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FIELD PROJECT TO OBTAIN PRESSURE CORE, WIRELINE LOG, AND PRODUCTION TEST DATA FOR EVALUATION OF CO_2 FLOODING POTENTIAL

Texas Pacific Bennett Ranch Unit Well No. 310, Wasson (San Andres) Field, Yoakum County, Texas

Final Report

By
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Raj M. Kumar
R. L. McCoy
Miles H. Wilhelm
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John H. Goodrich
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May 1982
Date Published

Work Performed Under Contract No. AC21-79MC08341

Gruy Federal, Inc.
Houston, Texas

U. S. DEPARTMENT OF ENERGY

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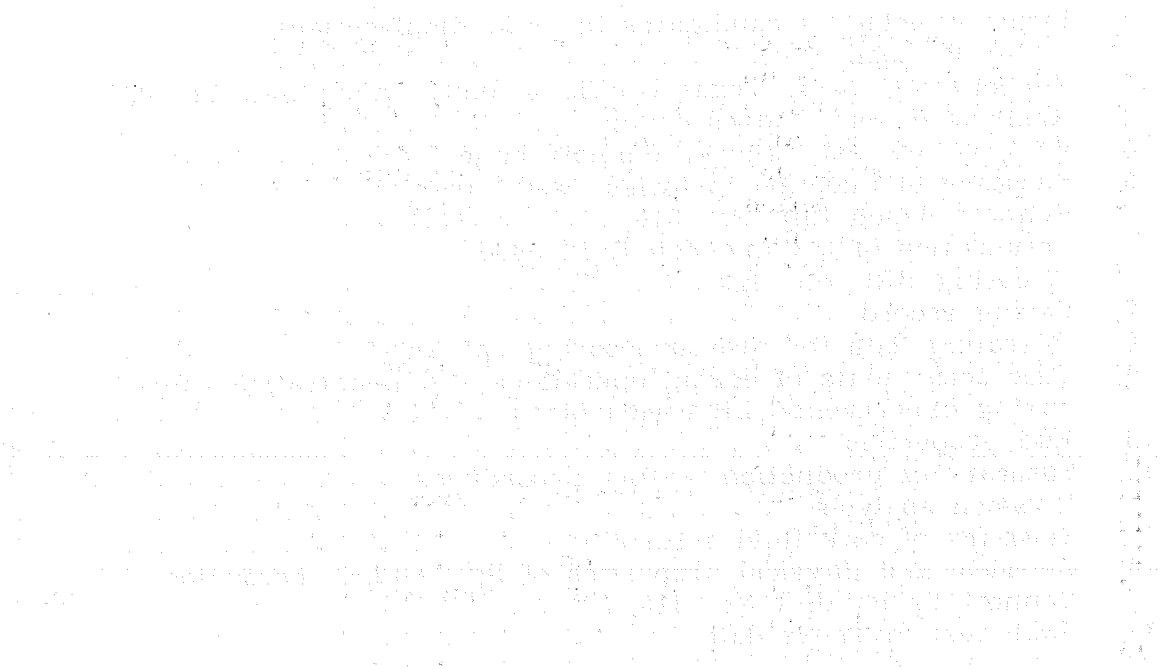


EXECUTIVE SUMMARY

The coring, logging and testing of Bennett Ranch Unit well No. 310 was a cooperative effort between Texas Pacific, owner of the well, and Gruy Federal, Inc., undertaken to fulfill a contract awarded to Gruy Federal, Inc. by the Department of Energy (DOE) on February 12, 1979. The requirements of the contract, which are summarized in Enclosure 1, Appendix A, include drilling and coring activities. The pressure-coring and associated logging and testing programs in selected wells are intended to provide data on in-situ oil saturation, porosity and permeability distribution, and other data needed for resource characterization of fields and reservoirs in which CO_2 injection might have a high probability of success. This report presents detailed information on the first such project.

The well was spudded on September 15, 1979, and drilled to 5,150 feet, where Gruy Federal assumed responsibility after 8-5/8-inch protective casing was set and cemented on September 28, 1979. The shoe was drilled out to a depth of 5,175 feet, where coring was begun on September 30, 1979. A total of 27 core barrel runs were made by Diamond Oil Well Drilling Company to recover 26 cores in a 210-foot interval from 5,175 to 5,385 feet. Of the 26 core barrel runs that recovered core, 20 retained pressure for a 77 percent success ratio. Failure to obtain pressured cores in the other six runs was attributed to no evident reason once, core slipping in the catcher, blocking the ball valve twice and failure of the ball valve to close three times.

Upon completion of the coring phase, a complete suite of geophysical logs were run by Schlumberger after which Texas Pacific resumed responsibility for the well, which was completed and tested.

Core analysis performed by Core Laboratories, Inc. included measurement of porosities, fluid saturations, permeabilities and pore-water chlorides, and gas chromatography was used to determine the composition of gas released from cores recovered with pressure. Samples were also selected for determination of the concentrations of the tracers in the pore water, by Teledyne Isotopes.

Log analysis performed by Gruy Federal, Inc. and results of swab tests and production pumping tests performed by Texas Pacific were also used in evaluating this field for CO_2 flooding potential.

Porosity and water saturation, as determined by core and log analysis, agreed well in intervals where cores were successfully retrieved under pressure and agreed poorly in intervals where cores were not retrieved under pressure. Four test intervals, 5,168-5,234 feet (first porosity), 5,248-5,302 feet (main pay), 5,325-5,332 feet (basal main pay) and 5,342-5,348 (transition zone through the oil-water contact) were the selected based on core and log analysis.

Core and log data were useful in determining the residual oil saturations and production data confirmed the validity of oil saturation determinations. Residual oil saturation, as arrived at by log and core analysis, ranged from 287 STB/acre-ft for the first porosity zone, to 419 STB/acre-ft for the main pay, to 345 STB/acre-ft for the basal main pay, to 417 STB/acre-ft for the transition zone. An established pumping production rate of 48 BOPD for the main pay and no oil production from the remaining zones qualitatively confirmed the residual oil saturations as well as permeabilities derived from core and log analysis.

This project demonstrates the usefulness of integrating pressure core, log and production data to realistically evaluate a reservoir for carbon dioxide flood. The engineering of tests and analysis of such experimental data requires original thinking, but the reliability of the results is higher than data derived from conventional tests.

FIELD PROJECT TO OBTAIN PRESSURE CORE, WIRELINE LOG, AND PRODUCTION TEST DATA FOR EVALUATION OF CO_2 FLOODING POTENTIAL

TEXAS PACIFIC BENNETT RANCH UNIT WELL NO. 310 WASSON (SAN ANDRES) FIELD, YOAKUM COUNTY, TEXAS

INTRODUCTION

This report is part of the work required to fulfill a contract awarded to Gruy Federal, Inc. by the Department of Energy (DOE) on February 12, 1979.[1,2] The requirements of the contract are summarized in Enclosure 1, Appendix A. The contract, originally awarded by DOE's Oak Ridge Operations Office,[3] is now administered by the Morgantown Energy Technology Center,[4] Morgantown, W. Va. It provides for DOE funding of research and development in the following areas:

- Summary of available CO_2 field test data.
- Summary of existing reservoir and geological data for carbonate reservoirs in West Texas, southeast New Mexico, and the Rocky Mountain states.
- Selection of target reservoirs.
- Selection of specific reservoirs for CO_2 injection tests.
- Selection of specific sites for test wells.
- Drilling and coring activities.

This program is designed to provide a solid engineering foundation upon which field mini- and pilot tests or full-scale projects can be implemented in carbonate reservoirs.

The pressure-coring and associated logging and testing programs in selected wells are intended to provide data on in-situ oil saturation, porosity and permeability distribution, and other data needed for resource characterization of fields and reservoirs in which CO_2 injection might have a high probability of success. This report presents detailed information on the first such project.

General Background Information

As a result of Gruy Federal's early work devoted to reviewing field test data (Task One of the contract) and summarizing existing reservoir and geologic data for selected carbonate reservoirs in West Texas, southeast New Mexico, and the Rocky Mountain states (Task Two of the contract), it was recognized that the contract program could be expedited by an "early

well" effort in reservoirs clearly identified as having CO_2 flooding potential. This program was planned to parallel continued work on contract Tasks One and Two.

To accomplish this, Gruy sought operators who planned, for their own purposes, to drill infill or replacement wells to or through reservoirs identified as having CO_2 flooding potential. These wells could be utilized to carry out a proposed coring and logging program.

The program provides for taking cores through the reservoir intervals of interest, using a core barrel that retains the cores under pressure for subsequent analysis. This would provide a more direct measure of in-situ oil and water saturations as well as porosity and permeability for comparison with data obtained from a comprehensive suite of wireline logs.

If, for the operator's purposes, a well is to be completed in the target reservoir, Gruy would propose to conduct or monitor production tests to obtain further data on the CO_2 flooding potential. These tests would be designed by Gruy on the basis of data from core and log analysis.

Specific Project Background

Gruy's preliminary screening work on Task Two identified the Grayburg-San Andres reservoirs as having the highest apparent potential for CO_2 flooding in the Permian basin of west Texas. A published study showed the San Andres reservoir of the Wasson Field to have a potential of some 670 million barrels recoverable from full-scale CO_2 flooding.[5] The data of Doscher and Wise, shown in Table 1, indicate that Wasson has the highest CO_2 flooding potential of the 12 Grayburg-San Andres reservoirs listed. As additional evidence of CO_2 flooding potential, pilot projects involving CO_2 injection had been or were being conducted on other waterflood units in the large Wasson field.[6] Hence Wasson was a logical candidate for an "early well" pressure-coring program.

Texas Pacific Well Site Selection. To implement the "early well" program, Gruy engaged the services of Chandler and Savage, a Midland (Texas) petroleum consulting partnership, to provide leads to opportunities of this type drawn from their numerous contacts with Permian basin oil operators. This was particularly fruitful; their efforts resulted in expressions of interest from ARCO, Cities Service, Continental, Exxon, Phillips, and Texas Pacific, all of whom were conducting or planning Permian basin drilling programs during the next one to two years. Texas Pacific is the operator of the 7,200-acre Bennett Ranch unit in the Wasson field and was planning an infill development program for 1979.

Gruy met with Texas Pacific's engineering staff to discuss methods by which pressure cores and other data could be obtained in the Bennett Ranch Unit No. 310 well, programmed for drilling as a San Andres producer in the Bennett Ranch waterflood unit. At this meeting, Texas Pacific indicated plans for pursuing a program to evaluate CO_2 displacement potential for tertiary recovery in the Bennett Ranch unit. This program would be materially aided by information from pressure cores; however, they considered that the expense could not be justified to their management and

TABLE 1

FIELDS SELECTED AS CANDIDATES
FOR CO_2 DISPLACEMENT IN THE PERMIAN BASIN*

Field Name	District/ State	Major Reservoir	Cumulative** production to 1976, bbl	Hypothesized recovery, MMbbl
Wasson	8A/Texas	San Andres	875,657,116	670
Slaughter	8A/Texas	San Andres	642,687,368	260
Levelland	8A/Texas	San Andres	242,675,781	200
Seminole	8A/Texas	San Andres	203,777,244	80
Fullerton	8/Texas	Permian	177,379,697	160
Kelly-Snyder	8A/Texas	Canyon	816,372,830	310
Diamond M	8A/Texas	Canyon Lime	196,622,305	60
Goldsmith	8/Texas	San Andres	285,990,706	130
North Cowden	8/Texas	Permian	259,005,979	130
South Cowden	8/Texas	San Andres	105,536,037	80
Foster	8/Texas	Grayburg	177,647,850	90
Howard-Glasscock	8/Texas	Yates	302,775,723	230
Ward Estes	8/Texas	Yates-Seven Rivers	315,080,915	120
Sand Hills	8/Texas	San Andres	94,933,812	220
McElroy	8/Texas	Grayburg	321,110,539	380
Yates	8/Texas	Grayburg-San Andres	619,642,206	500
Hobbs	N.M.	San Andres	226,978,885	160
Vacuum	N.M.	Grayburg	159,307,712	270

* Doscher, T. M., and Wise, F. A.: "Enhanced Crude Oil Recovery Potential--An Estimate," J. Pet. Tech. (May 1976), 575-585.

** Texas Railroad Commission Annual Report 1975 and Annual Report of the New Mexico Oil and Gas Engineering Committee, Hobbs, New Mexico, 1975.

other working-interest owners at this stage of their work. This meeting produced agreement that Texas Pacific would consider allowing pressure cores and other data to be taken while drilling this well, provided DOE approval of their required financial arrangements could be obtained. These conditions are outlined in a letter from Gruy Federal to Texas Pacific included here as Enclosure 2, Appendix A.

Following this, a proposal was submitted recommending that DOE provide funds to support a pressure-coring project in Bennett Ranch Unit No. 310.[7] Estimated costs of the project as proposed are shown in Table 2. This recommendation was based on the conclusion that use of DOE funds to pay for pressure cores and related data would:

- advance the state of the art of CO_2 flooding in general;
- provide Texas Pacific with information that could accelerate their justification for installing a CO_2 displacement project on the Bennett Ranch unit;
- provide information not otherwise available in the public domain (private project results will probably be kept confidential for a considerable period of time).

This would serve to advance toward DOE's stated goal of producing 124,000 incremental barrels of oil per day from CO_2 flooding by 1985. Approval of this proposal was received in early September 1979.[8]

Business Arrangements. The basic business arrangements agreed to before the start of field operations provided for:

- reimbursement of Texas Pacific for the additional costs incurred as a result of well plan revisions necessitated by pressure-coring operations;
- direct subcontracting by Gruy Federal for drilling rig costs during actual pressure coring and related operations;
- direct subcontracting by Gruy Federal for coring mud and related tracer material and service costs;
- direct subcontracting by Gruy Federal for pressure-coring services, core analysis services, and related special tool rentals, transportation, etc.;
- direct subcontracting by Gruy Federal for workover rig and completion costs for any special production tests not related to the operator's original well completion plans.

These arrangements proved both workable and economical in this specific case because pressure-coring operations were continuous and had identifiable starting and ending times.

TABLE 2

SUBCONTRACT COSTS
TEXAS PACIFIC BENNETT RANCH UNIT NO. 310

Description	Cost
Incremental costs to operator	$ 62,000
Pressure coring	126,854
Core analysis	96,810
Coring time on rig, 16 days @ $3,300/day	52,800
Coring mud	14,521
Logging	16,416
Workover rig, 15 days, 10 hr/day @ $69.55/hr	10,433
Perforation, 3 intervals	14,300
Stimulation, 3 intervals @ $7,587	22,761
Tool rental, 3 intervals @ $1,656	4,968
General liability insurance	838
Total Field Costs	$422,701
Materials acquisition and handling burden, 1.3% (Applied to materials and subcontracted costs in support of field operations)	5,495
Total	$428,196

WASSON FIELD GENERAL INFORMATION[7]

Location and History

The Wasson field encompasses 68,500 acres in Gaines and Yoakum Counties, on the southeastern edge of the North Basin platform of the Permian basin in West Texas (Fig. 1). Production from the San Andres dolomite of Permian age occurs at an average depth of 5,100 feet. Figure 2 shows the stratigraphic position of San Andres production in the geologic column. The San Andres pay, discovered in 1936, was largely developed by 1941. Waterflood operations began in 1964. Cumulative oil production from the San Andres through 1976 was 875 million barrels[9]; remaining reserves are estimated at over 600 million barrels. Production during 1977 was 80,203,000 barrels. Wasson is one of the largest oil fields in the United States to be completely unitized; the waterflood units and their present operators are:

Unit	Operator	Productive Area (acres)
Denver	Shell	25,505
ODC	Amoco	7,455
Willard	ARCO	13,500
Roberts	Texaco	11,240
Cornell	Cornell Oil Co.	1,920
Bennett Ranch	Texas Pacific	7,027
Mahoney	Mobil	640

The Bennett Ranch unit, formed by Texas Pacific in 1964, occupies 7,210 surface acres in the northeastern portion of Wasson (Fig. 3).

Geologic and Petrophysical Data

The Wasson structure is more or less domal, measuring about 15 miles from east to west and 14 miles from north to south. It is controlled by a NW-SE trending pre-Permian structural axis and by the buried Wichita-Albany shelf margin. The structure has two principal axes, one trending N. 60° W. and the other N. 30° E. The top of the first porous dolomite pay is encountered some 400 feet below the top of the San Andres formation. On the basis of perceptible petrophysical differences, the producing interval has customarily been divided into two major zones, an upper zone termed "First Porosity" and a deeper zone termed "Main Pay."

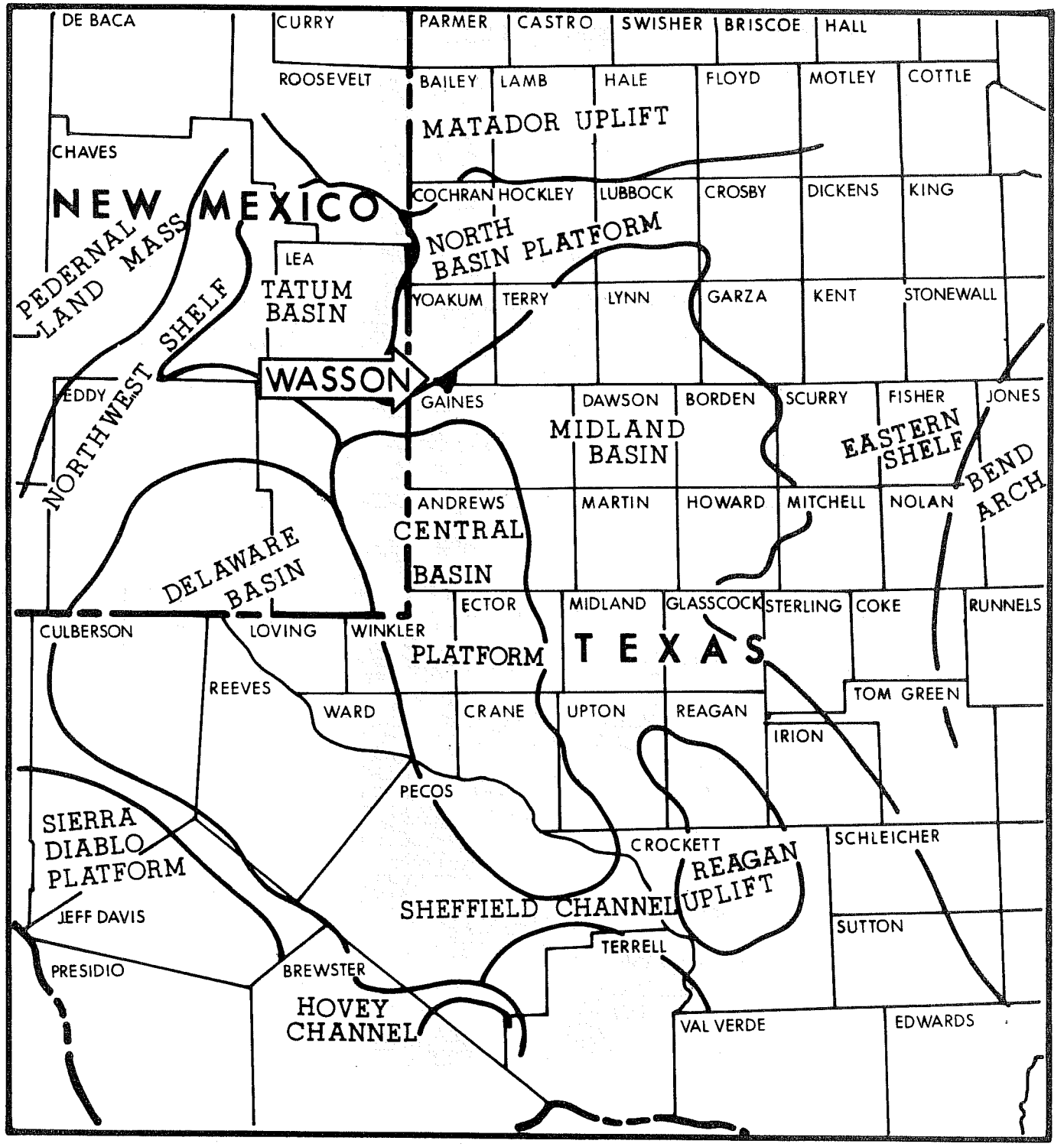


Figure 1.--Location of the Wasson field in west Texas.

