OKLAHOMA GEOLOGICAL SURVEY
Chas. N. Gould, Director

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PETROLEUM ENGINEERING IN THE PAPOOSE OIL FIELD

Okfuskee and Hughes counties, Oklahoma

By
JOHN R. BUNN

With chapter on the
GEOLOGY OF THE PAPOOSE OIL FIELD

By
LOUIS ROARK

Published in cooperation with the United States Bureau of Mines,
Scott Turner, Director

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FOREWORD

This manuscript was submitted for publication to the Oklahoma Geological Survey by the author, Mr. John R. Bunn, who wrote it while in employ of the United States Bureau of Mines. It was originally intended to be used as a Bureau of Mines report, but it was necessary that this manuscript take its turn with other publications, so considerable time would be lost in approving and printing the manuscript. The author in presenting the manuscript to the Survey, hoped to place the information in the hands of those who can best use it at the earliest possible moment.

The Oklahoma Geological Survey has secured the services of Mr. Louis Roark to write up the geology of the Papoose field, which has been added to Mr. Bunn's original report.

The director wishes to take this opportunity to express his sincere thanks, to Messrs. Bunn and Roark, the authors, as well as to Mr. E. P. Campbell, superintendent of the Bartlesville Station, United States Bureau of Mines, for his help and criticism in the preparation for the press of this very comprehensive report.

Chas. N. Gould, Director
Oklahoma Geological Survey

Norman, Oklahoma, December 1925.

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INTRODUCTION

LOCATION OF AREA

The Papoose oil field is located in secs. 33, 34, 35, and 36, T. 10 N., R. 9 E., and secs. 1, 2, 3, 4, 5, and 9, T. 9 N., R. 9 E., Okfuskee and Hughes counties, Oklahoma.

A small pool of minor importance adjacent to the Papoose field, and locally known as the Gilcrease pool is also included in this report. It is located in secs. 17, 18, 19, and 20, T. 9 N., R. 9 E.

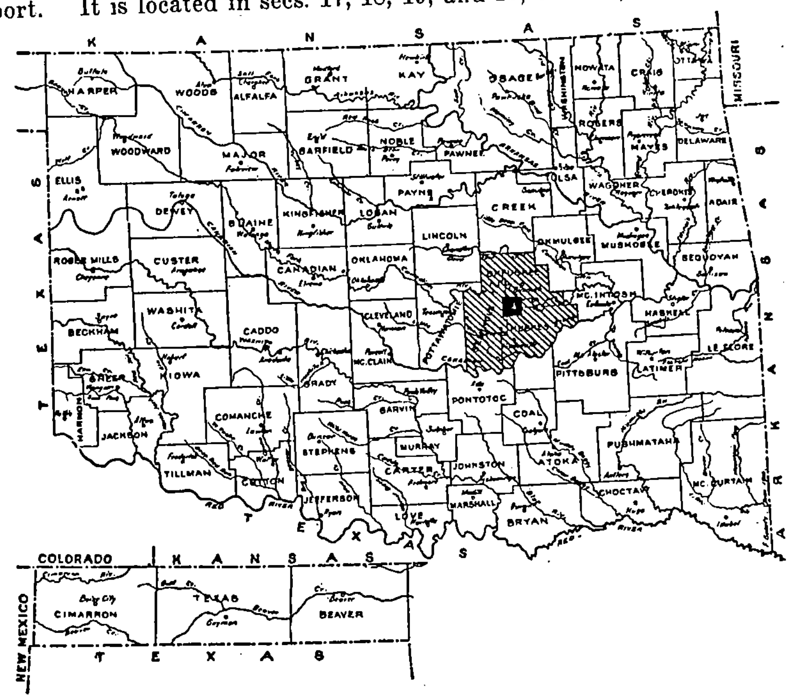


PLATE I.

HISTORY OF DEVELOPMENT

The discovery well in the Papoose field, Simon No. 1, located in the SE¼, SE¼, SW¼, sec. 4, T. 9 N., R. 9 E., was completed August 25, 1923, by the Papoose Oil Co., at a depth of 3330 feet, and with an initial production of 400 barrels.

The first producing well drilled in what is locally known as the Gilcrease pool, is located in the NW¼, NW¼, NE¼, sec. 20, T. 9 N., R. 9 E. It was drilled by the Gilcrease Oil Company, and completed October 6, 1923, with an initial production of 500 barrels from the sand first penetrated at 3048 feet depth. Early development in both areas was slow, several dry holes being drilled beyond the limits of the productive area. The average daily production from six completed wells in both areas during the week ending April 2, 1924, was only 1337 barrels.

On May 31, 1924, the Berry Petroleum Company completed Alexander No. 1 well in sec. 4, T. 9 N., R. 9 E., with an initial production of 1920 barrels per day. During the week ending June 4, 1924 the average daily production had increased to 5,314 barrels per day from seventeen wells. The bringing in of the Berry Petroleum Company's well stimulated development in the field and six months later on January 13, 1925, ninety completed wells were producing 39,814 barrels of oil per day. This was the peak production from the field and since that time the field has steadily declined. Till the week ending April 7, 1925, the daily average production from 149 wells was 26,662 barrels.

FIELD WORK

Field work in the Papoose area was begun in February, 1925. This work consisted of first obtaining by actual survey the derrick floor elevations of all wells. Later other data was collected such as the logs of all wells completed, water and oil samples for analyses, well shooting records, evidences of underground water troubles, and production and drilling statistics. Since all the information and data concerning the field was collected for use in this report by May 1, 1925, the report should be considered as of that date.

SCOPE OF REPORT

It is attempted in this report to present a clear description of the character of the field, discussing the operating methods used in development and also the application and use of other recommended operating procedure. It is intended that this will be an aid to those drilling new wells or repairing old wells in the field and that the information contained herein will have a good influence on operators in other fields of similar characteristics towards

recovering oil and gas with economic conservation and at a minimum of waste.

The report is divided into four parts:

Part I. Geology.
Part II. Drilling Procedure.
Part III. Production.
Part IV. Sub-Surface Water Conditions.

ACKNOWLEGEMENTS

This report was prepared by the writer while employed by the U. S. Bureau of Mines under the general supervision of F. B. Tough, Chief Petroleum Engineer; R. A. Cattell, Superintendent of the Bartlesville Experiment station and F. M. Brewster, petroleum engineer, who also read and criticised the manuscript. R. R. Brandenthaler and E. P. Campbell, petroleum engineers, U. S. Bureau of Mines, and M. J. Kirwan also criticized and revised the manuscript. The work was carried on in cooperation with the Department of the Interior, Office of Indian Affairs and the State of Oklahoma.

The writer wishes to acknowledge the cooperation of all companies operating in the Papoose oil field and especially that of the following individuals: Messrs. C. O. Rison, John E. Van Dall. E. H. McComber, and Roy Metcalf of the Indian Territory Illuminating Oil Company, M. V. Rushmore and A. I. Levorsen of the Gypsy Oil Company; J. M. Lovejoy and C. V. Millikan of the Amerada Petroleum Corporation; and W. M. Howell of the T. B. Slick Oil Company.

Louis Roark, geologist of the Kingwood Oil Company, Okmulgee, Oklahoma, has kindly written that portion, Part I, on geology relating to physiography, stratigraphy, subsurface formations, and surface structure.

The cross-sections, maps, and curves were drawn by Miss Ruth Brown. Water analyses used in this report were made by E. C. Lane. Floyd L. Swindell assisted in taking the well elevations.

Acknowledgement is also given to Miss Maude L. Owenby and to the drafting department of the U. S. Bureau of Mines, Petroleum Experiment Station, Bartlesville, Oklahoma, for their work in the collection and preparation of data used in this report.

PART I. GEOLOGY

By

Louis Roark[1]

LOCATION OF AREA

The area considered in this chapter includes the south half of

1. The writer is greatly indebted to E. G. Colton and A. I. Levorsen for aid and suggestions in the correlations of the Pennsylvania formations.

township ten north, range nine east, and most of township nine north, range nine east within which the Papoose field lies.

PHYSIOGRAPHY

The surface of the area is gently rolling prairie land. The topographic age of the area has reached maturity. It is well drained and free from swamps, lakes and other characteristic features of youthful and old age topography.

The relief of the area is about two hundred twenty-five feet, ranging from a few feet below seven hundred fifty feet above sea level along Little Wewoka Creek, to a maximum elevation of over nine hundred fifty feet. The highest topographic feature is found in the west-central part of T. 3 N., R. 9 L., south of Little Wewoka Creek in sec. 17.

The area is drained by the north fork of the Canadian River and its tributaries. The river flows along the north side of the area. The Little Wewoka Creek flows through the central part and is the principal drainage feature. Little Wewoka Creek flows eastward along the south side of the Papoose field proper, emptying into the north fork of the Canadian at a point east of Wetumka, Oklahoma, in sec. 17, T. 9 N., R. 11 E.

STRATIGRAPHY

The surface in the Papoose area consists of an alternating series of thick shale beds with thin sandstone and shaly sandstone lenses in the shale. This series of shale and sandstone are Pennsylvanian in age. The formations which outcrop in the area are:

Seminole conglomerate
Holdenville shale
Wewoka formation

The **Wewoka formation** is composed of massive cross bedded sandstones, interbedded with shale and sandy shale. Near the base and middle of the Wewoka are thin sandstone members which can be traced for a considerable distance. The upper portion of the Wewoka formation consists of many cross-bedded sandstones which are very difficult to trace for any distance with any degree of accuracy. Only the upper portion of the Wewoka formation outcrops in this area. The formation occurs along the east side of T. 9 N., R. 9 E., and covers the east one-third of the township.

The **Holdenville shale** in this area contains many thin bedded sandstones and shaley sandstones but is primarily a shale formation; the sandstone members of the Holdenville shale can be mapped over short distances but no one sandstone bed can be traced or

mapped with any degree of accuracy. The Holdenville shale is the principal formation outcropping in the Papoose area and occurs in the central part of Tps. 9 and 10 N., R. 9 E., in a belt three to four miles wide overlying the Wewoka formation. The shaly beds of the Wewoka formation grade into the overlying Holdenville shale so that the division line between the formations can not be easily determined stratigraphically nor very accurately mapped.

Overlying the Holdenville shale is the **Seminole Conglomerate**, which is exposed along the west side of the area. The Seminole conglomerate in this area is predominately a massive sandstone conglomeratic in places. The conglomeratic portion of the sandstone does not always occur in the same place. In some places the conglomerate is at the top, in others at the base, and in still others, may occur within the sandstone; the pebbles in this conglomerate are composed almost entirely of light colored chert pebbles with a sprinkling of quartz pebbles.

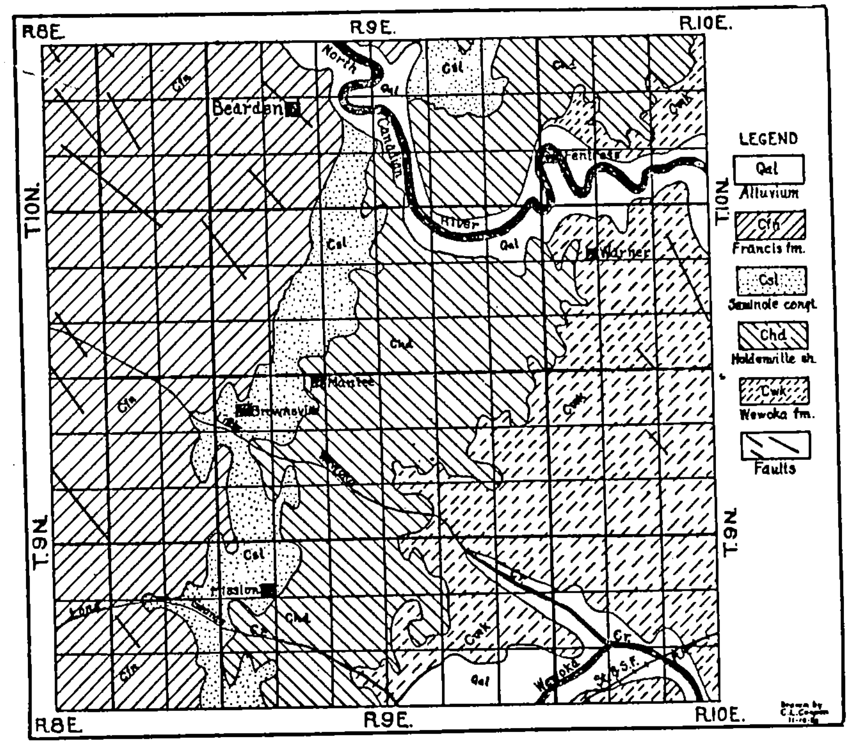


PLATE II. AREAL GEOLOGY OF THE PAPOOSE FIELD.

Formatons shown obtained from advance copy of Geological Map of Oklahoma, U. S. Geol. Survey.

SUB-SURFACE FORMATIONS

The lower Pennsylvanian formation and older rocks have been penetrated by wells drilled in the Papoose field.

For description of the formations penetrated by wells in the Papoose field see U. S. Geological folios of the Muskogee, Coalgate, and Tishomingo quardrangles by J. A. Taff; Oklahoma Geological bulletin No. 2 by C. W. Honness; Bureau of Geology bulletin No. 2 by George D. Morgan; U. S. Geological Professional Paper No. 31 by J. A. Taff, and Bauer and Clarke in American Association of Petroleum Geologists bulletin No. 5, pages 283 to 292.

Below are given logs of the Kingwood Oil Company, Sands No. 4, located in the SW corner of SE¼, SW¼, sec. 35, T. 10 N., R. 9 E., and T. B. Slick's Dunson No. 2 in the SE corner of NE¼, sec. 35, T. 10 N., R. 9 E., showing correlation of the various formations penetrated. In making these correlations the writer realizes that he is opening himself to severe criticism by many. This correlation is made without any discussion and with the hope that later discussion may throw more light on the subject and correct any errors that may exist in this correlation.

Company	T. B. Slick, et al.,
Farm	Andy Dunson No. 2
Location	SE¼ of SE¼ of NE¼ of 35-10N-9E
County	Okfuskee
Total depth	4166 feet
Production	Dry hole
Drilling commenced	11-24-24
Drilling completed	5-14-25
Standard tools	

Formation	Top	Bottom	
Surface	0	48	
Blue shale	48	170	
Black shale	170	180	
Gray shale	180	195	
Lime	195	202	
Gray shale	202	289	WEWOKA
Black shale	289	394	
Lime	394	404	
Gray shale	404	434	
Sand—2 b. w.	434	443	
Gray shale	443	490	
Sand—hole full water	490	525	
Shale gray	525	607	
Blue shale	607	659	
Black slate	659	682	
Blue shale	682	685	
Lime	685	695	
Gray shale	695	715	WETUMKA
Lime	715	725	
Sand—hole full water	725	761	
Lime	761	768	
Gray shale	768	829	
Black shale	829	835	
Gray shale	835	858	

Formation	Top	Bottom	
Lime	858	866	
Sandy lime	866	876	
Gray shale	876	895	
Blue shale	895	905	
Gray shale	905	995	CALVIN
Blue shale	995	1005	
Lime	1005	1090	
Sand—6 b. w. 1100	1090	1115	
Blue shale	1115	1125	
Broken lime brown	1125	1145	
Gray shale	1145	1280	
Black shale	1280	1300	
Sandy lime	1300	1307	
Gray shale	1307	1340	
Sandy lime	1340	1345	
Gray shale	1345	1565	
Sand	1565	1570	
Gray shale	1570	1602	
Lime shell	1602	1608	
Gray shale	1608	1655	SENORA AND
Hard lime	1655	1665	
Gray shale	1665	1666	STUART
Sand—10 b. w.	1666	1690	
Black shale	1690	1730	
Gray shale	1730	1785	
Black shale	1785	1815	
Gray shale	1815	1864	
Hard lime	1864	1874	
Gray shale	1874	1920	
Black shale	1920	1941	
Lime	1941	1952	
Shale	1952	1985	
Gray shale	1985	2060	
Lime	2060	2074	
Sand—hole full water	2074	2095	THURMAN
Sand	2095	2138	
Shale	2138	2142	
Blue slate	2142	2192	
Blue shale	2192	2220	
Lime	2220	2223	
Gray shale	2223	2300	
Gray sandy shale	2300	2310	
Lime	2310	2445	
Blue slate	2445	2495	BOGGY
White slate	2495	2505	
Gray shale	2505	2515	
Lime	2515	2596	
Blue shale	2596	2625	
Gray shale	2625	2635	
Lime	2635	2650	
Blue slate	2650	2728	
Gray shale	2728	2740	
Lime	2740	2753	SAVANNA
Blue shale	2753	2880	
Sandy lime little gas	2880	2891	
Black shale	2891	2895	McALESTER
Hard lime	2895	2915	
Black shale	2915	2965	
Hard lime	2965	3020	
Sandy lime	3020	3028	
Gray shale	3028	3060	
Hard sand	3060	3070	
Gray shale	3070	3105	
Sandy lime	3105	3114	HARTSHORNE
Black shale	3114	3118	(Gilcrease sand)
Lime	3118	3122	
Black shale	3122	3135	
Sandy lime—8 b. w.	3135	3140	
Black slate	3140	3148	
Lime	3148	3205	

Formation	Top	Bottom	
Gray slate	3205	3240	(Papoose Sand)
Lime	3240	3245	Pitkin
Gray shale	3245	3340	(Wapanucka
Black shale	3340	3420	of some)
Sandy lime	3420	3427	
Black shale	3427	3437	
Hard lime	3437	3440	
Black shale	3440	3460	LOWER CANEY
Broken lime	3460	3470	(3800-3810
Shale black	3470	3540	probably Boone)
Brown shale	3540	3600	
Brown shale	3600	3800	
Hard lime	3800	3810	
Brown sandy shale	3810	3830	
White sand hole full water	3830	3850	
Hard lime	3850	3852	
Sand—HFW	3852	3854	
Black hard sand	3854	3868	
Gray sandy lime	3868	3876	HUNTON
White sandy lime	3876	3884	
Soft white lime	3884	3895	
Sandy lime	3895	3914	
White lime	3914	3926	
Sandy lime hole full water	3926	3970	
Soft white sandy lime	3970	3985	
Black lime	3985	4000	SYLVAN
Black slate	4000	4065	
Black lime	4065	4070	VIOLA
White lime	4070	4080	
White lime	4080	4090	
Hard lime	4090	4100	
Hard sharp sandy lime	4100	4110	
Hard sand	4110	4160	
Hard black lime	4160	4165	
Hard sand	4165	4170	SIMPSON
Black sandy hard lime	4170		
White salt sand hole full water	4170	4173	
Corrected depth—sand line measurement	4165		
Black lime	4165	4166	
Total depth	4166		

6-30-25—ch

Company	Kingwood Oil Company
Farm	Hully Sand No. 4.
Location	SW¼ of SE¼ of SW¼ of 35-10N-9E.
County	Okfuskee
Total depth	4240 feet
Production	Dry
Elevation	801 feet
Drilling commenced	11-19-24
Drilling completed	4-25-25 Standard Tools

Surface	0	14	
Sand stone	14	26	
Blue mud	26	66	
Blue slate	66	140	
White slate	140	190	
Black slate	190	200	
Hard sand	200	212	
Soft sand, 4 b. w. 212-220	212	220	WEWOKA
Hard sand	220	230	
Slate	230	251	
Dark slate	251	400	
Dark slate	400	430	
Sand	430	438	
White slate	438	457	
Dark slate	457	504	
Sand 14 b. w. per hour	504	539	

Formation	Top	Bottom	
Slate 8 b. w. from sand 504	539	705	
Sand	705	720	
Slate	720	725	WETUMKA
Hard sand	725	740	
Water sand	740	760	
Slate	760	860	
Lime shale	860	865	
Slate	865	870	
Hard sand	870	887	CALVIN
White slate	887	1060	
Sand, show O & G 1060' 3 b. w.	1060	1085	
Slate, per screw 1060-1085	1085	1200	
Lime	1200	1210	
Slate	1210	1400	
White slate	1400	1425	
Sand shell, 2 b. w. 1425-1430	1425	1430	
White slate	1430	1490	
Slate	1490	1555	
Hard sand	1555	1560	
Slate	1560	1600	
Hard sand, 2 b. w. 1600-1610	1600	1610	
Slate	1610	1615	
Hard sand	1615	1620	SENORA &
Sand	1620	1625	
Slate	1625	1690	STUART
Hard lime	1690	1695	
White slate	1695	1710	
Black slate	1710	1725	
Gray lime	1725	1735	
White slate	1735	1760	
Slate	1760	1800	
Sand shell	1800	1803	
Slate	1803	1815	
Slate	1815	1860	
White slate	1860	1870	
White lime	1870	1880	
White slate	1880	2055	
White lime	2055	2060	THURMAN
White slate	2060	2160	
Black slate	2160	2170	
Gray lime	2170	2185	BOGGY
Dark slate	2185	2595	
Dark slate	2595	2685	
Sand, show oil & gas 2685-2710	2685	2710	SAVANNA
Dark slate	2710	2860	McALESTER
Sandy lime	2860	2868	
Slate	2868	2875	
Hard sand	2875	2885	
Slate	2885	2895	
Lime	2895	2900	
Dark slate	2900	2905	
Sandy lime	2905	2945	
Slate	2945	2955	
Sand	2955	2959	
Black slate	2959	2970	
Sandy lime, hole began to cave	2970	2985	
Slate	2985	2990	
Lime	2990	2995	HARTSHORNE
Slate	2995	3000	(Gilcrease sand)
Hard sand, bits won't stand	3000	3009	
Slate	3009	3015	
Sand	3015	3020	
Slate (3026-3031 of oil)	3020	3026	
Sand, show of oil 3026-3031	3026	3031	
Hard sand	3031	3048	
Slate	3048	3056	
Hard sand	3056	3072	
Sand, show O & G 5 b. w. per hour 3022-3031	3072	3087	
Slate	3087	3090	
Sand, hole full water 3090-3097	3090	3110	

Formation	Top	Bottom	
Slate lumps of coal in hole	3110	3115	
Slate	3115	3198	
Lime	3198	3204	
Slate	3204	3268	
Slate	3268	3298	
Slate	3298	3308	
Lime	3308	3309	
Shale	3309	3317	ATOKA
Sand	3317	3319	
Hard lime (steel line 3319')	3319	3320	PITKIN
Dark grey sand	3320	3327	(Wapanucka
Slate	3327	3331	of some)
Gray sand	3331	3336	
Gray sand	3336	3340	
Sand, little show oil	3340	3346	(Papoose sand)
Water sand, hole full water	3346	3352	
Sand (show oil)	3352	3357	
Sand	3357	3369	
White sand	3369	3375	
Sand	3375	3379	
Slate	3379	3390	
Black shale	3390	3427	LOWER
Black lime	3427	3432	
Blue shale	3432	3435	CANEY
Blue shale—caving bad	3435	3530	Probably Boone
Brown shale	3530	3725	3785-3805
Black lime	3725	3730	Chattanooga
Black shale	3730	3735	3805-3825
Brown shale, firm and gritty	3735	3785	
Black lime	3785	3805	
Brown shale, top of sand	3805	3825	
Hard lime	3825	3832	
White sand—hard 1st water	3832	3848	
Water sand—hole full water 3848'			HUNTON
Hard lime	3848	3861	
White lime	3861	3965	
Gray lime	3964	3975	
White slate	3975	4019	SYLVAN
Slate	4019	4050	
Gray lime	4050	4069	VIOLA
Hard sand	4069	4075	
Gray lime	4075	4110	
Lime	4110	4124	
Sand (hard shays)	4124	4136	
Blue sand	4136	4140	
Hard sand	4140	4150	SIMPSON
Hard sand lime	4150	4152	(Wilcox sand)
Hard sand	4152	4174	
Hard white sand	4174	4180	
Hard sand	4180	4184	
White sand	4184	4240	

' 4192 total depth of hole 4240, 4-25-25

The wells start near the contact of the Holdenville shale and Wewoka formation and penetrate nearly the entire thickness of the Wewoka. The Wewoka occurs from the surface to 535 feet depth in the Kingwood well and from the surface to 525 feet depth in the Slick well.

