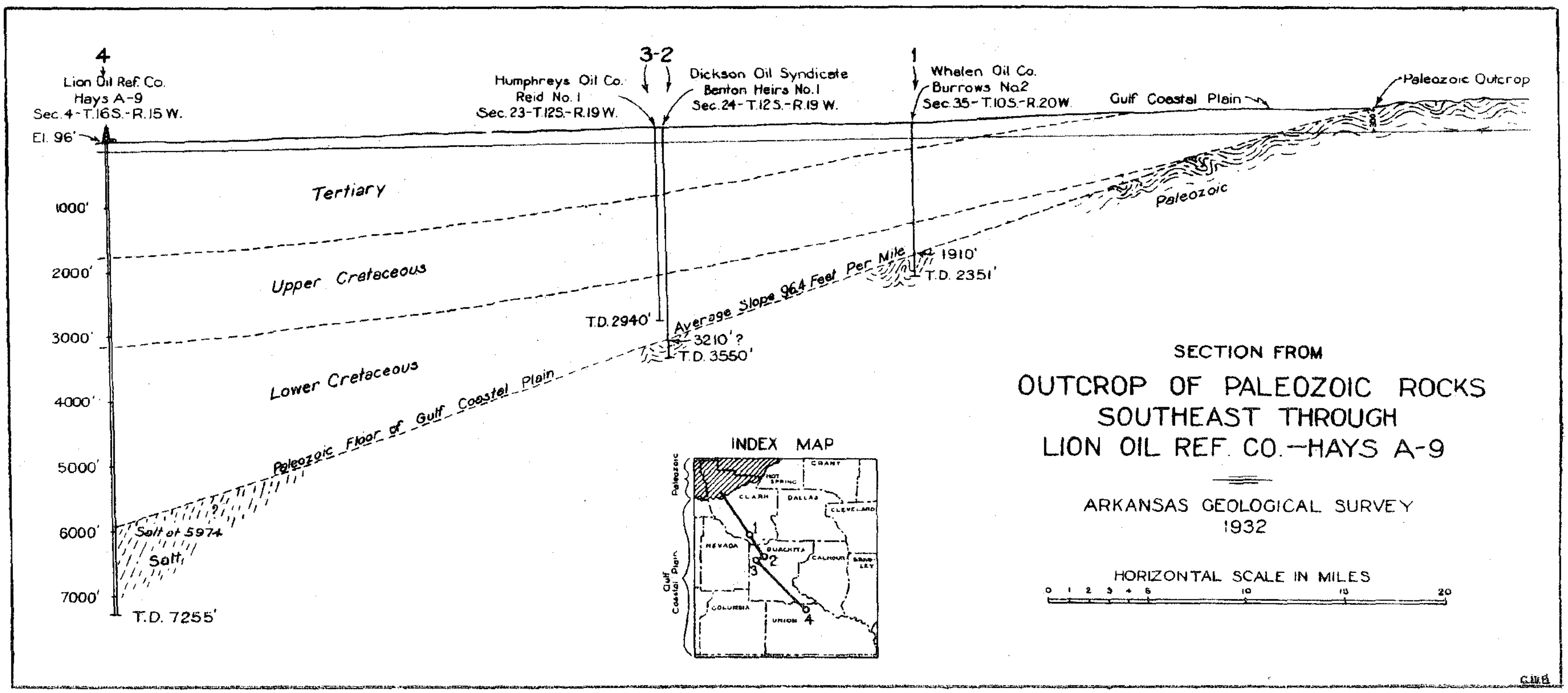
4
Lion Oil Ref. Co.
Hays A-9
Sec. 4-T.16S.-R.15 W.
El. 96'
3-2
Humphreys Oil Co.
Reid No. 1
Sec. 23-T.12S.-R.19 W.
Dickson Oil Syndicate
Benton Heirs No. 1
Sec. 24-T.12S.-R.19 W.
1
Whelen Oil Co.
Burrows No2
Sec. 35-T.10S.-R.20W.
Gulf Coastal Plain
Paleozoic Outcrop
Tertiary
Upper Cretaceous
Lower Cretaceous
Paleozoic
Paleozoic Floor of Gulf Coastal Plain
Average Slope 96.4 Feet Per Mile
1910'
T.D. 2351'
T.D. 2940'
3210'?
T.D. 3550'
Salt at 5974
Salt
T.D. 7255'
1000'
2000'
3000'
4000'
5000'
6000'
7000'
INDEX MAP
Paleozoic
Gulf Coastal Plain
SECTION FROM
OUTCROP OF PALEOZOIC ROCKS
SOUTHEAST THROUGH
LION OIL REF. CO.—HAYS A-9
ARKANSAS GEOLOGICAL SURVEY
1932
HORIZONTAL SCALE IN MILES
0 1 2 3 4 5 10 15 20

FIGURE 2.

indicated by gravimetric surveys 7/.