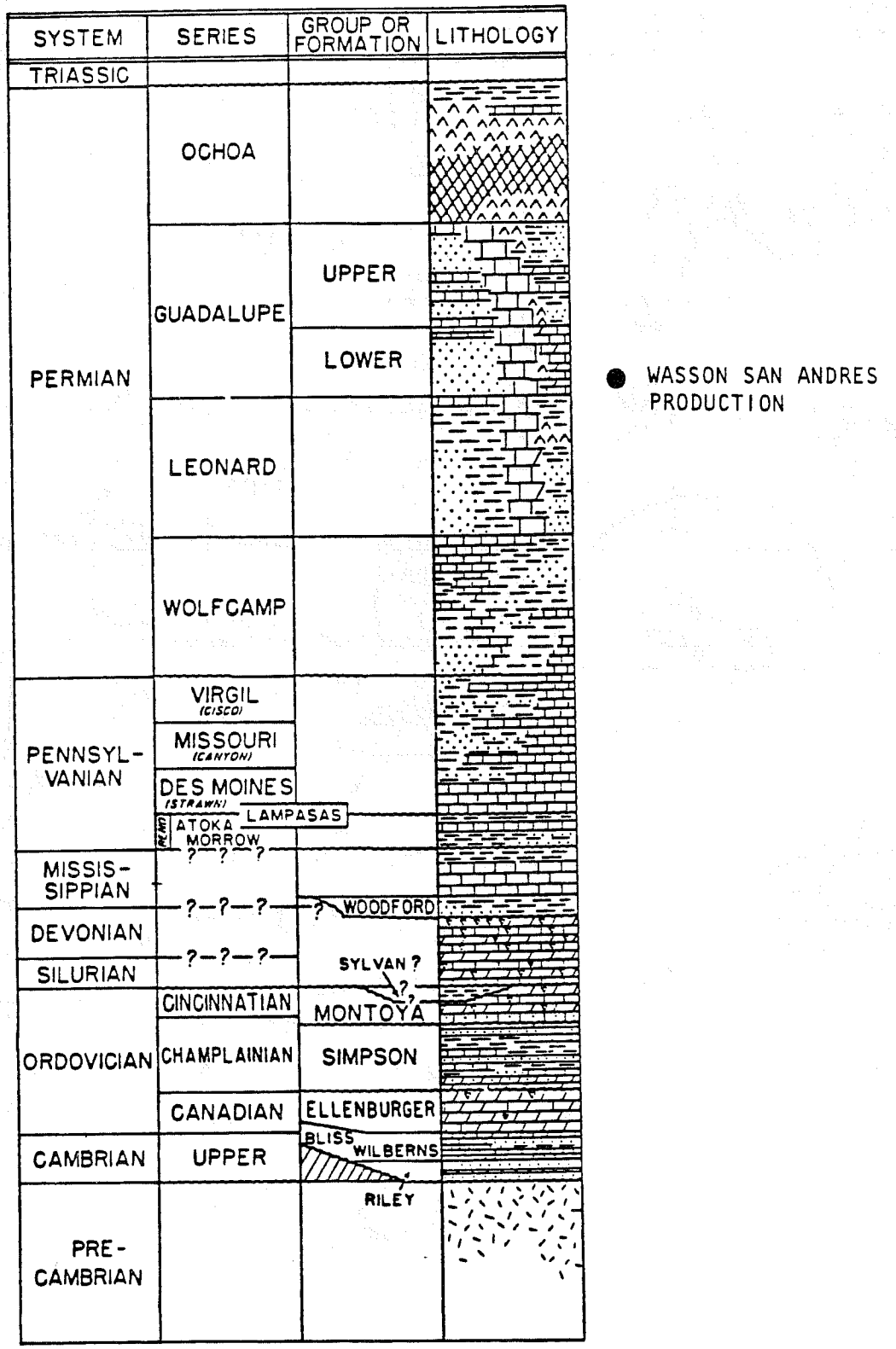


Figure 2.--Stratigraphic position of San Andres production in the Wasson field area.

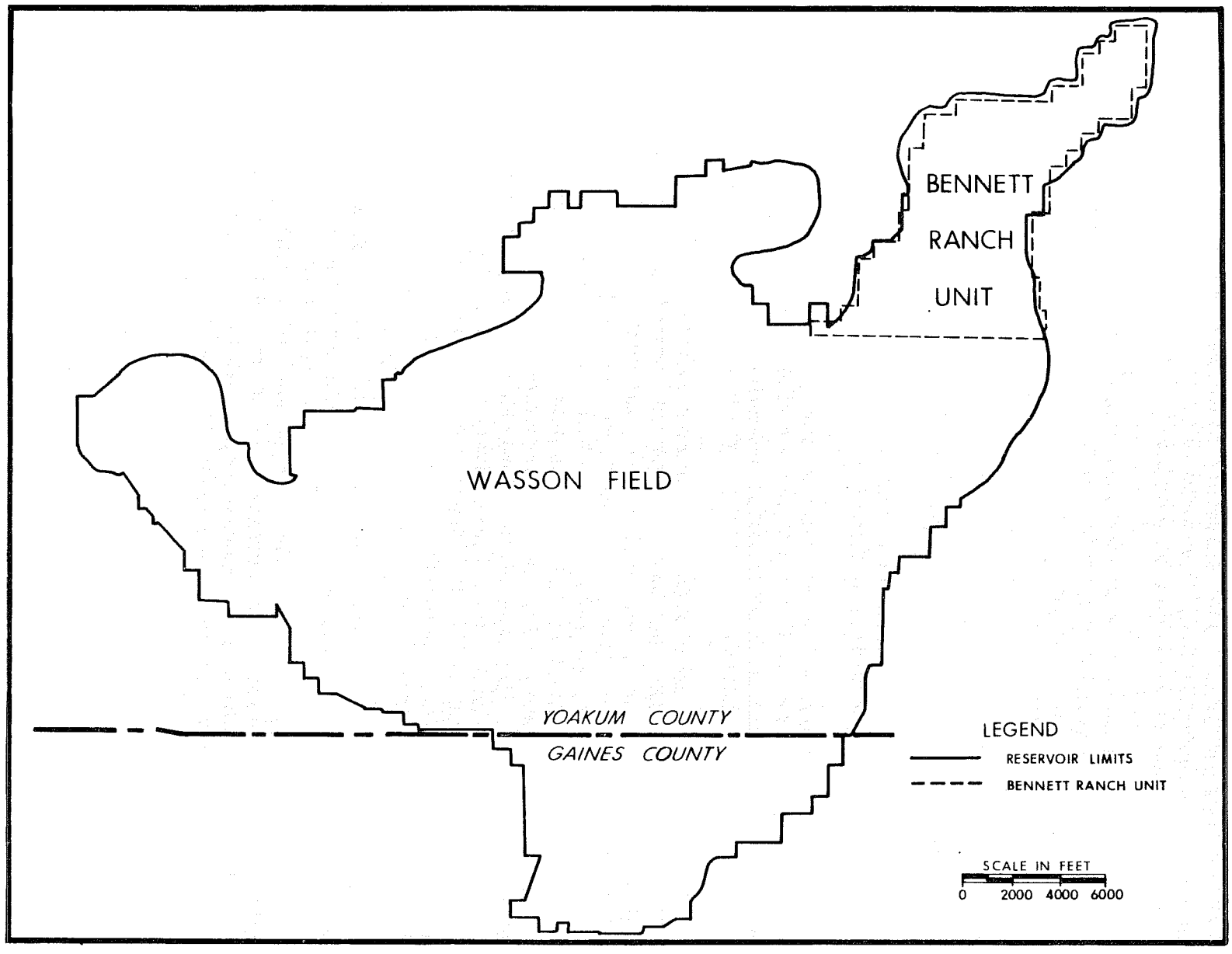


Figure 3.--Location of Bennett Ranch unit in Wasson field.

Figure 4 shows the structure on top of the First Porosity. The pay zone is a finely crystalline dolomite with intergranular porosity. Sediments comprising the pay zone are calcareous particles, fragments, and grains mixed in various combinations. The sediments have been altered by diagenetic processes and dolomitization, commonly with loss of secondary porosity through deposition of secondary anhydrite.

Most waterflood projects in west Texas carbonate reservoirs were originally implemented using peripheral patterns, which required good lateral and vertical pay continuity to be effective much beyond the outermost row of producing wells. Performance reviews of these projects, coupled with geologic studies[10], (Fig. 5) showed that west Texas carbonate reservoirs typically showed two types of heterogeneity:

(1) lateral discontinuity of porous (pay) intervals,

(2) barriers to vertical flow that prevented movement of fluids in other than a horizontal direction.

These "new" concepts led to widespread infill drilling and realignment of waterflooding patterns to line-drive and/or five- and nine-spot patterns. The various units of the Wasson field, including the Bennett Ranch unit, typically have this history.

The San Andres oil accumulation at Wasson was (and is) overlain by a primary gas cap. On the basis of gas-oil ratios[5] and individual well completion interval data, an engineering committee study found gas-oil contact depths ranging from 1,310 to 1,340 feet subsea.[11] This range of depths appeared to be randomly distributed, and it was judged that a horizontal gas-oil contact at 1,325 feet subsea, common to both the First Porosity and the Main Pay, best represented the data. Because of structural elevation, the area of the First Porosity zone occupied by gas cap is considerably larger than the equivalent area of the Main Pay zone, being some 28,000 acres for the former and 12,500 acres for the latter. Both areas are in the structurally higher central and southern portions of the Wasson (San Andres) field.

A significant feature of the reservoir is the tilted oil-water contact. This contact is encountered at 1,400 feet subsea in the south and 1750± feet subsea in the north. This tilting is consistent with the known regional dip of the potentiometric surface and with salinity gradients.[3] Figure 6 is a potentiometric surface map of the San Andres formation illustrating the down-to-the-northeast nature of this surface, and Fig. 7 is a regional salinity gradient map of the San Andres formation. These data indicate that hydrodynamic forces[13] are the cause of the tilted oil-water contact, which dips about 23 feet per mile at an azimuth of approximately N.30°E.

Based on unpublished engineering committee studies[11], the following petrophysical and volumetric data apply to the Wasson field as a whole:

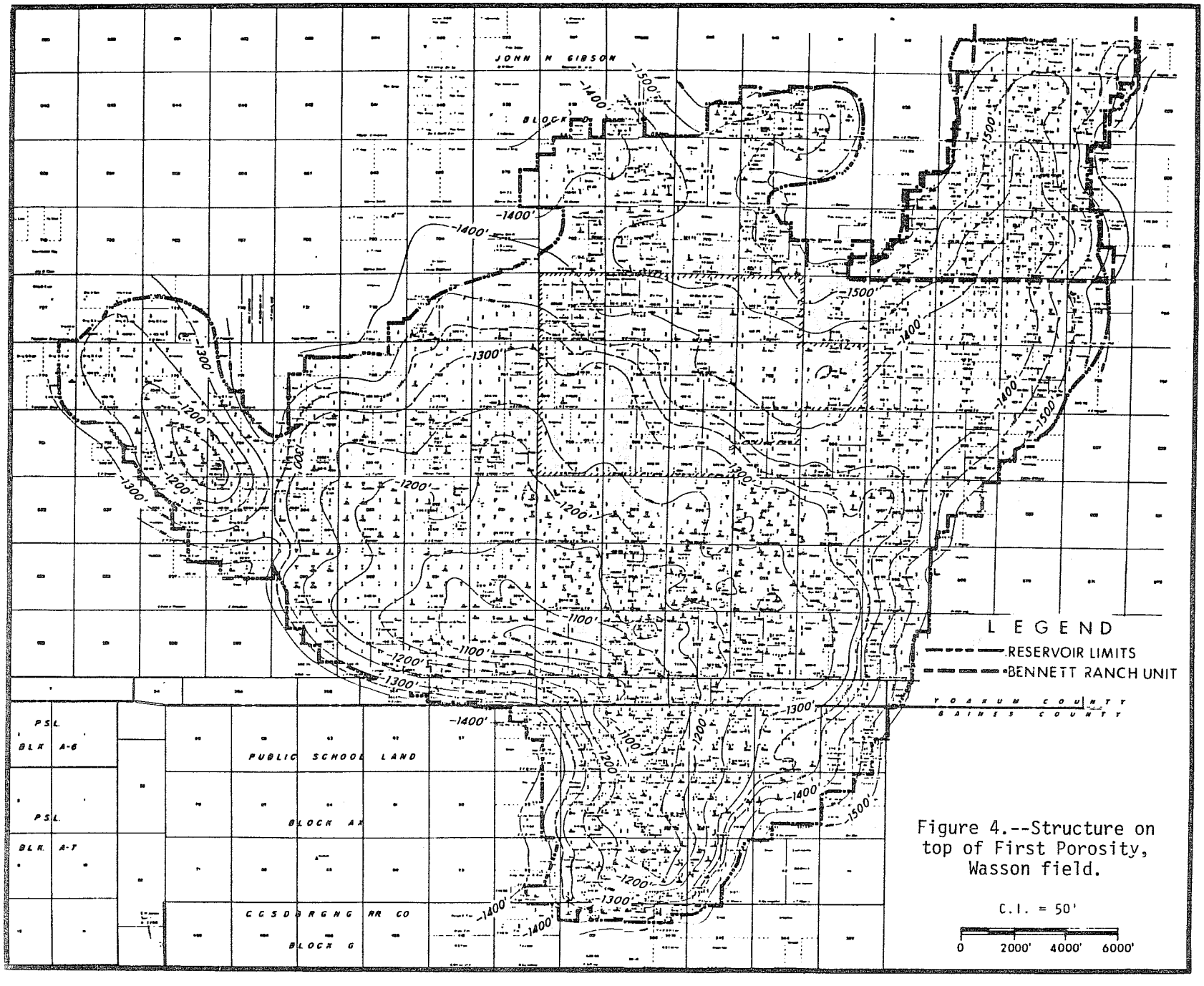


Figure 4.--Structure on top of First Porosity, Wasson field.

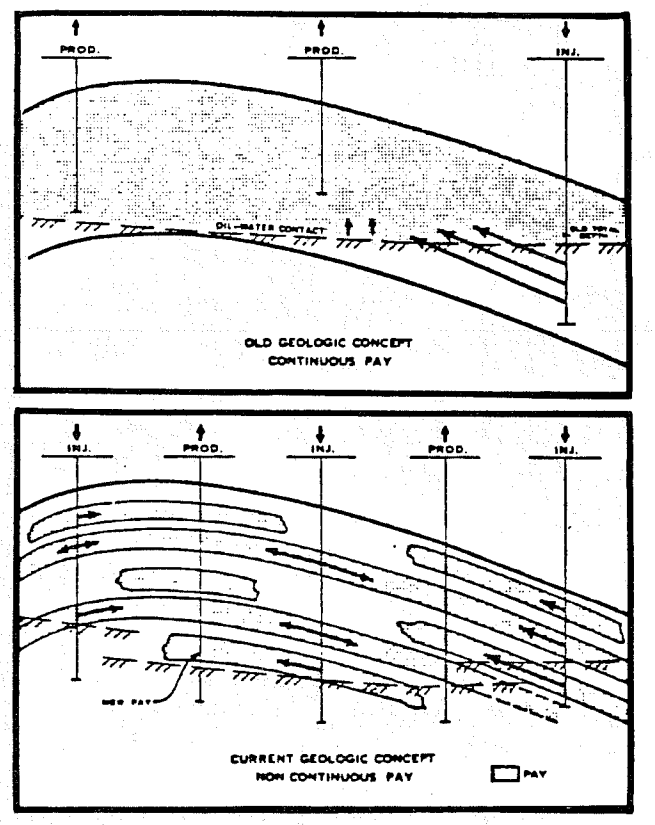


Figure 5.--The concept of discontinuous porosity zones.

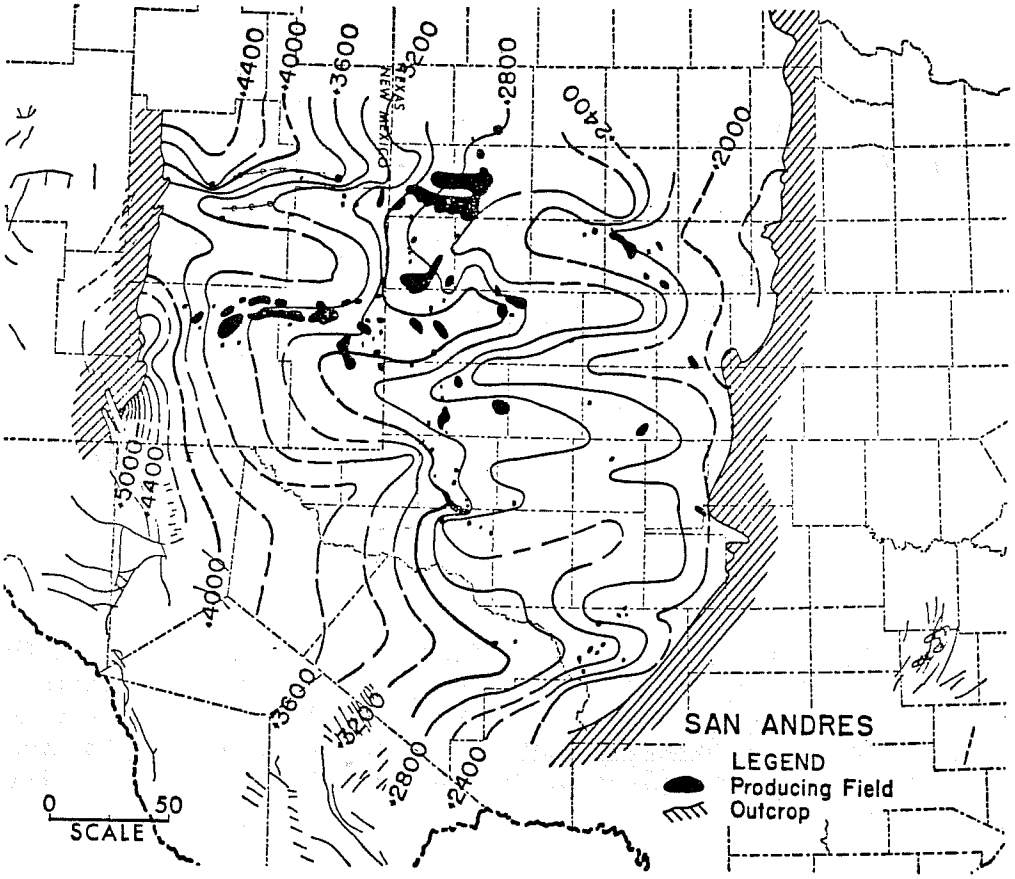


Figure 6.--Potentiometric surface map of the San Andres formation. Contour interval, 200 ft; datum, sea level.

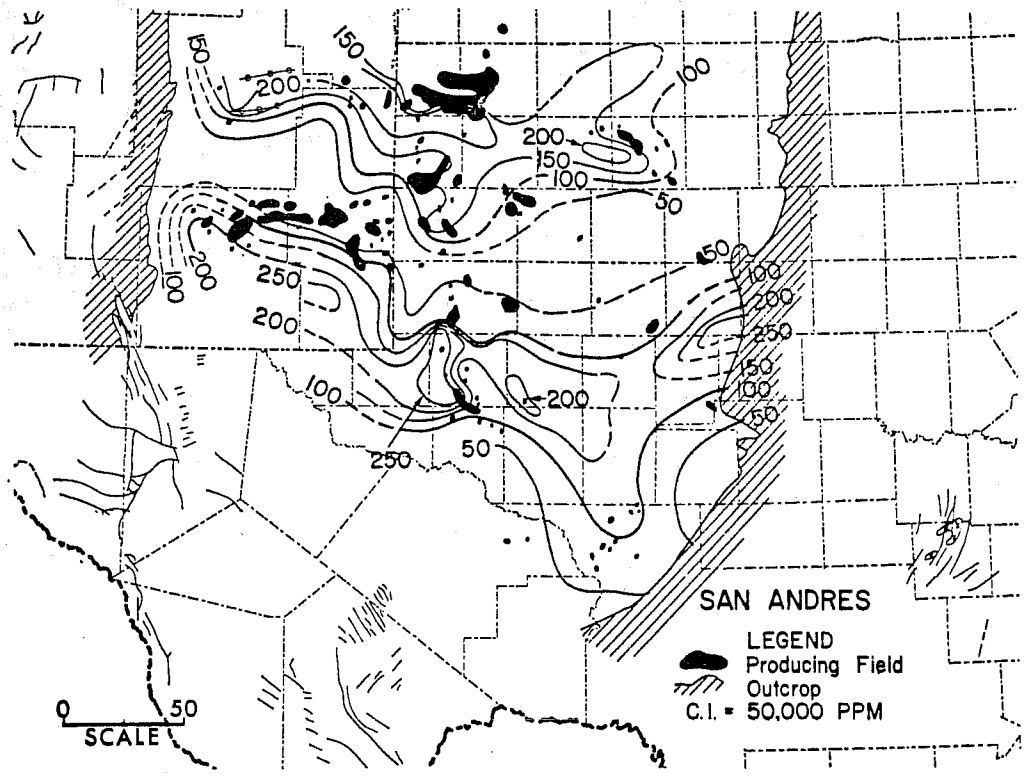


Figure 7.--Salinity map of the San Andres Formation. Contour interval, 50,000 ppm total solids.

Surface acres	72,840	
Productive acres	67,840	
Average porosity, percent	11.2	
Initial S_w, percent	15	
Average net pay, ft	115	
Original reservoir pressure, psig	1,805	at 1,350 ft subsea datum
Initial oil saturation, percent	85	
Initial formation volume factor, vol/vol	1.312	
Initial gas/oil ratio, scf/STB	588	
Original oil in place, MMbbl	4,360	

These values are averages for the field and vary somewhat from unit to unit in this large reservoir.

Reservoir Fluid Data

The oil from the Wasson San Andres reservoir has a stock-tank gravity of 33°API and a bubble-point viscosity of 1.18 cp. The original reservoir pressure of 1,805 psi (-1,350 ft datum) was also bubble-point pressure. The original reservoir formation volume factor was 1.312. The Wasson San Andres crude has been analyzed by the Bartlesville Energy Technology Center; the results are shown in Table 3.[14]

General Reservoir Performance Data

Early production performance of the Wasson field indicated that the production mechanism was essentially solution-gas drive, with limited assistance from the gas cap. Reservoir pressure declined steadily and it became obvious to the field operators that a pressure maintenance program should be initiated to improve recovery. Unitization efforts were actively pursued beginning in 1960, and seven waterflood units were formed to cover the entire field.

Original oil in place is estimated at 4.4 billion barrels; ultimate recovery is projected to be 1.4 billion barrels, giving a recovery efficiency of 32.7 percent. This combined primary and secondary (waterflood) recovery leaves a field-wide target of some 3 billion barrels for enhanced oil recovery methods.