The Wetumka shale occurs from 539 to 860 feet in the Kingwood well and from 525 to 858 feet in the Slick well. There is a water sand about 50 to 60 feet thick occuring within the Wetumka shale in the Papoose field and the surrounding area which has been commonly mapped as the top of the Calvin series. This sand

member when projected to the outcrop checks with the thick sandstone near the base of the Wetumka.

The Calvin sandstone series is represented in the Kingwood well from 860 to 1085 feet and from 858 feet to 1115 feet in the Slick well. This Calvin series is represented by two to four water bearing sands in the various wells in the Papoose field and surrounding area.

The Senora and Stuart formations are not differentiated in these wells but occur from 1085 to about 2055 feet in the Kingwood well and from 1115 to 2060 feet in the Slick well.

The Thurman sandstone is probably represented by the thick water sand in the Slick well occuring from 2060 to 2138 feet; the Thurman sandstone seems to be represented only by thin lime shell from 2055 to 2060 feet in the Kingwood well; samples were not obtained above 3300 feet, therefore it is not known whether the Thurman sandstone was missing in the Kingwood well or absent due to being improperly logged.

The Boggy shale probably occurs from 2060 to 2685 feet in the Kingwood well and from 2138 to 2740 feet in the Slick well.

The Savanna is represented in the Kingwood well from 2685 to 2710 feet and from 2740 to 2753 feet in the Slick well.

The McAlester shale was penetrated from 2753 to 2955 feet in the Slick well and from 2710 to 2860 feet in the Kingwood well.

The Hartshorne sandstone which is the Gilcrease producing horizon varies greatly in thickness in the Papoose field and the surrounding area. The Hartshorne occurs from 2965 to 3205 feet in the Slick well and from 2860 to 3110 feet in the Kingwood well.

The black shale underlying the Hartshorne has been correlated with the Atoka formation and occurs in the Kingwood well from 3110 feet to 3308; and from 3205 to 3420 feet in the Slick well.

The above correlation of the Pennsylvania is based entirely upon a stratigraphic correlation. If the various formations are projected to the outcrop it will be seen that the above correlations in general are fairly accurate.

The correlations given below of the pre-Pennsylvanian formations in the Kingwood's Sand No. 4 have been made by Mr. G. S. Buchanan of the Carter Oil Company, from examination of samples and are given here with his permission. The correlations of the formations in the T. B. Slick Dunson No. 2 are made by comparison of the log with the Kingwood log.

The Papoose sand is well represented in the Kingwood well from 3308 to 3379 feet; while it is represented by a few thin lime shells in the Slick well from 3420 to 3470 feet. The Papoose sand has been correlated with the Cromwell sand of the Cromwell pool in Tps. 10 and 11 N., R. 8 E.; and with the Lyons-Quinn sand of the Lyons-Quinn pool in secs. 13, 24 and 36, T. 11 N, R. 11 E. The age of this sand is still an open question. Many class it as the Wapanucka limestone equivalent or lower Pennsylvanian in age. Whereas, from paleontologic evidence others class it as Pitkin or Mississippian age. From a stratigraphic correlation, the Wapanucka correlation would be correct. However, Pitkin fossils have been found in samples from this horizon; some have correlated the Papoose sand with the Wapanucka on lithology after examination of samples. Mr. Buchanan correlates the Papoose sand as Pitkin in age.

The shale interval from 3379 to 3805 in the Kingwood well is placed in lower Caney by Mr. Buchanan; the lower Caney in the Slick well is found from 3470 to 3810 feet.

The writer believes the Boone limestone is represented by the thin lime occuring in the Kingwood well from 3785 to 3805 feet and from 3800 to 3810 feet in the Slick well.

The shale from 3805 to 3825 feet in the Kingwood well Buchanan calls the Chattanooga; in the Slick well the Chattanooga is represented by the sandy shale from 3810 to 3830 feet.

The Hunton is represented from 3825 to 3961 feet and the sandy lime and lime from 3830 to about 3985 represents the Hunton in the Slick well.

The shale interval from 3961 to 4050 feet in the Kingwood well is the Sylvan shale; the same horizon occurs from 3985 to 4065 feet in the Slick well.

Buchanan places the Viola limestone from 4050 to 4070 in the Kingwood well; probably the lime from 4065 to 4080 represents about the Viola equivalent in the Slick well.

The Simpson is found from 4070 to 4240 in the Kingwood well and from 4080 to 4166 in the Slick well.

STRUCTURE

SURFACE

The normal dip of the surface rocks is to the northwest there being little indication of variation from normal structural conditions other than a broad gentle terrace at the east end of the producing area. In sec. 36, T. 10 N, R. 9 E., and sec. 1, T. 9 N., R. 9 E., there is a pronounced terracing of the beds, the dip changing from normal northwest to north for a short distance across section 36.

SUBSURFACE

The subsurface structure of the field, as shown by present development, consists of an anticlinal fold on which are superimposed two minor folds or domes separated by a structurally low area over which production extends. The axes of the minor fold and the structurally low areas are roughly parallel, and have a northeast trend.

The high point of the west dome is in the NW¼, sec. 3, T. 9 N., R. 9 E., the SE¼, sec. 33, T. 10 N., R. 9 E., and the SW¼, sec. 34, T. 10 N., R. 9 E. The high area of the east dome as defined at present is in the NE¼, sec. 1, T. 9 N., R. 9 E. The limits of production in this direction are unknown.

The subsurface structure of the Papoose sand was determined by correlation of intersecting cross-sections constructed from graphic logs of all completed wells in the field. A map of the Papoose field is shown in Figure 1 and indicates this structure. The contours with 10 foot intervals are based on the top of the lime and sandy lime cap rock overlying the productive portion of the sand.

PRODUCING HORIZONS

UPPER FORMATIONS

A series of water sands separated by shale beds of varying thicknesses are penetrated to a depth of 1200 to 1350 feet. Six water sands occur uniformly in this interval. The lower or sixth water sand horizon is encountered at depths of 1050 to 1200 feet. Showings of oil and gas were encountered in this sand in certain wells, but no commercial production has been obtained. The interval from the base of the water sand horizon to the top of a sand occuring at a depth of 2650 to 2800 feet is composed largely of shales with irregular lime ledges and sandstone members.

GILCREASE SAND ZONE

The Gilcrease sand zone consists of a zone of limes, sands, and sandy limes, ranging from 160 to 230 feet in thickness. The top of the zone is encountered at a depth of 2850 to 2950 feet in the Papoose field.

The Gilcrease sand zone is the productive horizon in the Gilcrease pool, where several wells with initial daily oil productions ranging from 100 to 500 barrels, were completed.

In the Papoose field the Gilcrease zone where penetrated, contained oil, gas, and water. Several gas wells were completed in this sand during the early development of the field. While some commercial oil wells have been obtained, the general practice is to case off the zone and deepen the well to the Papoose sand. However, certain wells in the S½, sec. 33, T. 10 N., R. 9 E., have been completed as oil wells in the Gilcrease sand zone.

Production from the sand zone seems to be governed chiefly by its porosity where wells are located most favorably. The producing sands occur in the lower portion of the sand and lime zone.

PAPOOSE SAND

The Papoose sand is the main producing sand of the Papoose field. The top of the sand is penetrated at depths ranging from 3250 to 3350 feet, depend'ng on location in the field. Thickness of sand in wells that have been drilled entirely through the sand body, varied from less than 60 feet to more than 80 feet. The upper part of the sand in many wells is not productive and is recorded as lime or sandy lime. The calcareous portion of the sand which constitutes the cap rock varies in thickness from one to twenty feet. Because of the existence of this nonporous and barren cap rock, several wells located low on the structure reached the water level of the sand without obtaining oil production. In certain parts of the field shale breaks have been recorded between the cap rock and the productive portions of the sand. Due to the existence of a barren cap rock and shale breaks in the upper part of the sand, the production of wells where this condition exists, is relatively low since the productive thickness of the sand is small.

The structural relationship of the Papoose sand to the other underground formations from a depth of 2500 feet down, are shown by an east-west cross-section, Figure 2; and two north-south cross-sections, Figures 3 and 4.

DEEPER SANDS

No production has been obtained from deeper sands in the Papoose field. Three wells in this area have been drilled to a sand and sandy lime, occuring from 380 to 514 feet below the bottom of the Papoose sand, where considerable water was encountered. These wells are as follows:

Independent Oil and Gas Company's Rose Caroline No. 1, Section 11-9-9; total depth 3960 feet.

T. B. Slick Oil Company's A. Dunson No. 2, Section 35-10-9; total depth 3876 feet.

Kingwood Oil Company's H. Sands No. 4, Section 35-10-9; Total depth 4240 feet.

PART II. DRILLING PROCEDURE

By

John R. Bunn

GENERAL STATEMENT

Cable tools have been used almost exclusively in the development of the Papoose field; only two wells were completed with the rotary. Eight rotary wells have been drilled in the Gilcrease pool in secs. 17 and 20, T. 9 N., R. 9 E.

The first wells drilled in the Papoose field were located on a 400 foot spacing distance basis between wells even along property lines or one well to every four acres. Eight wells are thus located in secs. 3, 4, and 9, T. 9 N., R. 9 E. The operators later adopted the spacing of four wells to each forty acres; or, one well in the center of each ten acre tract.

CABLE TOOL DRILLING

When drilling in unproven or semi-proven territory, in general cable tools have the advantage over rotary tools as they permit of obtaining samples of the formations encountered while drilling. In addition, the fulid content of sands can be tested as they are penetrated. However it is a question whether this is better than the use of the rotary drill where systematic and proper coring is maintained. The chief disadvantages of cable drilling are loss of time in drilling and the increase in well cost because of the additional casing that is required.

In completing wells with cable tools it has been the general practice of operators to set a string of 8-¼ inch, 32 pound casing in the upper part of the Gilcrease sand zone and a string of 6-⅝ inch, 24 or 26 pound casing below the Gilcrease sand zone at some point in the shale interval between this sand zone and the Papoose sand. A few of the casing strings have been cemented. (See table No. 12)

It is recommended that a small size bit be used in "drilling in" the well as a safety measure after the casing has been set above the Papoose sand. If 8-¼ inch casing is the last string set, then a smaller sized bit should be used, so that if strong gas is encountered, there will be less danger of the tools being blown from the hole, or lifted up by the gas and then dropped causing a difficult fishing job. After the sand has been drilled with the smaller size bit, the hole can be reamed with full sized tools.

In two wells heavy strings of cable tools were blown completely from the hole: namely, Independent Oil Company's S. Alexander No. 2, sec. 2, T. 9 N, R. 9 E.; and Indian Territory Illuminating Oil Company's Rogers No. 2, sec. 1, T. 9 N., R. 9 E.

Table 1 gives certain data on holes lost in cable tool drilling in the Papoose field.

ROTARY DRILLING

Due to the small number of rotary drilled wells, it is apparent that operators in the Papoose field have not favored the use

Table 1. Holes lost in cable tool drilling.

Company	Lease	Well No.	Location	Total Depth	Remarks
Independent	Bruner	1	1-9-9	3125	Pipe trouble
Independent and Atlantic	Bruner	3	1-9-9		Lost tools
Slick	Bruner	11	2-9-9		
Slick	Ryan	1	2-9-9	2485	Collapsed casing
Phillips Pet.	Bliss	2	3-9-9	1620	Pipe trouble
Slick	McKay	2	3-9-9	3308	Collapsed casing
Slick	McKay	4	3 9-9	3085	Parted casing
Slick	McKay	4A	3-9-9	3055	Lost bit and crooked hole?
Slick	Scott	4	3-9-9	3324	Collapsed casing
Berry Petroleum	W. Alexander	1	4-9-9	3420	Fishing job
Mutual	Turner	2	4-9-9	1327	Lost tools
Mutual	Turner	3	4-9-9	2913	Collapsed pipe
Transcontinental	C. Tiger	6	4-9-9		Crooked hole?
Arkansas Fuel	Barnett	1	33-10-9	740	Lost tools
Indian Territory	Darnell	1	34-10-9	3118	Pipe trouble
Phillips Pet.	Booze	1	34-10-9	2925	Fishing job—bad pipe.
Prairie	Westbrook	5	35-10 9		Lost Hole

of rotary tools. However, rotary drilling in proven territory possesses advantages, which should be given due consideration.

Rotary drilling is more rapid than cable tool drilling when drilling through shales, soft sandy lime, and sandy shales. Four strings of pipe could be eliminated if rotary equipment was used in wells drilled to the Papoose sand. This item alone represents a saving of approximately $15,000; which saving does not, however, take into account the salvage value of the large pipe when same is pulled from a cable tool hole. The mud fluid circulated by the rotary method protects the formations above the top of the cement back of the first string of pipe landed and prevents the migration of oil, gas, or water from one statum to another.

SUGGESTED USE OF ROTARY TOOLS IN THE PAPOOSE FIELD

Wells could be drilled to the top of the Papoose sand with rotary tools and then completed into the sand with cable tools.

The Gilcrease sand zone and the intervening shale between the top of the Papoose sand and the bottom of the Gilcrease sand zone should be the markers used in correlation when drilling to the Papoose sand. (See cross-sections). The shale interval varies from 140 to 210 feet in thickness. Approximate depth to the top of the Papoose sand may be determined from the subsurface contour map, but unexpected local high or low areas in the sand may make such a determination erroneous and cause the casing to be set too high or too low. Water shutoff points determined by means of cross-sections are more accurate. It is usually desirable to set and cement the casing immediately on top of the producing sand or the cap rock. A liner is not required when casing is set immediately above the producing sand. However, setting casing

directly on top of the sand or the cap rock has one disadvantage, in that later shooting of the sand as such close proximity to the casing shoe may cause serious damage.

When the last member of the Gilcrease sand has been passed through and the shale interval below penetrated 125 to 150 feet, extreme care must be taken to note any change in formation. Cores should be taken at every formation change, as this change in formation suggests the penetration of the top of the Papoose sand. These cores should be tested for their gas, oil, and water content, especially the latter, since in some wells water has been found in an upper member of the Papoose sand. In the event that cores show the presence of water in an upper member of the sand, drilling should be continued and cores taken continuously, or at very short intervals. When the cores show definitely that the Papoose sand has been penetrated and no water is present in the upper members, the casing should be set and cemented. It is advisable to penerate the sand several feet, coring continually in order to be certain that the main productive sand body has been reached. The casing can then be cemented off bottom, just above the top of the productive part of the sand, as shown by the cores taken.

ROTARY CORES AND CORING PRACTICE

Sands penetrated in rotary drilling may be tested for content, character of material, and porosity by coring. Rotary cores are also of great value to the geologist in determining the age and correlation of underground strata from the fossil content of the cores. They are much more satisfactory for these purposes than broken and pounded up drill cuttings from cable tool holes, since rotary cores are unaltered and representative of the formations as they exist in place. If great accuracy is desired, the drill pipe may be carefully measured and the depth at which the core was taken can be determined to within a few inches. If an adequate number of cores are taken in the first wells drilled, sufficient information can many times be obtained which will eliminate a great deal of coring in later wells.

Cores may be taken by the ordinary saw-tooth or basket core barrel, also known as the single core barrel, which consists of a piece of pipe from 4 to 6 feet in length and of various sizes, usually 5-3/16 or 6⅝ inch pipe. Six to eight teeth are cut in the lower end with a hack-saw or oxyacetylene flame. The core barrel is attached to the drill pipe and rotated slowly to the bottom of the hole. When enough core has been cut, the pipe is given considerable weight to bend the teeth in, forming a basket which holds the core that is broken off by this operation.

This type of core barrel has the advantages of low initial cost and ease of manufacture, however it has many disadvantages.

Very seldom is a core taken more than one foot in length. More often they are only a few inches in length. There is danger of injury to the core due to heart caused by friction in cutting and the possibility of the core being lost by teeth not closing or barrel becoming plugged before a core is cut.

Another type of coring tool used successfully in rotary drilling is the double tube type, and several makes are on the market, having similar general features but differing as to the details of construction. This type has been widely used in California and has recently been introduced into the Mid-Continent area.

During the development of the Cromwell oil field, a double-barrel core drill was furnished the Bureau of Mines for experimental work in that field. The first cores taken in the Cromwell sand were cut and recovered with this barrel, which was so designed that a core two inches in diameter was extracted from a hole drilled 7-3/4 inches in diameter. A sketch drawing of this barrel is shown in Figure 5. (See following page.) The outer reamer cutters and inner reamer cutters are especially arranged and designed to give the best cutting surface.

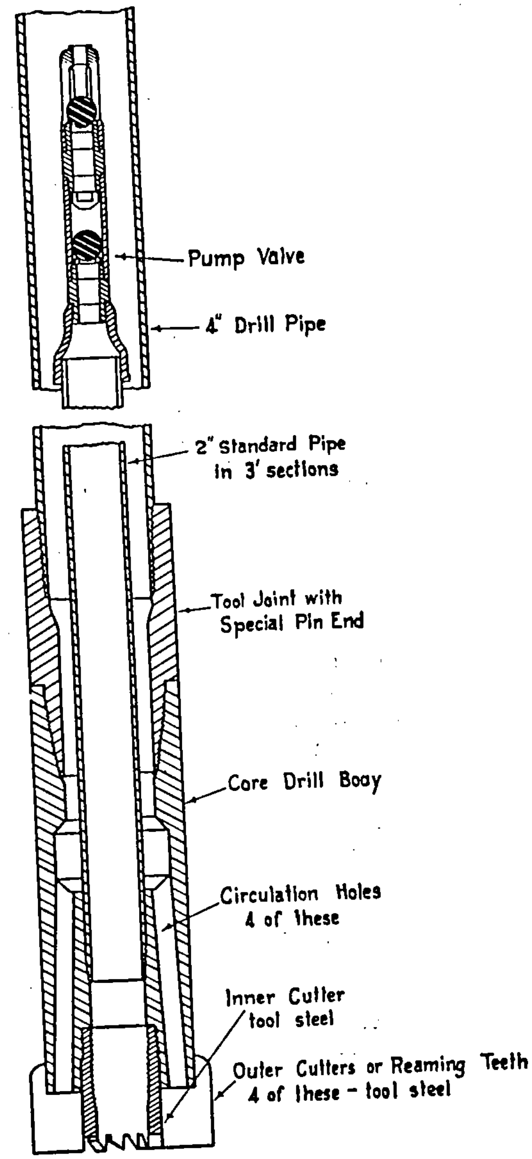
The advantage of this type of core barrel over the single barrel type is that longer cores may be recovered, the hazard of losing cores is much less, unaltered and representative samples of the formation are obtained, and cores are not so apt to be burned.

The length of the core taken depends largely on the hardness of formation cut. The hard, consolidated sands penetrated in the Mid-Continent fields cut out the teeth and necessarily make the taking of cores not equivalent in length of those taken with this type of barrel in the California fields impossible, where cores from 6 to 18 feet long have been taken successfully in unconsolidated sands.

The first core cut with this barrel in the Cromwell sand was 14 inches in length, the sand was extremely hard, fine grained, and consolidated. The cutters were considerably worn in cutting this core, but a longer core could have been taken before the cutters were completely worn out. Whereas the cutters were made from a special steel, it may be possible to use cutters of still greater hardness, and thus obtain longer cores in such hard, consolidated sands.