4. Intermittent vertical uplifts, apparently due to salt movement, are recognized above the salt domes of northwest Louisiana. Both in the Homer and Bellevue fields, there is recognized a marked post-Trinity -- pre-Gulf Cretaceous movement; and a late Tertiary movement; both of which correlate approximately with the dome uplifts at Smackover 8/.

5. The salt is apparently in contact with limestone, or is separated from the limestone by only a very few feet of shales. This sequence is not the usual sedimentary sequence found above salt deposits as the salt is usually overlain by red shales with thin, interstratified streaks of salt and anhydrite 9/.

It should be mentioned, however, that at, or immediately above, the salt there was an interval of about 14 feet in which the character of the formation was not determined. It was apparent in this interval that the drill had passed from hard lime to something softer. Several attempts were made to core the softer formation but without success.

A few salt crystals were first picked up in the core barrel at 5,974 feet. It was, therefore, assumed that the salt had been encountered at 5,960 feet. However, it is possible that the beds immediately above the salt consist of interstratified salt, shale, and sand.

### Conclusions

In weighing the above facts, the writer is inclined to believe that the hypothesis that the salt occurs as a stratified deposit older than the Trinity beds offers the most satisfactory explanation of the situation. A gravimetric survey of the area would probably eliminate or substantiate the salt dome hypothesis finally.

## MECHANICAL PROCEDURE

The drilling contractor for the Hays A-9 was Joe Modisette, of El Dorado, Arkansas. The test was spudded in April 15, 1931, and drilling was carried on continuously with two 12-hour shifts of five men each.

### Equipment

Derrick - 122-foot steel Ideco No. 3
Engine - 10 x 10 Twin Ajax-Union Tool Company
Draw works - Union Tool Company No. 5C 3
Rotary - Oil Well Supply Company, "Imperial"
Crown Block - Union Tool Company
Traveling Block - Oil City Iron Works
Drill Stem - 4"
Tool Joints - Hughes Acme and National
Core Barrel - Oil City Iron Works "Perfection"

7/ Hazzard, Roy T., Personal communication dated May 5, 1933.
8/ Hazzard, Roy T., Idem.
9/ Hazzard, Roy T., Idem.

One 12 x 6 3/4 x 14 Union Tool Company Mud Pump
One 12 x 6 3/4 x 12 Union Tool Company Mud Pump
Two 75 h.p. Broderick boilers
Wire line - 1" x 1250' 6 x 9 right lay hemp core at first, later wire line core. Williamsport and McWhyte
Weight Indicator - Martin - Decker
Drill Stem Testers - Johnson, Miller

Surface casin was $12\frac{1}{2}$" and was set and cemented at 272 feet. An $11\frac{1}{2}$" hole was then drilled to 4,011 feet. The presence of the usual producing sands was noticed in drilling as was expected, since the Hays A-9 was drilled on a lease that is producing from the Nacatoch, Meakin, and Graves sands. Before entering the Nacatoch sand, Aquagel was added to the mud in order to give it better walling quality and to minimize its travel through the sand. Aquagel is an impalpable powder which, with water, forms a colloidal fluid and increases the visocosity and walling-up properties of the drilling mud, but does not add materially to its weight. This material was found very useful in preventing caving and in holding artesian salt waters found below 3,000 feet.

The drilling mud, which was continually examined during circulation, was kept at an average weight of 9.4 pounds per gallon.