TABLE 3

ANALYSIS OF WASSON SAN ANDRES CRUDE

Item 696
Sample 58004

IDENTIFICATION

Wasson field
San Andres, Upper Permian
4,900-5150 feet

Texas
Gaines County

GENERAL CHARACTERISTICS

Gravity, specific, 0.861 Gravity, °API, 32.8 Pour point, °F below 5
Sulfur, percent 1.76 Color, brownish-black
Viscosity, Saybolt Universal at 100°F, 43 sec Nitrogen, percent, 0.081

DISTILLATION, BUREAU OF MINES ROUTINE METHOD

Stage 1--Distillation at atmospheric pressure, 750 mm Hg
First drop, 82 °F

Fraction No.	Cut temp. °F	Percent	Sum. percent	Sp. gr. 60/60°F	°API 60°F	C.I.	Refractive index, n_D at 20°C	Specific dispersion	S.U. visc. 100°F	Cloud test, °F
1	122	2.4	2.4	0.645	87.9					
2	167	2.6	5.0	.679	76.9	12	1.38199	128.5		
3	212	5.3	10.3	.723	64.2	23	1.40351	137.4		
4	257	7.0	17.3	.754	56.2	28	1.42009	144.8		
5	302	6.4	23.7	.775	51.1	31	1.43256	146.2		
6	347	5.1	28.8	.787	48.3	30	1.43924	147.0		
7	392	4.5	33.3	.798	45.8	29	1.44477	143.3		
8	437	4.5	37.8	.813	42.6	30	1.45135	138.9		
9	482	4.9	42.7	.830	39.0	33	1.46051	142.6		
10	527	5.6	48.3	.848	35.4	37	1.47087	161.3		

Stage 2--Distillation continued at 40 mm. Hg

11	392	2.6	50.9	0.860	33.0	38	1.47973	-	39	10
12	437	6.4	57.3	.872	30.8	40	1.48630	-	44	30
13	482	4.3	61.6	.886	28.2	44	1.49372	-	54	54
14	527	5.3	66.9	.904	25.0	49			77	70
15	572	4.8	71.7	.914	23.3	51			140	90
Residuum		17.8	99.5	.987	11.9					

Carbon residue, Conradson: Residuum 5.2 percent; crude 1.7 percent. Residuum:
Sulfur, percent -
Nitrogen, percent -

APPROXIMATE SUMMARY

	Percent	Sp. gr.	°API	Viscosity
Light gasoline	10.3	0.694	72.4	
Total gasoline and naphtha	33.3	0.750	57.2	
Kerosine distillate	4.5	.813	42.6	
Gas oil	19.6	.854	34.2	
Nonviscous lubricating distillate	8.7	.880-.907	29.3-24.5	
Medium lubricating distillate	5.6	.907-.917	24.5-22.8	50-100
Viscous lubricating distillate	-	-	-	100-200
Residuum	27.8	.987	11.9	above 200
Distillation loss	.5			

BENNETT RANCH UNIT INFORMATION[7]

General Bennett Ranch Unit Data

Authority to form the Bennett Ranch unit in the Wasson Field was granted by the Texas Railroad Commission in Special Order No. 8-54,413 dated June 14, 1964. The operator, Texas Pacific Oil Company, Inc., owns a 35.36 percent working interest share of the unit. Other current working interest owners, listed in Table 4, include a number of independent operators as well as major oil companies such as Amoco, ARCO, and Shell, who are active in CO_2 flooding research and application.

Bennett Ranch Unit History and Waterflood Performance

The first well in the Bennett Ranch unit area was completed in 1936. Before unitized operations began in January 1965, the area was produced competitively by numerous operators, with depletion occurring under primary solution-gas drive. Petrophysical and volumetric data pertinent to this unit, as reported to the Texas Railroad Commission by the operator, are:

Surface acres	7,210
Productive acres	7,027
Average porosity, percent	10.8
Initial water saturation, percent	18
Average net pay, feet	95
Initial oil saturation, percent	82
Initial formation volume factor, vol/vol	1.312
Initial gas/oil ratio, cu ft/STB	588
Original oil in place, MMSTB	305

At the time of unitization an estimated 32 million barrels (10.5 percent of OOIP) had been produced by competitive primary depletion.

Water injection for unitized waterflooding operations began in July 1965. The performance history of the unit since that time is shown in Fig. 8. Excellent waterflood response has been realized; oil production increased from a pre-flood rate (restricted by Texas allowable proration) of 2,000 barrels per day to a peak rate (unrestricted) of some 12,000 barrels per day in 1974. This response, coupled with declining gas-oil ratios, is clear evidence of excellent oil bank buildup and movement.

The Bennett Ranch unit waterflood uses a direct line-drive pattern with rows of water injection wells aligned east-west driving oil north and south to the offset rows of producers. The unit presently contains 135 active water injectors and 152 producing wells. Operating statistics for May 1979 (see Fig. 8) are:

TABLE 4

WORKING INTEREST OWNERS, BENNETT RANCH UNIT,
WASSON FIELD, GAINES AND YOAKUM COUNTIES, TEXAS

American Petrofina Company of Texas
Amoco Production Company
Atlantic Richfield Company
Estoril Producing Company (Midland, Texas)
Getty Oil Company
Great Western Drilling Company (Midland, Texas)
Gulf Oil Corporation
Helmerich and Payne, Inc. (Tulsa)
Jack H. Hixson (Dallas)
W. D. Keller (Ft. Worth)
Marathon Oil Company
Mobil Oil Corporation
W. A. Moncrief (Fort Worth)
L. T. Pate (Denver City, Texas)
Joseph B. Ruppe (Midland, Texas)
Shell Oil Company
Sohio Petroleum Corporation
Sun Oil Company
Texaco, Inc.
Texas Pacific Oil Company, Inc.
Three M Oil Company (Dallas)
Union Oil Company of California
Joe Warren (Dallas)

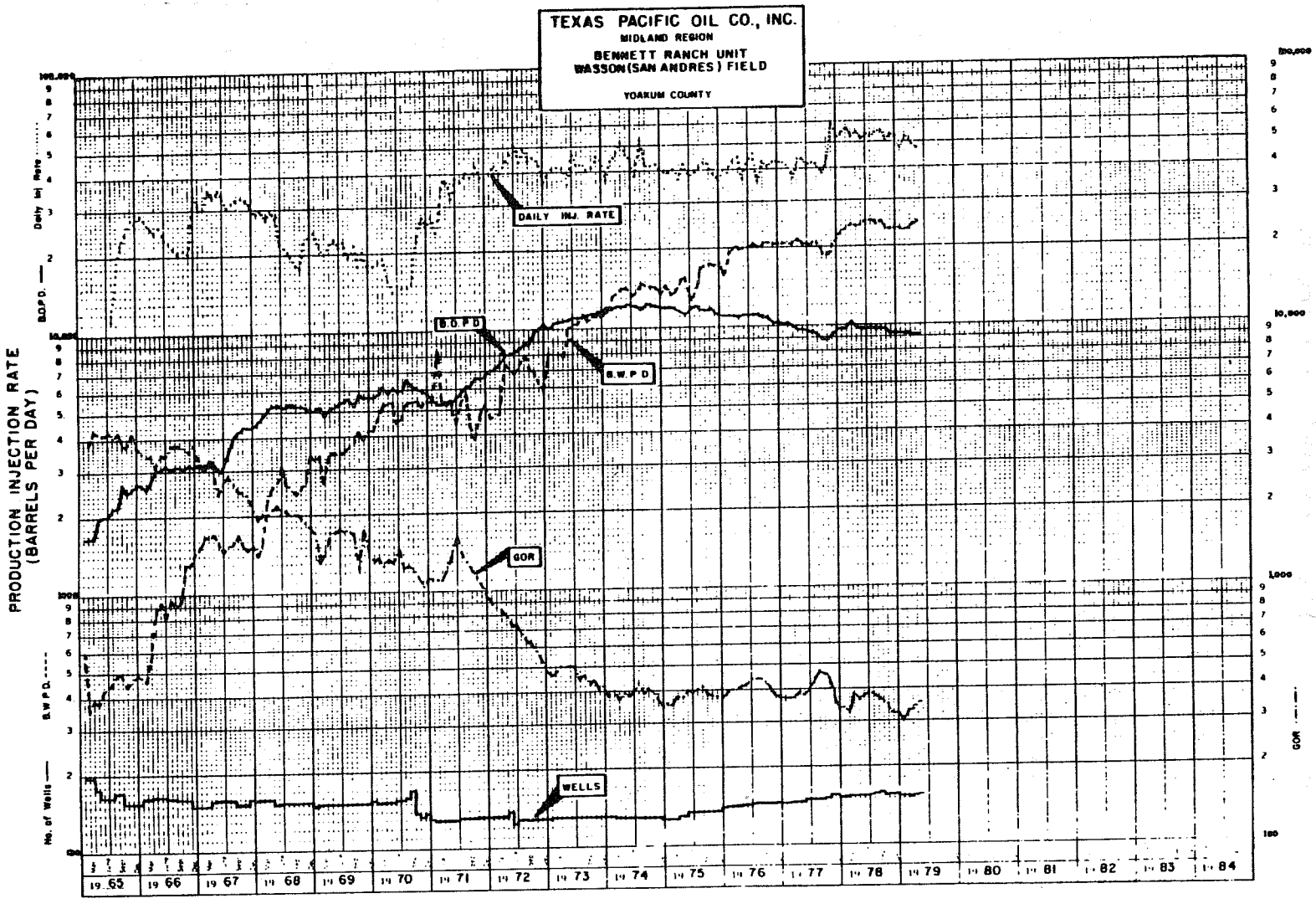


Figure 8.--Waterflood performance history of Bennett Ranch unit.

Average oil production	9,100 B/D
Average water production	23,200 B/D
Producing water cut	72% of total fluid
Average water injection	44,000 B/D

Cumulative oil production from the start of unit operations to March 1, 1979, is 38.9 million barrels. The operator estimates average current oil saturation at 63 percent of pore space.

An estimated 33.5 million barrels of waterflood oil remain to be recovered, for a total waterflood recovery of 72.4 million barrels and a primary plus waterflood recovery of approximately 104 million barrels (34 percent of OOIP). The operator estimates that at abandoment of waterflood an average residual oil saturation of 43 percent will remain.

Geology of Bennett Ranch Unit

The structure of the San Andres in the Bennett Ranch unit area is shown in Fig. 9, drawn on the top of the San Andres marker (the first nonpay interval below the top of the Main Pay). The cross section given as Fig. 10 shows the continuity of the pay zones within the Main Pay interval.

This cross section also displays the decided lack of continuity of porous intervals in the First Porosity section of the San Andres in this portion of the field. An isovolumetric map (an isopach where net feet have been multiplied by the appropriate fractional porosity) is provided as Fig. 11. The net pay criteria are those used historically by Texas Pacific, i.e., a permeability cutoff of 0.1 md and a porosity cutoff of 5 to 6 percent. These cutoff criteria are based on core analysis.

Bennett Ranch Unit Well No. 310

Reason for Drilling. The Bennett Ranch Unit No. 310 (BRU 310) was planned as part of a program to continue development of this waterflood unit on 20-acre spacing. Locations of the 15 wells in this program are shown in Figs. 9 and 11. The BRU 310 was part of a five-well "package" intended to develop the northern fringe area of the waterflood unit (Fig. 12). Texas Pacific had planned to drill this well by mid-1979 and to obtain a conventional core through the entire San Andres section to a point just below the estimated water-oil contact at 5,340 ft (-1,765 ft subsea). As the figure shows, Bennett Ranch Unit No. 310 was planned as a producing well offset by Bennett Ranch Unit No. 282 (a producer) on the west and by Bennett Ranch Unit No. 20 (an injector) on the south. Three additional new wells, Bennett Ranch Unit Nos. 311, 312, and 313, were planned as "next line" wells to the north of Bennett Ranch Unit No. 310. These three wells were drilled in June 1979 and had been completed at the time Bennett Ranch Unit No. 310 was drilled.

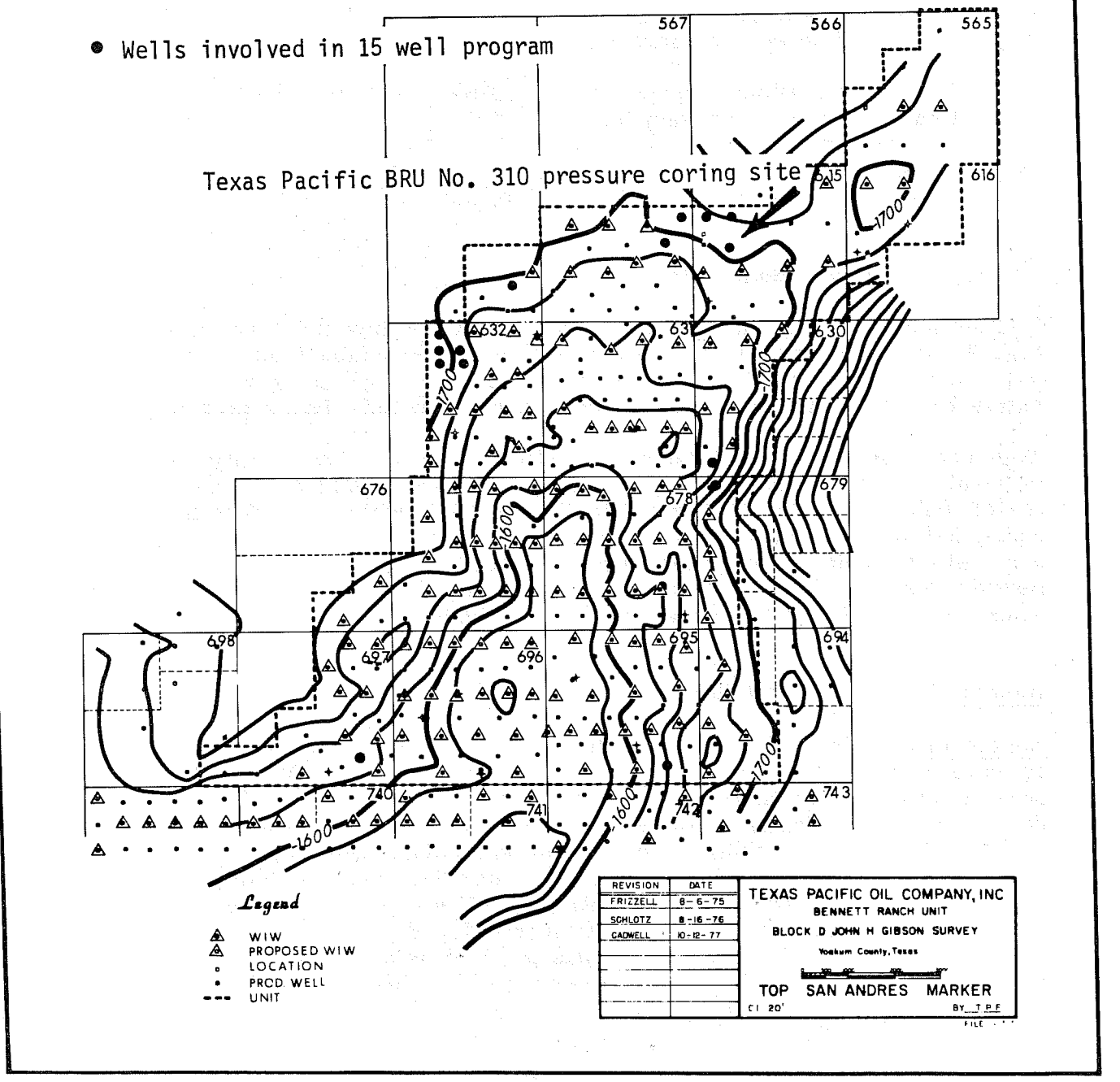


Figure 9.--Structure map of San Andres Formation in the Bennett Ranch unit area, drawn on top of the first nonpay interval below the top of the Main Pay.

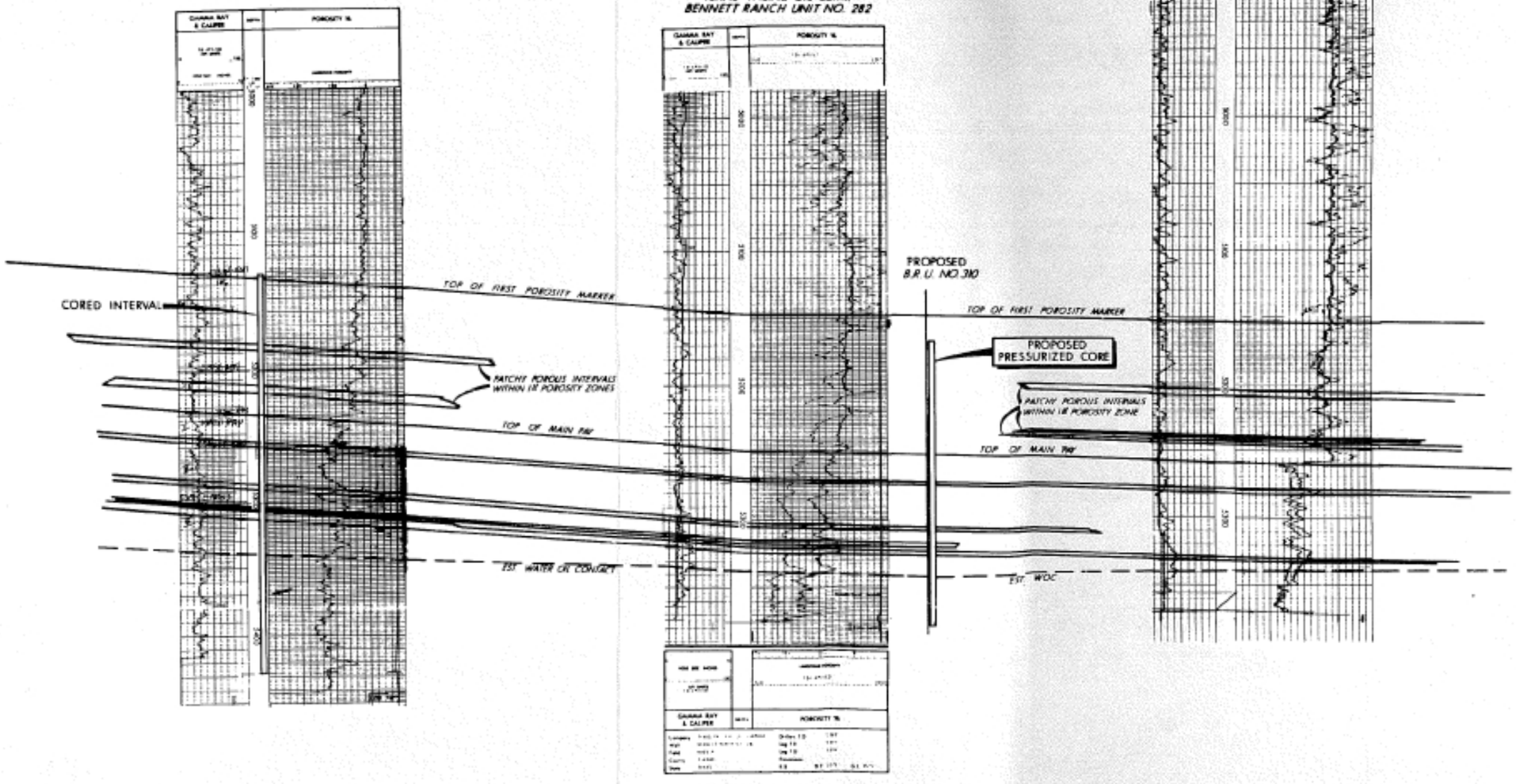
A

A'

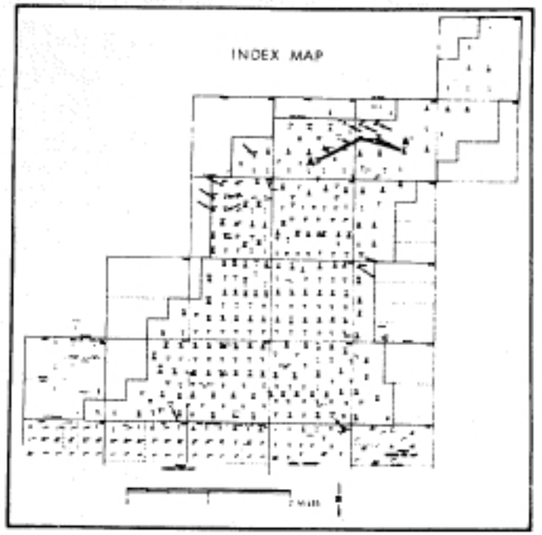
TEXAS PACIFIC OIL COMP.
BENNETT RANCH UNIT NO. 280

TEXAS PACIFIC OIL COMP.
BENNETT RANCH UNIT NO. 282

TEXAS PACIFIC OIL COMP.
BENNETT RANCH UNIT NO. 242



INDEX MAP



GRUY FEDERAL, INC
HOUSTON TEXAS

FIGURE 10
WASSON FIELD
(BENNETT RANCH UNIT)
YOAKUM COUNTY, TEXAS

CROSS SECTION THROUGH THE IMMEDIATE AREA OF THE PROPOSED BRU NO. 310

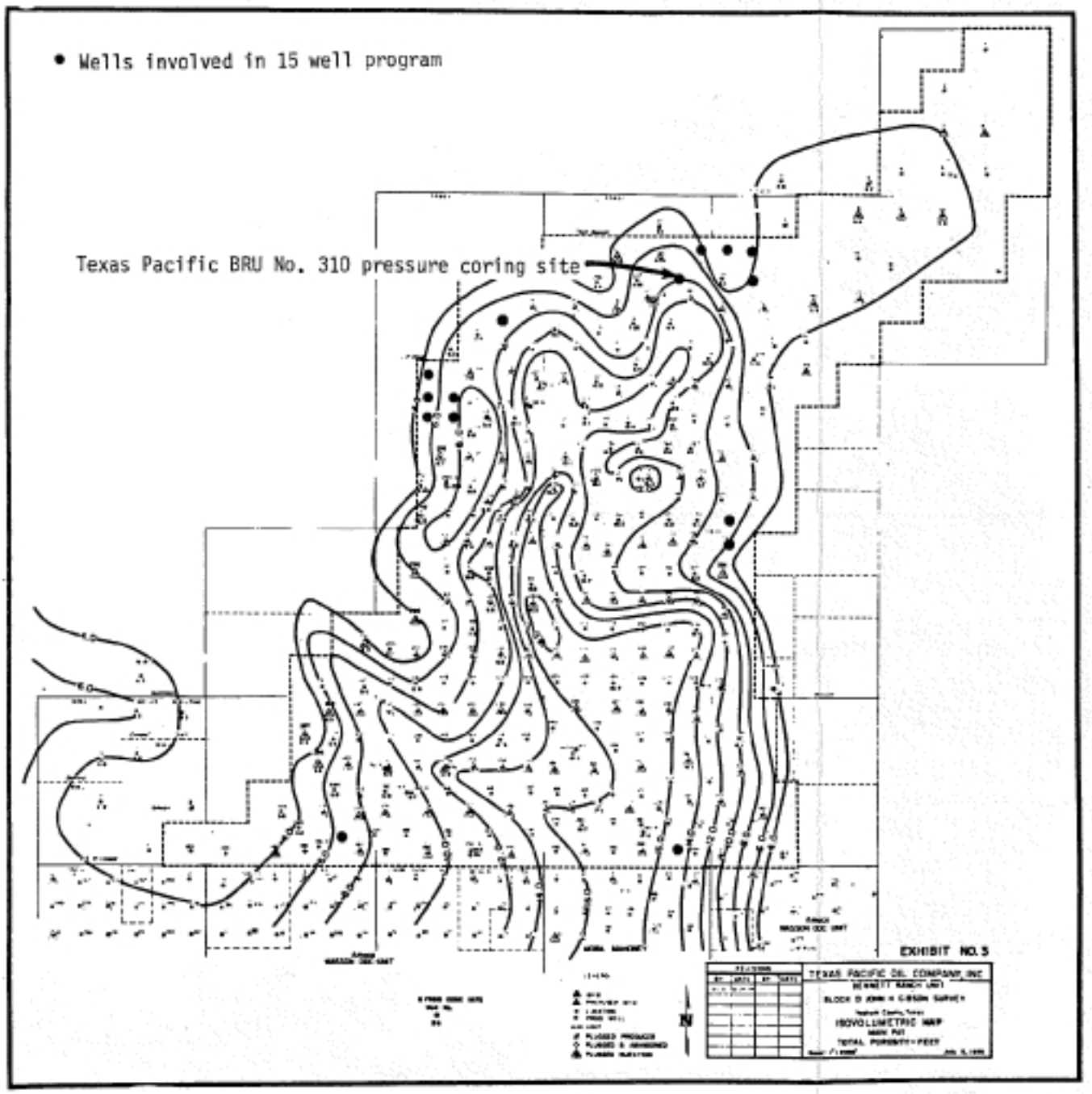


Figure 11.--Isovolumetric map of San Andres Formation in Bennett Ranch unit area.