COMPLETING WELLS WITH ROTARY TOOLS

The completion of wells in this district with rotary tools is practically unknown. Very few wells in the Cromwell and Papoose areas have been completed in this manner, however, conditions in the Papoose field are very favorable for the successful use of this method when conducted in a correct and careful manner.



DOUBLE BARREL CORE DRILL

Figure – 5

Operators in the fields of southern Oklahoma have found that rotary completions have resulted in as high and often higher initial gas and oil production than completions with cable tools[1]. Completion of wells with rotary tools is especially advantageous in areas of high gas pressure and high initial production of wells, since the wells can be completed and brought in under absolute control without any waste of oil and gas.

In completiing wells in this area with rotary tools, the encountering of the top of the sand should be accurately determined by coring. The hole should then be drilled to a sufficient depth so that 6⅝ inch, 26 pound, lap-weld, or 6⅝, 24 pound, seamless, steel casing be cemented with the shoe just below the top of the sand. A good method is the two plug method. From 200 to 500 sacks of good quality Portland cement should be used, or an amount sufficient to place a column of cement from six to eight hundred feet behind the pipe. This amount can be determined by reference to Table 2. The casing should be slowly spudded while the cement is passing around the shoe of the casing to prevent the cement from channeling through the mud fluid behind the pipe.

The total depth to which the sand may be penetrated depends on the structural position of the well. As a safety measure, this depth in the sand should be several feet above the known water level in adjacent wells. Cores should be taken continously through the sand or at short intervals, as from these cores the operator can derive much valued information about the sand.

After the well is cemented it should stand so for not less than three days if accelator was used and not less than ten days if only pure neat cement was employed. At the end of this time the fluid should be bailed down to a safe known level and let stand for at least twelve hours after which the bailer should be run to determine whether the casing is leaking. This proving satisfactory the cement plug should be drilled out below the casing shoe with the hole full of fluid. This done the well should again be bailed to a safe depth, dry if possible, and then stand for at least 12 to 24 hours and another bailing test made to determine the effectiveness of the shut-off against water inflow. Caution must be used in this procedure, as cement plugs have been blown out of wells located in areas of high rock pressure when the hole was bailed. Prior to bailing down the fluid the well should be connected up for immediate control.

If a tight water shutoff has been obtained, the rotary tools may be run in the hole, and cleaned to bottom. The well may then be brought in by bailing down the fluid level. When the sand has a high rock pressure the well will generally clean itself

Sup. 1. George, H. C., and Bunn, John R., Petroleum engineering in the Fox-Graham oil and gas field, Carter County, Oklahoma; U. S. Bureau of Mines, July 1924.

Table 2. Number of linear feet filled by one sack of cement, when set, in the annular space outside various strings of casing in various sizes of holes.

Size of casing in inches		Diameter of hole to be cemented (in inches)									
Nominal Diam.	Outside Diam.	6	7	8	9	10	11	12	13	14	15
4	4½	12.8	7.0	4.6	3.3	2.5	2.0				
4¼	4¾	15.0	7.6	4.9	3.5	2.6	2.05				
4½	5	18.4	8.4	5.2	3.6	2.7	2.1				
5	5¼	23.9	9.4	5.5	3.8	2.8	2.2	1.7	1.4		
5-3/16	5½	35.1	10.8	6.0	4.0	2.9	2.2	1.8	1.5		
5⅝	6		15.5	7.1	4.4	3.2	2.4	1.9	1.5	1.2	
6¼	6⅝			10.0	5.4	3.6	2.6	2.0	1.6	1.3	
6⅝	7			13.4	6.3	4.0	2.8	2.1	1.7	1.4	1.1
8	8⅝				30.5	7.9	4.3	2.9	2.1	1.7	1.3
8¼	8⅝				30.5	7.9	4.3	2.9	2.1	1.7	1.3
10	10¾						37.0	7.1	3.8	2.5	1.8
11	11¾							34.0	6.5	3.5	2.3
11⅝	12								8.1	3.9	2.5
12½	13									7.5	3.6
13⅝	14										7.0

NOTE: One sack of "dry" cement contains approximately 1-cu. ft. One sack of "set" cement contains approximately 1.10 cu. ft.

Example: It is desired to find the number of linear feet filled by one sack of cement, when set, in the annular space between a casing having an outside diameter of 6⅝" and a 9" hole. Above the table will be seen a vertical column for the "outside diameters" of casings in inches; 6⅝" being the O. D. of the casing considered. Look down the column until you find 6⅝, then follow to the right in this horizontal column until you come to the vertical column for the 9" hole. The figure 5.4 is the number of linear feet which will be filled.

as soon as the fluid has been lowered a few hundred feet. In areas where the rock pressure of the sand has largely declined the well is swabbed cautiously after the sand has been thoroughly washed.

In the Papoose field the sand is not of great thickness and it is consolidated, so it is not likely that a liner of screen perforated pipe would be necessary where the water string is landed at the top of the producing sand.

The efficiency of completing wells with rotary tools was demonstrated in the Cromwell field when the Roxana Petroleum Corporation's Edward Brown No. 6, sec. 10, T. 10 N., R. 8 E., was completed and brought in under control with a reported initial production of 1500 barrels of oil and a volume of 53 million cubic feet of gas.[1]

Very good results have been obtained in many field by tubing wells before completion and flowing them initially through tubing. When a well is to be tubed before its completion, in areas of high initial production rotary completions are very desirable since the tubing may be run and set in the well without difficulty and with no loss of oil or gas.

The general practice before "bringing in" is to wash the sand and hole free from mud fluid circulating clear water through the tubing and out of the casinghead. The lower joint of the tubing is sometimes perforated to obtain a jet action on the walls and thus increase the efficiency of the washing operation The well is then brought in by lowering the fluid with a tubing swab.

ROTARY COMPLETION THROUGH DEPLETED SANDS.

There were many instances where wells were drilled with rotaries through partially depleted upper sands and casing cemented below these oil measures. The wells produced from a lower horizon for a long time then were plugged back and were recompleted in the partially depleted sand where clean oil was produced. The Santa Fe Springs field in California may be cited as a good example where the above practices were followed with excellent results.

Swigart and Schwarzenbek[2] have shown that virgin oil sands will take very little water and practically no mud fluid under pressure. Experiments[3] have shown that consolidated sands of good porosity will not take mud fluid under great pressure. In these

1. Rison, C. O., and Bunn, John R., Petroleum engineering in the Cromwell oil field, Seminole and Hughes Counties, Oklahoma: U. S. Bureau of Minees, December 1924.
2. Swigart, T. E., and Schwarzenbek, F. X., Petroleum engineering in the Hewitt oil field, Carter County, Oklahoma, U. S. Bureau of Mines, January 1921.
3. Work conducted under the direction of M. J. Kirwan, at U. S. Bureau of Mines, Bartlesville, Oklahoma.

experiments, when mud fluid was forced into the sand, a filtering action took place, the clay in the mud fluid being filtered out or caught on the surface of the sandstone, forming a clay deposit or sheath on the surface near the point of entrance of the mud fluid into the sand. The sandstone used in these experiments was a core taken from one of the productive sands in the Tonkawa oil field.

Although these experiments have shown that consolidated sands will not take mud fluid under pressure, the sheath formed on the face of the sand, with some of it penetrating the pores of the sand for a fraction of an inch, must be thoroughly washed off before maximum production can be obtained from a depleted sand.

This would indicate as experience shows that a sand once mudded, especially a depleted sand, should be washed or underreamed down to break mud sheath so that good production conditions are obtained. Excellent results have been obtained by using oil fluid in the well instead of water when drilling through a partially depleted oil sand.

SUGGESTIONS FOR THE COMPLETION OF WELLS IN THE AREA OF HIGH GAS PRESSURE

Considerable high pressure gas has been encountered in the east end of the Papoose field. In the Cromwell field the sand body thickened greatly on the high points of the structure, so that wells could be drilled through the gas bearing portion of the sand body into the oil bearing part of the sand. Such conditions of thickened sand body may exist on the high part of the structure in the east end of the Papoose field.

To prevent the dissipation and waste of enormous volumes of gas, which will take place during the drilling of the gas bearing portion of the Papoose sand with cable tools, it is recommended that operators in the Papoose field follow a similar type of procedure as outlined by Rison and Bunn[1] in a recent Bureau of Mines report on the Cromwell field. It was suggested that:

> "In future wells drilled to produce from the Cromwell sand zone, a string of casing should be cemented below the Harjo sand above the Cromwell sand zone. Enough cement should be used to extend at least above the Brunner sand. Within certain areas of the field, where high gas pressures are known to exist in the upper part of the Cromwell sand zone, it would appear to be good practice to land an additional string of casing in top of the oil bearing portion of the sand zone. This casing string could be set in mud fluid, care being taken to see that sufficient mud fluid was placed behind the casing to

1. Rison, C. O., and Bunn, John R., Petroleum engineering in the Cromwell oil field, Seminole and Okfuskee Counties, Oklahoma, U. S. Bureau of Mines, December, 1924.

hold down the gas pressure and prevent the well from blowing out later between the casing strings.

"The last two casing strings landed could be connected together with a high pressure bradenhead, thereby preventing a blowout if, at any time, the casing shoe failed to retain the mud fluid behind the pipe. The bradenhead should be closed in with suitable gate valves to prevent any flow of gas from between these casing strings, as any passage of gas through the mud fluid would tend to lighten it and reduce its effectiveness. It is possible that the weight of a string of casing might cause it to cut its way down into the sand, therefore a considerable part of the weight of the last string landed should be supported on the bradenhead. With the two strings of casing landed and bradenhead together, the well could then be completed in the lower oil productive portion of the sand zone and produced through the last string of casing set.

"When drilling a well (to be cased in the manner described above) with cable tools, a sufficient amount of mud fluid carried in the hole would prevent waste while drilling through the Brunner, Harjo, and Cromwell sands, and also prevent a blowout, should an unexpected gas pressure be encountered in any of these sands. The use of mud fluid would probably aid in securing successful cementing job, particularly when there is agitation by gas or water above the casing point. The disadvantages of having a cable tool hole filled with mud fluid while drilling are that the speed of drilling is reduced materially, and it is more difficult to obtain an accurate record of the formations.

"The rotary method is considered more effective than the cable tool method of drilling in preventing the migratory loss of oil or gas from productive formations exposed in a drilling well. This method of drilling is particularly effective against high gas pressures, such as those existing in the formations penetrated in the Cromwell field, and it is probable that a rotary outfit, properly equipped to take cores, would be more efficient than cable tools in drilling and completing new wells in the manner previously discussed.

"Although there is no available market at the present time for the large volume of free gas produced from the upper portion of the Cromwell sand zone, the waste of this gas itself is not the only economical loss to be considered. Aside from the fact that the gas has certain value as fuel, a relatively larger loss may be sustained if the rock pressure of the gas bearing sand is dissipated. A diminished rock pressure will probably transform the upper gas bearing portion of the sand zone from a potential source of energy into a hugh reservoir, more or less barren, into which gas given up by the oil sand will flow. As has been pointed out, this is likely to result in large amounts of oil being carried into this depleted sand where it will remain, beyond recovery.

"Primarily, the objects sought to be accomplished by setting a string of casing in mud fluid below the gas bearing portion of the Cromwell sand zone are to conserve the gas by retaining it in the sand until needed, thus utilizing its propulsive power by forcing it to seek an exit through the oil sand, thereby assisting in oil production. If these objects

are accomplished it is probable that waste of gas will be minimized, fire hazards will be reduced, the amount of emulsion formed will be decreased, the daily or ultimate oil production will be increased, and there will be less danger of pulling in top or lower water. In many cases, when a well declines to the economic limit of oil production the lower portion of the sand may be plugged back, the last string (which has been set in mud fluid below the gas sand) may be salvaged, and the well shut in on the next larger size of casing as a gas well."

The above method described for completing wells in high pressure areas where a gas body overlies the oil body in a sand applies where the sand is consistent. If an impervious parting exists between the two bodies such a method might result in a wasteful dissipation of free gas to the well without aiding the oil production. In such cases individual circumstances will govern the method to be used.

COMPARISON OF CABLE TOOL AND ROTARY DRILLING SPEED AND COSTS

A summary of the total drilling time in days, the total number of feet drilled, the average drilling time per well, the average number of feet drilled per day and the average depth per well by cable tools in the Papoose field is shown in Table 3.

Table 3. Analysis of Cable Tool Drilling.

Number of Wells	Total Drilling Time in Days	Total No. of Feet Drilled	Average Drilling Time per Well (Days)	Average No. of Feet Drilled Per Day	Average Depth Per Well
143	9.304	477,727	65.06	51.34	3340.7

This tabulation includes the total number of wells completed in the Papoose field proper at the time of compilation, using the data as reported by the various companies. The figures include time lost in fishing, cementing, and running casing in all completed wells. Wells, where the holes were lost and abandoned, are not used in the compilation.

As only three wells in the Papoose field proper have been drilled to the 8¼ inch casing point with rotary tools, a comparison based on the average of these three wells against 143 cable tool wells, is not a representative comparison. In addition to the results obtained in averaging these three wells, data on 32 rotary drilled wells in the Cromwell field, where very similar conditions prevailed and identical formations penetrated are given in Table 4.

Table No. 4. Analysis of Rotary Tool Drilling in the Papoose and Cromwell Oil Fields

Field	No. of Wells	Total Drilling Time In Days	Total No. of Feet Drilled	Average Drilling Time Per Well	Average No. of Feet Drilled Per Day	Averge Depth Per Well
Papoose	3	170	9,422	56.66	55.42	3140.66
Cromwell[1]	32	1,168	101,082	36.50[2]	86.54[2]	3159

1. Rison. C. O., and Bunn, John R., Petroleum engineering in the Cromwell oil field, Seminole and Okfuskee Counties, Oklahoma, U. S. Bureau of Mines, December 1924.
2. Includes time lost while fishing, running casing, and while cement was setting.

A comparison of the bare cost of drilling wells in the Papoose field with rotary tools and cable tools is given in Table 5. The table is based on data shown in Tables 3 and 4. It takes into consideration the cost of casing and drilling that prevailed in June, 1925. The cost of derrick, production equipment, cementing,

Table 5. Itemized Cost of Completing Wells in the Papoose and Cromwell Fields.

CABLE TOOLS.

DRILLING CONTRACT: 3340 Feet at $4.00 per foot $13,362.50

CASING COST:

20 Inch	90 lbs.	(Lap-weld)	55 Feet at $7.78	$427.90
15½ Inch	70 lbs.	(Lap-weld)	619 Feet at 5.44	3,367.36
12½ Inch	50 lbs.	(Lap-weld)	1,023 Feet at 3.10	3,171.30
10 Inch	40 lbs.	(Lap-weld)	1,765 Feet at 2.42	4,271.30
8¼ Inch	32 lbs.	(Seamless)	2,863 Feet at 2.24	6,413.12
6⅝ Inch	24 lbs.	(Seamless)	3,112 Feet at 1.58	4,916.96
5-3/16 Inch	17 lbs.	(Seamless)	3,320 Feet at 1.15	3,818.00

TOTAL COST (Less value of pulling casing)------------------$39,748.74

ROTARY TOOLS

DRILLING CONTRACT: 3340 Feet at $6.00 per foot, $20,040.00

CASING COST:

12½ Inch	50 lbs.	(Lap-weld)	40 Feet at $3.10	$124.00
6⅝ Inch	24 lbs.	(Seamless)	3,290 Feet at 1.58	5,198.20

Estimated cost of coring, 5 Days at $80.00 per day------400.00

TOTAL COST --$25,762.20

COMBINATION (ROTARY AND CABLE TOOLS)

DRILLING CONTRACT:

3140 Feet (Rotary) at $6.00 per foot --------	$18,840.00
200 Feet (Cable) at $4.00 per foot --------	800.00
Day work ----------------------------------	1,200.00

CASING COST:

12½ Inch	50 lbs.	(Lap-weld)	40 Feet at $3.10	$124.00
8¾ Inch	32 lbs.	(Seamless)	3,140 Feet at 2.24	7,033.60
6⅝ Inch	24 lbs.	(Seamless)	3,290 Feet at 1.58	5,198.20

TOTAL COST --$33,195.00

fuel, water, and the hauling of casing and equipment have not been included in the tables. For an itemized statement of costs incurred in drilling and completing wells in this district by cable tool and combination methods, see a report entitled, "Petroleum Engineering in the Cromwell Oil Field," published by the U. S. Bureau of Mines, December, 1924.

The saving of a few days time in the completion of a well and the consequent flush production obtained are advantages gained by drilling and completing with rotary tools. In addition to the decreased expense of rotary drilled and completed wells and the time saving involved, account should be taken of the increased efficiency of this method over cable tools by bringing in large wells under absolute control with no waste of oil and gas.

CASING USED.

The total amount of casing of various sizes used in completing 149 wells in the Papoose field is shown in Table 6. This table also shows the average length per string and the total number of strings pulled.

Table 6. Wells in which various sizes and weights of casing was used.

(Giving total number of feet and average depth at which landed)

Size Casing	20 Inch	15½ Inch	12½ Inch	10 Inch	8¼ Inch	6⅝ Inch	5-3/16 Inch
Weight of casing per ft.	lbs. 90	lbs. 70	lbs. 50	lbs. 40	lbs. 32	lbs. 24-26	lbs. 17-20
No. of wells in which used	132	147	149	145	148	137	45
Total No. ft. of casing used	7,313	91,046	152,540	255,986	423,799	426,358	149,433
Average depth landed in ft.	55.6	619.4	1,023.8	1,765.4	2,863.5	3,112.1	3,320.84
No. of wells in which casing has been pulled	31	112	111	106	16	8	

In table No. 6 it is shown that the average casing program used in the field was to start with 20 inch then 15½ inch, 12½ inch, 10 inch, 8¼ inch and 6⅝ inch. In the majority of wells the 15½ inch, 12½ inch, and 10 inch were pulled before the well was completed and in some cases the 20 inch conductor. This left most of the completed wells cased with 8¼ inch—32 pound set at an average depth of 2863 feet and 6⅝—24 or 26 pound set at an average depth of 3112 feet. The use of lap-welding casing has predominated in the Papoose field. However, several operators

Table 7. Collapsing pressures and capacities of lap-weld casing.

Nominal Size	Weight Per Ft. with Collars	Actual Outside Diam.	Actual Inside Diam.	Thickness	Collapsing Pressure Per Sq. In.	Equivalent Water Column	Water Column With Safety Factor of 2	Capacity Per Linear Ft.	Capacity Per Linear Ft.	Capacity Per 100 Linear Ft.
Inches	Pounds	Inches	Inches	Inches	Pounds	Feet	Feet	U. S. Gal	Cu. Ft.	Bbls.*
4¼	16	4.750	4.082	.334	4,710	10,850	5,425	.6792	.0908	1.62
4½	9.5	4.750	4.364	.193	2,140	4,920	2,460	.7702	.1039	1.83
4½	13	5.000	4.506	.247	2,900	6,680	3,340	.8281	.1107	1.97
4½	15	5.000	4.421	.288	3,610	8,320	4,160	.7982	.1067	1.90
4¾ †	8	5.000	4.696	.152	1,250	2,880	1,440	.8997	.1203	2.14
4¾	13	5.000	4.500	.250	2,950	6,790	3,395	.8262	.1104	1.97
4¾	15	5.000	4.408	.296	3,750	8,630	4,315	.7928	.1060	1.89
5-1	16	5.250	4.648	.301	3,580	8,260	4,130	.8814	.1178	2.10
5-3/16 ‡	13	5.500	5.044	.228	2,210	5,090	2,545	1.0380	.1388	2.47
5-3/16 ‡	17	5.500	4.892	.304	3,400	7,840	3,922	.9764	.1305	2.32
5⅝	20	6.000	5.352	.324	3,290	7,580	3,790	1.1677	.1561	2.78
6¼ ‡	13	6.625	6.257	.184	1,020	2,350	1,175	1.5973	.2135	3.80
6¼ ‡	17	6.625	6.135	.245	1,820	4,190	2,095	1.5356	.2053	3.66
6¼	20	6.625	6.049	.288	2.380	5,480	2,740	1.4916	.1994	3.55
6¼	24	6.625	5.921	.352	3,220	7,420	3,710	1.4295	.1911	3.40
6¼	26	6.625	5.855	.385	3,650	8,410	4,205	1.3974	.1868	3.33
6¼	28	6.625	5.701	.417	4,070	9,380	4,690	1.3667	.1827	3.25
6⅝	17	7.000	6.538	.231	1,470	3,400	1.700	1.7440	.2331	4.15
6⅝	20	7.000	6.456	.272	1,980	4.560	2,280	1.6988	.2271	4.04
6⅝	24	7.000	6.336	.332	2,730	6,280	3,140	1.6379	.2190	3.90
6⅝	26	7.000	6.276	.362	3,100	7,140	3,570	1.6061	.2147	3.82
6⅝	28	7.000	6.214	.393	3,480	8,020	4.010	1.5739	.2104	3.75
6⅝	30	7.000	6.154	.423	3,850	8,870	4,435	1.5440	.2064	3.68
7⅝	26	8.000	7.386	.307	1,940	4,470	2,235	2.2240	.2973	5.30
8 §	32	8.625	7.917	.354	2,170	5,000	2,500	2.5572	.3419	6.09
8¼	28	8.625	8.017	.304	1,670	3,850	1.925	2.6204	.3503	6.24
8¼	32	8.625	7.921	.352	2,150	4,950	2,475	2.5583	.3420	6.09
8¼	36	8.625	7.825	.400	2,630	6,060	3.030	2.4062	.3337	5.94
8¼	38	8.625	7.775	.425	2,880	6,640	3.320	2.4648	.3295	5.87
8¼	43	8.625	7.651	.487	3,510	8,090	4.045	2.3863	.3190	5.69
9⅝	33	10.000	9.384	.308	1,280	2.950	1,475	3.5899	.4799	8.55
10	40	10.750	10.054	.348	1,420	3.270	1.635	4.1210	.5509	9.81
10	45	10.750	9.960	.395	1,800	4,150	2.075	5.0440	.5406	9.63
10	48	10.750	9.902	.424	2,030	4.680	2 340	3.9976	.5344	9.52
10	54	10.750	9.784	.483	2,510	5.780	2.890	3.9062	.5217	9.29
11	47	11.750	11.000	.375	1,380	3.180	1.590	4.9334	.6595	11.74
11	60	11.750	10.775	.489	2,220	5,120	2.560	4.7307	.6324	11.26
11⅝	40	12.000	11.384	.308	840	1.940	970	5.2827	.7062	12.58
12½	40	13.000	12.438	.281	500	1,150	575	6.3083	.8433	15.02
12½	45	13.000	12.360	.320	750	1,730	865	6.2298	.8328	14.83
12½	50	13.000	12.282	.359	1.010	2,330	1.165	6.1497	.8221	14.61
12½	54	13.000	12.220	.390	1,210	2.790	1,395	6.0869	.8137	14.49
13½	50	14.000	13.344	.328	640	1,470	735	7.2598	.9705	17.29
15½	70	16.000	15.198	.401	790	1,820	910	9.4150	1.2586	22.42
19 3/16	90	20.000	19.182	.409	430	980	490	15.012	2.0068	35.74

* U. S. Gallon, 231 Cu. In. 42 U. S. Gallons, 1 Barrel.
† 14 Thread. ‡ 11½ Thread. § 8 Thread drive pipe. Unless otherwise indicated pipe is 10 inch.