At first the drilling was done with four lines, then six, and finally eight. An even number of lines had to be used in order to have one end anchored to the derrick floor for the purpose of attaching the weight indicator. The clamps of this device forced the "dead line" out of a straight line. The varying pulls on the line operated a calibrated diaphragm which was connected hydraulically with the spring gage of a weight-indicating mechanism. At any particular depth the full weight of the drill stem, bit, block, and hook can be noted. Then the number of points of weight put on the bit can be noted as it is set on bottom. This instrument is a valuable aid in keeping a hole straight, for fishing for lost tools, and for making drill-stem tests. This is especially true in drilling below 2.000 feet. It was found that five points of weight on the bit should not be excedded with a bit as large as $11\frac{1}{2}$ inches (4-inch drill stem and six lines) and that about three points of weight were sufficient with a 7-7/8 inch bit and eight lines. This, however, is only an approximation, as each type of rock drilled required a particular weight. While drilling the salt with eight lines, not over one point of weight was used. This was mainly for the purpose of straightening up the hole in the soft formation. When drilling the harder formations, little weight was used and rapid rotation was employed. When drilling gumbo or sticky shale with either a fish-tail bit or a rock bit, care was used not to drill too fast, as this would have resulted in "balling-up." This condition of gumming up the bit is often troublesome as it hinders circulation and drilling.

A few examples of actual weight on the bit while drilling are given. The weight of the lines, block and hook was about eight points. Four point weight on the bit was equivalent to 7,290 pounds for four lines; 10,930 pounds for six lines; and 14,580 pounds for eight lines, when at a depth of 7,000 feet. One point was 1,840 pounds, 2,760 pounds, and 3,680 pounds with four, six, and eight lines respectively. These weights vary with the size of the line, depth, and number of lines. The maximum weight supported by the lines was about 100,000 pounds when just off bottom at a depth of 7,255 feet.

The formations encountered in the "red beds" constituted a particular drilling hazzard on account of their tendency to cave and the presence of many artesian water sands. When these beds were encountered, it soon became evident that the hole could not be carried to any great depth unless the mud was kept in a high state of walling efficiency. Throughout the whole operation 19 tons of Aquagel and two tons of Baroid were added to the mud. In addition, about 25 tons of mud were hauled from other locations to help supply the deficiency of the formations as mud yielders below 2,640 feet. When the mud became too thin (about 9.0 pounds per gallon), the salt water would break in after sufficient time had elapsed for the thinned mud to take up some of the mud cake from the walls of the hole. The circulating pressure of the mud pump was usually 400 pounds.

While drilling in the "red beds," the drill pipe became stuck three times by sand and other small cavings, but circulation was not lost. In each case crude oil was added and slowly mixed with the mud. After about two days, when the oil had thoroughly soaked into the sand bridges, the pipe was freed and pulled out. The oil, of course, lightened the drilling fluid considerably and care had to be taken to have good mud with it and not let light mud circulate for any length of time. The idea was to preserve the cake and hold the salt water. Trouble was experienced when considerable oil was added to fairly thick mud. A compounding took place and the fluid became about as viscous as warm axle grease. The heat of the earth may have caused the compounding as the temperature at 7,000 feet was probably 130° F. The returns on the ditch from that depth had a temperature of 116° F. If the compound had not remained hot after forming, it would have been impossible to circulate. The difficulty was met by thinning the compound with water, but it was a slow process due to the large volume of fluid and to temperarily reduced speed. In such emergencies, both pumps were used in tandem. The 12 x 6 3/4 x 14 took the suction; the 12 x 6 3/4 (reduced to 5 3/4) x 12 delivered at 1,150 pounds, which was sufficient to move the thick, tarry mud.

Four drill stem tests were made between 3,380 and 3,542 feet, but only slight showings of oil and gas were noted. Salt water under high pressure was found in three of these tests.

The 11½-inch hole was carried to 4,011 feet. At that point, the caving tendency of the "red beds" became a serious menace, as there were 3,739 feet of open hole. A string of 9-inch O.D., A.P.I. 40-lb. - 8 thread, seamless steel grade C Spang casing was run to 4,011 feet and cemented with 500 sacks of O.K. cement. The Haliburton Cementing Company did this work.

The casing was partly floated into the hole, enough mud being filled in the casing as it was lowered to relieve excessive pressure on the pipe and float valves. The amount of mud inside of the casing was controlled so that the weight on the lines and derrick was not excessive. The weight indicator was valuable in this operation. The casing went in with practically no trouble, but the mud was stiffened considerably with Aquagel before stopping circulation.

A Larkin guide shoe and float valve were placed on the bottom of the casing. Following this was a short nipple; then a Lorraine side port shoe or collar; then a joint of pipe. On top of this was a Larkin float collar. These connections were all made up and welded.

The 500 sacks of cement used consisted of 250 sacks of normal put in first, followed by 250 sacks of "Lightning". No accelerator was mixed with the cement. The setting period was seven days.