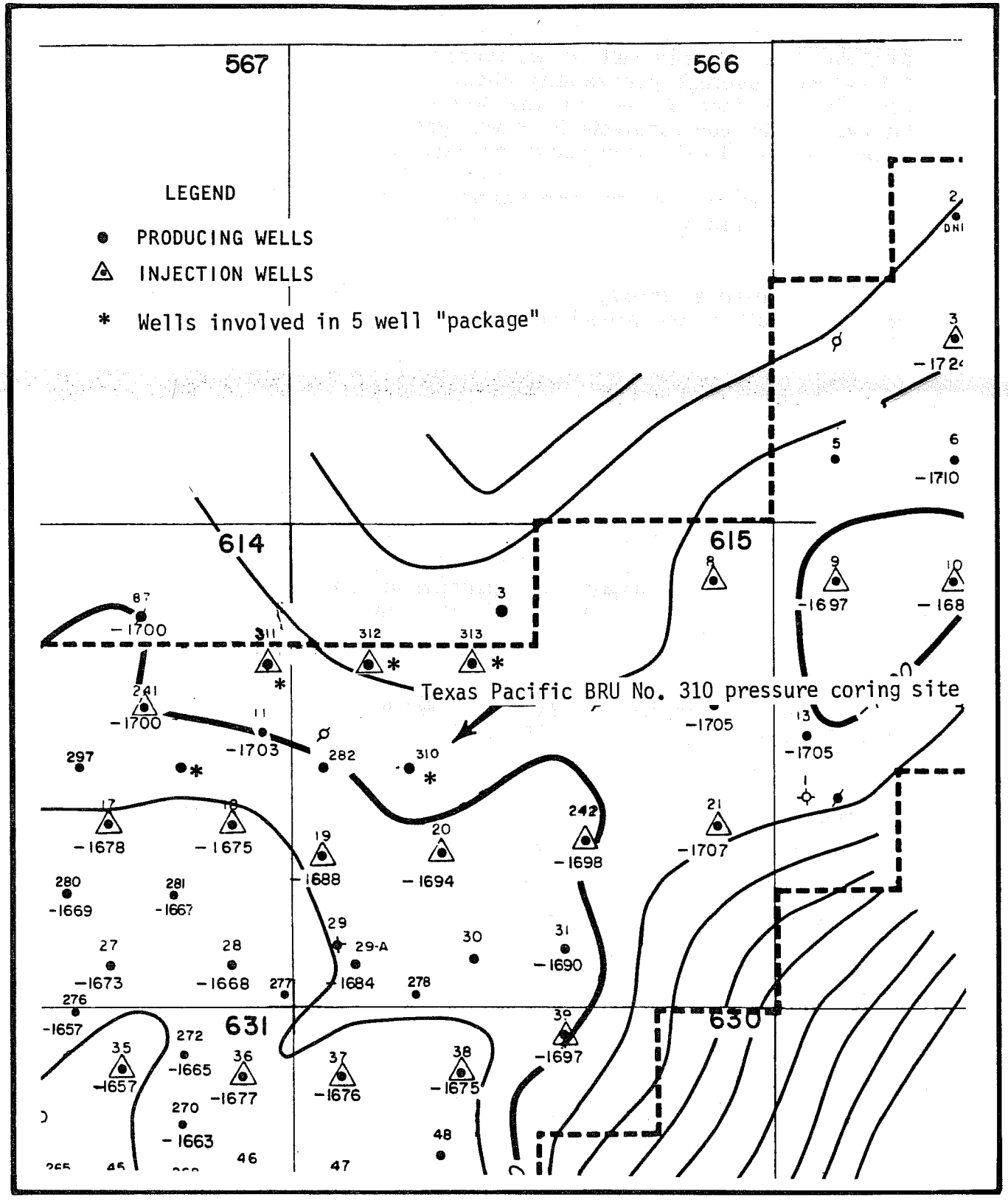


Figure 12.--Structure map of San Andres marker in the vicinity of BRU No. 310.

Information for the Immediate Area of the Well.[7] Core analysis of the BRU No. 280, a nearby well, shows average porosity over the gross pay about 8.5 percent; average permeability about 3 to 5 md; net pay 94 feet, with an additional 28 feet of net in the lowest portion of the First Porosity interval. The core analysis is shown graphically in Fig. 13. Continuity of pay has previously been shown on Fig. 10.

Production histories for the two nearest producing wells, BRU No. 11 and BRU No. 282, are shown in Figs. 14 and 15. Both wells have low water-oil ratios.

Injection statistics through April 1979 for the active water injection wells just south of the proposed well are summarized in Table 5.

TABLE 5

SUMMARY OF INJECTION HISTORIES
WELLS NEAR BENNETT RANCH UNIT NO. 310

Date First Injected	Injection Well No.	Avg. BWPD	Wellhead Pressure, psi	Cumulative water injected, bbl
3/22/1971	18	225	1,220	452,536
7/03/1965	19	350	1,250	1,895,329
9/12/1970	20	300	1,320	599,768
5/15/1972	242	300	1,300	568,549

FIELD OPERATIONS IN BENNETT RANCH UNIT NO. 310

Field operations were conducted as a cooperative effort between Texas Pacific and Gruy Federal with the understanding that Texas Pacific had ultimate responsibility and authority for the operation at all times. The letter agreement between Texas Pacific and Gruy Federal under which the operation was executed is included in Appendix A. This agreement and related contracts with the drilling contractor provided for transfer of financial responsibility to Gruy at the time the cementing plug "bumped" in the 8-5/8 inch protective casing string. This responsibility would end after coring and logging when the core hole was reamed down and full circulation established. At that time, Texas Pacific assumed financial responsibility for running and cementing production casing preparatory to completion.

Drilling Operations From Surface to Casing Point

The well was spudded on September 15, 1979, and drilled to 467 ft, where 13-3/8 inch conductor casing was cemented. Drilling operations resumed after 24 hours "waiting-on-cement" time. Drilling proceeded routinely to 5,150 ft, where 8-5/8 inch protective casing was set and cemented preparatory to coring. The cementing operation was completed (i.e., plug bumped) at 9:45 a.m. on September 28, 1979. Drilling progress during this phase of the operation is shown in Fig. 16.

The operation described above required a number of departures from the operator's original well plan, which is shown in Fig. 17. This plan provided for 2,500 ft of 8-5/8 inch casing cemented in a 12-1/4 inch hole. (Note: casing set at this depth was deemed necessary by the operator to protect the hole from excessive sloughing of the up-hole red beds during conventional coring. Texas Pacific's routine drilling practice generally provided for only 500± ft of conductor casing, drilling to total depth of 5,300± ft, and cementing production casing.) Because of the time required for a pressure-coring operation, in which only 8 to 10 ft of core can be taken per barrel run, additional hole protection was required. This was obtained by cementing casing into the San Andres objective. Thus, the 12-1/4 inch hole had to be carried an additional 2,650± ft and an additional 2,650 ft of 8-5/8 inch casing set. Estimated additional costs to Texas Pacific for these changes in procedure are:

CORE LABORATORIES, INC. *Petroleum Reservoir Engineering*

COMPANY TEXAS PACIFIC OIL CORP., INC. FIELD WASSON FIELD FILE 3102-10282

WELL BENNET RANCH UNIT NO. 280 COUNTY OAKLEY CO. DATE 2-24-77

LOCATION 1,00 FSL 2,00 FEL SEC 2 BLK D STATE TEXAS ELEV. 3575 GL

J.H. GIBSON SURVEY

CORE-GAMMA CORRELATION

VERTICAL SCALE: 5" = 100'

UNDLE CORE ANALYSIS

TOTAL WATER 0000
PERCENT PORE SPACE
80 60 40 20 0

GAMMA RAY
RADIATION INCREASE →

PERMEABILITY
MILLIDARCYS
100.0 10.0 1.0 0.1

POROSITY
PERCENT
30 20 10

OIL SATURATION XXXX
PERCENT PORE SPACE
0 0 20 40 60 80

5100
5150
5200
MAIN PAY
5250
REGIONAL MARKER
5300
5350
5400

FIGURE 13
CORE ANALYSIS
TEXAS PACIFIC
BENNET RANCH UNIT NO. 280
WASSON (CLEAR FORK, LOWER)
SAN ANDRES FORMATION

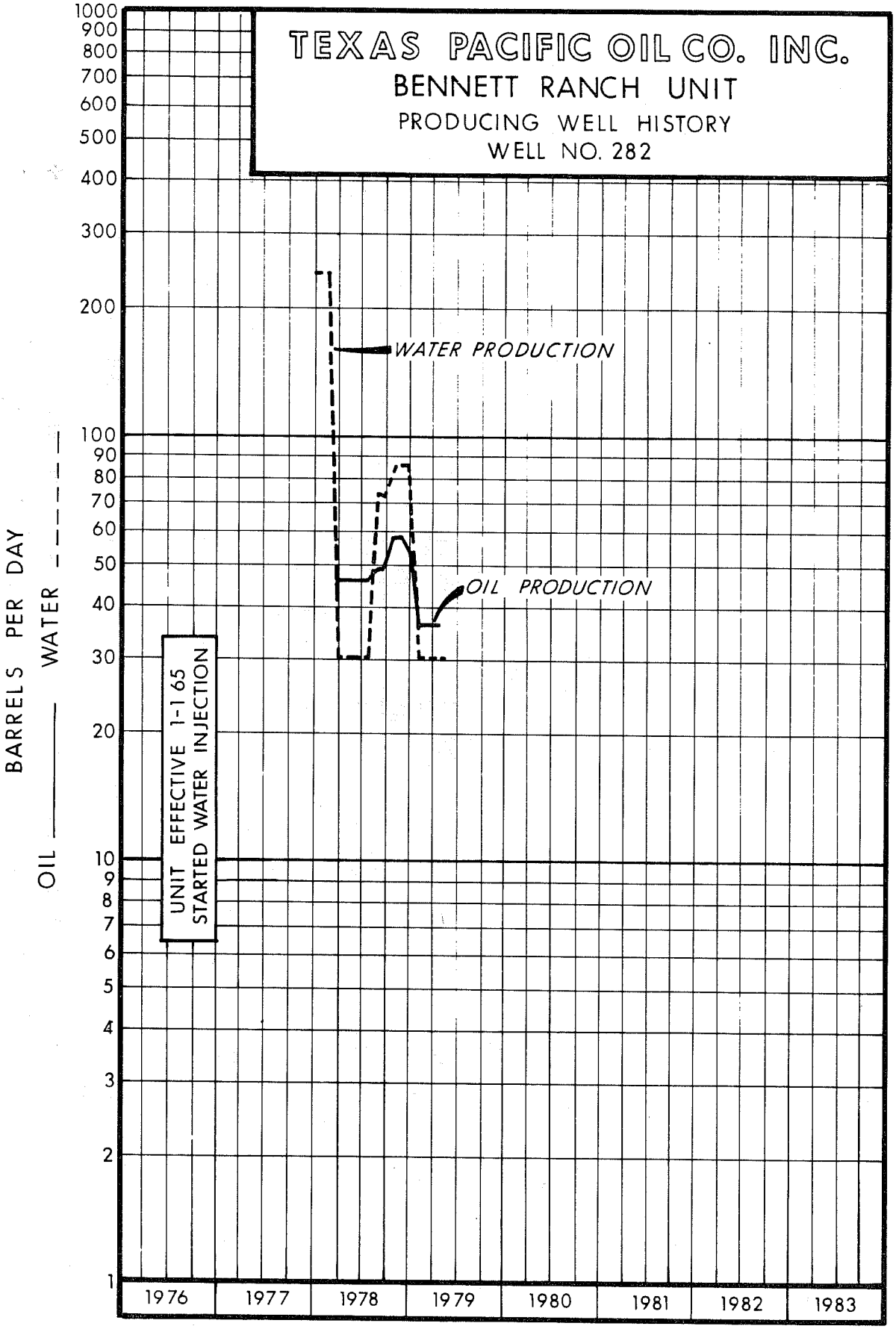


Figure 14.--Production history, BRU No. 282.

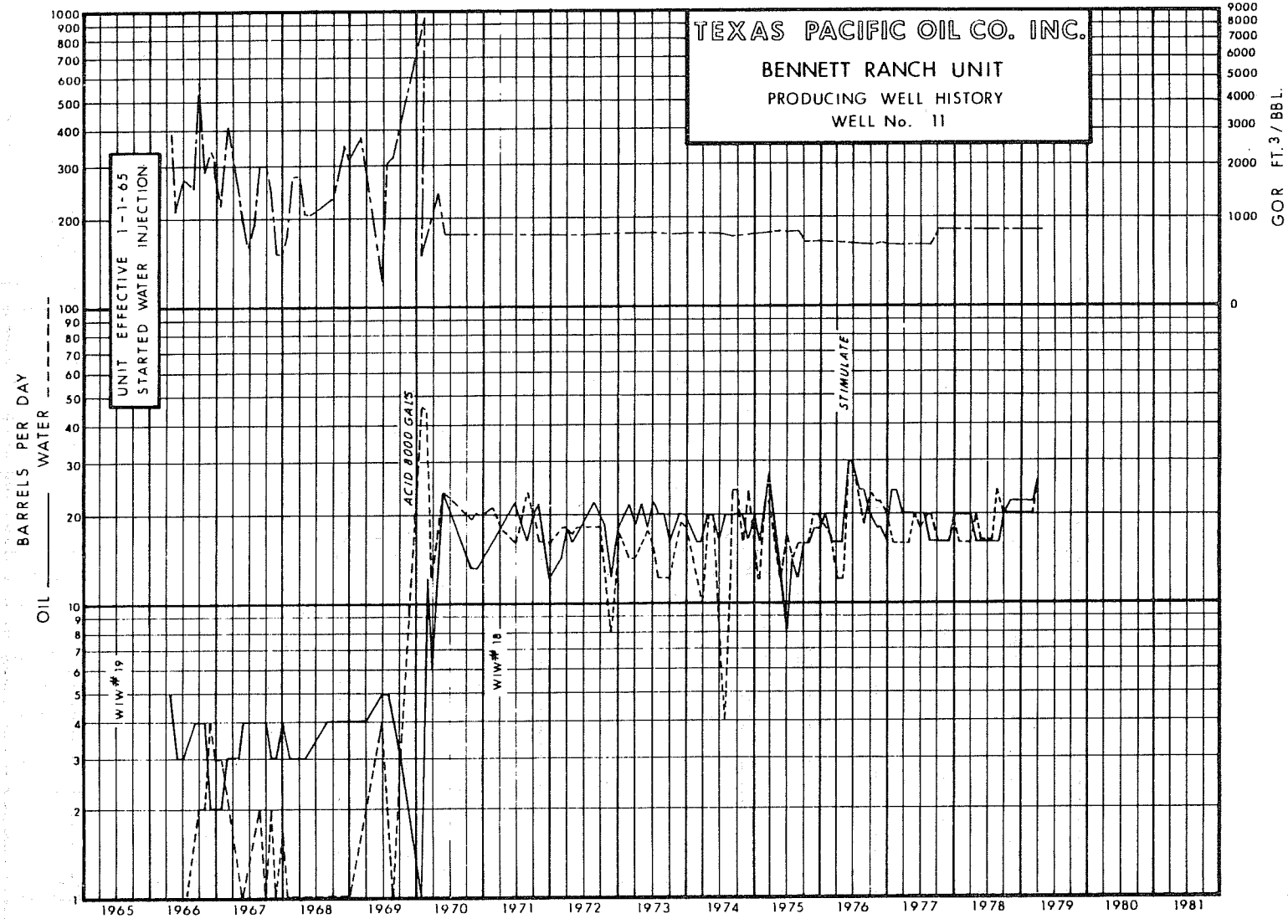


Figure 15.--Production history, BRU No. 11.

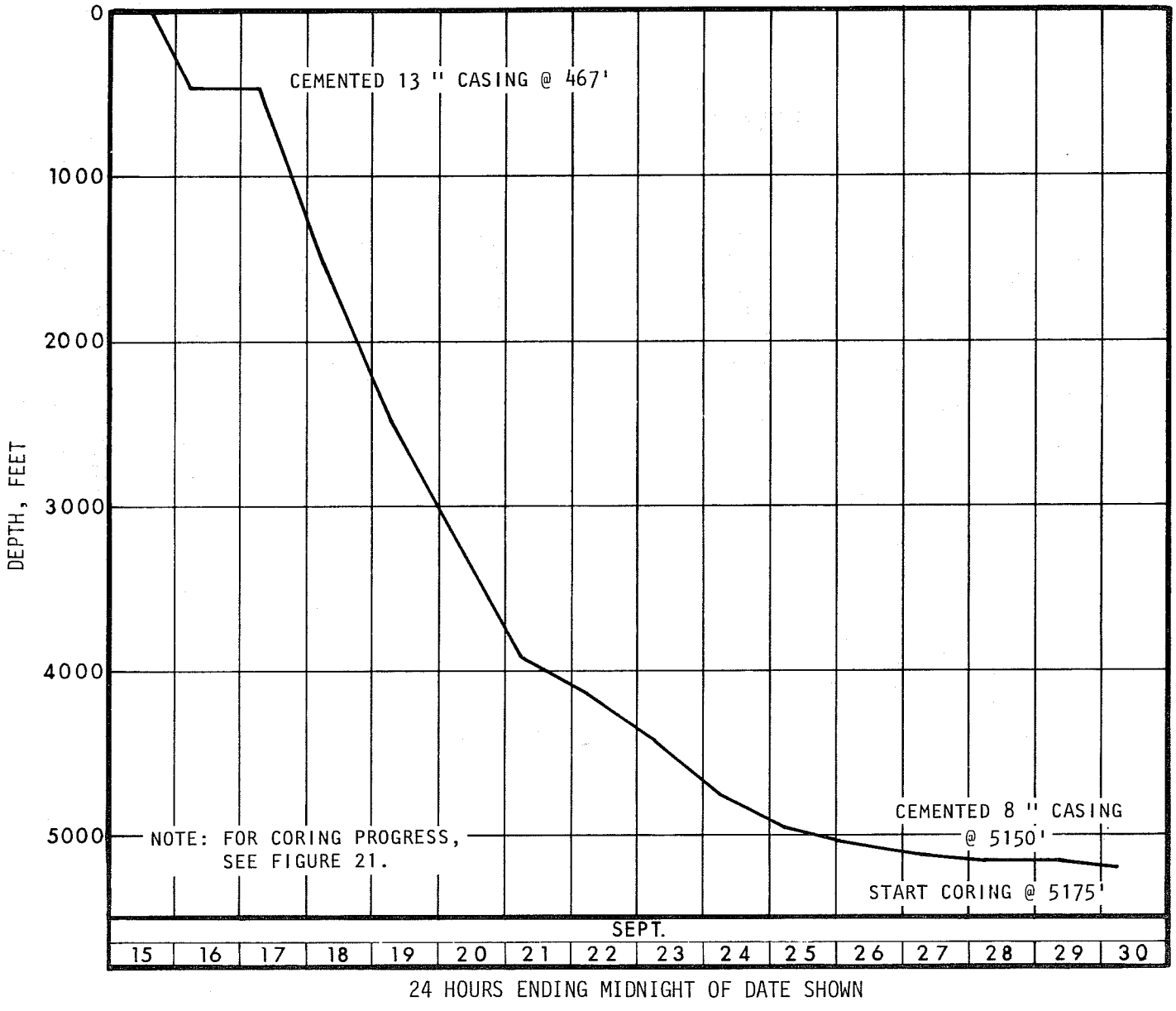


Figure 16.--Drilling progress curve for BRU No. 310.