NOTE: To determine the collapsing pressures for seamless casing, it is suggested that the collapsing pressures for lap-welded casing be increased by 20 percent. Read explanation on collapsing pressures of seamless casing.

have recently been using the smaller sizes of seamless steel casings with very successful results.

Table number 7 shows the collapsing pressures and capacities of different sizes of lap welded casing.

SEAMLESS CASING

The resistance to collapse is of unmost importance in the selection of casing size and weight, and must be given serious consideration in the casing of deep wells in any field. Some of the chief factors that effect the resistance to collapse in steel casing are the diameter of the casing, the thickness of the wall, the yield point of the steel in compression, the elasticity of the steel, variation in wall thickness, and initial out of roundness of the cross-section. It is claimed that these factors in seamless steel casing make it superior to lap-weld casing in resisting collapse.

Professor H. A. Thomas, of the Carnegie Institute of Technology, has carried on an investigation with reference to the collapsing pressures for standard seamless and welded casing. He has taken into consideration previous investigations pertaining to the resistance of tubular products that were conduced by the British Mannesmann Company and Professor C. B. Stewart of the University of Pittsburg.

Tess have indicated than on an average, seamless casing has a collapsing strength of 20 percent greater than Dr. Reid T. Stewart's formula indicates for lap-weld material. The lighter weights of the various sizes of seamless casing show a somewhat higher value than 20 per cent additional collapsing strength over the corresponding weights of lap-weld tubes, but the heavier weights of seamless casing show slightly less than 20 per cent increase. In the light of present data available it is felt that in general not more than 20 per cent additional strength can be assigned to seamlesss casing. This applies to tubes which are being manufactured on a commerical basis and sold as casing.

It is possible to add alloys to material to be made into seamless casing which could not be used in lap-weld tubes. Collapsing tests on seamless tubes manufactured from certain alloy steels have shown results 80 per cent higher than those indicated by Dr. Stewart's formula. It is possible that extremely deep wells may justify the additional expense incurred by the use of such alloys in the manufacture of special casing.

Casing manufactured from these expensive alloy steels could be used on one-third of the string at the bottom of the hole where the collapsing pressure is the greatest, and on the one-third of the string at the top where failure might result due to the parting of the string. The center of the string could be made up of cheaper casing but of material strong enough to meet the collapsing and tensile strength required for that depth.

The following prices shown in Table 8, are based on quotations of June 1, 1925, f. o. b. Okemah or Holdenville, Oklahoma.

Table 8. Cost of Seamless and Lap-weld Casing

Size	Weight	Cost per Foot
	SEAMLESS CASING.	
5-3/16 inch	17 lbs.	$1.15
6⅝ inch	24 lbs.	1.58
8¼ inch	32 lbs.	2.24
	LAP-WELD CASING	
5-3/16 inch	17 lbs.	$0.96¼
6⅝ inch	24 lbs.	1.36
8¼ inch	32 lbs.	1.91
10 inch	40 lbs.	2.42
12½ inch	50 lbs.	3.10
15½ inch	70 lbs.	5.44
20 inch	90 lbs.	7.78

From the above quotations, it would seem that when additional margin of safety is necessary the use of seamless casing is within reason from an economical standpoint.

SUGGESTIONS FOR RUNNING AND MEASUREMENT OF CASING

The importance of care in the running and making up of long casing strings can not be over emphasized. With improper handling the best casing can not be expected to give satisfactory results. Galling or "seizing" of the metal in the pipe threads with the metal threads of the coupling, may be caused by increased pressure in making up the joints; by excessive speed in making up the joints; by damaged pipe or coupling threads; by foreign material imbedded in the threads; or by lack of proper lubrication. The increased power and speed now used in drilling machinery has materially increased the danger of ruining threads when casing is screwed together.

Before the casing is put together in the derrick, the threads on both the pipe and the coupling should be carefully cleaned and thoroughly examined for burrs and dents. In the event of any burrs or dents showing on the entering threads, they should be carefully removed. Frequently in handling or in transit, the recessed end of a coupling is bumped, causing a small projection on the interior, which should always be removed beyond the depth of the thread. The ends should also be examined to see that they have not been flattened on either the pipe or the coupling. Protectors should never be entirely removed from the casing, until the casing is hanging free in the derrick.

Another frequent source of galling, is the improper stabbing of casing. This frequently causes the breaking off of a portion of one of the end threads; which, coming in contact with the remaining threads is liable to result in galled threads and leaky casing. Whenever casing has been improperly stabbed, it should be raised out of the coupling and examined, so that any defect may be corrected prior to screwing up.

One of the large casing manufacturers states that in screwing pipe together that not more than a circumferential speed of 15 to 20 feet per minute be used after the threads have been rolled in until they have become hand-tight, and that any faster speed may result in heating, which will likely cause the threads to seize and gall.

MEASUREMENT OF CASING.

The proper measurement of casing as put into a well is by means of a steel tape from the top of the collar to the base of the thread on each joint and is obviously more accurate than the overall method used in warehouse practice. The joints as measured should be accurately tallied as put into the well.

Although this method is practically accurate it does not give the accuracy as when measurements are taken after being screwed up. This can be done by placing a perforated wooden or cast iron disc at some measured point above the shoe joint in a collar recess, which depth in the well measured from time to time by a steel or aluminum covered line will give the amount of casing inserted. It should be checked however with the individually measured joint tally. This method has been used with success in the Deaner field by the Kingwood Oil Company.

PIPE THREAD LUBRICANT

All thread joints should be properly lubricated before screwing up. The best lubricant is one that will interpose a permanent film between the metal of the pipe or casing and the metal of the coupling. Various types of lubricants have been used. Until very recently, crude oil or engine oil have been largely used in cable tool areas for this purpose, while in rotary territory, the tool joints on the drill pipe have been lubricated with various compounds of lead and zinc oxide mixed with oili. A disadvantage in the use of oil alone is that friction and heat will break down the protective film between the metal contacts.

A thread lubricant consisting of a compound of ground metallic zinc mixed with oil is used by one of the larger manufacturers of tubular products for lubricating threads preliminary to the screwing up of the pipe couplings on the collar end. This lubricant is being used successfully by many of the larger operators in the Papoose and other Mid-Continent fields. The metallic zinc content of the lubricant forms a permanent film between the metal of the pipe and the metal of the coupling. The oil content is used largely as a medium for creating a mixture easily applied that will stick to the threads. By using this lubricant, it is claimed that joints can be screwed up much tighter with less liability to thread damage. The lubricant should be freely and thoroughly brushed on with a small stiff brush after thoroughly cleaning and examining the threads. A soft pine stick is more suitable for cleaning threads than a wire brush, since any damaged thread or indentation will be noted by this method and can be remedied before screwing up a joint.

The cost of lubricant is negligible compared to the results obtained by its use. In small quantities it can be purchased for twenty-five cents per pound. The amount used varies. On a certain deep well in Lincoln County, 30 pounds of zinc thread lubricant were used in running a 5-3/16 inch string to a depth of approximately 4000 feet.

PROTECTING CASING FROM CORROSION.

Casing, either in a well or awaiting use in the supply yard, especially if recently pulled, should be protected from the elements of corrosion. Casing when in the well, should be protected from the action of circulating corrosive waters. It has been pointed out by R. Van A. Mills, that this may be accomplished by filling the annular spaces between the casing and the rock walls by mud fluid, oil mud fluid, or by the use of a cement jacket obtained through the cement shut off method.

Various protective coatings have been used for protecting casing in stock. Crude oil, lubricating oil, and metallic base paint are commonly used. Casing manufacturers can recommend protective paints which have proved successful. If the casing has been exposed for sometime and has become rusty, it should be cleaned by wire brushes and some protective application given. The application is, of course, more effective, if each joint is treated separately by dipping or by means of brushes or cloths saturated with the protective paint or lacquer. If the material is piled and, the operator does not wish to treat each joint separately spraying can be done with a pressure spray or ordinary lawn sprinkling can. In this way the protective oil or paint is carried down through the pile.

WILD WELLS IN THE PAPOOSE FIELD

There has been comparatively little waste from wild wells in this field. Two wells have blown the tools from the hole when the sand was first penetrated. Considerable damage resulted

when the tools were blown out of Independent Oil and Gas Company's Alexander No. 2, sec. 2, T. 9 N., R. 9 E.

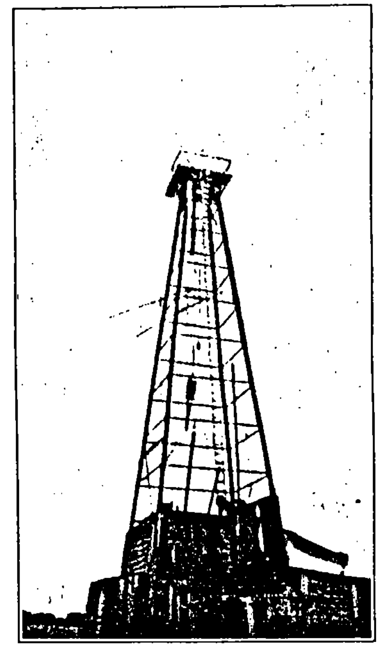


PLATE III.

The well was allowed to blow directly into the air for several days at the rate of several thousand barrels a day, causing damage by oil saturation to property around the well for some distance. This would not have occured if the well had been properly taken care of. Such occurrences are always liable to happen in areas where oil and gas wells are being drilled to high pressure producing zones, and too much precaution cannot be exercised in preparing a well with proper fittings to handle such an emergency with no waste or property damage.

A large gas well located in sec. 22. T. 10 N., R. 9 E., blew wild for several weeks; the Bureau of Mines assisting the operators in bringing it under control with the use of mud fluid. The well during drilling could have been so provided with cemented casing that the time and expense lost in bringing it under control would have been unnecessary. It is fortunate that it was controlled without disasterous results.

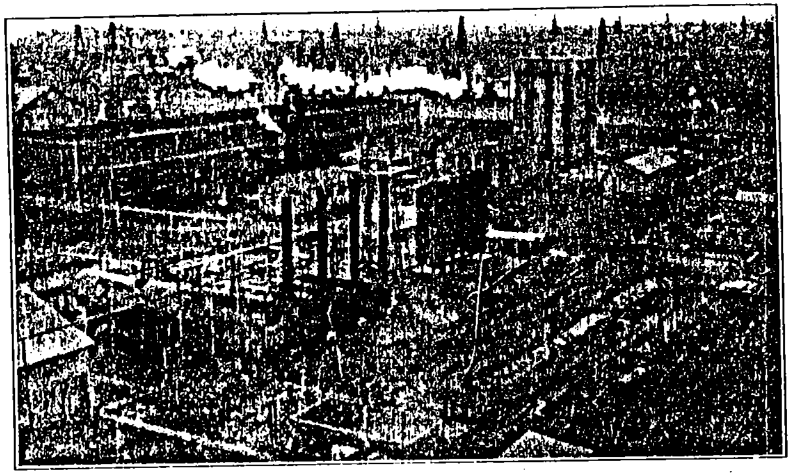


PLATE IV.

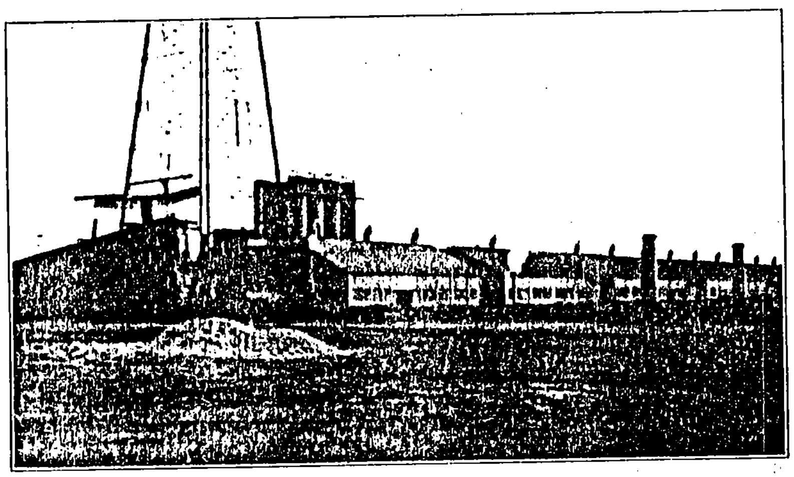


PLATE V.

PART III. PRODUCTION

By

John R. Bunn

PRELIMINARY DISCUSSION

There are many factors involved in the rate and ultimate production obtained from producing properties. Certain underground conditions affecting the production of a given area are its position on the structure, the thickness and extent of the producing horizon, the porosity, texture and saturation of the pay strata, and of its content, the nature and characer of the oil produced, the amount of free and dissolved gas and the rock pressure, also the position, proximity and nature of any water bearing strata. Additional factors influencing the production of a well or property are the proximity and number of adjoining wells and the times of their bringing in. Mechanical features in handling producing properties, including the methods and effectiveness of water shut-off, the sand penetration, manner of final completion, regulation of gas and oil flow, pumping equipment and recovery methods employed, are important factors in the ultimate production of producing properties.[1] These factors have clearly shown their influence in controlling the production of wells in the Papoose field.

RELATION OF PRODUCTION TO STRUCTURE.

It has been clearly shown in the Cromwell field that properties located on the structural high points, have produced enormous volumes of gas, but correspondingly little oil. This gas was largely dissipated into the air during the attempt of the operators to obtain oil, by reducing the subsurface gas volume and pressure, or by deepening the wells into the productive part of the sand. The enormous dissipation of gas, which for sometime was estimated at five million cubic feet per well per day, resulted in reducing the gas pressure over the entire productive area of the field and converting the depleted gas area of the sand into a potential reservoir for oil migration with the consequent underground waste of thousands of barrels oil.[2]

Fortunately such conditions have not prevailed in the Papoose field, due, no doubt, to the fact that development of the field has been comparatively slow, and has only recently extended to

1. Kirwan, M. J., and Schwarzenbek, F. X., Petroleum engineering in the Deaner oil field. Beal, C. H., and Lewis, J. O. Some principals governing the production of oil, Bulletin 194, Bureau of Mines, 1921.

2. Rison C. O., and John R. Op. cit.

the higher portions of the structure, where the producing sand contained free gas.

This condition of conservative field development has contributed largely to the relatively slow decline of wells in the Papoose field, and the increased yield per acre. What effects, however, the development will have on the undrilled properties located on the higher structural points can not yet be cited. The few gas wells recently completed in this area, although of large size, have certainly not had initial volumes comparable to many of the larger gas wells completed in the Cromwell field. Gas wells have not yet been deepened to the oil level in the producing sand; hence, it is not known what oil production could be obtained. It is quite likely that the drainage of the producing sand in the developed area of lower structural elevations has reduced the rock pressure of the gas area by increasing its extent, thus, tending to displace considerable oil occuring in the lower part of the sand over the structural high, undrilled area.

Should this latter assumption hold, it is quite apparent that properties located high structurally, where the sand is largely filled with free gas, will not yield wells of high initial oil production, and ultimately, a comparatively small amount of oil per acre, either when completed, during the initial development of the field, or at a later date.

It is true that the greatest amount of oil ultimately produced on such properties on top of the structure could be obtained by early completion of the wells and the dissipation of the gas. Such procedure, however, as amply demonstrated in the Cromwell field, is accompanied with disasterous results to all operators and is against the policies and spirit of conservation.

Producing properties in the Papoose field as a whole, have paid out rapidly and have already given a profitable return to their operators. In the Cromwell field many properties have not yet paid out and it is extremely doubtful if some of them ever will. Using these two areas as different types of field development, where conditions although not exactly similar, are quite comparable, it is conclusively shown that conservative field development and maintenance of the free gas area through gas conservation, results in a slower well decline, and consequest greater ultimate recovery of oil per acre.

GAS CONSERVATION

The increased recovery and ultimate production of a field obtained in the conservation of the free gas area through maintaining it undrilled as a free gas area has been previously discussed. Additional recovery and ultimate production can be obtained by the utmost utilization of the free and occluded gases associated with the oil. The forces of natural gas either absorbed in or closely

associated with the oil are the chief factors in its movement toward the well; the latter being a point of diminished pressure. Because of the important part played by natural gas in the recovery of oil, the conservation of the gas within the oil sand is worthy of the closest study by an oil producer of methods employed for such conservation.

In the Papoose field very little attention has been paid to the systematic flowing of wells by increasing the lifting efficiency of the gas. Back pressures, other than those imposed by the use of gas traps have not been employed. With few exceptions the wells are allowed to flow through 6⅝ to 5-3/16 inch casing and only tubed preliminary to pumping operations. There has been practically no use made of the advantages gained by flow beans, constant and intermittent back pressures, and the flowing of wells through small sizes of tubing. The application of these features on flowing wells can be used advantageously in this field.

The latest known measure of efficiency in oil recovery is the quantity of gas produced per barrel of oil; the smaller the gas-oil ratio, the greater the efficiency of recovery. The belief that the ultimate production can be increased if the decrease in rock pressure can be delayed by increasing the lifting efficiency of the gas produced per barrel of oil, is based on this principal.

Before a producing sand is first penetrated it is reasonable to expect that the rock pressure is practically uniform throughout the productive area. As wells are completed, the pressure will be lowered throughout the field, but because of the resistance offered to passage of oil and gas through the sand, this reduction in pressure does not take place uniformily throughout the field. The oldest producing areas become lowest in pressure, while undeveloped areas are found to still have high gas pressures when new wells are drilled in.

Every completed well is a point of low pressure as compared to the pressure in the producing sand at some distance from the well. Hence, with other factors being equal, the volume of oil and gas produced by well depends on the differential pressure between the well and the producing sand adjacent to the well. The greater the differential pressure the greater the flow of gas and oil toward the well.

Swigart[1] said regarding the theory of differential pressure:

> "It seems reasonable to expect that to obtain the greatest ultimate quantity of oil from a sand, the differential pressure between the well and the oil sand from which it produces should not be so great as to cause, 'bypassing of the gas.' Thus, while the rock pressure in a field is high, the back pressure in a producing well should be comparatively high. As the

1. Swigart, T. E., Notes on the efficiency of flowing wells in the Dominguez field. California. Production engineer, Shell Company of California.

field rock pressure declines the back pressure held on a well should be stepped down ahead of the rock pressure.

"Eventually no back pressure can be held without seriously reducing the daily oil production, but by that time the gas pressure in the oil sand should be so low that the tendency for by passing of gas is small.

"While back pressure may be desirable from the standpoint of efficient recovery, too much back pressure will usually reduce the present daily oil production. The operator may be forced to decide whether he prefers to produce oil at present, but at the expense of lost work by some gas, or choose a slower rate of oil recovery with more efficient use of the gas. The proximity of neighboring wells and the manner in which they are handled will obviously influence this decision to a great extent."

BACK PRESSURE ON FLOWING WELLS.

Back pressure on flowing wells is applied in two ways, either constantly or intermittently. A constant back pressure is secured by placing a valve that may be regulated for any desired pressure in the lead line between the well and the gas trap, or by placing a flow bean or nipple in the lead line at the gas trap at the top of the well or in the bottom of the tubing. Intermitten application of back pressure or stop-cocking, as it is sometimes called, consists in closing the well in entirely and then relieving the pressure by opening the well at regular periods respectively.

During the summer of 1923 and spring of 1924 a series of experiments with back pressures on some flowing wells in southern Oklahoma were conducted.[1] The application of both constant and intermittent pressures were used in these experiments.

The more favorable results were obtained by stop-cocking as compared to the use of constant pressure valves. In stop-cocking the well was closed in part of the time without the escape of any oil or gas, and when opened after the well had rocked up to a given pressure, resulted in a flow of oil. When constant back pressure was applied by a valve set for a given pressure, gas escaped continuously through the valve and was not accompanied by a flow of oil.