The hole was tested for verticality about every 500 feet as drilling progressed. Most of the check tests were made with a Haliburton acid bottle case run with a measuring line and odometer. About an inch of dilute solution of hydrofluoric acid was placed in a long, narrow glass bottle which fitted into a tight metal case. When in position and at rest, the acid etches a line at the surface of the liquid. The inclination of this line is measured with a goniometer.

In running the measuring line in and out of the hole for the acid bottle tests, considerable time was consumed, during which there was no circulation. For this reason, the drill stem nearly stuck several times and did stick at 4,250 feet. After using 195 barrels of oil, the pipe was freed. The drill stem again stuck at 5,236 feet while making an acid bottle test. This time 267 barrels of oil were required to free it. All acid bottle tests below that depth were made by dropping the case through the mud to bottom and timing it. The bottle was dropped just before pulling out the drill stem. The lowering of the bottle was expedited by pumping and the drill stem was rotated at the same time. After the case was on bottom, all motion was stopped for five minutes, then several turns of the rotary table were made, after which there was no motion for four or five minutes longer. There was no further sticking after this method was used.

The acid bottle tests showed inclinations as follows:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 500 | feet | - 1.25° | 2,750 | feet | - 1.25° | 5,000 | feet | - 17.00° |
| 1,000 | " | - 1.50° | 3,000 | " | - 1.75° | 5,243 | " | - 17.00° |
| 1,500 | " | - 1.50° | 3,500 | " | - 3.00° | 5,307 | " | - 15.00° |
| 2,000 | " | - 1.00° | 4,250 | " | - 7.50° | 5,425 | " | - 15.00° |
| 2,250 | " | - 1.25° | 4,500 | " | - 1.75° | 5,600 | " | - 14.00° |
| 2,500 | " | - 2.50° | 5,000 | " | -17.50° | 5,800 | " | - 10.00° |

The above record did not appear commendable and the circumstances are explained as follows: The first danger signal was the 3.00° at 3,500 feet, and the weight on the bit was decreased. No test was made at 4,000 feet because that was the casing point. At 4,250 feet the deflection was shown to be 7.50°. The weight on the bit was then reduced to three points. The test at 4,500 feet was 1.75° and it appeared that the hole had straightened so use of the same weight was continued. The number of tests was minimized on account of the danger of causing the drill stem to stick. Then, at 5,000 feet, the test showed 17.50° off the vertical. This was at first thought to be an error as some of the tests had, for an unknown reason, resulted in two etched lines being found on the acid bottle.

The Dan Dee Driftmeter was used as a check and it showed the deflection at 4,500 feet to be over 15.00° (15.00° limit of reading). The record of this instrument was as follows:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 4,089 | feet | - 6.0 ° | 4,453 | feet | - 12.0° | 4,800 | feet | - 15.0° plus |
| 4,200 | " | - 9.0 ° | 4,530 | " | - 15.0° plus | 4,900 | " | - 15.0° " |
| 4,300 | " | - no test (needle was up) | 4,620 | " | - 15.0° " | 5,000 | " | - 15.0° " |
| | | | 4,715 | " | - 15.0° " | | | |

It was hard to believe that the hole was as much as 12.0° off the vertical at 4,500 feet, and, as an additional check, the Sperry-Sun "Surwell" machine was employed to survey the hole when it had reached 5,236 feet. The in and out trips checked very closely and gave the following inclinations:

| | | |
|---|---|---|
| 800 feet - 1.0° | 2,400 feet - 2.0° | 4,000 feet - 6.5° |
| 1,000 " - 0.5° | 2,600 " - 1.5° | 4,200 " - 8.0° |
| 1,200 " - 2.0° | 2,800 " - 1.0° | 4,400 " -11.0° |
| 1,400 " - 3.0° | 3,000 " - 2.0° | 4,600 " -14.0° |
| 1,600 " - 3.0° | 3,200 " - 3.0° | 4,800 " -17.5° |
| 1,800 " - 3.0° | 3,400 " - 3.0° | 5,000 " -20.0° |
| 2,000 " - 2.0° | 3,600 " - 3.0° | 5,164 " -19.0° |
| 2,200 " - 2.0° | 3,800 " - 4.0° | |

The meandering of the hole started in a clockwise direction and changed to a counterclockwise at about 3,500 feet. The vertical correction to this depth was only 39 feet. The net horizontal migration of the bottom of the hole at 5,164 feet was 321 feet.