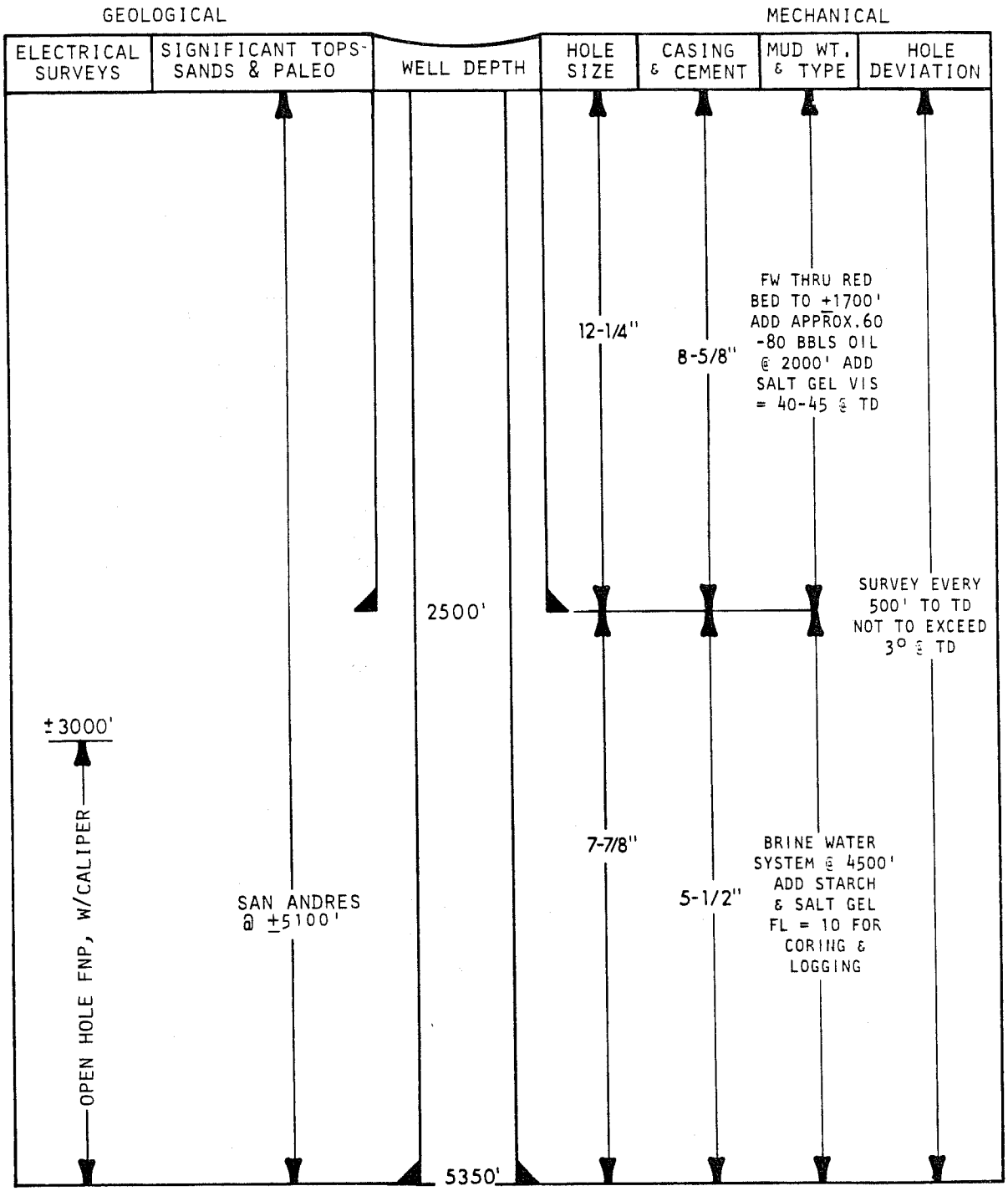


Figure 17.--Original well plan for BRU No. 310.

Item	Estimated Added Cost
Additional required site work	$ 5,000
Additional rig costs	20,000
Additional 8-5/8 inch casing from 2,500± ft to 5,165± ft, est. 2,665 ft @ $8.51/ft	22,679
Additional cementing	7,000
Miscellaneous other additional costs	5,000
Additional mud pump, with fuel, est. 20 days @ $375/day	7,500
TOTAL ESTIMATED ADDITIONAL COST	$ 67,179

These costs are comparable to the item "Incremental Costs to Operator" in Table 2.

Coring Operations

Equipment to obtain cores in which formation fluids are retained under pressure has been under development and improvement for 40 years.[15,16] The Exxon-Loomis improvements to the basic Carter design are reported to have achieved 60 percent recovery in coring some 2,000 ft of rock in 43 different projects between 1960 and 1971.[17] Other investigators report successful pressure-coring in well consolidated formations where the pressure is sufficient to permit use of normal-weight drilling fluids.[18] This work (by Amoco) included West Texas San Andres examples. In 1976, Arco took 19 pressure cores of the San Andres in the Willard unit of the Wasson field, recovering 100 percent of the cores, 18 of 19 with pressure retained.[19] Shell Oil Company experienced similar success with a San Andres coring program in their Wasson Denver unit in 1977.[20] Since then, experience with an improved barrel reportedly attained virtually 100 percent core recovery, with 85 percent recovered under pressure, during 63 barrel runs in 5 different jobs.[21] These data and word-of-mouth information indicate that "the system has been developed to a state of acceptable reliability," a conclusion published by experts working with an Interstate Oil Compact Commission study group in 1978.[22] This was the background against which the pressure coring operation described below took place.

Operations Preparatory to Coring. At pre-spud planning meetings held between Texas Pacific, Gruy Federal, and others, it was agreed that (as originally proposed) the entire San Andres pay intervals would be pressure-cored from a depth of approximately 5,175 ft to approximately 5,385 ft. This 210-ft interval would provide for coring some 50 ft below the estimated original oil/water contact, to evaluate the possibility that CO_2-floodable oil saturation was present but immobile to water in the transition zone.

Mechanical Operations. In the operation, this plan was implemented by drilling out the 8-5/8 inch casing shoe at 5,150 ft using the original drilling mud and a 7-7/8 inch rock bit, drilling ahead to 5,175 ft, circulating to clean the hole, and displacing the drilling mud with a specially prepared low-solids, low-water-loss coring mud designed to minimize flushing during coring operations while allowing optimum operation of the pressure-coring equipment.

Coring Mud Preparation and Maintenance. The coring mud used in this operation was a fresh-water base gel/CMC (carboxymethyl cellulose) mud prepared using mud-making materials and chemicals in the following proportions:

Bentonite clay	12.5 lb/bbl water
Barites	40.0 lb/bbl water
Magco Poly-Sal	4.0 lb/bbl water
Regular CMC	1.0 lb/bbl water

This produces a mud containing approximately 6 percent solids by volume with average properties approximately as follows:

Weight, lb/gal	9.9
Funnel viscosity, sec/qt	65
Plastic viscosity, cp	31
Yield point, lb/100 sq ft	19
Gel strengths, lb/100 sq ft:	
10-second	5
10-minute	11
Water loss, cc/30 min	4.4

New mud made according to this recipe cost approximately $14 per barrel FOB the mixing plant in Hobbs, N. M. Because Shell Oil Company had just completed a large pressure-coring project in the Denver unit of the Wasson field (some 10 miles southwest of the BRU 310 well site) using a mud of this makeup, it proved possible to reduce mud costs by salvaging and reconditioning the mud used by Shell. Negotiations between Gruy Federal, Shell, and Magcobar resulted in an arrangement whereby Magcobar paid Shell $4 per barrel for 577 barrels of mud salvaged from their field site. This mud was trucked to Magcobar's plant in Hobbs for reconditioning and volume building before delivery to the BRU 310 well site. Total volume of mud was increased to 700 barrels by adding water and mud-making materials as follows:

10 50-lb sax CMC
10 50-lb sax Poly-Sal
20 100-lb sax Magcogel

As delivered at the well site, the mud had the following properties:

Weight, lb/gal	9.7
Funnel viscosity, sec/qt	46
Plastic viscosity, cp	18
Gel strengths, lb/100 sq ft:	
10-second	9
10-minute	19
Water loss, cc/30 min	4.2

This resulted in a total cost of $6,481 for 700 barrels of mud, a savings of over $4 per barrel. This mud proved entirely suitable for the pressure-coring operation.

Operations During Pressure Coring. Pressure coring operations began at approximately 9 a.m. on September 30, 1979, when the core barrel was first picked up preparatory to cutting Core No 1. In all, 27 core barrel runs were made to cut 26 cores over the 210-ft interval from 5,175 to 5,385 ft. Pressure-coring equipment and services were supplied by Diamond Oil Well Drilling Company (DOWDCO) of Midland, Texas. A description of the equipment and its operation is contained in Appendix B. Coring operations ended at approximately 11:30 p.m. October 11, 1979, when the core barrel was laid down. The actual coring operation thus required 11-1/2 days to complete.

It had been agreed at the pre-spud meeting that Core 1 would be a practice run to familiarize rig and service crews with the details of a pressure-coring operation. It had also been agreed that Cores 2 through 10 would be taken using a systematic variation of bits and fluids to provide data for analysis by Sandia Laboratories and Bartlesville Energy Technology Center. They are seeking to evaluate the efficiency of various experimental coring techniques as compared to "conventional" pressure coring using a commercial diamond coring bit. Thereafter, coring proceeded routinely to completion using a standardized procedure.

Coring Bits and Fluid Descriptions. As part of the experimental coring procedure, 4 different bits were used in cutting the first 10 cores. In the discussion that follows, these are designated by the numbers shown below:

Type	Bit Number	Remarks
Diamond core bit	C7048	
Core bit with STRATAPAX® cutters	CS103	"Standard"
Core bit with STRATAPAX® cutters	CS106	Fluid courses on bit face
Core bit with STRATAPAX® cutters	CS100	"Standard"-- used previously on Shell job

The diamond bit (C7048) is of commercial manufacture and is pictured in Fig. 18. The core bit with STRATAPAX® cutters shown in Fig. 19 are not commercially available; they are experimental bits being developed by Sandia Laboratories in cooperation with DOWDCO as part of a DOE-supported research program to improve pressure-coring techniques.[23] The designation refers to a technique and design developed by Sandia using General Electric's polycrystalline diamond compact cutters to improve performance of drill bits.[24] As shown in Fig. 19, a photograph of the "standard" design bit CS103, the cutters are attached to the bit by mounting studs. Bit CS100 was also a "standard" design. A variation of design, in which fluid courses are cut into the face of the bit, is shown in Fig. 20. This variation was developed to facilitate use of a low-invasion fluid inside the core barrel.

Use of a low-invasion fluid inside the core barrel is another aspect of Sandia's research program.[23,25] The low-invasion fluid is a high-viscosity, brine-based polymer system containing sized calcium carbonate bridging particles. The fluid is stored inside the core barrel and extruded around the core as it is cut, with the objective of sealing and protecting the core from continued exposure to mud filtrate invasion. The composition of the low-invasion fluid[26] used in coring BRU 310 is given in Table 6. A nitrate ion tracer was incorporated to allow monitoring of invasion of this core. Results are presented in a later section (Analysis of Data) of this report.

Coring Operation. As stated earlier, 26 cores were cut over the interval from 5,175 to 5,385 ft. Of these, 20 (77.8 percent) were recovered with pressure on the inner barrel. The other six failed for a variety of reasons:

Core No.	Apparent Reason for Pressure Failure
3	Ball valve failed due to weak closing spring. Some weight material buildup around ball valve could have been a contributing factor.
4	Ball valve failed due to weak closing spring.
9	Core slipped in catcher and would not allow ball valve to close.
11	No apparent reason.
13	Core slipped in catcher and would not allow ball valve to close.
25	Ball valve failed with no apparent malfunction.

A summary of the coring record and the bits and fluid used is shown in Table 7.[27]

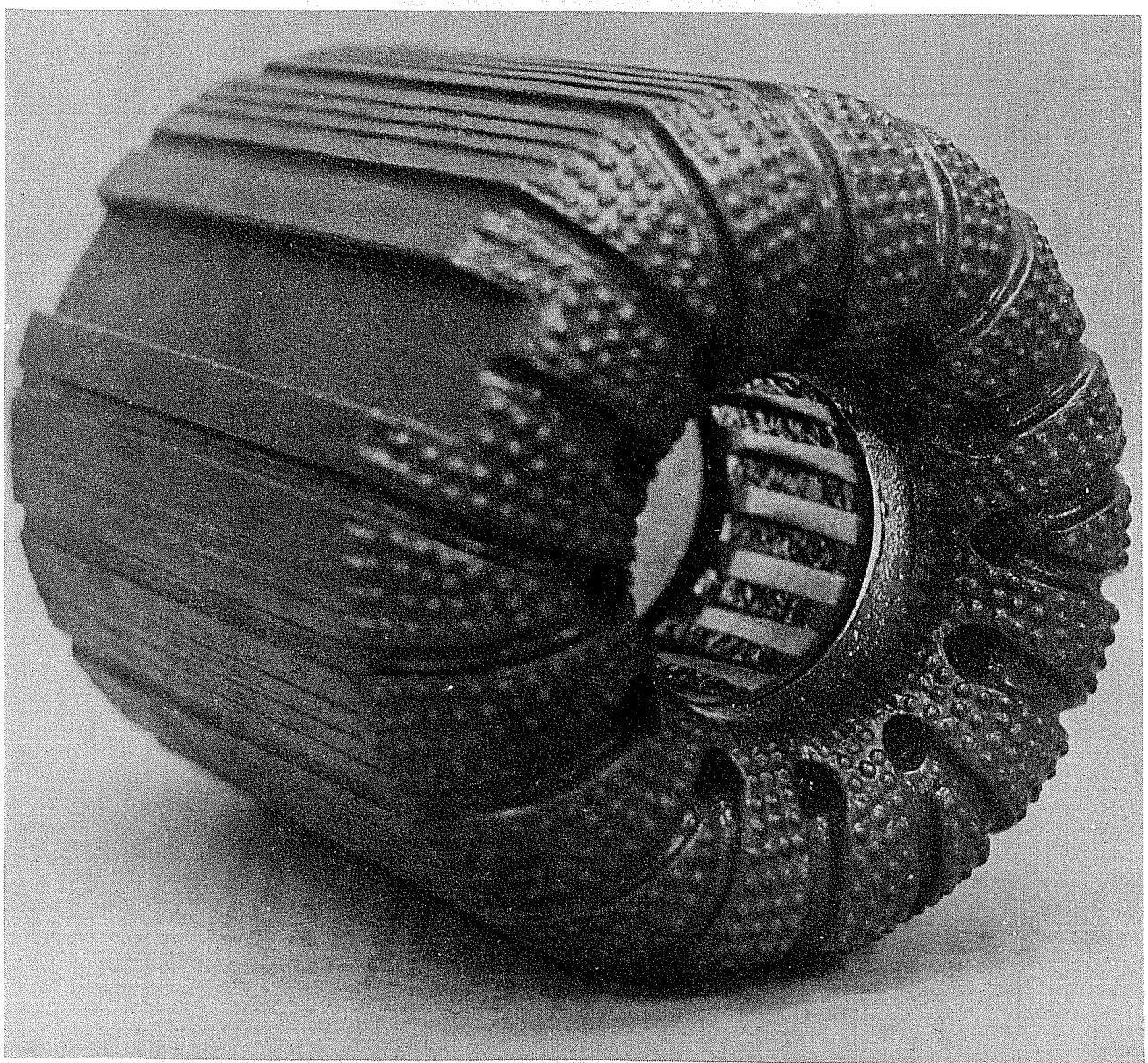


Figure 18.--Photograph of standard diamond coring bit (no. C7048).

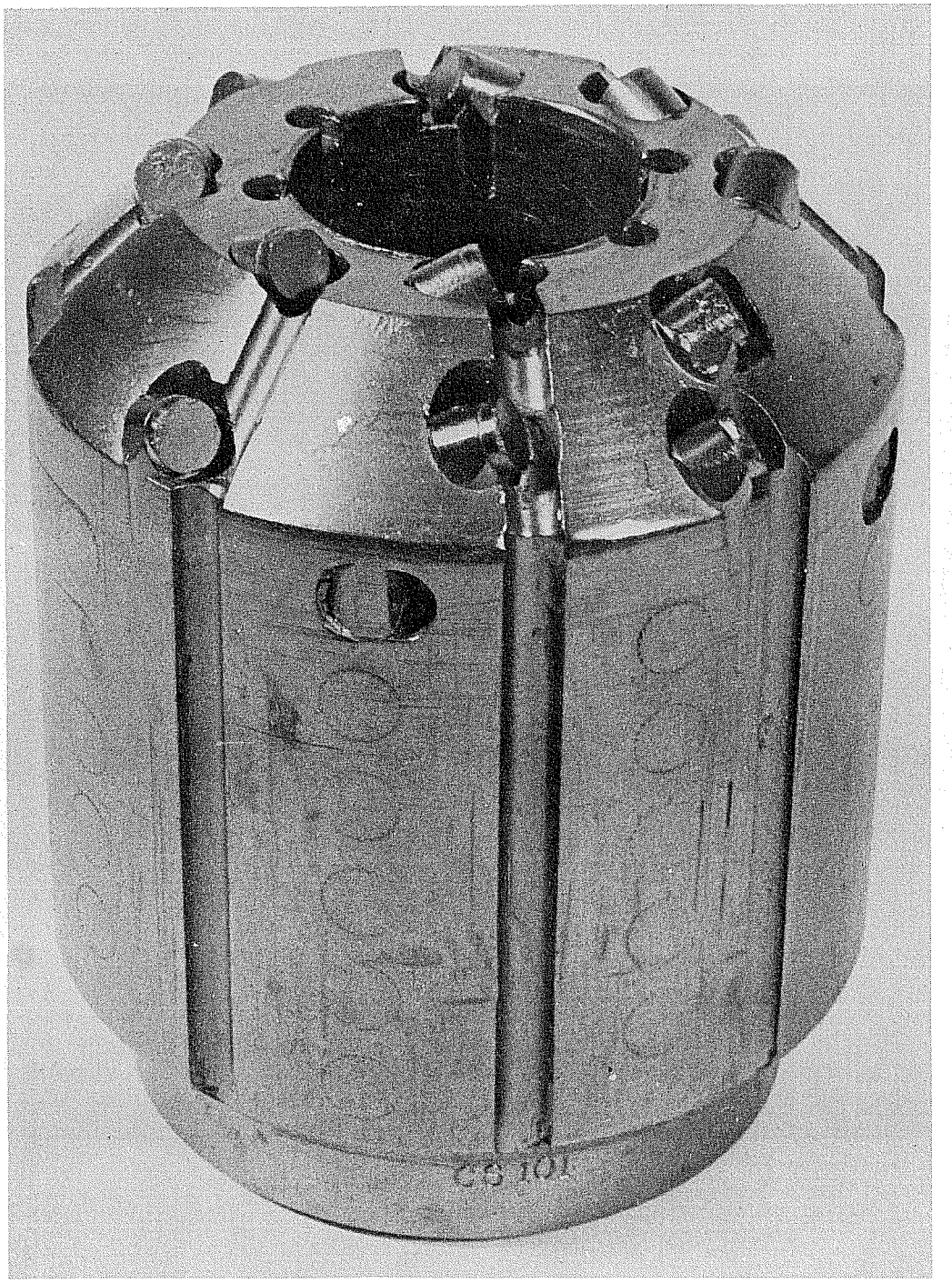


Figure 19.--Photograph of "standard" DOWDCO coring bit with STRATAPAX® cutters

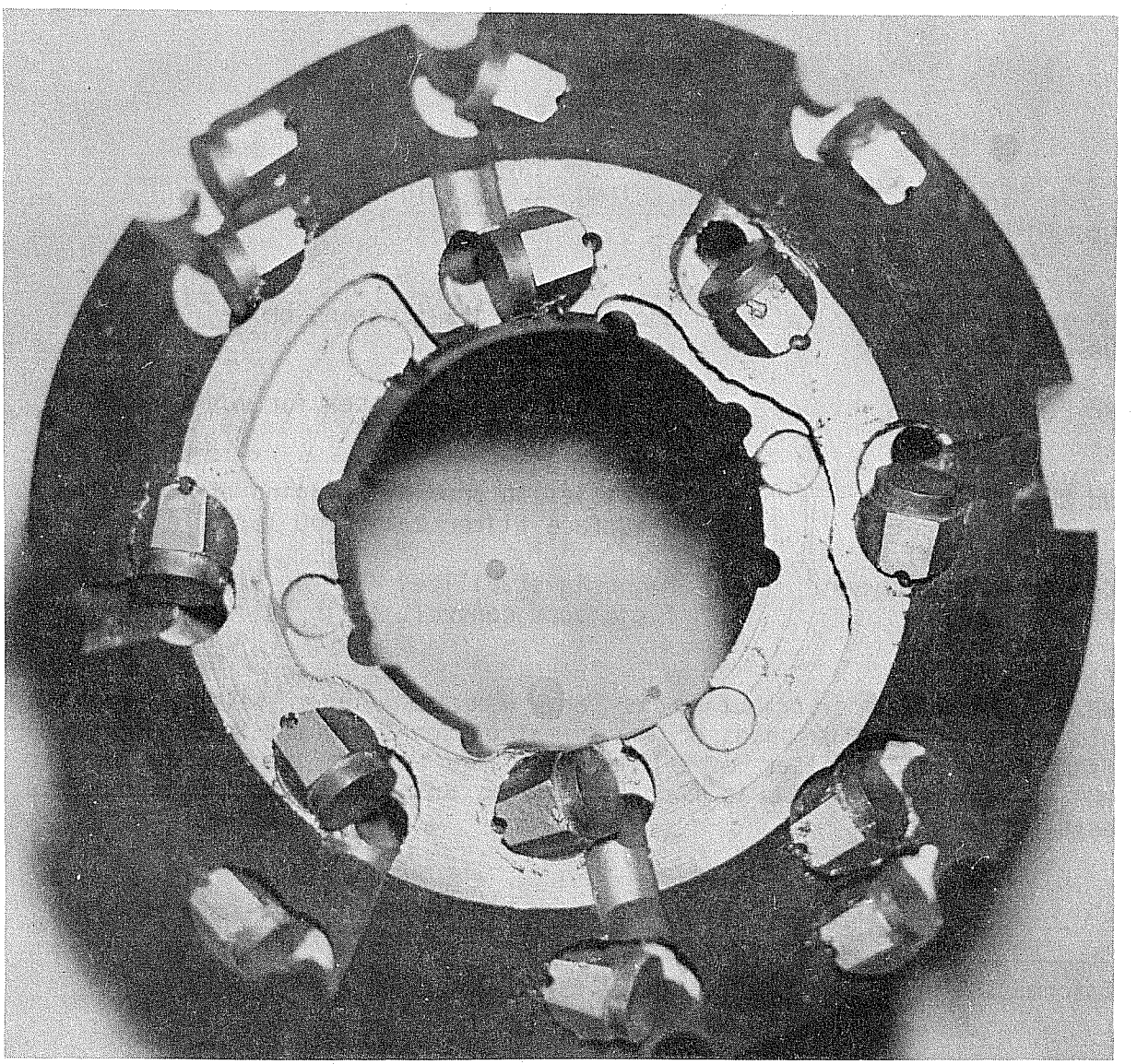


Figure 20.--Photograph of DOWDCO coring bit showing STRATAPAX® cutters and fluid courses

TABLE 6

COMPOSITION OF LOW INVASION FLUID
USED IN CORING BRU NO. 310*

906 gm H_2O 389 gm $CaCl_2$	One liter of low-freezing brine (freezes at -60°F)
Add 2.64 gm $NaNO_3$	2,000 ppm nitrate tracer for monitoring invasion
Add 286 gm $CaCO_3$	Particles to provide bridging of pores and a surface filter cake, 100 lb/bbl
Add 43 gm HEC polymer	Magnesia-stabilized HEC for viscosity and fluid loss control, 15 lb/bbl

The particle size distribution is very important in minimizing invasion into the core. The bridging of the formation pores and the formation of an effective surface filter cake are both affected by the choice of the $CaCO_3$ particles. Sandia is currently using Brinadd Sluggit in the field tests.