Experiments with flow nipples were carried on in the Graham oil field of Carter County, Oklahoma. The most interesting result was obtained at the Kaufman, McNaughton well No. 1, sec. 31, T. 2 S., R. 2 W. The condition of this well and the results obtained as described in the engineering report on the Graham field, follows:[1]

"This well was producing from one sand zone and was

1. George, H. C., and Bunn, John R., Petroleum engineering in the Fox and Graham oilfield, Carter County, Oklahoma, U. S. Bureau of Mines, 1924.

drilled to 2650 feet where an 8¼ inch water string was set at 2550 feet, with no oil string or perforated liner used. The packer was set 150 feet off bottom. The bottom of the tubing was closed with a plug and a perforated nipple placed in the tubing about 10 feet below the bottom of the packer. The well had been producing from 20 to 25 barrels per day for several months through two inch packed tubing. At 8:00 a. m. on March 27, 1924, a flow nipple with one-fourth inch diameter opening was placed in the lead line at the well. During the first 24 hours the well flowed 135 barrels. During the second 24 hours about 100 barrels per day. At the end of two months the well was still folwing 45 barrels per day or twice the production at the time the flow nipple was introduced. Up to June 1, 1924, the well had not been touched since placing the flow nipple in the line."

The flow nipple used on this well consisted of a piece of two inch steel shafting six inches in length, threaded on both ends with a two inch pipe thread. A one-fourth inch hole was bored lengthwise through the center of the shafting. The ends were turned on a lathe, forming a beveled recess to the one-fourth inch hole. It is possible that an opening three sixteenths inch in diameter would have given even better results on this well, since the well did not flow continuously, but by very short intervals. It is also likely that a flow bean in the bottom of the tubing would have resulted in a more efficient gas lift, since the expansive action of the gas would have been more fully utilized. The result of the first experiment on this well was so satisfactory that the operator did not want to run the chance of changing the favorable condition existing through further experimenting.

From the results of these experiments with back pressures and flow nipples, it was apparent that the use of flow nipples or small tubing of only sufficient internal sectional area to accommodate the oil production by constant flow would result in the greatest efficiency of gas lift and consequent oil recovery; also that the degree of success attained by using flow nipples, depend largely on their size and position. Obviously each well presents an individual problem and must be handled to fit existing conditions of depth, gas pressure and volume, and gas-oil ratio.

Experiments on the effect of back pressures on pumping wells have been carried on by Bureau of Mines engineers and summarized by T. E. Swigart and C. R. Bopp in Technical Paper 322, Experiments in the Use of Back Pressures on Oil Wells.

INFLUENCE OF EARLY WELL COMPLETION

The date of well ocmpletions on a property compared to the time of offset completions on adjoining properties has a very important bearing on the flush and ultimate production obtained from producing leases. It is well known as shown in the Cromwell and Papoose fields that the first wells drilled in an area will attain large flush production and drain considerable acreage. The extent of the area drained without interference depends, of course, on the porosity and uniformity of the sand, structural position and the differential pressure between the well and the producing sand. It is clear that the operator who wishes to recover the greatest amount of oil from his property must be prepared to conduct his drilling campaign in such manner as to offset any advantage his immediate neighbors might gain by early well completions.

Cutler[1] has discussed the effect of the time of drilling on ultimate recovery in detail and gives much valuable data on this question.

The law of equal expectation as advanced by Beal, Lewis, Nolan, Darnell, and others, states that within the same pool, wells of equal output, regardless of their relative ages, will in the future, have approximately similar decline curves, equal lives, and approximately equivalent ultimate productions, or as worded by Lewis and Beal:[2]

> "If two wells under similar conditions produce equal amounts during any given year, the amounts they will produce thereafter, on the average, will be approximately equal, regardless of their relative ages."

The truth of this law is now generally accepted, but it is governed by many factors, any one of which may vary and cause unusual irregularity.

METHODS OF STIMULATING PRODUCTION

In the Papoose field, agitation, swabbing, and shooting of wells were tried to stimulate or sustain production.

AGITATION

Agitation, or swinging of the tools in the hole was practiced on many leases during the flowing periods of the wells. The operators of the Indian Territory Illuminating Oil Company's lease in sec. 34, T. 10 N, R. 9 E., ran a twenty-four test to determine the effect of agitation by tools on their flowing wells. Facilities were such that individual well gages could be made. These tests showed that agitation by swinging the tools in the fluid caused no increase in production of these wells.

SWABBING.

Agitation by swabbing was then tried with very satisfactory results. It was found that by pulling the swab a comparatively short distance through the fluid, the well would immediately respond with a flow. All wells were then equipped with swabbing

1. Cutler, W. W. Jr. Relation of drilling to campaign to income from oil properties, Bureau of Mines Report of Investigations, No. 2270, August, 1921.
2. Lewis, J. O., and Beal, C. H., Some new methods of estimating the future production of oil wells, Trans. A. I. M. E., Vol. 59, pages 492-525, 1918.

strings. One well crew swabbed all wells at short intervals to induce the flowing of the wells by starting the swab out of the hole. The production of all wells on the lease was materially increased by this method.

SHOOTING

While some wells have been shot to obtain the maximum initial production, the shooting of wells in the Papoose field has been largely resorted to in an effort to sustain the production of flowing wells. The shooting record and the results obtained by shooting wells on certain leases in this field is shown in Table 9.

Table 9 shows that wells have been shot with shells of various sizes, containing from 3 to 15 quarts of liquid nitroglycerine. The effects derived from shooting have been variable. Any increase in production, due to shooting, has been of short duration.

The greatest increase in production from shooting shown in Table 9 was on the Gypsy, Williams, well No. 1, sec. 34, T. 10 N.,

Table No. 9. Shooting records of certain wells in the Papoose Field.

Well No. and Location	Shot No.	Amt. Qts.	Shell Size	Anchor Size	Shot Top	Placed Bottom	Date of Shot	Production bbls. per day Before	After	Increase
Kingwood Sands No. 2	1	2	1"x10'		3323	3333	11-20-24	193	246	49
Kingwood Sands No. 2	1	3	2½"x5'	1"x3'	3308	3313	3- 6-25	34	43	9
	2	5	3"x5'	1"x3'	3308	3313	3- 9-25	25	47	22
	3	7	3"x5'	1"x3'	3308	3313	3- 9-25	25	47	22
	4	10	3"x5'	1"x2'	3308	3313	3-13-25	17	31	14
Kingwood Sands No. 3	1	3	2"x5'	1"x7'	3320	3325	3-16-25	383	393	10
	2	5	2½"x5'	1"x5'	3318	3323	3-25-25	492	512	20
	3	7	3"x5'	1"x3'	3308	3313	3-30-25			
	4	10	3"x5'	1"x2'	3308	3313	4- 1-25	439	575	136
Kingwood Sands No. 7	1	5	2½"x5'	None	3324	3329	2- 6-25	10	29	19
Kingwood Sands No. 8	1	5	2½"x5'	None	3320	3325	2- 7-25	63	62	-1
	2	10	3"x7'	None	3315	3322	2-26-25	31	44	13
Gypsy W'l'ms No. 1	1	5	1¾"x10'	12'	3303	3313	4-10-25	345	1015	670
	2	10	2½"x5'	12'	3299	3304	4-10-25	*		
Gypsy Will'ms No. 2	1	5	3"x5'		3309	3314	5- 7-25	260	278	18
Cosden Alex. No. 4	1	15	3½"x8'		3302	3310	4-23-25			
Cosden Alex. No. 7	1	10	2½"x10'		3304	3314	4-21-25			
	2	15	3"x10'		3303	3313	4-22-25			
Cosden Alex. No. 10	1	10	2½"x10'	2'	3313	3325	4-10-25			
Cosden Alex. No. 11	1	10	2½"x10'	2'	3318	3330	4-28-25			
Cosden Alex. No. 12	1	5	1¾"x10'	3'	3295	3308	4-21-25			

*Note: Wells Nos. 1 and 2 are guaged together.

R. 9 E. Two shots of 5 and 10 quarts, respectively, on the same day increased the production of this well 670 barrels. The two producing wells on the lease are gaged together, hence the increase is only approximate. The combined production before shooting the two wells was 345 barrels. The production the following 24 hours was 1015 barrels. This shot resulted in an increase of production for several days and within 18 days the daily production from the two wells had dropped to 335 barrels.

In oil well shooting, the charge is usually fired by some type of squib, either a jack line or bumper squib. All of these types have disadvantages which make their use in unskilled hands dangerous. Line of bumper squibs should be strung in carefully, and an accurate measurement taken to the top of each shell placed in the well to eliminate damage to casing and liner by shooting too high in the hole.

Certain mechanical and electrical timing devices for detonating the charge have been successfully used, especially where a large charge was fired. The devices are enclosed in small cast metal shells and can be set for any predetermined time of detonation and lowered to the top of the shell on the torpedo and detached. The use of these timed detonators result in a much higher degree of safey than is involved in detonating by the various types of squibs. They are less expensive than ordinary electrical detonators, and also eliminate the danger of wire bridging when shooting in this manner. However, they have some diadvantages, especially in light shooting.

When using one of these devices in firing small charges of one and two quarts in deep wells, it is often difficult to determine whether the explosion actually took place, unless a light line is attached to the bomb and the explosion determined by the jerk of the line. There is one case on record in the Papoose field, where an electrical bomb did not detonate at the time set. The charge was a small one, so the operators were uncertain as to whether or not the charge had been fired. Finally, a three prong grab was run and the unfired bomb was fished out of the hole.

PUMPING WELLS

It has been the practice in the Papoose field to begin pumping the wells when they have declined to the stage where more oil can be obtained by pumping than by infrequent flows. This stage varies with conditions and individual wells. They are handled in much the same way as are pumping wells in other deep fields where the wells are pumped on the beam. Methods and equipment used in the pumping of oil wells have been discussed in a U. S. Bureau of Mines Bulletin.[1]

1. George, H. C. Surface machinery and methods for pumping oil wells, Bureau of Mines Bulletin 224, 1925.

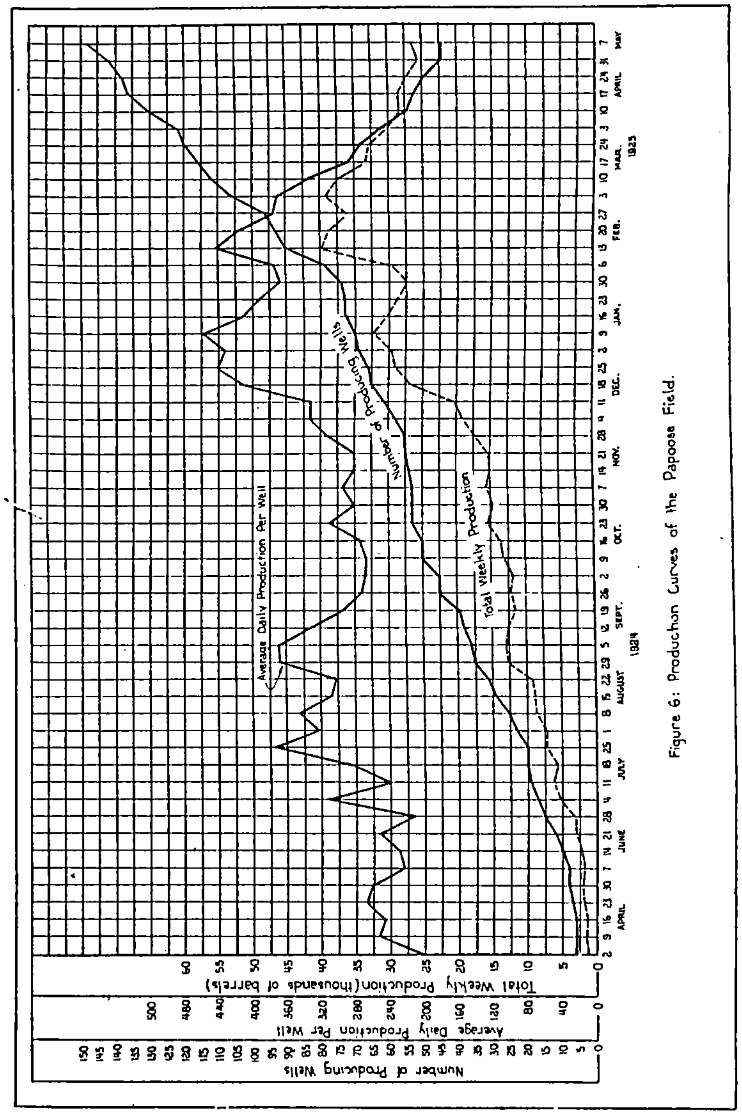


Figure 6: Production Curves of the Papoose Field.

PRODUCTION CURVES AND STATISTICS

The average daily production of the Papoose field, the number of producing wells, and the average daily production per well by weekly periods, are shown by the graphic curves in Figure 6. The data represented in the curves cover a period of 53 weeks ending April 7, 1925. During the week ending April 2, 1924, six wells were producing an average of 1337 barrels per day; thus the curve does not show the small initial production of the field up to April 2, 1924. It may be noted from the curves that the peak or highest average daily production of the field. (Papoose and Gilcrease together) was reached during the week ending January 13, 1925, when 90 wells produced an average of 39,814 barrels per day.

The average daily production per well increased from 223 barrels during the week ending April 2, 1924, to 442 barrels per day during the week ending January 13, 1925, when 90 wells were producing 39,814 barrels per day. The average daily production per week has since gradually declined until, during the week ending April 7, 1925, 140 wells were producing an average of 179 barrels per well per day. The total production of the field up to and including April 7, 1925, was approximately 6,878,772 barrels.

INITIAL PRODUCTION

The initial daily oil production from wells in the Papoose field varied from 25 to 3600 barrels. The well of largest initial production was the Independent Oil and Gas Company's S. Alexander No. 2, located in the NE¼, NE¼, NE¼, sec 2, T. 9 N., R. 9 E. This well had a reported initial production of 3600 barrels. The oil wells of highest initial production were those located just above the oil and gas contact. These wells have produced considerable gas with the oil. Some wells, completed in the higher structural areas and which produced from immediately above the gas-oil contact, were completed as oil wells. They produced from 25 to 40 million cubic feet of gas per day. No gas wells with volumes comparable to many completed in the Cromwell field have yet been completed in the Papoose field. The average initial oil production from 124 wells, as reported by the operating companies, was approximately 801.33 barrels per well.

Two samples of oil were collected as produced in the field, one from the flow line of Charity Brown No. 3 in sec. 17, T. 9 N., R. 9 E., and producing from the Gilcrease sand. The results of this analysis are shown in Table No. 10. The other sample was from Toble Hill No. 1 well in sec. 9, T. 9 N., R. 9 E., and producing from the Papoose sand. The results of this analysis are shown in Table No. 11.

Table No. 10. Analysis of Crude Oil from Papoose-Gilcrease field. Gilcrease Sand

Sample Number 25334

Oklahoma **Charity Brown No. 3** **Wilcox**

17-9-9. From Flow line. Gilcrease sand

3061-3075'

Specific gravity, 0.840 A. P. I. gravity, 37.0
Per cent sulphur, 0.1 Per cent water, nil
Saybolt Universal viscosity at 70°F., 57 sec. Pour point 20°F
Saybolt Universal viscosity at 100°F, 45 sec.

Distillation, Bureau of Mineis, Hempel Method

Air distillation **Barometer 743 mm.** **First drop: 38°C (100°F)**

Temperature °C	Per Cent Cut	Sum Per Cent	Sp. Gr. Cut	°A. P. I. Cut	Viscosity 100 °F	Viscosity 212 °F	Cloud Test °F	Temperature °F
UP to 50	0.3	0.3						Up to 122
50— 75	1.0	1.3	.697	71.5				122—167
75—100	3.4	4.7						167—212
125—150	5.5	16.3	.752	56.7				257—302
100—125	6.1	10.8	.733	61.5				212—257
150—175	5.3	21.6	.768	52.7				302—347
175—200	2.1	23.7	.782	49.5				347—392
200—225	5.8	29.5	.797	46.0				392—437
225—250	5.5	35.0	.813	42.6				437—482
250—275	6.3	41.3	.825	40.0				482—527
Vacuum distillation at 40 mm.								
Up to 200	4.5	4.5	.845	36.0	41			Up to 392
200—225	5.4	9.9	.849	35.2	46		24	392—437
225—250	6.2	16.1	.860	33.0	58		44	437—482
250—275	5.2	21.3	.872	30.8	89		60	482—527
275—300	6.5	27.8	.878	29.7	152		80	527—572

Residuum 27.6%. Distillation loss 3.3%.
Carbon residue of residuum 4.0%. Carbon residue of crude 1.10%.

Approximate Summary

	Per cent	Sp. Gr.	°A. P. I.	Viscosity
Light gasoline (end point 212°F)	4.7	.679	71.5	
Total gasoline and naphtha	23.7	.743	58.9	
Kerosene distillate	17.6	.812	42.8	
Gas oil	9.0	.847	35.6	
Nonvicisious lubricating distiilate	10.9	.853-.873	34.4-30.6	50-100
Medium lubricating distillate	8.0	.873-.881	30.6-29.1	100-200
Viscous lubricating distillate	0.0			Above 200
Residuum	27.6	.920	2.3	
Distillation loss	3.3			

Table No. 11. Analysis of Crude Oil from Papoose-Gilcrease field. Papoose Sand.

Sample Number 25335

Oklahoma — Papoose Oil Company

Tobe Hill No. 1 in 9-9-9 Sand 3326' to 3332' depth.

Specific gravity, 0.865 — A. P. I. gravity, 32.1

Per cent sulphur, 0.1 — Per cent water, Trace

Saybolt Universal viscosity at 70°F., 160 sec. — Pour point 40°F.

Saybolt Universal viscosity at 100°F., 69 sec.

Distillation, Bureau of Mines, Hempel Method

Air distillation — Barometer 743 mm. — First drop: 112°C (234°F)

Temperature °C	per Cent Cut	Sum Per Cent	Sp. Gr. Cut	°A. P. I. Cut	Viscosity 100 °F	Viscosity 212 °F	Cloud Test °F	Temperature °F
Up to 50								Up to 122
50—75								122—167
75—100								167—212
100—125	0.3	0.3						212—257
125—150	0.3	0.6	.775	51.1				257—305
150—175	2.4	3.0						302—347
175—200	5.6	8.6	.790	47.6				347—392
200—225	5.7	14.3	.803	44.7				392—437
225—250	7.1	21.4	.816	41.9				437—482
250—275	8.9	30.3	.828	39.4				482—527
Vacuum distillation at 40 mm.								
Up to 200	5.3	5.3	.847	35.6	42			Up to 392
200—225	9.7	15.0	.848	35.4	45		28	392—437
225—250	7.0	22.0	.859	33.2	57		48	437—482
250—275	8.1	30.1	.871	31.0	80		68	482—527
275—300	7.8	37.9	.877	29.9	123		84	527—572

Residuum 30.9%. Distillation loss, 0.9%.

Carbon residue of residuum, 3.06%. Carbon residue of crude, 0.95%.

Approximate Summary

	Per cent	Sp. Gr.	°A. P. I.	Viscosity
Light gasoline (end point 212°F)	0.0			
Total gasoline and naptha	8.6	.785	48.8	
Kerosene distillate	12.8	.810	43.2	
Gas oil	22.6	.841	36.8	
Nonviscous lubricating distillate	16.1	.853-.874	34.4-30.4	50-100
Medium lubricating distillate	8.1	.874-.880	30.4-29.3	100-200
Viscous lubricating distillate	0.0			Above 200
Residuum	30.9	.918	22.6	
Distillation loss	0.9			

PART IV. SUB-SURFACE WATER CONDITIONS

By

John R. Bunn

POSITION OF WATER IN THE PAPOOSE SAND

The normal water level in the Papoose sand is not uniform throughout the producing area of the field. Certain wells have

found water much deeper stratigraphically in the sand than other nearby wells, while other wells have found water occuring higher in the sand than was expected. This later condition is more apt to occur on the lower structural points where an irregular water level is due to a combination of coning up and pulling in of the edge or bottom water line, caused by the intensive drilling and the large initial production of adjacent wells located higher on the structure.

Water in the Papoose sand has occured high structurally in certain wells located on the north and east edges of the field. This condition may be attributed largely to the structural position

Table No. 12. Reported data on certain wells producing water from the Papoose Sand

Company and Lease	Well No.	Location Section Twp. & Range	First Water Depth	Surface Elev.	Depth Below Sea Level	Remarks
Foster Inv. Co. C. Tiger	2	4- 9-9	3337	793	2544	
Champ. & Wink'r Simon	1	4- 9-9	3359	814	2545	Water in top sand. Abandoned
Champ. & Wink'r Simon	2	4- 9-9	3347	810	2537	Water in top sand. Abandoned
Sinclair O & G Co. Fredonia Willis	1	5- 9-9	3328	784	2544	Water in top sand. Abandoned
Transcontinental Betsey Carter	2	5- 9-9	3360	802	2568	Water in top sand. Abandoned
T. B. Slick McKay	5	3- 9-9	3308-12	766	2542	
Mid-Continent W. Alexander	2	2- 9-9	3321-32	774	2547	
T. B. Slick Bruner	2	2- 9-9	3343-45	792	2551	
C. L. McMahon Dunson	1	35-10-9	3379-89	803	2571	Water in top sand. Abandoned
Prairie O & G Co. Westbrook	4	35-10-9	3351 ?	822	2529 ?	
Prairie O & G Co. B. F. Davis	1A	34-10-9	3321	776	2545	
Prairie O & G Co. B. F. Davis	8A	34-10-9	3304-16 ?	783	2521 ?	
Mid-Continent W. Alexander	3	3- 9-9	3304-12	770	2534	Abandoned.

of the sand at these points. A study of the subsurface contour map shows that comparatively steep dips prevail along the north and east edges of the field. It has been noted in many fields that the water level of a sand is affected by the sand's structural inclination, the water level being higher where the dip is steeper and lower where a flatter dip prevails.