The above complete survey definitely established the fact that the hole was much more crooked than had been suspected. After considering cementing and sidetracking, thereby losing considerable hole, it was decided to continue drilling with very little weight on the bit. The lime series had been encountered below the "red beds" at 5,220 feet, and it was hoped that commercial production would soon be found. Beyond that depth not over two points of weight were put on the bit. The acid bottle tests were continued by the dropping method, which was considered reasonably reliable and consistent in its performance after the technique had been developed.

At 5,800 feet, the test indicated that the hole had straightened to 10.0° and no further tests were made. The salt was encountered 160 feet below that point and drilled so easily that only one-half to one point of weight was used. It was reasonably certain that the hole was practically vertical at 7,255 feet.

At a depth of 6,071 feet, the drill stem became stuck when rotation was stopped for a few seconds to permit the bit to be pulled three feet off bottom. This was 111 feet below the top of the salt and it was first thought possible that the salt had squeezed in on the tools. Rock salt (halite), however, has a crushing strength of about 6,000 pounds per square inch. The average weight of the formation overlying the salt is assumed to be 144 pounds per cubic foot, or one pound per square inch per foot of depth. Assuming that the mud in the hole has an average weight of 72 pounds per cubic foot, or one-half pound per square inch per foot of depth, then the unbalanced pressure which would cause the formations of the hole wall to fail would be the difference between the two pressures, or one-half pound per square inch per foot of depth. The salt should consequently not fail by crushing above a depth of 12,000 feet in this area.

Referring again to the drill pipe stuck at 6,071 feet, oil was circulated and the pipe worked with hydraulic jacks for 9½ days, when it came loose. It did not drag at any point above the bottom of the hole. The evidence showed that cavings from the "red beds" had worked down to the drill collar and bit and caused the sticking. The cavings were pieces of shale and rock rather than sand. These became wedged between the drill stem and the salt walls and it is probable that the circulation of mud free of salt water would have quickly freed the bit. Mud was scarce, however, and oil was added to prevent the sand from the "red beds" from causing trouble higher in the hole. Some salt was dissolved by the oil.

On December 2, 1931 the drill stem again became stuck in the salt at the present depth of 7,255 feet. The stretch in the pipe again indicated that coarse cavings had caught just above the bit. No sand was noted in the circulating mud. Circulation was maintained and regained several times after a shut-down occasioned by high water in Smackover Creek. Finally, after an enforced idleness of three weeks, circulation was no longer obtainable, although an internal pressure of 3,200 pounds per square inch was maintained by the pumps while the pipe was being worked. At other times, as little as 1,200 pounds had been sufficient to reestablish circulation.

A set of Thrift hydraulic jacks, supplied by Earl Patterson of El Dorado, was used in attempting to free the drill stem. Crude oil was run through the pump which had six 1-inch pistons. The operating pistons for lifting were 2 - 5¼ inch. This gave a lifting power with the jacks of 55 times the poundage shown by the gage. The highest gage pressure used was 4,600 pounds, but the gage had been used for some time without being calibrated and its indications were probably too high. Assuming that 4,000 pounds was the correct amount, the total lift on the pipe was 220,000 pounds, or 60,800 pounds per square inch on the cross section of the normal wall of the drill pipe of 3.62 square inch. This is very close to the elastic limit for the grade of drill pipe used.

In attempting to re-establish circulation and free the drill pipe, a total permanent upward movement of 10 feet was secured. Probably not over three feet of this was permanent stretch, so the bit moved up about 7 feet. At that time, another period of flood forced a shut-down. It is highly probable that the bit would have been recovered if there had been no forced shut-downs.

In the latter part of March, 1932, it was decided to recover as much drill stem as practicable. The first attempt was made with the rotary table and 2,450 feet were secured. A Mack reversing tool was then rented from the Houston Engineers, Inc., and in seven days the drill pipe was removed to 4,550 feet.

As the hole was quite crooked at 4,500 feet, there was no economy in removing second-hand drill stem below the logical side-tracking point, because the value of the pipe removed did not equal the cost of removal. On April 12, 1932, it was decided to suspend operations until economic conditions should improve, at which time the drill stem may be side-tracked and another effort made to penetrate the salt and secure production. If, however, the salt should prove to be in the form of a dome, with or without truncation, it will doubtless prove impossible to penetrate it.