*Information received from Sandia Laboratories.

TABLE 7

CORING RECORD
BENNETT RANCH UNIT NO. 310

Core no.	Depth from	Depth to	Feet	Hours	Bit no.	Type*	Low-invasion fluid	Remarks
1	5175	5181	6	1-1/4	CS106	SP	yes	Practice; OK
2	5181	5190	9	3	CS103	SP	no	OK
3	5190	5198	8	4-1/2	CS106	SP	yes	Ball valve failed; comp. spring
4	5198	5207	9	5	C7048	Dia	no	Ball valve failed; comp. spring
5	5207	5216	9	3	CS100	SP	no	OK
6	5216	5224	8	3	CS106	SP	yes	OK
7	5224	5233	9	4-3/4	C7048	Dia	no	OK
8	5233	5242	9	1-1/2	CS103	SP	no	OK
9	5242	5250	8	3-1/4	CS106	SP	yes	Ball valve failed; core slipped
10 **	5250	5259	9	4-1/2	C7048	Dia	no	OK 1600 psi
11	5259	5267	8	1-1/4	CS103	SP	yes	No pressure; unexplained
12	5267	5273	6	1-3/4	CS103	SP	"	OK
13	5273	5281	8	2-3/4	CS103	SP	"	Ball valve failed; core slipped
14	5281	5289	8	1-3/4	CS103	SP	"	OK
15	5289	5297	8	1-1/2	CS103	SP	"	OK
16	5297	5305	8	1-3/4	CS103	SP	"	OK 1500 psi
17	5305	5313	8	2	CS103	SP	"	OK
18	5313	5321	8	2-1/4	CS103	SP	"	OK
19	5321	5329	8	2	CS103	SP	"	OK
20	5329	5337	8	1-1/4	CS103	SP	"	OK
21	5337	----	0	1-1/2	CS103	SP	"	Junk on bottom
	Drill 1 ft							
22	5338	5345	7	2-1/2	CS103	SP	"	OK
23	5345	5353	8	3	CS103	SP	"	OK
24	5353	5361	8	2-1/2	CS103	SP	"	OK
25	5361	5369	8	2-3/4	CS103	SP	"	OK
26	5369	5377	8	3	CS103	SP	"	OK
27	5377	5385	8	2-3/4	CS103	SP	"	Ball valve failed

*SP = Stratapax; Dia = diamond.
**Core 10 ended experimental program; cores 11 through 27 were routine.

The timing of this coring operation by days is shown in Fig. 21. The dotted portions of the graph show two minor delays, encountered when it became necessary to clean junk from the hole. The first of these was between Cores 2 and 3, when aluminum junk, apparently from the drillable casing shoe, was found. Later, core barrel run 21 (called "Core No. 21") encountered two or three hardened steel dies from pipe tongs, which had evidently fallen in the hole (unreported) and prevented any penetration. Most of this junk was recovered by running a junk basket before coring resumed with Core 22, but some minor junk problems persisted to the end of the job.

Figure 21 also shows that an average recovery of three cores per day was achieved after the experimental program, discussed below, was completed. All of these cores were cut with the STRATAPAX® equipped CS103 bit using core barrels containing low-invasion fluid.

DOWDCO has supplied additional data on the coring operation, stressing operational aspects. This report includes detailed data for each barrel run and a narrative description of the coring runs (Appendix C). A summary of operating data from DOWDCO's reports is given in Table 8.

The experimental program conducted while cutting Cores 2 through 10 was a sequential operation in which bits of the three designs (i.e., "standard" DOWDCO bit with STRATAPAX® cutters, fluid-course DOWDCO bit with STRATAPAX® cutters, and diamond) were run in succession through three cycles. Time components of the coring cycle (run in, core, pull out) and average penetration rates are shown in Table 9. In general, the standard STRATAPAX® equipped DOWDCO bits CS103 and CS100 showed penetration rates superior to either the CS106 STRATAPAX® equipped design or the commercial diamond bit. However, since the time required to complete the rest of the coring cycle is essentially unaltered, the total time saved is not proportional to the improvement in penetration rate. A 50 percent improvement is suggested by data from the remainder of the operation, in which the CS103 bit was used; on the average, about three cores per day were obtained, compared to two per day using the CS106 or diamond bits. In the earlier phase of the operation, low-invasion fluid was used only in the CS106 bit runs.

Coring Mud Properties. Coring mud properties as recorded by daily mud checks during the operation are listed in Table 10.

Logging Operations

A complete suite of Schlumberger logs for the cored interval of the BRU 310 is shown in Fig. 22. The cored intervals have been located on the logs to aid in the log and core analysis. Depth measurements were recorded from the kelley bushing (3,577 ft). The bottom of the 8-5/8 inch casing was

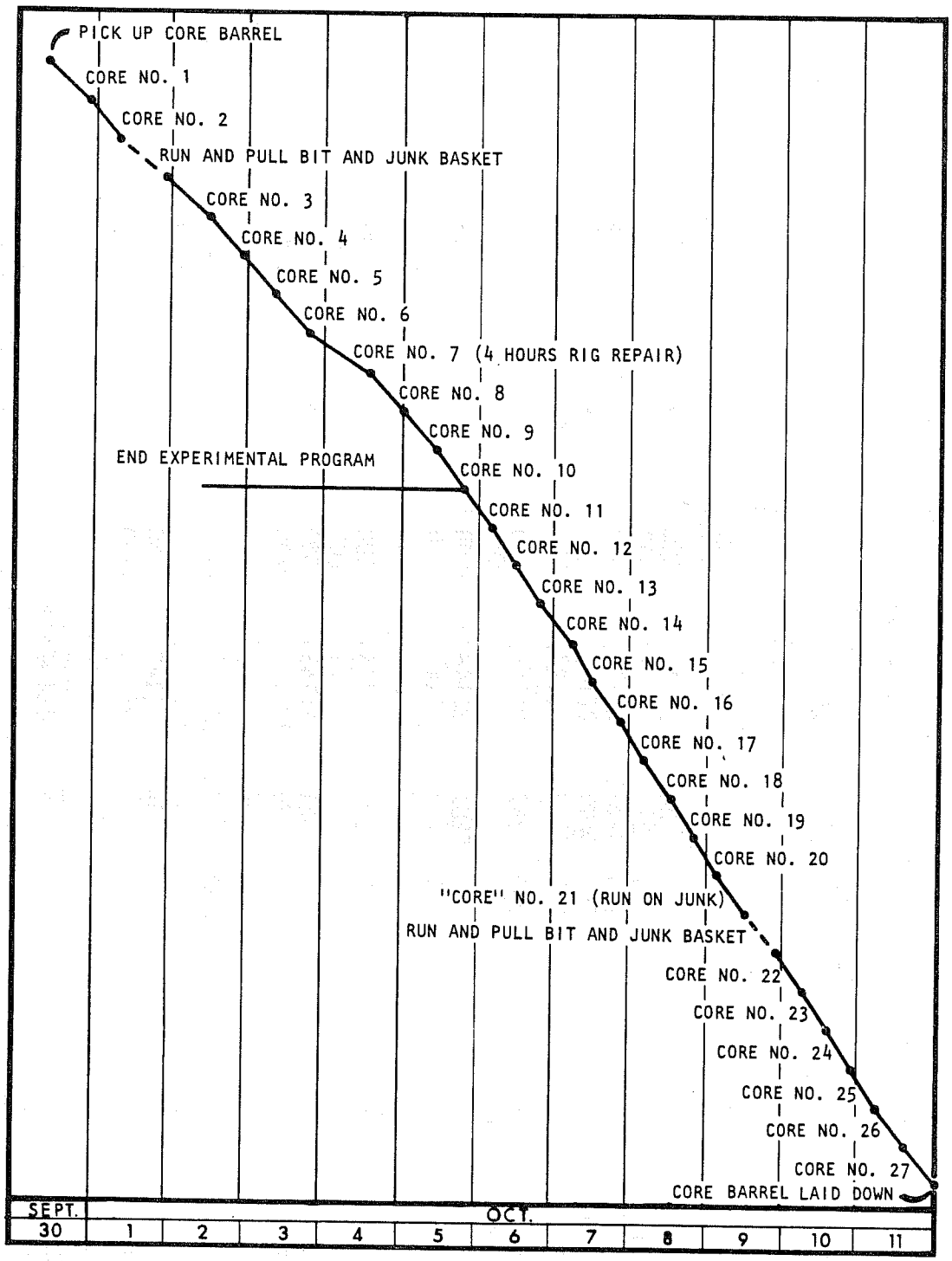


Figure 21.--Daily sequence of pressure coring operations, BRU No. 310.

TABLE 8

OPERATING DATA FOR PRESSURE-CORING OPERATION
BENNETT RANCH UNIT NO. 310

Run no.	Bit no.*	RPM	Weight, 000 lb	Depth, ft in	Depth, ft out	Strokes (gal/min)	Barrel pressure, psi	Low invasion gel	Drilling rate, ft/hr	Remarks
1	CS106	80	5-6	5175	5181	39(174)	2750	yes	1.92	Drilled on junk
2	CS103	80	5-6	5181	5190	39(174)	2550	no	5.93	Drilled on junk
3	CS106	80	8	5190	5198	39(174)	0	yes	2.04	
4	dia.	60-72	8	5198	5207	32(143)	0	no	1.95	
5	Shell SP	70	6	5207	5216	32(143)	2600	yes	3.46	
6	Shell SP	70	6	5216	5224	32(143)	1600	yes	1.74	
7	dia.	70	8	5224	5233	32(143)	2800	no	1.96	
8	CS103	80	9	5233	5242	32(143)	3600	no	5.93	
9	CS106	80	9	5242	5250	32(143)	0	yes	2.56	
10	dia.	75	9	5250	5259	32(143)	1600	no	2.22	
11	CS103	80	9	5259	5267	32(143)	0	yes	6.23	
12	CS103	80	9	5267	5273	32(143)	3300	yes	4.09	
13	CS103	80	9	5273	5281	32(143)	2600	yes	3.13	
14	CS103	80	9	5281	5289	32(143)	0	yes	4.84	
15	CS103	90	9	5289	5297	32(143)	2900	yes	6.00	
16	CS103	80	9	5297	5305	32(143)	1500	yes	6.00	
17	CS103	80	9	5305	5313	32(143)	2600	yes	4.48	
18	CS103	80	9	5313	5321	32(143)	2600	yes	3.60	
19	CS103	80	9	5321	5329	32(143)	2700	yes	5.45	
20	CS103	80	9	5329	5337	32(143)	2400	yes	6.66	
21	CS103	80	9	5337	5337	32(143)	----	yes	----	Tong dies in hole
22	CS103	80	11-12	5338	5346	32(143)	3600	yes	3.05	
23	CS103	80	11-12	5346	5354	32(143)	3100	yes	3.66	
24	CS103	80	11-12	5354	5362	32(143)	2700	yes	4.40	
25	CS103	80	11-12	5362	5370	32(143)	3300	yes	2.40	
26	CS103	80	11-12	5370	5378	32(143)	2900	yes	3.09	
27	CS103	80	11-12	5378	5386	32(143)	0	yes	2.79	

*Abbreviations: CS106--Stratapax bit with recess CS103--Stratapax bit without recess
Shell SP--Shell Stratapax dia.--standard diamond bit

TABLE 9

TIME COMPONENTS OF CORING OPERATIONS AND PENETRATION RATES DURING EXPERIMENTAL BIT COMPARISONS

Core no.	Bit no.	Pick up and run in hole, hours	Coring time, hours	Pull out and lay down, hours	Total time, hours	Footage cored, feet	Coring rate, ft/hr
First Sequence							
2	CS103	4.00	3.00	4.25	11.25	9	3.00
3	CS106	3.75	4.50	4.50	12.75	8	1.78
4*	C7048	3.50	5.00	2.75	11.25	9	1.80
Second Sequence							
5*	CS100	2.25	3.00	3.50	8.75	9	3.00
6	CS106	3.50	3.00	3.00	9.50	8	2.67
7	C7048	3.50**	4.75	3.50	11.75	9	1.90
Third Sequence							
8	CS103	3.50	1.50	3.50	8.50	9	6.00
9*	CS106	3.50	3.25	3.50	10.25	8	2.46
10	C7048	2.25	4.50	3.75	10.50	9	2.00

*Cores recovered with no pressure.
**Excludes 4 hours used for rig repairs.

TABLE 10

BENNETT RANCH UNIT NO. 310
MUD PROPERTIES

Date	Depth, ft	Tritium Activity 10^{-6} Picocuries	Weight, lb/gal	Viscosity, funnel	Pl.vis., cp	Yield point	Gels	pH	Filtrate, API	Cl, ppm	Ca, ppm
9/30	5175	--	9.7	46	18	12	9/19	10.0	4.2	8,500	160
10/1	5190	--	9.7	45	17	10	12/20	10.0	4.0	12,000	160
10/2	5204	--	9.7	55	25	17	10/	9.5	4.2	15,000	160
10/3	5217	--	9.7	62	32	24	14/27	10.0	4.0	11,000	120
10/4	5233	--	9.8	66	35	23	16/29	9.5	4.0	12,000	120
10/5	5251	5.40 + -0.54	9.7	66	35	24	14/26	9.5	4.0	11,500	160
10/6	5272	5.09 + -0.51	9.7	65	32	21	12/20	9.5	4.2	11,700	160
10/7	5292	4.79 + -0.48	9.6	66	33	22	14/26	9.0	4.0	12,000	160
10/8	5321	4.55 + -0.46	9.7	62	30	17	10/22	9.5	4.0	13,000	160
10/9	5338	4.72 + -0.47	9.5	76	39	26	10/16	10.0	3.6	18,000	160
10/10	5348	4.18 + -0.42	9.6	85	37	29	9/16	10.0	3.2	17,000	180
10/11	5371	4.13 + -0.41	9.6	70	34	22	11/18	9.5	2.8	18,000	80
10/12	5385	--	9.5	68	33	23	10/17	9.6	2.8	18,000	100

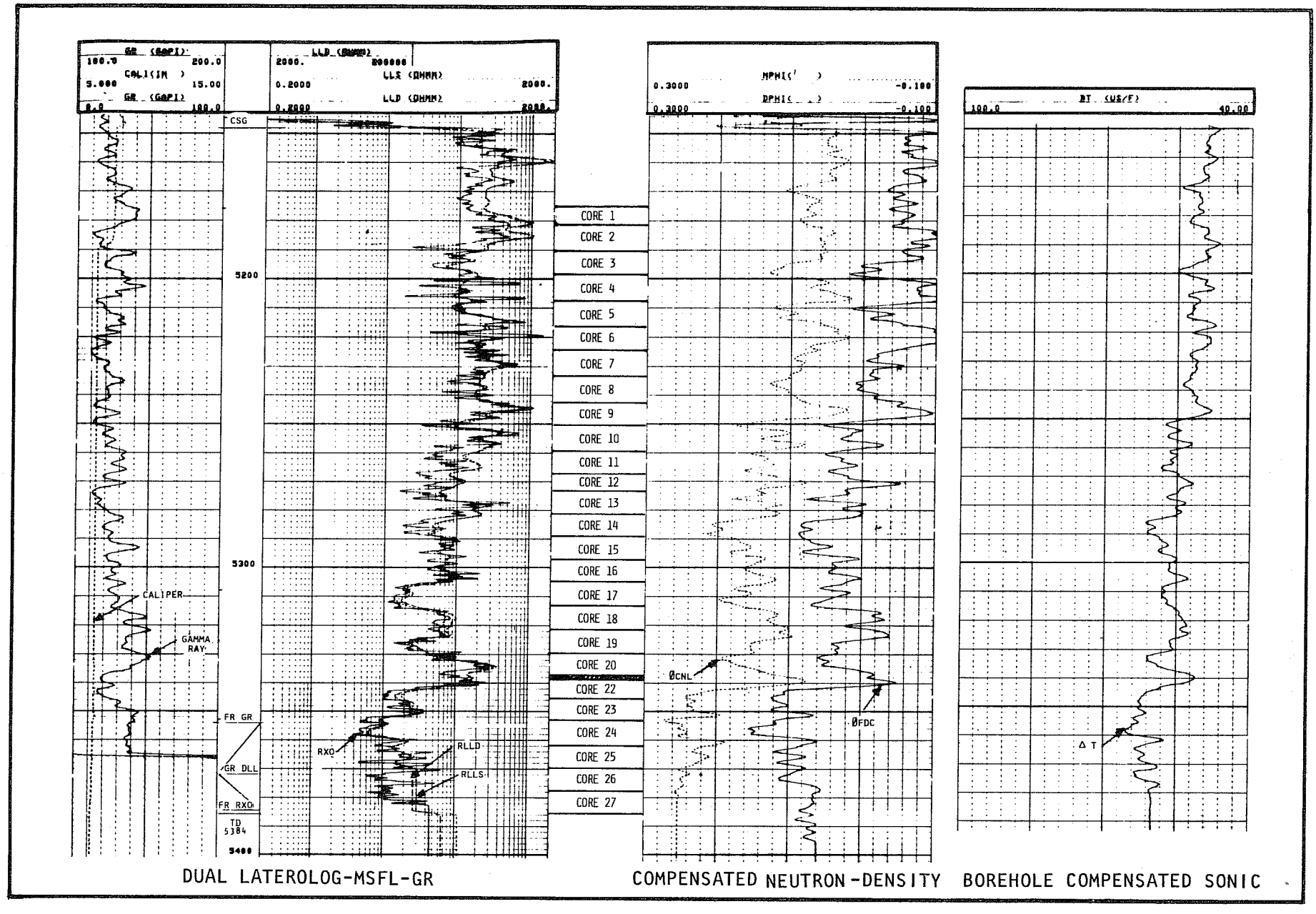


Figure 22.--Schlumberger logs, BRU No. 310.

detected at 5,148 ft by the logger. The total depth of the BRU 310 was 5,386 ft. The maximum recorded bottomhole temperature was 105°F. The resistivity log was used as the base log. The porosity logs were run on a limestone matrix value of 2.71 gm/cc. All three porosity tools indicate two distinct porosity breaks at 5,248 and 5,342 ft.

Completion Operations

Following the logging of the BRU 310, Texas Pacific began completion procedures. The 6-1/2 inch core hole was reamed with a 7-7/8 inch bit and 30 ft of additional hole was drilled. On October 15, a 5-1/2 inch production string was cemented with the float collar located at 5,372 ft. The remaining completion operations were performed during the production testing procedures. Figure 23 is a schematic of the cased well.

Production Testing Procedures

After completion of log and core analysis, the proposed test intervals were selected. On May 3, 1980, the testing procedure agreed on by Gruy Federal and Texas Pacific was begun. The production testing procedure consisted of four separate phases (Table 11). Four intervals were isolated, perforated and treated with 20% HCl-Fe acid. Three of the intervals were swab tested for a minimum of one day, after which the Main Pay interval from 5,248 to 5,302 ft was production tested with a pumping unit. A summary of the production testing procedure is presented in Table 11. Complete details of the testing procedure can be found in the daily drilling reports (Appendix D).