The reported data on certain wells obtaining water in the Papoose sand is shown in Table 12. Several of these wells were outside wells where the top of the Papoose sand occured several feet below the water level in the producing area.

STRATIGRAPHIC DEPTH OF WATER SHUTOFF

Since the position of upper water sands in this area is well known, little trouble resulted from upper water where casing has been set below the Gilcrease sand zone and a tight shutoff secured. The casing program generally followed in the field has been to set a 6⅝ inch water string immediately below the Gilcrease sand zone; the average depth of 6⅝ inch casing point for 137 completed wells, is 3,112 feet. When the 6⅝ inch casing is set immediately below the Gilcrease sand zone it becomes necesary to set a liner or full string of 5-3/16 inch casing on top of the Papoose sand to prevent the caving of the intervening shale beds.

The use of several hundred feet of liner is not recommended. Gas may work up behind the liner carrying shale particles over the top of the liner tending to help cut the oil if water is also produced. Later water troubles or shooting of the well may make it necessary to pull the liner. This is often accompanied with considerable difficulty and the hazard of a dangerous fishing job.

A full length 5-3/16 inch oil string is preferable to a few hundred feet of liner. The advantages in safety and operation derived from such practice, however, may be offset by the increased cost. Should any swabbing or prolonged fishing operations be carried on, an oil string should be run for protection to the water string from line cutting and attendant difficulties.

The use of a liner or full length oil string may be avoided by setting and cementing the 6⅝ inch casing just above the Papoose sand. The formation shutoff has been used in most instances in setting the last water string. This procedure and the fact that it was desirable to case off gas and water encountered in the Gilcrease sand zone, has doubtlessly contributed largely to the fact that the 6⅝ inch casing has been set, in many instances, from 150 to 200 feet above the Papoose sand; thus, necessitating the additional use of a liner or full length oil string.

CEMENTING CASING

Casing may be cemented by either the dump bailer, tubing method, displacement method using two plugs or displacement method without plugs. These methods have been thoroughly discussed in previous Bureau of Mines publications.[1]

The two plug displacement process, as controlled and carried on by the Halliburton Oil Well Cementing Company has been used for cementing casing in certain wells of this field. This process is considered the most efficient from the standpoint of operation and convenience. Casing may be successfully cemented off bottom with this method.

The number of completed wells cemented by the two plug process in this area previous to April 30, 1925, is shown in Table 13. This tabulation shows the number and location of wells, the depth and size of casing string, the date of cementing, and the amount of cement used.

WATER PRODUCTION IN THE PAPOOSE FIELD

Considerable water is now being produced from the earlier completed wells in the Papoose field, as shown by Table 14. It probably can be accounted for as encroaching edge water or bottom water in the lower portion of the producing sand.

When water is produced with oil there is danger of its emulsification with the oil which is due largely to agitation in producing and to the presence of colloidal matter which acs as an emulsifying agent. In flowing wells the oid is agitated by the turbulent flow of the oil from the well aided generally by the stirring effect of the gas being produced with the oil. In pumping wells, there are two sources where agitation resulting in emulsification may take place; namely, in the working barrel and in the tubing. Wells producing water should be repaired at the earliest possible date, since the handling of large quantities of water means increased operating cost and may effect the marketability of the oil produced, because deterimental emulsions are often formed. Such emulsions are difficult and costly to break up so that clean pipe line oil can be made available for sale.

Besides adding to the expense of operations through extra cost of lifting, and cleaning emulsified oil when formed, water infiltration has a detrimental tendency in decreasing ultimate production. In flowing wells it reduces generally the flow period and in all wells it has a ruinous effect tending to flood the productive sands. The subsurface inflow of water to a well has an all

1. Tough, F. B., Methods for shutting off water in oil and gas wells. Bulletin 153. Bureau of Mines. 1918.
Swigart, T. E., and Beecher, C. E., Manual for oil and gas operations. Bulletin 232. Bureau of Mines. 1923.

Table No. 13. Wells cemented by the two plug method in the Papoose Field.

Date	Company	Well No.	Location	Depth	Size Pipe	Amt. of Cement Sacks
3-10-24	T. W. Adkins	1	19- 9-9	2500	6⅝	
3-22-24	Turman Oil Co.	1	15- 9-9	2894	8¼	200
3-28-24	Smyer & Stein	1	20- 9-9	2936	8¼	100
4-24-24	Papoose Oil Co.	1	4- 9-9	3321	6⅝	163
4-19-24	Mohawk Drilling Co.	1	17- 9-9	2951	8¼	175
5-21-24	Papoose Oil Co.	1	9- 9-9	3230	5-3/16	50
6-21-24	Champlin & Winkler	1	4- 9-9	3150	5-3/16	30
6-29-24	Gilcrease Oil Co.	2	20- 9-9	2962	8¼	300
6-30-24	Mohawk Drilling Co.	2	17- 9-9	2964	8¼	300
7-11-24	Margay Oil Co.	5	17- 9-9	3003	8¼	450
7-14-24	Gilcrease Oil Co.	3	17- 9-9	2956	8¼	450
7-21-24	Margay Oil Co.	6	17- 9-9	3000	8¼	450
7-29-24	Roxana Pet. Corp.	1	17- 9-9	2982	8¼	350
10-29-24	Gypsy Oil Co.	1	34-10-9	3175	6⅝	60
11-16-24	Ind. Terr. Ill. Oil Co.	2	34-10-9	3179	6⅝	50
11-18-24	Mid-West & Gulf Oil Co.	2	33-10-9	3339	5-3/16	50
11-29-24	Mid-West & Gulf Oil Co.	2	33-10-9	3339	5-3/16	75
12- 3-24	Gypsy Oil Co.	2	33-10-9	2188	6⅝	50
12-28-24	Cosden Oil & Gas Co.	4	3- 9-9	3250	6⅝	45
1- 8-25	Ind. Terr. & Barnsdall	3	34-10-9	3134	6⅝	35
1-12-25	Cosden Oil & Gas Co.	10	3- 9-9	3080	8¼	100
1-14-25	Phillips Pet. Co.	1	3- 9-9	3100	6¼	40
1-19-25	Ind. Terr. & Barnsdall	6	34-10-9	3434	6⅝	35
1-23-25	Cannon & Ryan	3	3- 9-9	3305	5-3/16	240
1-24-25	Indp. Oil & Gas Co.	4	2- 9-9	3137	6⅝	35
1-25-25	Indp. Oil & Gas Co.	5	2- 9-9	3335	5-3/16	25
1-26-25	Gypsy Oil Co.	3	34-10-9	3172	6⅝	50
1-26-25	Prairie Oil & Gas Co.	3	35-10-9	3357	6⅝	50
2- 3-25	Prairie Oil & Gas Co.	4	34-10-9	3285	6⅝	40
2-12-25	Cosden Oil & Gas Co.	10	3-- 9-9	3128	6⅝	20
2-15-25	Kingwood Oil Co.	4	35-10-9	3397	6⅝	20
2- 7-25	Cosden Oil & Gas Co.	4	35-10-9	3302	5-3/16	35
2-17-25	Cosden Oil & Gas Co.	1	35-10-9	3313	5-3/16	15
2-24-25	Gypsy Oil Co.	4	34-10-9	3160	8¼	100
2-28-25	Gypsy Oil Co.	9	3- 9-9	3282	6⅝	30
3- 4-25	Prairie Oil & Gas Co.	8	34-10-9	3283	6⅝	30
3-11-25	Cosden Oil Co.	12	3- 9-9	3265	6⅝	22
3-13-25	Indp. Oil & Gas Co.	6	2- 9-9	2748	8¼	50
3-13-25	Prairie Oil & Gas Co.	1B	34-10-9	3156	8¼	200
3-13-25	Carter Oil Co.	4	33-10-9	3130	6⅝	50
3-14-25	Cosden Oil & Gas Co.	11	3- 9-9		8¼	
3-30-25	Prairie Oil & Gas Co.	2	34-10-9	3150	8¼	200
4-12-25	Prairie Oil & Gas Co.	3	34-10-9	3112	8¼	200
4-13-25	T. B. Slick Oil Co.	1	2- 9-9	3328	5-3/16	50
4-13-25	Indp. Oil & Gas Co.	7	2- 9-9	2929	8¼	50
4-13-25	Indp. Oil & Gas. Co.	6	2- 9-9	3105	6⅝	35
4-17-25	Ind. Terr. Ill. Oil Co.	1	19- 9-9	3400	8¼	
4-21-25	Ind. Terr. Ill. Oil Co.	1A	34-10-9	3200	6⅝	30
4-23-25	Indp. Oil Co.	7	2- 9-9	3098	6⅝	35
4-26-25	Indp. Oil Co.	3	4- 9-9	3331	5-3/16	50

important place as a problem to an operator which demands most careful study in every field.

METHODS OF WATER EXCLUSION.

In remedial work on oil and gas wells for the exclusion of infiltrating water it is necessary to make a very systematic study of wells affected in conjunction with a study of the field. First a knowledge of the location of the possible sources of water in the

Table No. 14. Reported daily water production of the Papoose Pool, April 20, 1925.

Company	Farm	Location	Well No	Amount of water Produced in bbls. Per day
Amerada	Palmer	36-10-9	1	45% water 450 from 3 wells
Berry	Alexander	4- 9-9	2	Cuts oil and
Carter	P. Johnson	33-10-9		shows water
Carter	P. Johnson	33-10-9	5	Shows water
Carter	P. Johnson	33-10-9	4	35
Cosden	W. Alexander	3- 9-9	1	Cuts 4%
Cosden	W. Alexander	3- 9-9	8	Cuts 4%
Foster Inv. Co.	C. Tiger	4- 9-9	1	90
Foster Inv. Co.	C. Tiger	4- 9-9	2	40
Foster Inv. Co.	C. Tiger	4- 9-9	3	80
Foster Inv. Co.	C. Tiger	4- 9-9	4	2½
Foster Inv. Co.	Ogle	4- 9-9	1	80
Independent	Barnett	33-10-9	1	15
Independent	S. Alexander	2- 9-9	1	1
Independent	S. Alexander	2- 9-9	2	Cuts 7%
Kingwood	H. Sands	35-10-9	2	5
Kingwood	H. Sands	35-10-9	6	10
Kingwood	H. Sands	35-10-9	8	2
Continental	J. Turner	4- 9-9	1	150
Papoose	Alexander	4- 9-9	1	100
Papoose	Alexander	4- 9-9	2	20
Papoose	Alexander	4- 9-9	4	150
Papoose	Alexander	4- 9-9	5	175
Papoose	Alexander	4- 9-9	7	75
Papoose	Alexander	4- 9-9	9	100
Papoose	Tobe Hill	9- 9-9	1	150
Papoose	J. Simon	4- 9-9	1	100
Papoose	J. Simon	4- 9-9	2	100
Robinson & Amerada	M. Carter	4- 9-9	1	90
Robinson & Amerada	M. Carter	4- 9-9	2	45
Robinson & Amerada	M. Carter	4- 9-9	4	5
Robinson & Amerada	M. Carter	4- 9-9	5	60
Robinson & Amerada	M. Carter	4- 9-9	6	50
Prairie	Davis	34-10-9	1A	3
Prairie	Davis	34-10-9	8A	5
Prairie	Westbrook	35-10-9	2	5
Prairie	Westbrook	35-10-9	4	2%
Skelly	Carter	4- 9-9	1	10
Transcontinental	Tiger	4- 9-9	6	40

various formations must be had. These must be studied with reference to the structure. Next individual well studies of the wells needing repairs requires by test and investigation where the water is coming from and what work is necessary to overcome it. These tests include the inspection of production data, both oil and water, and the production methods used. The investigation includes an engineering study of the subsurface structure, and the mechanical conditions of the well, the latter being the depths and water shut off effectiveness of all casing shoe landings with respect to the various formations penetrated.

Base or edge water in the producing sand is the chief source of water trouble in the Papoose field. The production of water from this source is caused by drilling the wells too deep in the sand or from later encroachment of water in the sand as the oil is drained.

In order to shut off this water, the bottom of the well must be plugged. Lathe cuttings, lead wool, and mechanical plugs have

been successfully used in plugging off bottom water and encroaching edge water in the lower part of producing sands. In general these methods are unsatisfactory and not recommended, excepting that lead wool has found an emergency use in stopping a heavy flow of water long enough to allow a subsequent permanent cement plug to be placed. Lead wool might find another good use in plugging where the plug is not longer than one foot. It is advisable to make all such plugging jobs safe by using cement.

Practically all bottom hole plugging in the Papoose field has been done with lead plugs or lead wool. One well, namely, Indian Territory Illuminating Oil Company J. Williams No. 4, was successfully plugged back with cement. This well had been drilled to a depth of 3382 feet in order to determine the total thickness of the Papoose sand. The well was plugged back to 3305 feet with cement placed by the dump bailer method.

When cement has been correctly placed, sufficiently set and tested in the bottom of a hole the operator knows definitely that

Table No. 15. *ANALYSES OF PAPOOSE FIELD WATERS.* (*Parts per million.*)

	Papoose sand 3310'—3311' 34-10 9 I.T.I.O. Williams No. 4	Papoose sand 3347'—3374' 34-10 9 I.T.I.O. Williams No. 4	Papoose sand 3326'—3332' 9-9-9 Papoose Co. T. Hill No. 1	Gilcrease Sand 3090'— 34-10 9 I.T.I.O. Williams No. 4	Gilcrease Sand 3061'—3075' 17-9-9 Wilcox Charity Brow No. 3	Water Sand 2720'—2730' 22-9-9 Gypsy F. Bowlegs No. 1	Water Sand 1595'— 22-9-9 Gypsy F. Bowlegs No. 1	Water Sand 1055'— 22-9-9 Gypsy F. Bowlegs No. 1	Water Sand 825'—850 22-9-9 Gypsy F. Bowlegs No. 1	Water Sand 660'— 22-9-9 Gypsy F. Bowlegs No. 1	Water Sand 450'— 22-9-9 Gypsy F. Bowlegs No. 1	Water Sand 195'— 22-9-9 Gypsy F. Bowlegs No. 1
Silica SiO_2			200		400	400	150	300	200	200	90	30
Iron Fe	2,094	2,094	140	2,094	140	2,792	3,141	4,188	2,094	4,188	1,675	35
Calcium Ca	9,175	9,256	10,258	8,755	12,943	10,338	6,151	5,770	3,847	4,047	1,655	80
Magnesium Mg	1,424	1,424	1,533	1,369	2,497	1,883	1,522	1,664	1,205	1,336	542	39
Sodium Na	46,920	46,354	52,018	40,265	47,131	42,649	23,367	23,591	19,431	17,024	11,372	1,574
Carbonate CO_3												6
Bicarbonate HCO_3	43	18	37	61	24	55	61	55	49	140	12	1,110
Sulphate SO_4	495	483	247	240	242				23			74
Chloride Cl	95,032	94,324	102,834	84,040	102,834	93,083	55,318	56,736	42,552	42,552	24,171	2,021
Total Solids	155,184	153,953	167,267	136,824	166,211	151,200	89,710	92,304	69,401	69,487	39,517	4,969
Reactional values expressed in percentages (Palmer)												
Silica SiO_2												
Iron Fe	1.39	1.40	.09	1.58	.08	1.90	3.61	4.68	3.09	6.23	4.40	.81
Calcium Ca	8.51	8.65	8.81	9.19	11.11	9.82	9.83	8.99	7.92	8.40	6.06	2.59
Magnesium Mg	2.17	2.19	2.16	2.37	3.53	2.95	4.01	4.28	4.08	4.57	3.26	2.08
Sodium Na	37.93	37.76	38.94	36.86	35.28	35.33	32.55	32.05	34.91	30.80	36.28	44.52
Carbonate CO_3												.15
Bicarbonate HCO_3	.02	.01	.01	.02	.01	.02	.03	.03	.03	.10	.01	11.84
Sulphate SO_4	.19	.18	.09	.11	.09				.02			1.00
Chloride Cl	49.79	49.81	49.90	49.87	49.90	49.98	49.97	49.97	49.95	49.90	49.99	37.01
Total Solids	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Spec. Gravity	1.107?	1.108?	1.112	1.097	1.116	1.104	1.065	1.067	1.050	1.051	1.029	1.002

water from points below the top of the cement plug has been shut off and that any additional water produced must necessarily come from above the plug, at some point up the hole. The U. S. Bureau of Mines recognizes cement to be the best material for plugging off water and recommends its use in preference to any other product or mechanical plug. It has the advantage of flowing readily, thus filling all irregularities in the wall of the hole, and under favorable conditions makes an excellent bond with the side wall.

WATER ANALYSES.

Water analyses may be used in some fields to advantage in the determination of the source of water in a well when representative samples from the producing and overlying sands have been previously obtained and analyzed for comparison.

The analyses of waters from the diferent sands of this area are shown in Table 15. The samples of water from the different wells were obtained with the cooperation of the various companies that operated the wells, and are thought to be representative samples of the sands from which taken. Time and opportunity were not available for making a full study of the use of water analysis in the Papoose field but the analyses of several waters are included in Table 15 for the preliminary use of the engineer or operator doing any further water work by analysis in the field.

BOTTOM HOLE PLUGGING WITH CEMENT

In the repair of wells that produce edge or bottom water in the Papoose field, it is recommended that cement, placed in the hole either by the tubing or dump baling method, be used to plug off the water.

Before repair work is started, the well should be accurately gaged as to oil and water production over a period of at least three days and a similar gage taken after the repair work is done in order to determine the results obtained before commencing any additional work on the well.

The hole should be cleaned out to the bottom and the total depth accurately measured before the cement is placed. In measuring the well, the steel line measurement should be checked by cable or sand line measurement. In many instances a steel measuring line has become permanently stretched and will give inaccurate results; also, cavings or heavy mud and friction against the side wall will sometimes make the "pickup" difficult to determine.

THE TUBING METHOD

When the tubing method is used, the cement can be placed at any predetermined level by raising the tubing to that level after the cement has been placed, and all excess cement can be washed out by circulating water down through the tubing and up out of

the casinghead. A detailed description of this method is given in a U. S. Bureau of Mines publication.[1]

THE DUMP BAILER METHOD

As only a small amount of cement need usually be placed in bottom hole plugging, and since the irregular water level will necessarily make the procedure one of stage plugging, the dump bailer method is recommended in preference to the tubing method in the plugging back of the affected wells in the Papoose field.

Preparatory to the placing of cement in the well, the water coming into the hole from the sand should be allowed to reach its level so as to prevent the washing and channeling of cement by incoming water. A saving in time may be gained by filling the hole with clear, fresh water. This will also insure a hard setting of the cement plug.

In bottom hole plugging with the dump bailer method, the amount of cement necessary to fill the hole a given height should be computed before the cement is placed in the well. It is apparent that irregularities in the size of the hole will make the height of the cement plug uncertain and thus necessitate the placing of an additional amount of cement if the plug is not of sufficient height or the drilling out of a portion of the plug, should it be too high. This, however, can be readily accomplished, the only disadvantage being the time loss involved.

The amount of cement necessary to furnish a plug of a given height, may be computed by reference to Table 16, which gives the capacity per linear foot for holes of different diameter in cubic feet, and the number of linear feet filled by one sack of cement.

In computing the necessary amount of cement, a small allowance must be made for a certain amount of cement at the top of the plug that will not set, due to washing. Where only a small

Table No. 16. Capacity per lineal foot and capacity per 100 feet, in cubic feet for various sized holes; number of sacks cement required to fill 100 linear feet; and number of linear feet filled by one sack cement in various sized holes.

Size and Weight of Casing		Actual Inside Diameter	Capacity Per Linear Foot	Capacity Per 100 Linear Foot	Number Sacks Cement to Fill 100 Linear Feet*	Number of Linear Feet Filled by 1 Sack Set Cement
Inches	Lbs.	Inches	Cu. Ft.	Cu. Ft.	Sacks	Feet
10	40	10.054	.5509	55.09	50.081	2.00
8¼	28	8.017	.3503	35.03	31.836	3.14
8¼	32	7.921	.3420	34.20	31.090	3.22
6⅝	24	6 336	.2190	20.90	19.909	5.02
5-3/16	17	4.892	.1305	13.05	11.863	8.43

*One sack dry cement contains approximately 1 cubic foot.
One sack set cement mixed with 40% water contains approximately 1.10 cubic feet.

1. Tough, F. B., Methods of shutting off water in oil and gas wells, Bulletin 163. Bureau of Mines.

quantity of cement is used and the hole is of small diameter, not more than one linear foot should be computed.

SUGGESTIONS FOR USE OF DUMP BAILER.

A cement box should be provided and placed immediately adjacent to the casinghead on the rig floor. It should be of sufficient size, so that cement can be easily and quickly mixed. A convenient size for jobs on deep holes where a small bailer is used, is a cement box 4 feet by 6 feet, with side walls one foot high. A small sluice door or gate, should be built in one end with a sheet metal spout attached. The mixing box should be mounted on legs or blocked up to a height from 2½ to 3 feet above the derrick floor, and so placed that the spout end is above the casinghead and will pour mixed cement directly into the top of the bailer when it is hanging in the hole even with the spout.

When the mixing box stands above the floor, the cement is more easily mixed and conveniently handled, and the box is above all casinghead connections and fittings. The mixing box should be slightly inclined toward the casinghead so the cement will run readily through the sluice gate when opened.

The cement should be mixed neat (without sand) and with clean water to a consistency as thick as can be handled by a dump bailer and, at the same time, if free from all lumps and foreign matter. A relatively thick mixture consisting of 40 pounds of water (5 gallons) per sack of cement (about 94 pounds) is recommended. Mixing should be done as rapidly as possible and cement placed immediately after mixing. Not more than two hours should be used in placing any one portion of the plug and 24 hours should intervene between each stage. Only sufficient cement should be mixed at one time to fill the dump bailer. While the loaded bailer is being run in the hole another batch should be mixed to be ready for use when the empty bailer is withdrawn, if more than one bailer of cement is used.