BENNETT RANCH UNIT NO. 310
WASSON FIELD
YOAKUM CO., TEXAS

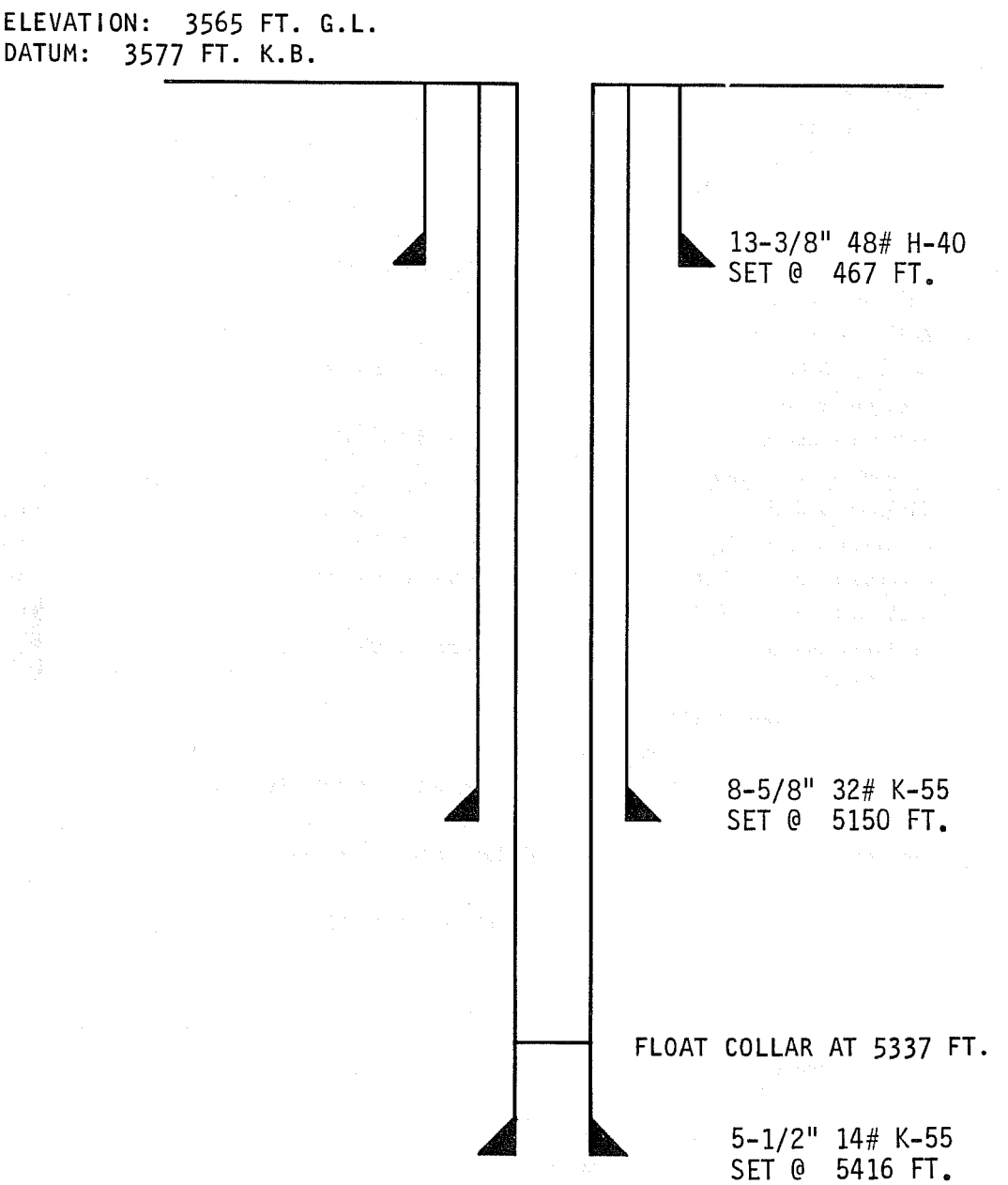


Figure 23.--Completion schematic, BRU No. 310.

TABLE 11

SUMMARY OF PRODUCTION
TESTING PROCEDURES FOR
BENNETT RANCH UNIT NO. 310

DATE	
5-3	Re-entered BRU No. 310
	Installed blowout preventers
	Tagged PBTD @ 5372'
5-4	Preparing to test
5-5	Preparing to test
5-6	Perforated interval 5342-58'
5-7	Acidized and swab tested
5-8	Swabbed 11 hours, recovered 113 bbl water, trace oil
5-9	Isolated and perforated interval 5325-32'
5-10	Acidized and swab tested
5-11	Swabbed 10 hours, recovered 105 bbl water and 2 bbl oil
5-12	Prepared to swab
5-13	Swabbed 9 hours, recovered 99 bbl water and 3 bbl oil
5-14	10 hour shut in tubing pressure 650 lbs
	Isolated and perforated 5248-5302'
	Acidized perforations
5-15	Swabbed 9 hours, recovered 230 bbl water and 42 bbl oil
5-16	Shut down due to weather
5-17	Isolated and perforated 5168-82', 5194-5200', 5209-5215', 5223-5234'
5-18	Acidized and swab tested
5-19	Swabbed 2 hours, no recovered fluids
	Swabbed 2 hours, recovered 25 bbl of load water, slight trace of oil and good gas blow
5-20	Swabbed 5 hours, recovered 10 bbl of load water with trace oil and good gas blow
5-21	Prepared to production test main pay interval 5248-5302' and upper pay zone
5-22	Put well on test
5-23	24 hours recovered 16 BO and 272 BW
5-24	24 hours recovered 25 BO and 236 BW
5-25	24 hours recovered 45 BO and 237 BW
5-26	24 hours recovered 40 BO and 265 BW
5-27	24 hours recovered 43 BO and 242 BW
5-28	24 hours recovered 42 BO and 240 BW
5-29	24 hours recovered 48 BO and 275 BW
5-30	24 hours recovered 48 BO and 276 BW
5-31	24 hours recovered 48 BO and 275 BW
6-1	24 hours recovered 49 BO and 280 BW
6-2	24 hours recovered 47 BO and 274 BW
6-3	24 hours recovered 46 BO and 277 BW
6-4	24 hours recovered 47 BO and 273 BW

ANALYSIS OF DATA

Core Data

Core analysis measurements were performed by Core Laboratories, Inc., on San Andres cores recovered using pressure retaining coring equipment. The cores were cut using a water-base mud containing a tracer (tritium) to aid in determining the degree of flushing of the core by the mud filtrate. Before coring certain depth intervals (Table 8), the inner core barrel was filled with a lowinvasion gel in an effort to minimize filtrate invasion of the core after it entered the core barrel. Sodium nitrate incorporated into the low-invasion gel served as a tracer.

Laboratory Core Analysis. All cores recovered with pressure were sent to Core Labs' Special Core Analysis laboratories in Dallas. Full-diameter segments of the recovered cores were selected for measurement of porosities, fluid saturations, permeabilities, and pore-water chlorides. "Plug" and "donut" portions* cut from full-diameter segments were chosen for testing to determine the concentrations of the tracers in the pore water. Gas chromatography was used to determine the composition of the gases liberated from the full-diameter cores recovered with pressure.

Cores recovered without pressure were sent to Core Labs in Midland, Texas, for routine core analysis. Porosities, fluid saturations, and permeabilities were measured for full-diameter, plug, and donut cores. The procedures used in the pressured and nonpressured core analysis are presented, along with the data obtained, in Appendix E.

Porosity, Saturation, and Permeability Data

The cores recovered with pressure are identified in Fig. 24, which is a plot of oil saturation, water saturation, and porosity versus depth. Porosity measurements from both pressured and nonpressured core are similar. However, both oil and water saturations in the nonpressured cores are generally lower than those measured in comparable pressured cores. Higher water saturations were observed in the lower porosity intervals.

Maximum horizonal permeability to air and vertical permeability to air, are plotted on Figs. 25 and 26, respectively. A plot of maximum horizontal permeability versus depth (Fig. 25) clearly indicates nonproducible intervals. These low-permeability intervals are scattered throughout the San Andres First Porosity from 5,150 to 5,260 ft. A major low-permeability zone can be identified, from 5,318 to 5,324 ft. The variation of vertical permeability with depth (Fig. 26) shows a pattern comparable to that of horizontal permeability; however, vertical permeability tends to be less than the horizontal by an order of magnitude.

In a few instances, high horizonal and vertical permeabilities indicated the presence of fractures. From the available data it was not clear

*The cylindrical inner portion cut from the full-diameter core is called the "plug"; the annular outer portion encompassing the plug is called the "donut."

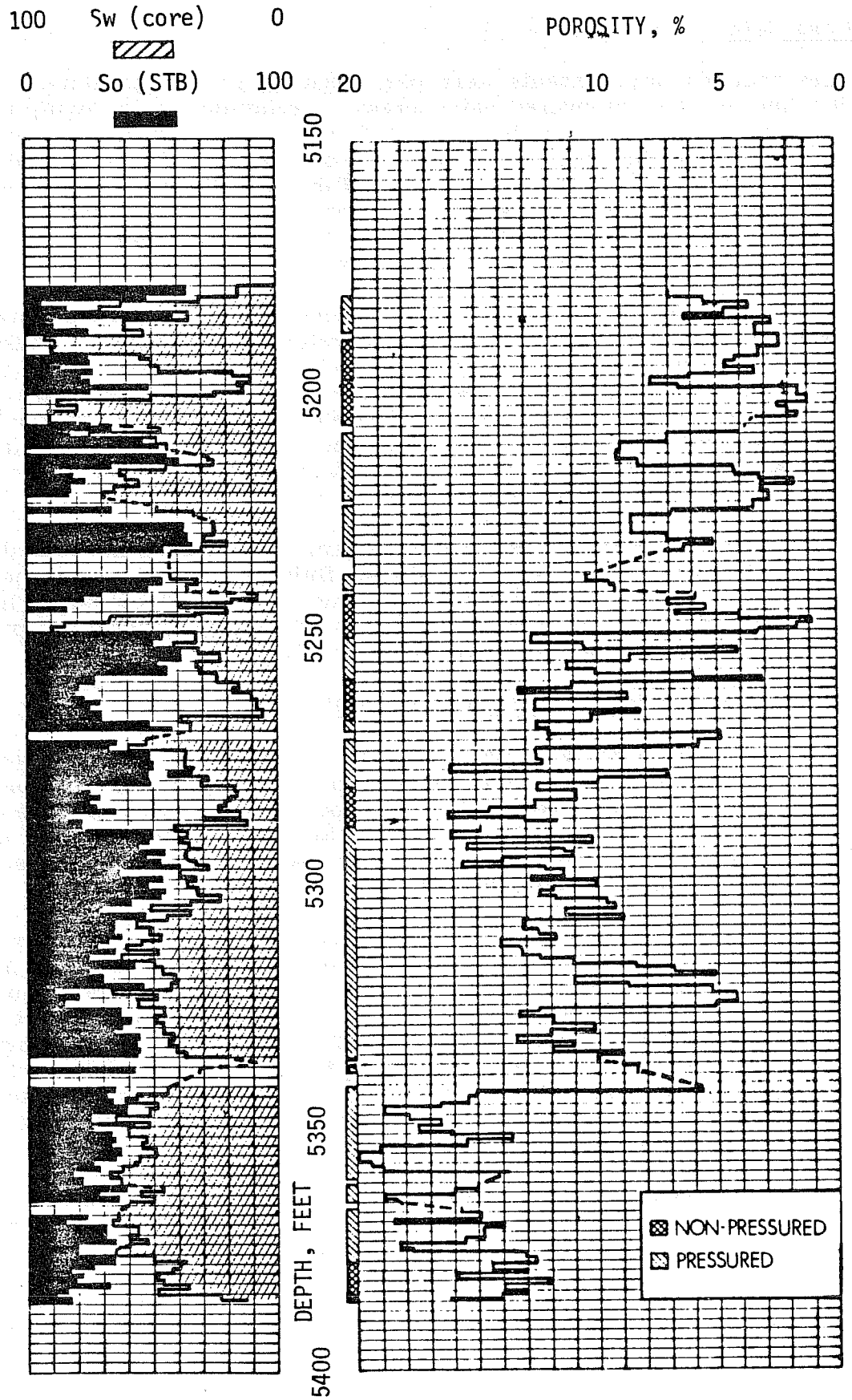


Figure 24.--Core analysis results: water saturation and porosity.

Texas Pacific BRU No. 310
Wasson Field, Texas
San Andres Formation
MAXIMUM HORIZONTAL PERMEABILITY, MD

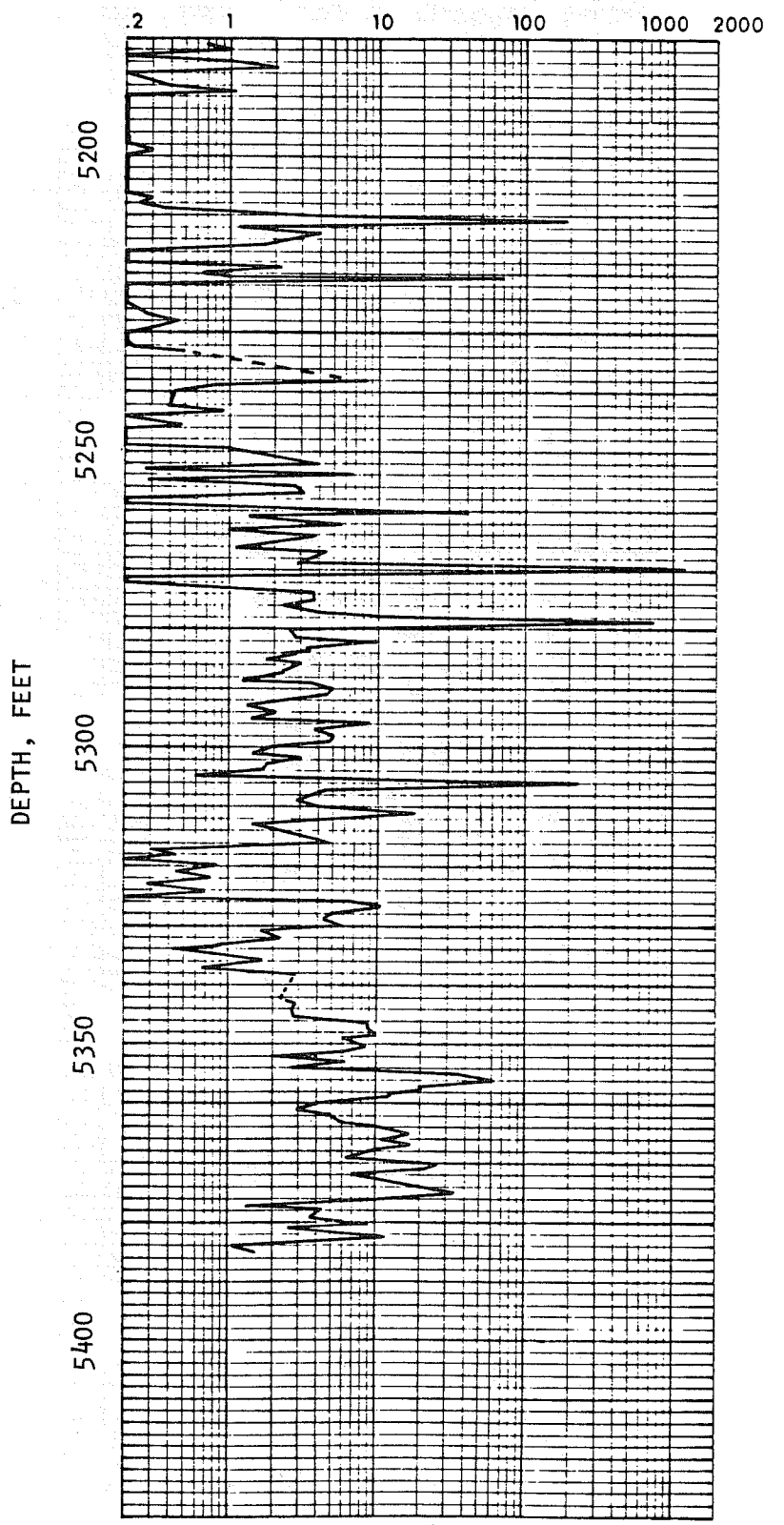


Figure 25.--Core data: maximum horizontal permeability to air vs. depth.

Texas Pacific BRU No. 310
Wasson Field, Texas
San Andres Formation
VERTICAL PERMEABILITY, MD

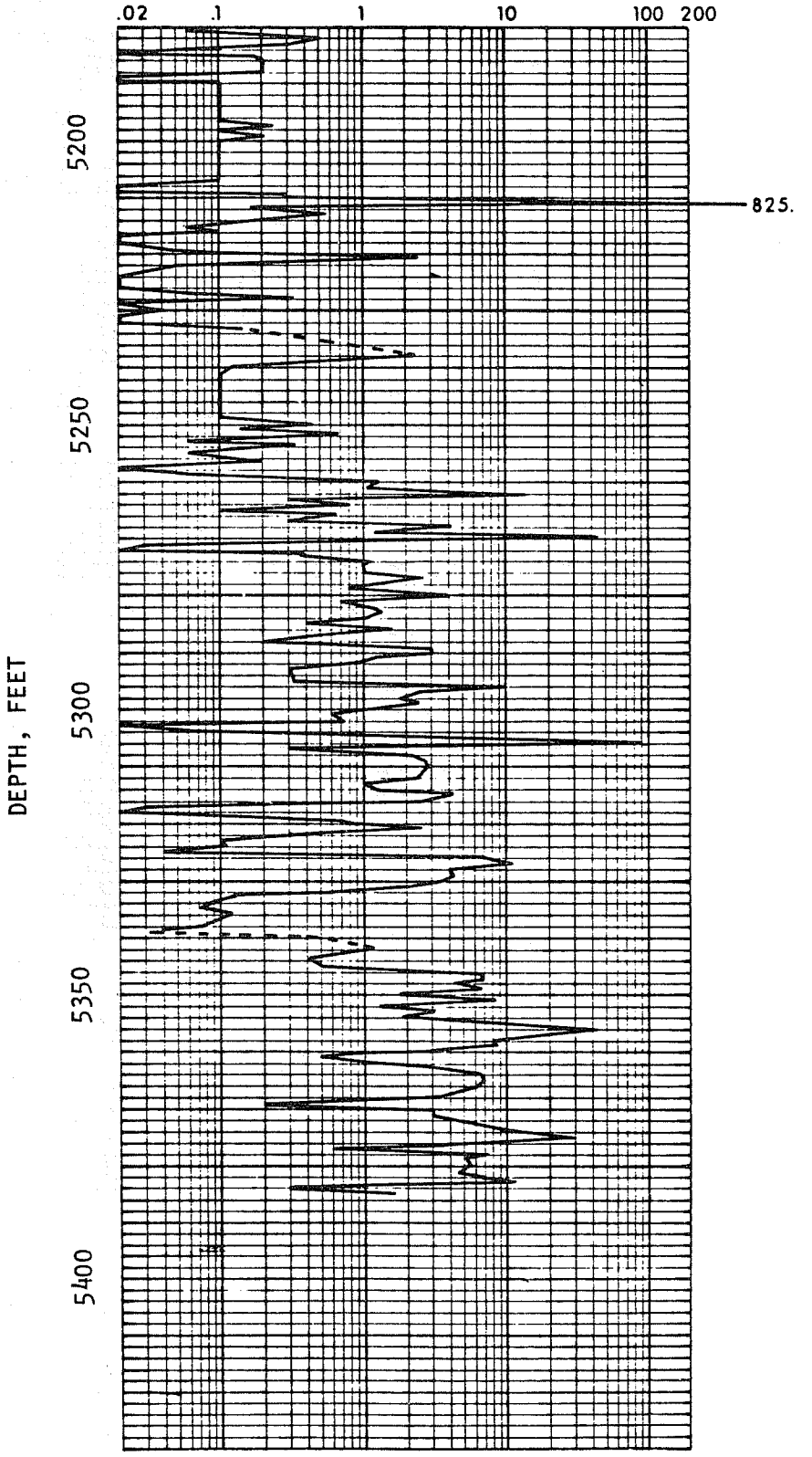


Figure 26.--Core data: vertical permeability to air vs. depth.

whether these fractures were natural or were induced during the drilling and core analysis. Both horizontal and vertical permeabilities increased below the estimated oil/water contact located at 5,335 ft.

Figure 27 is a semilog plot of porosity versus maximum permeability to air of core samples from the First Porosity zone; Fig. 28 is a similar plot for the Main Pay zone. Both plots are approximately linear, illustrating that permeability tends to increase with increasing porosity.

For a water-wet rock surface, the immobile (or irreducible) water saturation is dependent on the porosity of the rock. Since permeability is also dependent on porosity, the irreducible water saturation should also be related to the permeability. The interrelationship suggests that irreducible water saturation should be a function of the logarithm of permeability. For water-wet systems known to be at irreducible water saturation, a plot of water saturation against the log of permeability is linear. Figures 29 and 30 are semilog plots of water saturation versus permeability for the First Porosity zone and the Main Pay zone, respectively. Neither plot shows a linear trend, suggesting either that these two zones are not at irreducible water saturation or that the rock surfaces are partially oil-wet. Additional analysis indicates that both conditions are possible. However, these zones are too large to eliminate the possibility that specific intervals may be at the irreducible water saturation limits.

Grain Density and Chloride Data

The grain density measurements (Fig. 31) obtained by Core Labs were slightly higher than expected. Grain densities typical of limestone (2.71 gm/cc) were not observed, nor were typical anhydrite densities (2.94-2.98 gm/cc). The standard dolomite matrix density (2.87 gm/cc) seems to dominate the measurements, indicating smaller volumes of limestone and anhydrite in the rock matrix. High grain density measurements are correlated with low porosity and low permeability; for example, the high grain densities found at 5,208 and 5,220 ft correspond to porosities less than 3% and horizontal permeabilities less than 1 md.

Figure 32 is a plot of pore-water chloride concentration versus depth. A distinct change at 5,260 ft suggests either a lower degree of mud filtrate invasion or a change in formation salinity. Recognizing that porosities are lower above 5,260 ft, it is reasonable to assume that the San Andres First Porosity has a higher degree of invasion and a lower chloride concentration in the formation water.

The chloride content of the mud filtrate, 17,000 ppm, was much lower than the measurements of core-water chlorides shown in Fig. 32. Detailed analysis of the drilling reports showed that cores from intervals with high core-water chlorides were taken with the brine-based low-invasion fluid in the inner core barrel.