The loaded dump bailer must be lowered carefully in the hole to prevent tripping and dumping of the cement up the hole, likely to be caused when entering the top of the fluid or by coming in contact with some obstruction. When the bottom of the hole has been reached, as shown by pickup of bailer, and accurately placed flag on sand line, the bailer should be raised and lowered a few feet to insure tripping of latch-jack. The bailer should then be slowly withdrawn to allow the cement to pass out of bailer with as little agitation and washing action as possible. There are other good dump bailers than the latch-jack type which may be used and require different methods of dumping. After the first few hundred feet the bailer may be pulled more rapidly from the hole.

CEMENT.

Any standard brand of Portland cement in good condition may be successfully used in oil well cementing. It is considered good policy to first test a small portion of the cement to be used, before cementing of the well begins. In this test the cement should be mixed with the same water to be used in the mixing at the well and allowed to set in a suitable jar filled with the water that will be contained in the hole of the well and after 24 hours inspected for hardness of set. This will give an indication of whether the well water will have any disturbing influence on the setting of the cement.

One brand of cement now on the market containing a high percentage of aluminum hardens very quickly, although the initial set is slightly slower than Portland cement. Tests have shown this cement to take its final set in sixteen hours and to be as hard as ordinary Porland cement, which has set seven days. This cement has been widely recommended for oil field use and has been successfully used in most instances. It should find especial value in repair work where quick hardening qualities are required.

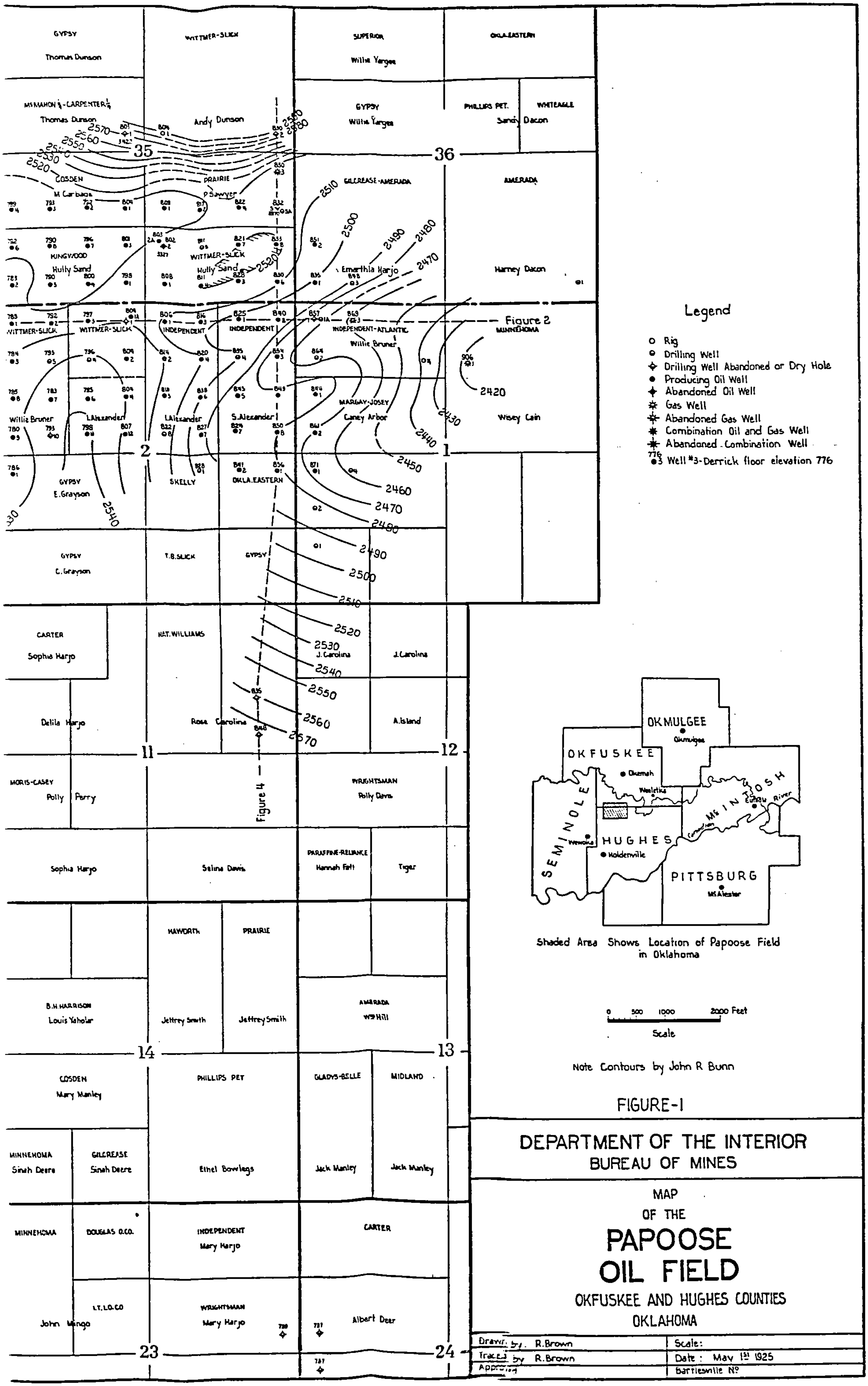
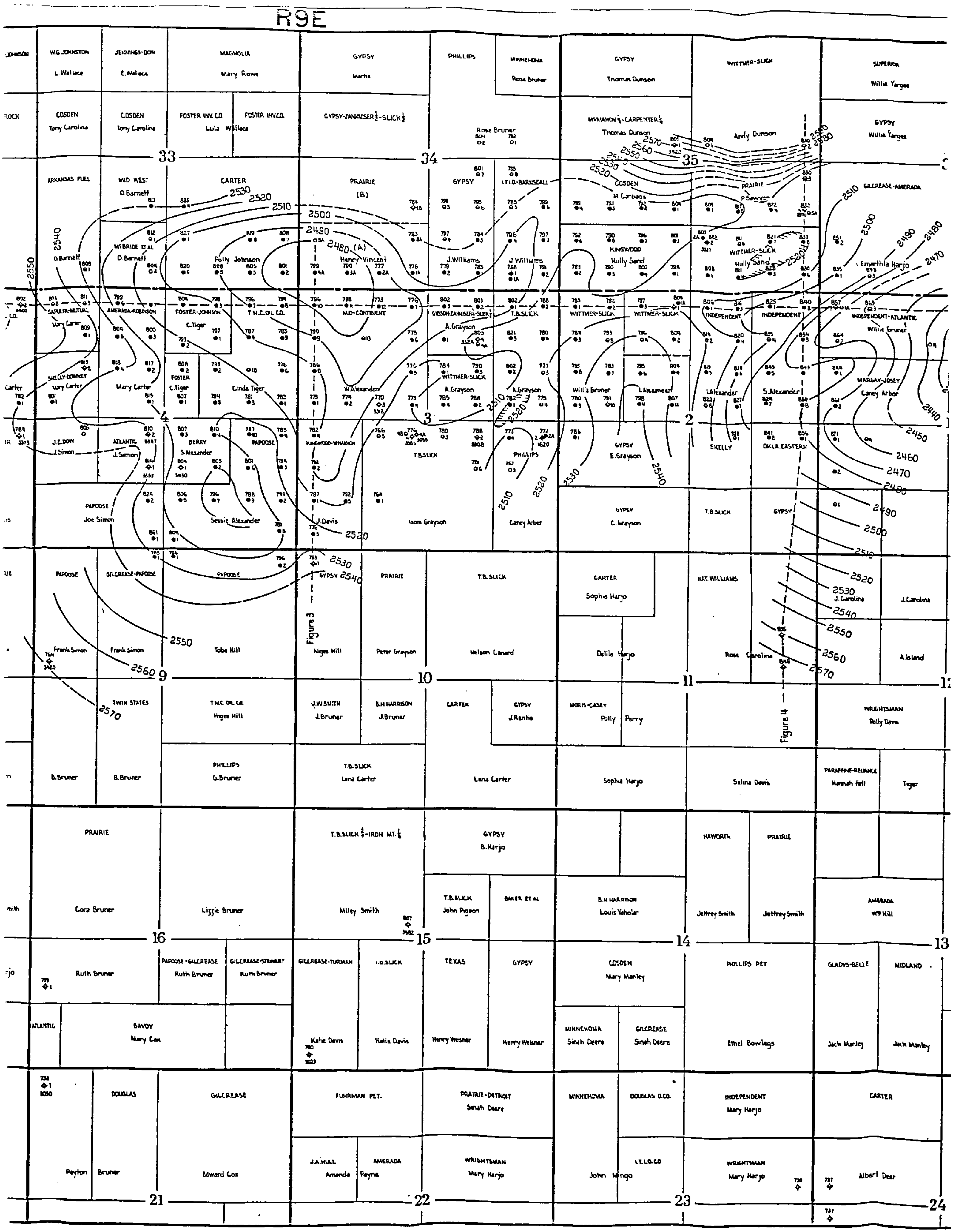


FIGURE-1

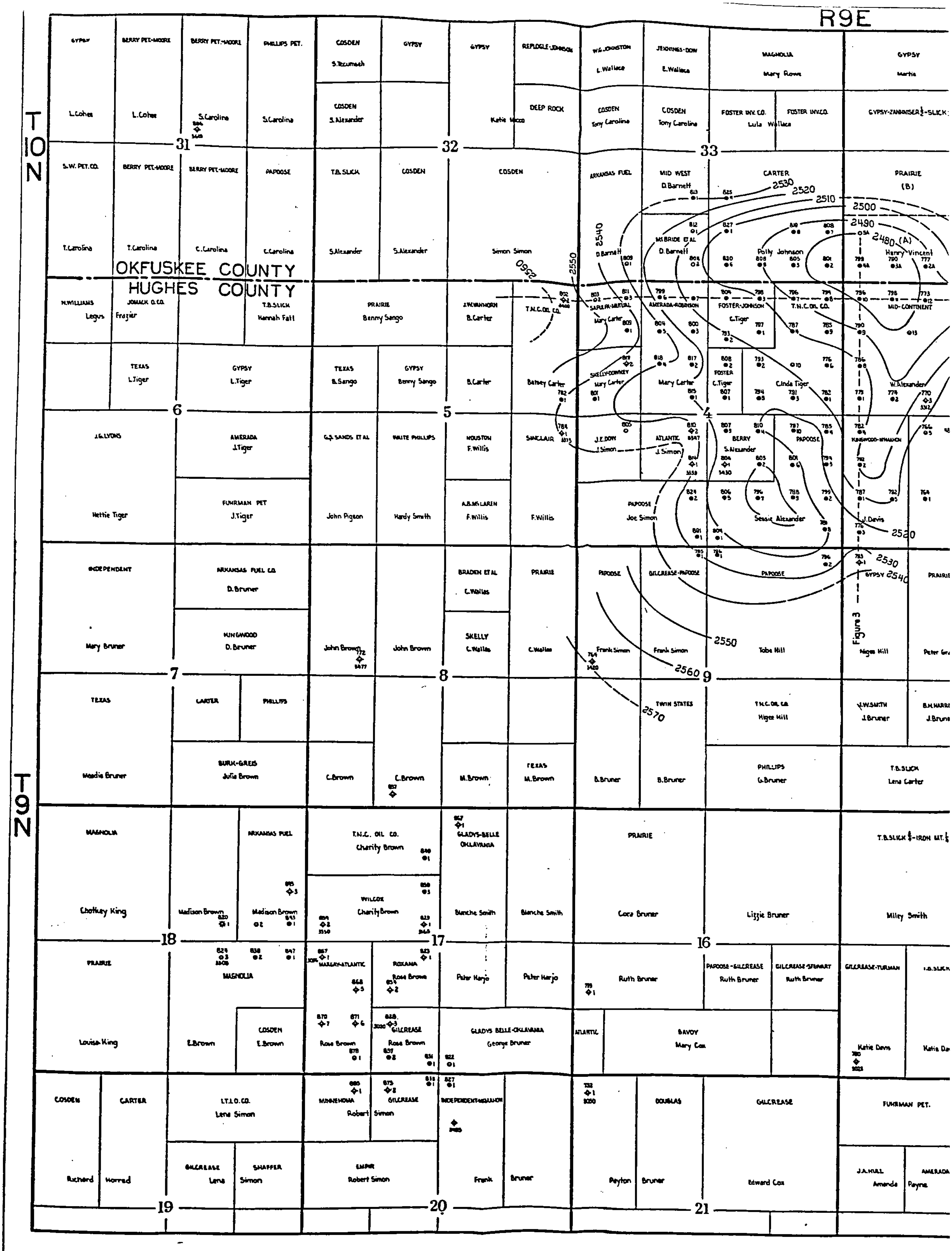
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

MAP
OF THE
PAPOOSE OIL FIELD
OKFUSKEE AND HUGHES COUNTIES
OKLAHOMA

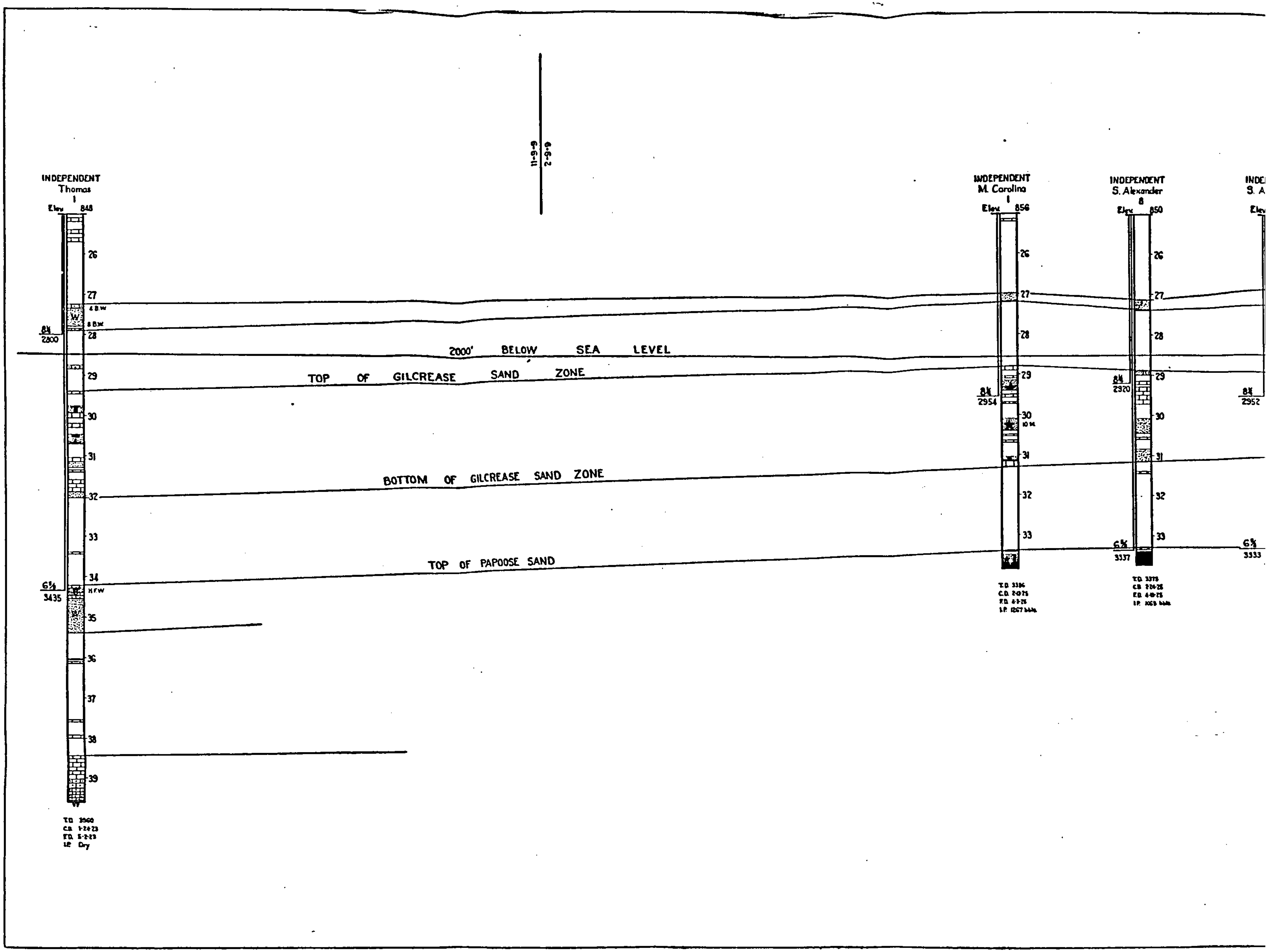
Drawn by R.Brown	Scale:
Traced by R.Brown	Date: May 1st 1925
Approved	Bartlesville No

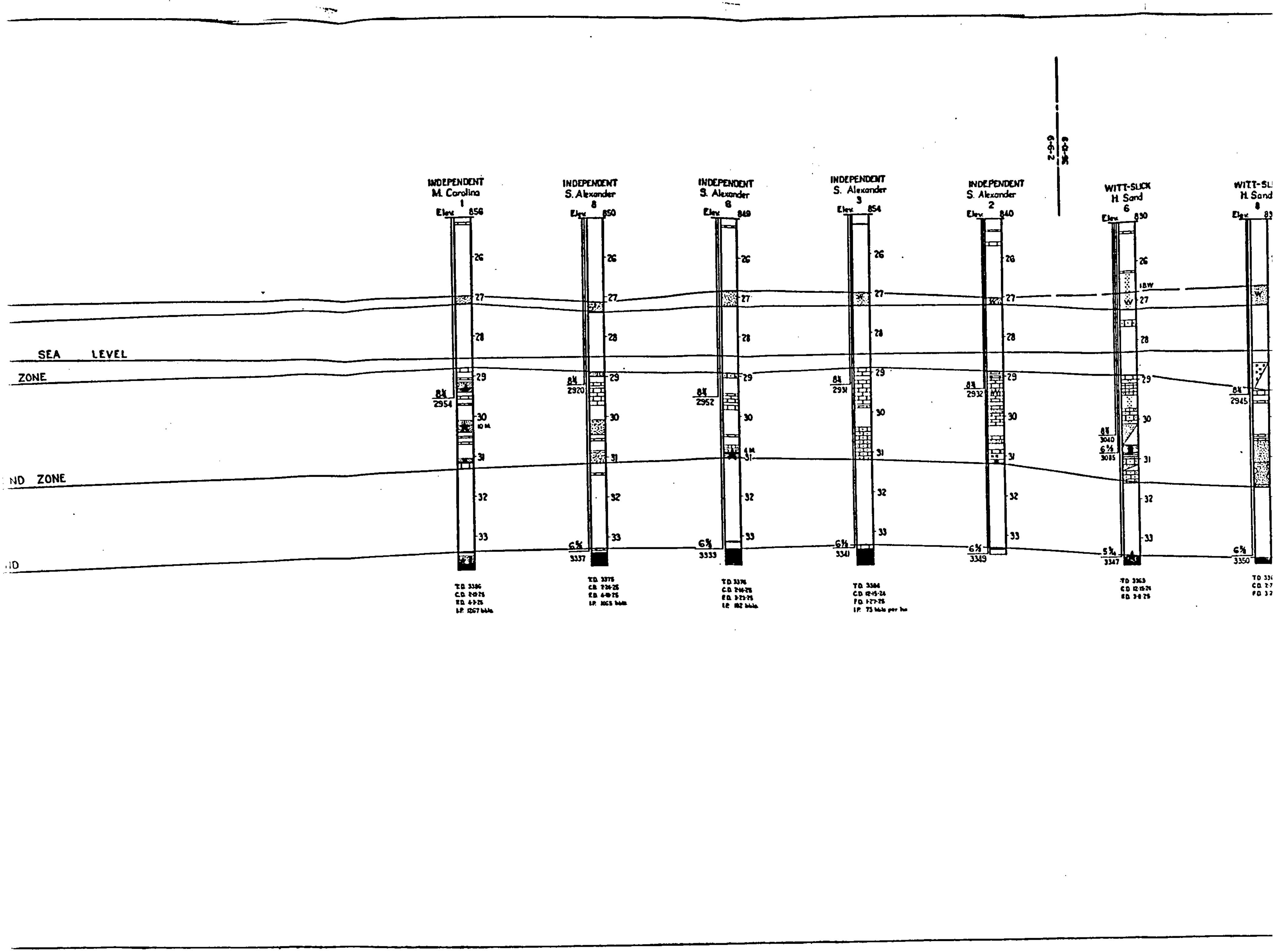


R9E
W.G. JOHNSTON
L. Wallace
JENNINGS-DOW
E. Wallace
MAGNOLIA
Mary Rowe
GYPSY
Martha
PHILLIPS
MINNEHOMA
Rose Bruner
GYPSY
Thomas Dunson
WITTMER-SLICK
SUPERIOR
Willie Yargee
COSDEN
Tony Carolina
COSDEN
Tony Carolina
FOSTER INV. CO.
Lula Wallace
FOSTER INV. CO.
GYPSY-ZANDPSER ½-SLICK ½
Rose Bruner
McMAHON ¾-CARPENTER ¼
Thomas Dunson
Andy Dunson
GYPSY
Willie Yargee
33
34
35
ARKANSAS FUEL
MID WEST
D. Barnett
CARTER
PRAIRIE
(B)
GYPSY
LT. LD.-BARNSDALL
COSDEN
M. Carbage
PRAIRIE
P. Sawyer
GILCREASE-AMERADA
McBRIDE ET AL
D. Barnett
Polly Johnson
Henry Vincent
(A)
J. Williams
J. Williams
KINGWOOD
Hully Sand
WITTMER-SLICK
Hully Sand
Emarthla Harjo
SAPULPA-MUTUAL
Mary Carter
AMERADA-ROBINSON
FOSTER-JOHNSON
C. Tiger
T.N.C. OIL CO.
MID-CONTINENT
GIBSON-ZANDPSER ½-SLICK ½
A. Grayson
T.B. SLICK
WITTMER-SLICK
WITTMER-SLICK
INDEPENDENT
INDEPENDENT
INDEPENDENT-ATLANTIC
Willie Bruner
SHELLY-DOWNEY
Mary Carter
Mary Carter
FOSTER
C. Tiger
Cinda Tiger
W. Alexander
WITTMER-SLICK
A. Grayson
A. Grayson
Willie Bruner
L. Alexander
L. Alexander
S. Alexander
MARGAY-JOSEY
Caney Arbor
4
3
2
J.E. DOW
J. Simon
ATLANTIC
J. Simon
BERRY
S. Alexander
PAPOOSE
KINGWOOD-McMAHON
T.B. SLICK
PHILLIPS
GYPSY
E. Grayson
SKELLY
OKLA. EASTERN
PAPOOSE
Joe Simon
Sessie Alexander
J. Davis
Isom Grayson
Caney Arbor
GYPSY
C. Grayson
T.B. SLICK
GYPSY
PAPOOSE
GILCREASE-PAPOOSE
PAPOOSE
GYPSY
PRAIRIE
T.B. SLICK
CARTER
Sophia Harjo
NAT. WILLIAMS
J. Carolina
J. Carolina
Figure 3
Frank Simon
Frank Simon
Tobe Hill
Nigee Hill
Peter Grayson
Nelson Canard
Delila Harjo
Rose Carolina
A. Island
9
10
11
12
TWIN STATES
T.N.C. OIL CO.
Nigee Hill
J.W. SMITH
J. Bruner
B.H. HARRISON
J. Bruner
CARTER
GYPSY
J. Rentie
MORIS-CASEY
Polly Perry
Figure 4
WRIGHTSMAN
Polly Dave
B. Bruner
B. Bruner
PHILLIPS
G. Bruner
T.B. SLICK
Lena Carter
Lena Carter
Sophia Harjo
Salina Davis
PARAFFINE-RELIANCE
Hannah Fell
Tiger
PRAIRIE
T.B. SLICK ¾-IRON MT. ¼
GYPSY
B. Harjo
HAWORTH
PRAIRIE
T.B. SLICK
John Pigeon
BAKER ET AL
B.H. HARRISON
Louis Yaholar
AMERADA
W.P. Hill
Cora Bruner
Lizzie Bruner
Miley Smith
Jeffrey Smith
Jeffrey Smith
16
15
14
13
Ruth Bruner
PAPOOSE-GILCREASE
Ruth Bruner
GILCREASE-STEWART
Ruth Bruner
GILCREASE-TURMAN
T.B. SLICK
TEXAS
GYPSY
COSDEN
Mary Manley
PHILLIPS PET
GLADYS-BELLE
MIDLAND
ATLANTIC
SAVOY
Mary Cox
Katie Davis
Katie Davis
Henry Weisner
Henry Weisner
MINNEHOMA
Sinah Deere
GILCREASE
Sinah Deere
Ethel Bowlegs
Jack Manley
Jack Manley
DOUGLAS
GILCREASE
FUHRMAN PET.
PRAIRIE-DETROIT
Sinah Deere
MINNEHOMA
DOUGLAS O.CO.
INDEPENDENT
Mary Harjo
CARTER
J.A. HULL
Amanda
AMERADA
Payne
WRIGHTSMAN
Mary Harjo
LT. LD. CO.
John Mingo
WRIGHTSMAN
Mary Harjo
Peyton Bruner
Edward Cox
Albert Dear
21
22
23
24



R9E
T10N
T9N
OKFUSKEE COUNTY
HUGHES COUNTY
31
32
33
6
5
4
7
8
9
18
17
16
19
20
21
2480 (A)
2490
2500
2510
2520
2530
2540
2550
2560
2570
Figure 3
CARTER
PRAIRIE (B)
MAGNOLIA
Mary Rowe
GYPSY
Polly Johnson
Harry Vincent
FOSTER-JOHNSON
C.Tiger
T.N.C. OIL CO.
MID-CONTINENT
AMERADA-ROBINSON
SAPULPA-MUTUAL
Mary Carter
SKELLY-COWDEY
Betsey Carter
Linda Tiger
W.Alexander
J.E.DOW
J.Simon
ATLANTIC
BERRY
S.Alexander
PAPOOSE
Joe Simon
Sessie Alexander
J.Davis
GILCREASE-PAPOOSE
Frank Simon
Tobe Hill
TWIN STATES
Higee Hill
Mary Bruner
D.Bruner
John Brown
C.Wallas
Charity Brown
Madison Brown
Chotkey King
Blanche Smith
Cora Bruner
Lizzie Bruner
Milley Smith
Peter Harjo
Ruth Bruner
Rose Brown
George Bruner
Mary Cox
Louisa King
Lena Simon
Robert Simon
Edward Cox


11-9-9
2-9-9
INDEPENDENT
Thomas
1
Elev 848
INDEPENDENT
M. Carolina
1
Elev 856
INDEPENDENT
S. Alexander
8
Elev 850
2000' BELOW SEA LEVEL
TOP OF GILCREASE SAND ZONE
BOTTOM OF GILCREASE SAND ZONE
TOP OF PAPOOSE SAND
8¼
2800
6¼
3435
8¼
2954
8¼
2920
8¼
2952
6⅝
3337
6⅝
3333
T.D. 3960
I.P. Dry


SEA LEVEL
ZONE
ND ZONE
INDEPENDENT
M. Carolina
1
Elev. 856
INDEPENDENT
S. Alexander
8
Elev. 850
INDEPENDENT
S. Alexander
6
Elev. 849
INDEPENDENT
S. Alexander
3
Elev. 854
INDEPENDENT
S. Alexander
2
Elev. 840
WITT-SLICK
H. Sand
6
Elev. 830
26
27
28
29
30
31
32
33
2954
2920
2952
2931
2932
2945
3040
3085
3337
3333
3341
3349
3347
3350

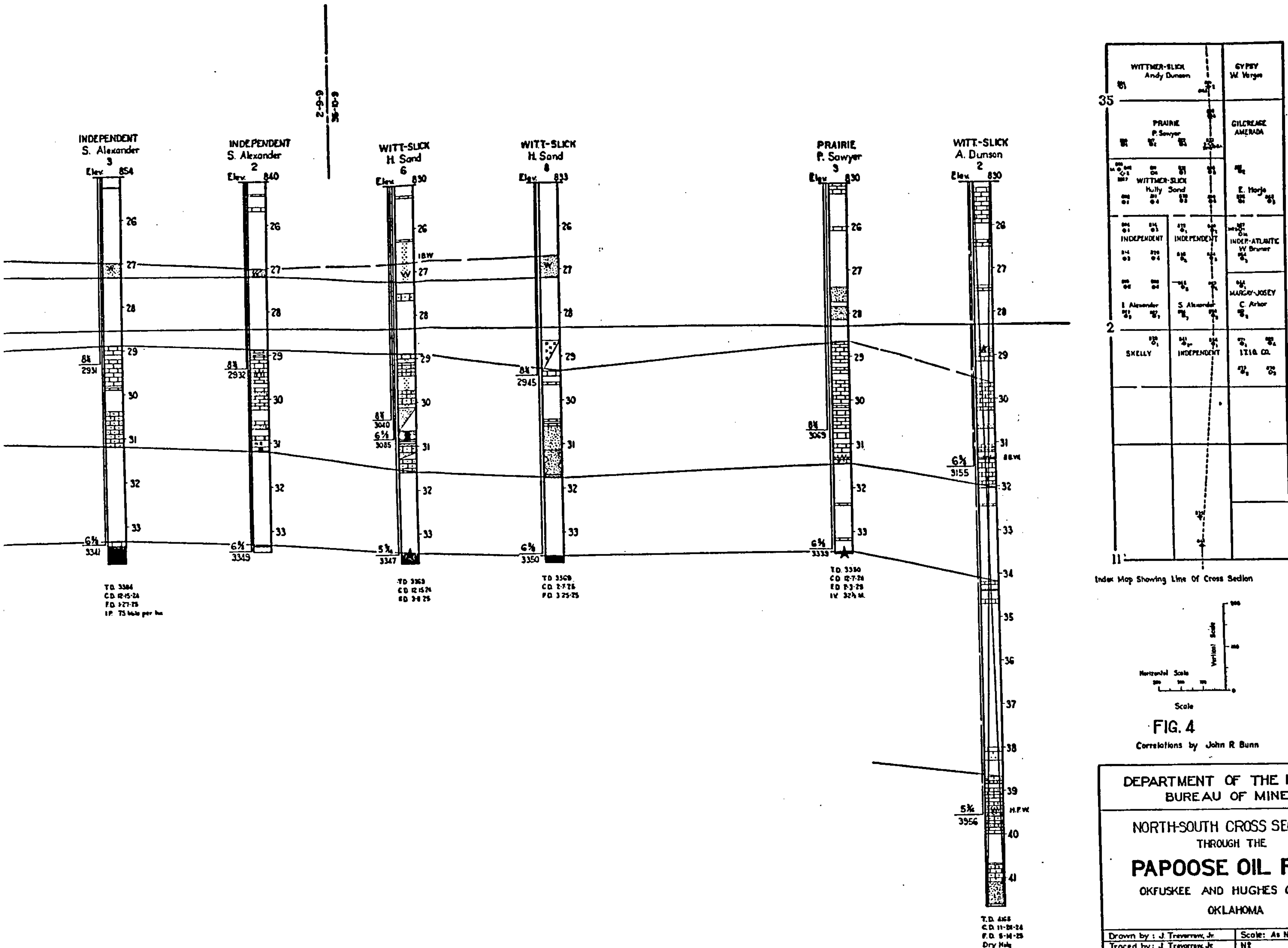


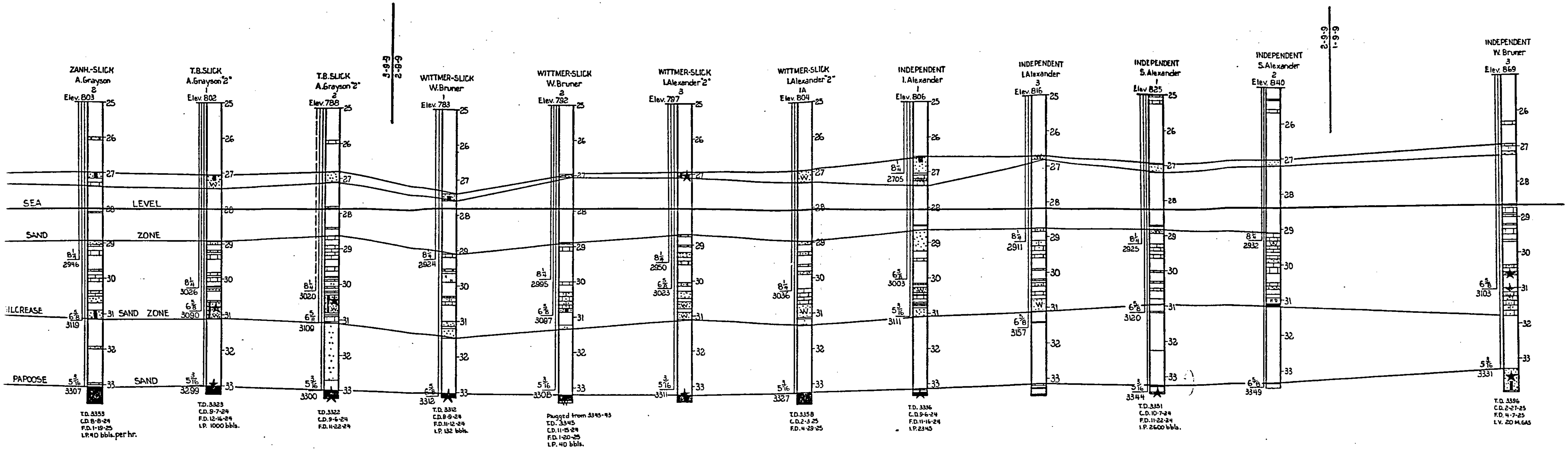
FIG. 4

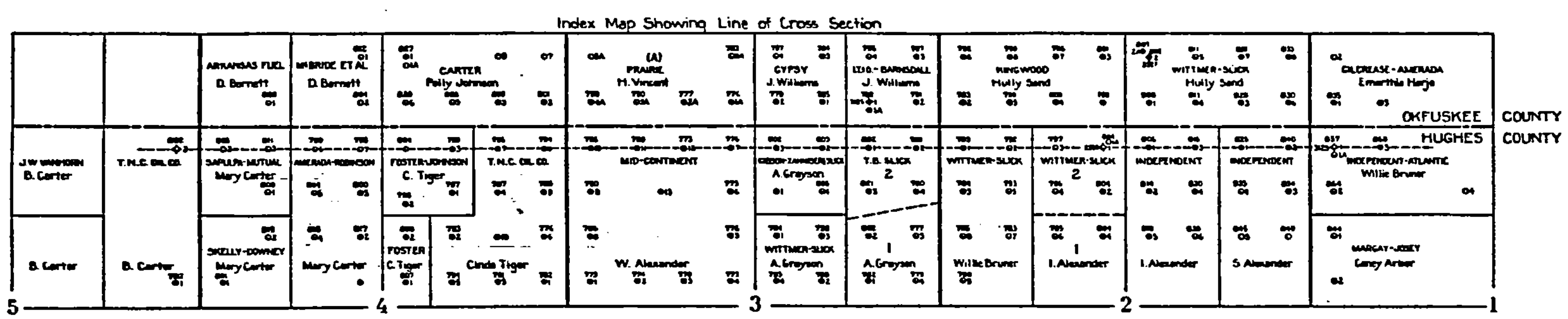
Correlations by John R. Bunn

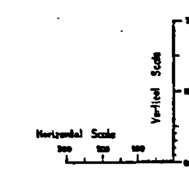
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

NORTH-SOUTH CROSS SECTION
THROUGH THE
PAPOOSE OIL FIELD
OKFUSKEE AND HUGHES COUNTIES
OKLAHOMA

Drawn by: J. Trevorrow, Jr.	Scale: As Noted
Traced by: J. Trevorrow, Jr.	No.
Approved by:	Date: May 1, 1925







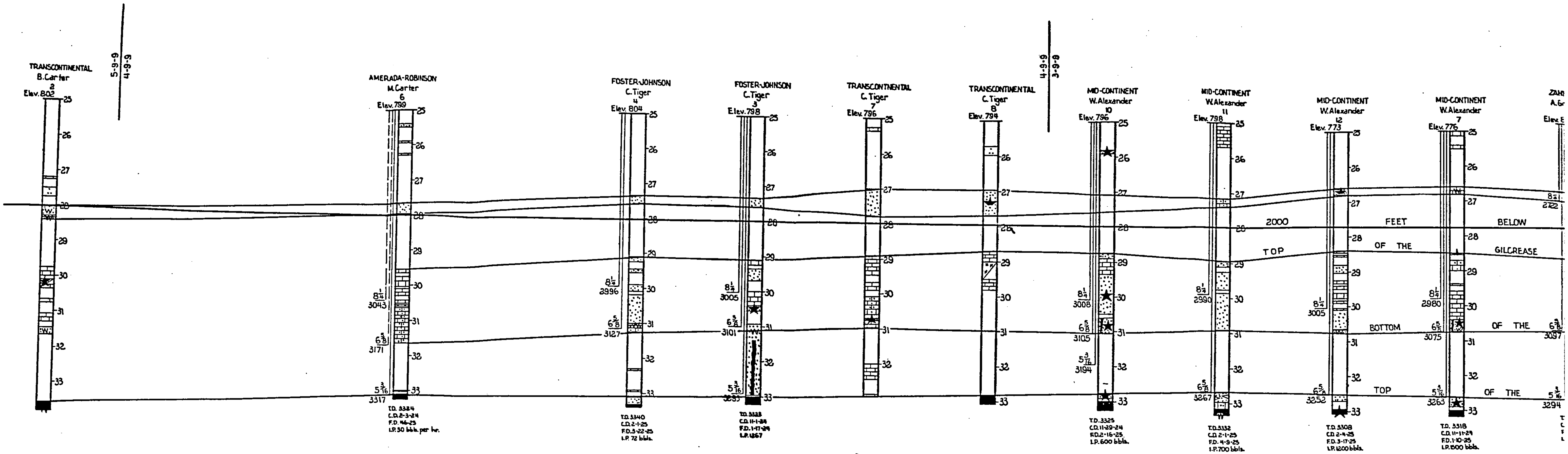
Correlations by John R. Bunn

FIGURE 2

DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

EAST-WEST CROSS SECTION
THROUGH THE
PAPOOSE OIL FIELD
OKFUSKEE AND HUGHES COUNTIES
OKLAHOMA

Drawn by: R. Brown	Scale: As Noted
Traced by: R. Brown	No.
Approved by:	Date: May 1, 1925



TRANSCONTINENTAL
B. Carter
2
Elev. 802
5-9-9
4-9-9
AMERADA-ROBINSON
M. Carter
6
Elev. 799
T.D. 3384
FOSTER-JOHNSON
C. Tiger
4
Elev. 804
T.D. 3340
C.D. 2-1-25
F.D. 3-22-25
I.P. 72 bbls.
FOSTER-JOHNSON
C. Tiger
3
Elev. 798
TRANSCONTINENTAL
C. Tiger
7
Elev. 796
TRANSCONTINENTAL
C. Tiger
8
Elev. 794
4-9-9
3-9-8
MID-CONTINENT
W. Alexander
10
Elev. 796
MID-CONTINENT
W. Alexander
11
Elev. 798
MID-CONTINENT
W. Alexander
12
Elev. 773
MID-CONTINENT
W. Alexander
7
Elev. 776
2000 FEET BELOW
TOP OF THE GILCREASE
BOTTOM OF THE
TOP OF THE

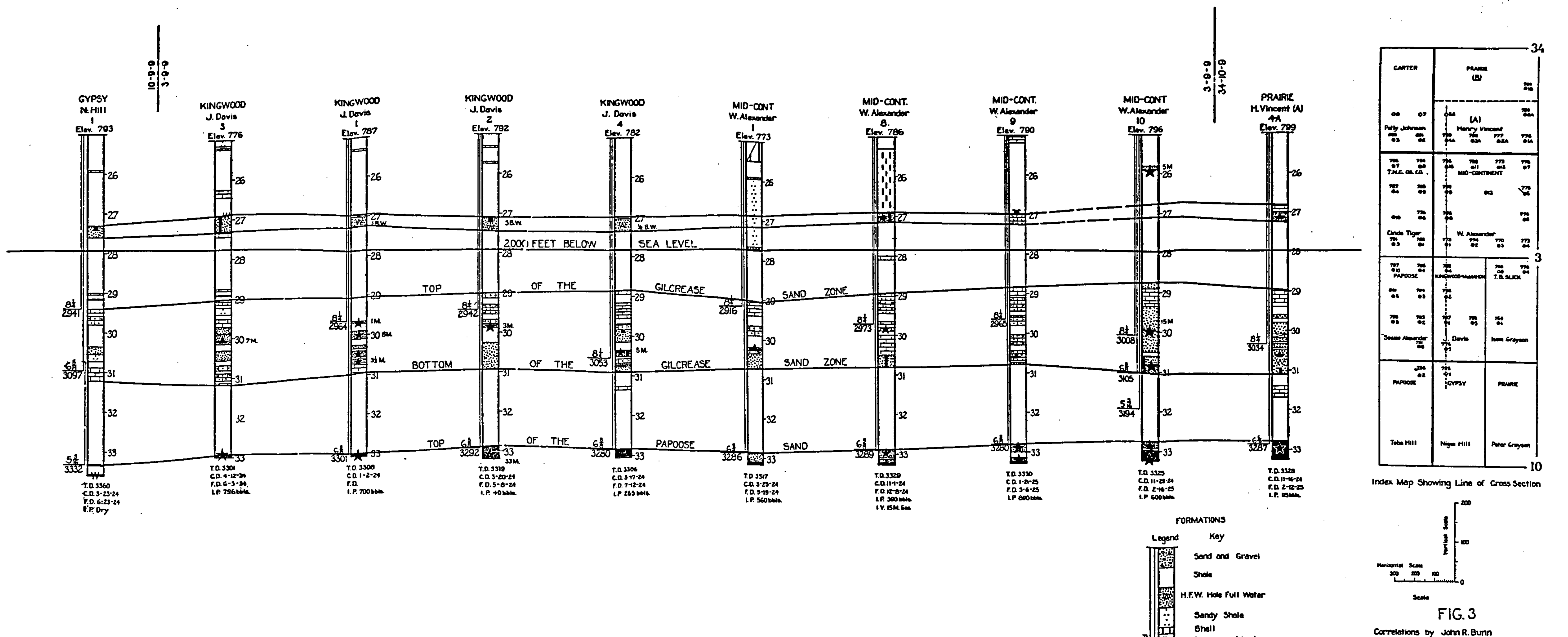


FIG. 3

DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

NORTH-SOUTH CROSS SECTION
THROUGH THE

PAPOOSE OIL FIELD

OKFUSKEE AND HUGHES COUNTY
OKLAHOMA

Drawn by: C.L. Cushman	Scale: As noted
Traced by: C.L. Cushman	No:
Approved by:	Date: May 1, 1925