Invasion Data. Permeability, porosity, and water saturation were measured for 28 plug and donut samples taken from full-diameter cores recovered with pressure. This method of core sampling provides a means of evaluating the

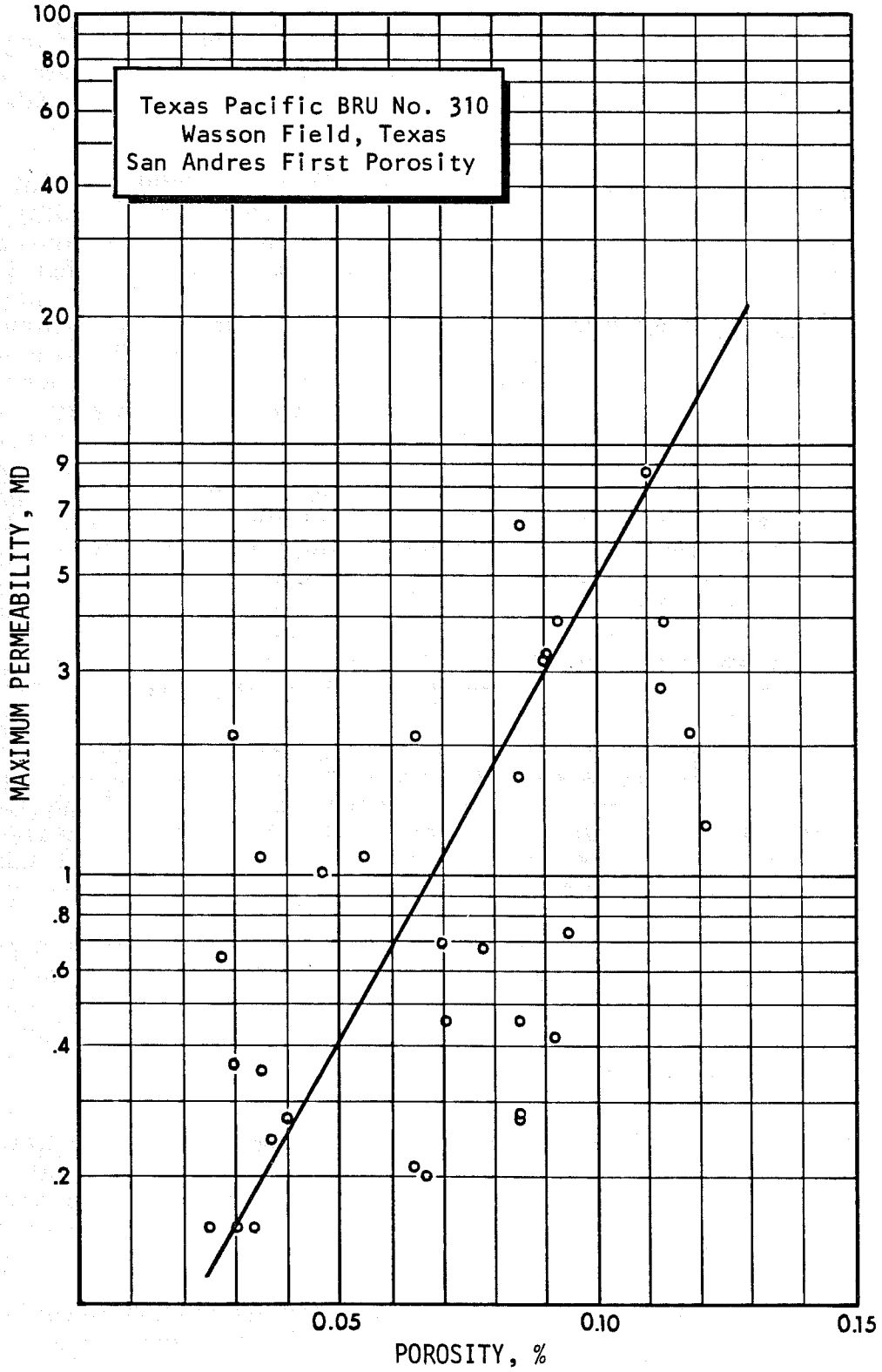


Figure 27.--Porosity vs. permeability, San Andres First Porosity.

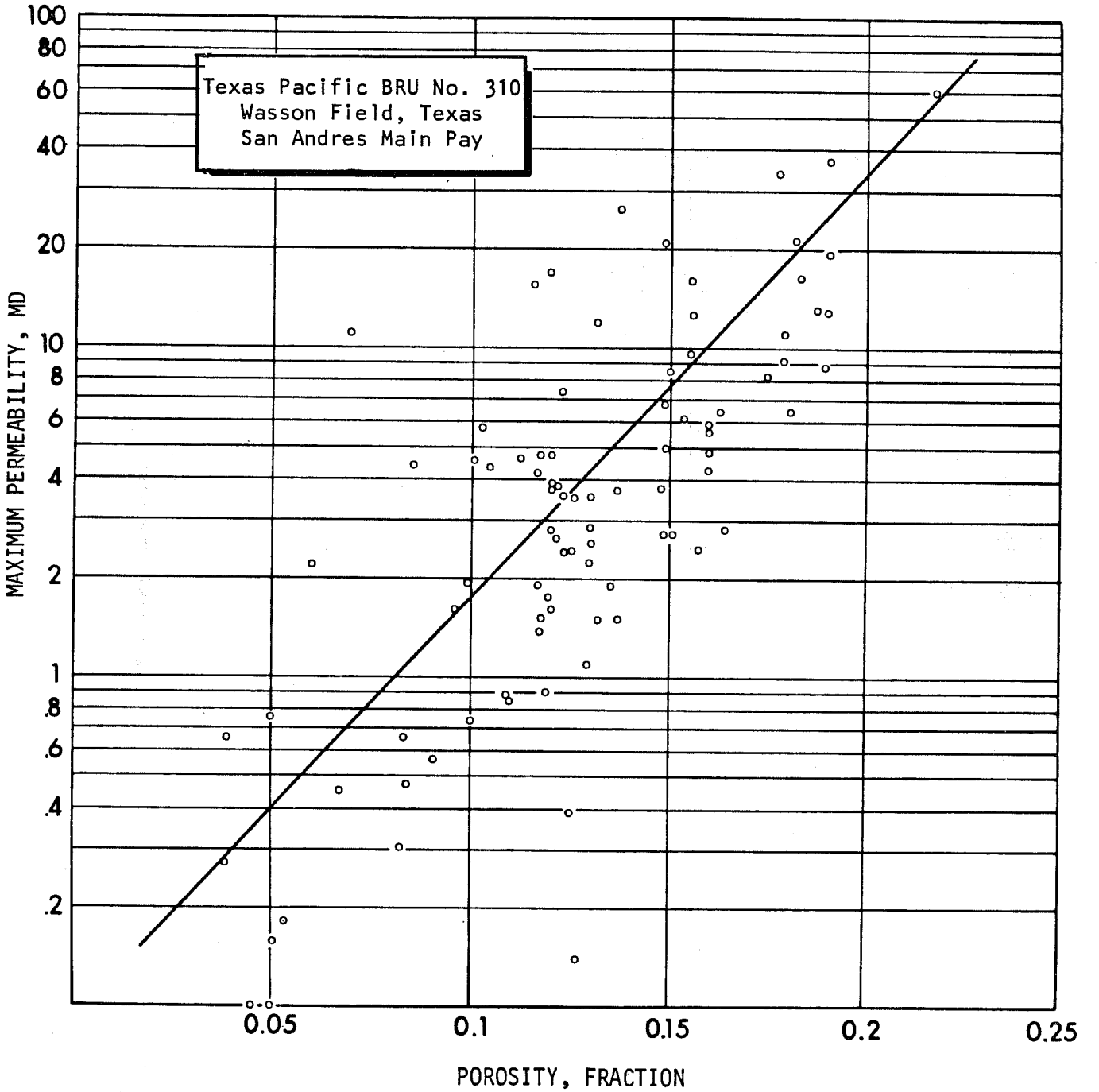


Figure 28.--Porosity vs. maximum permeability, San Andres Main Pay.

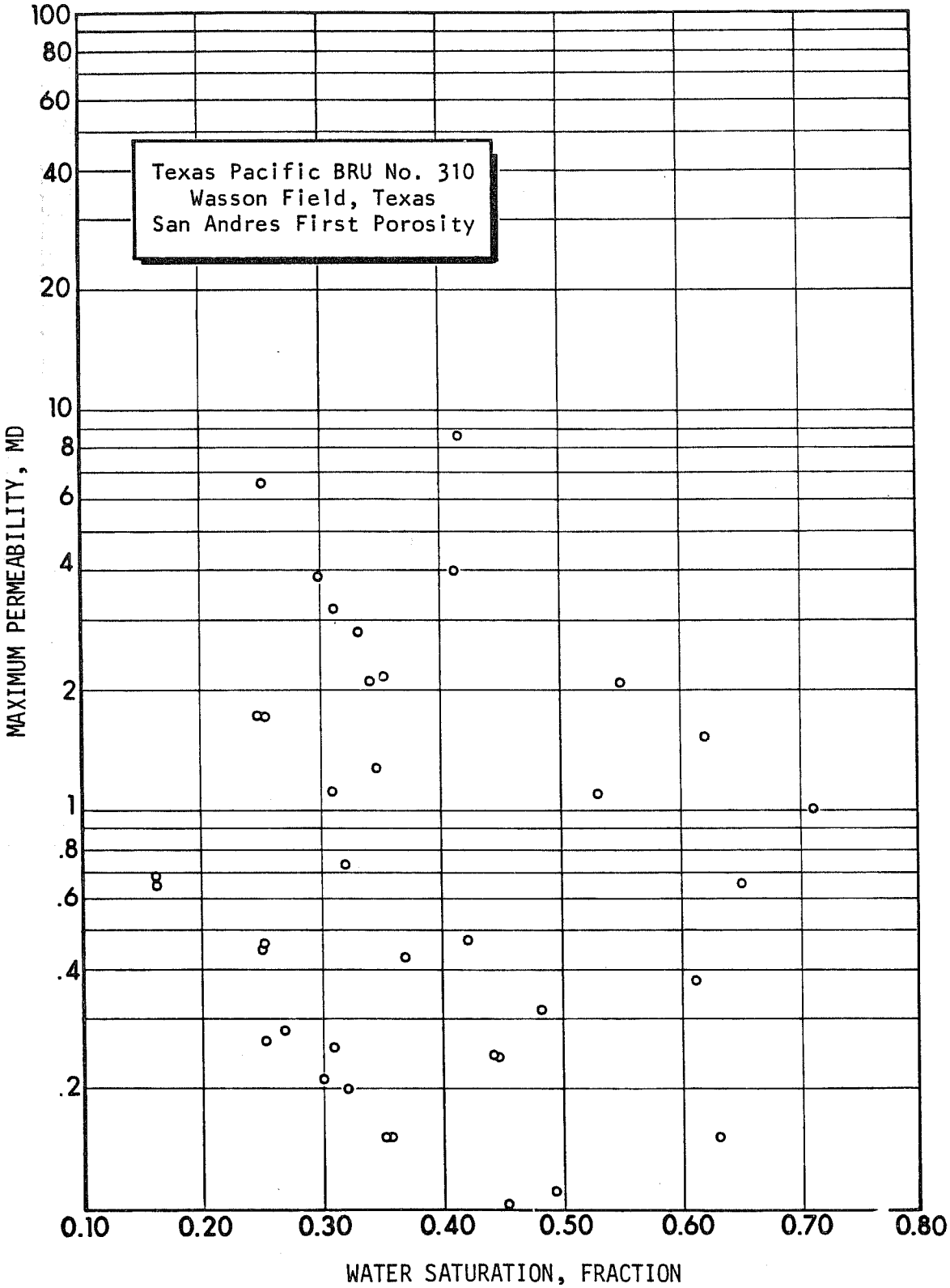


Figure 29.--Maximum permeability vs. water saturation, San Andres First Porosity.

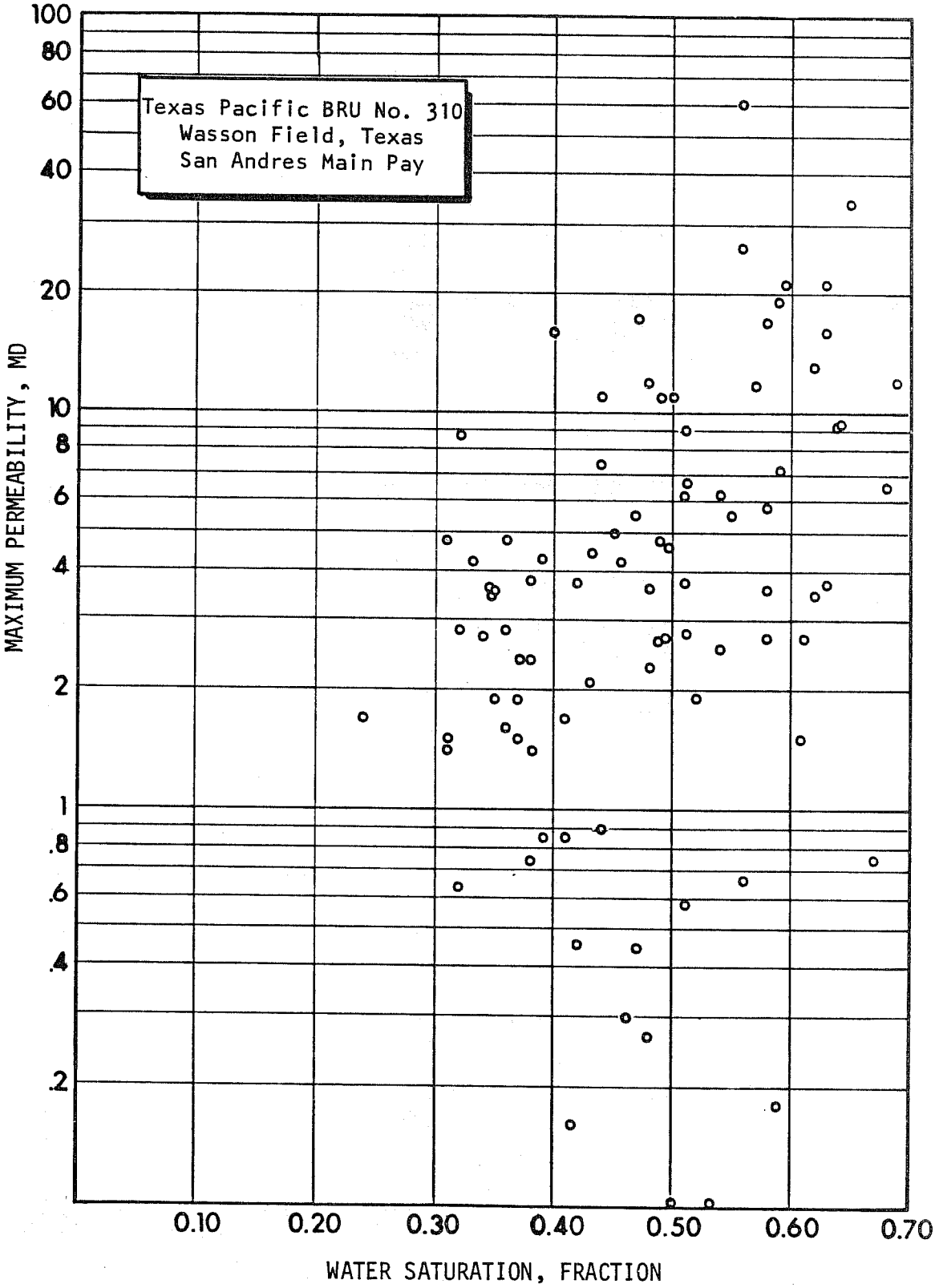


Figure 30.--Core water saturation vs. maximum permeability, San Andres Main Pay.

Texas Pacific BRU No. 310
Wasson Field, Texas
San Andres Formation

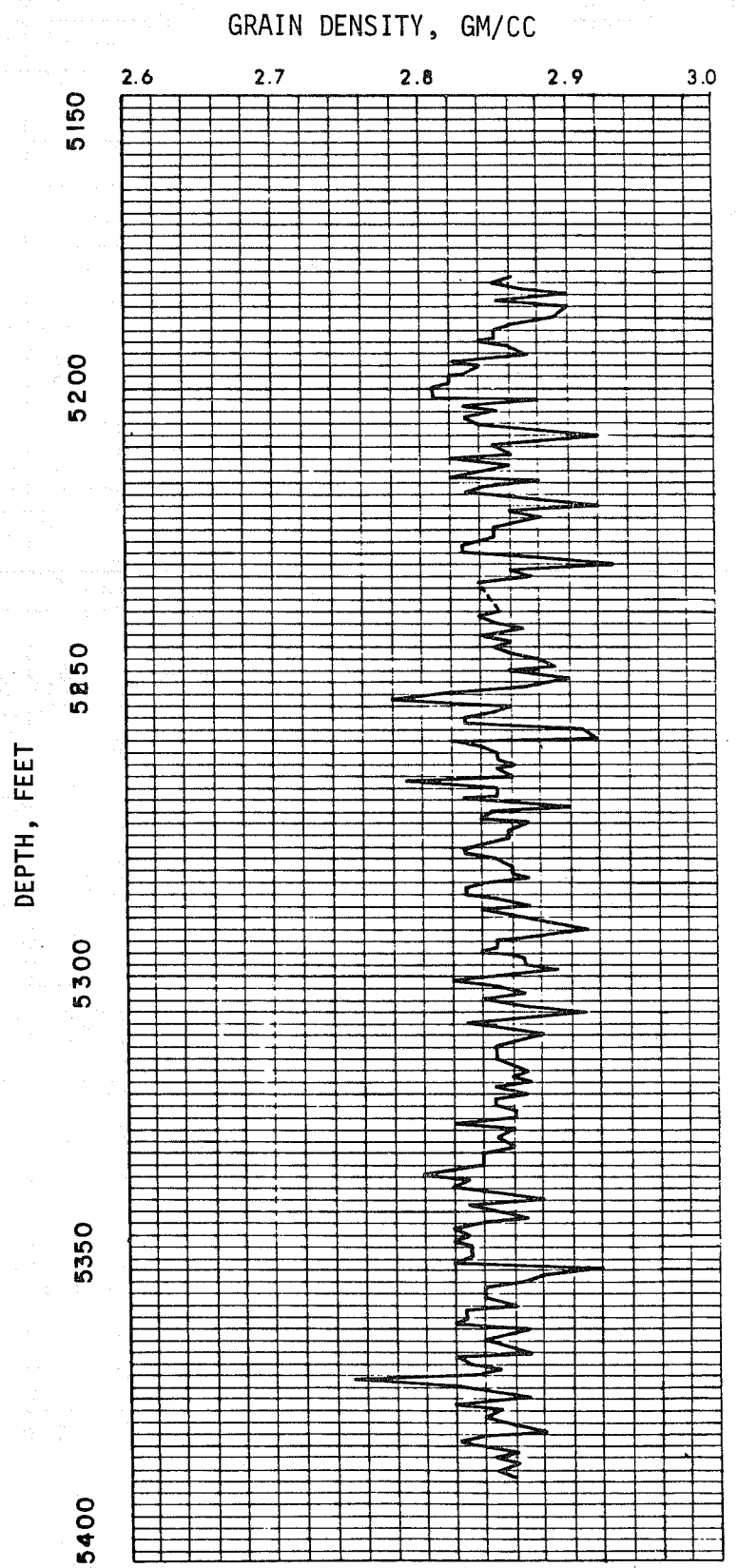


Figure 31.--Core data: grain density of recovered cores.

Texas Pacific BRU No. 310
Wasson Field, Texas
San Andres Formation

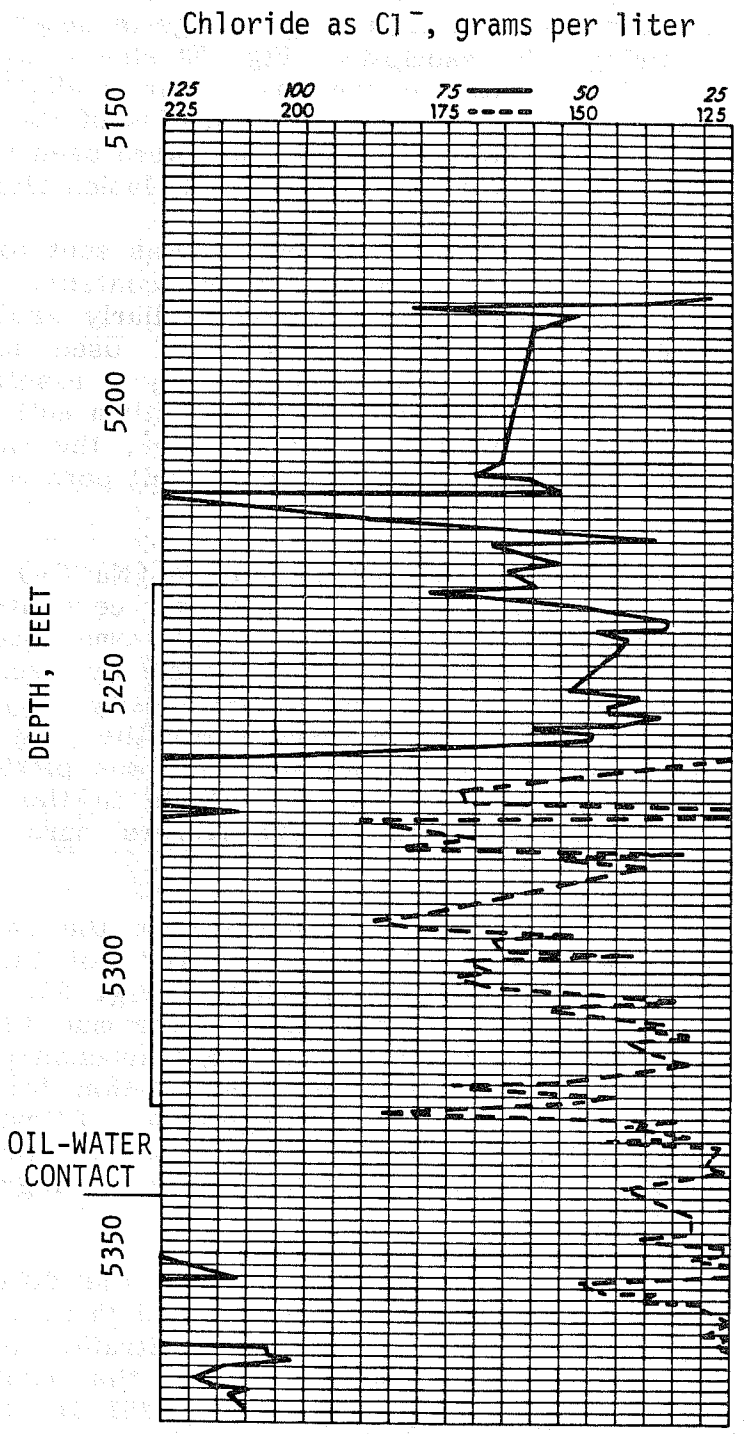


Figure 32.--Chloride content of pore water vs. depth.

degree of filtrate invasion into the full-diameter core. Figure 33 is a plot of porosity and water saturation for plugs and donuts. As a limiting assumption, the water saturation of the plug represents in-situ formation water saturation (i.e., not invaded by mud filtrate), while the water saturation of the donut reflects the water saturation of a flushed formation (i.e., invaded by mud filtrate). The difference between the in-situ and the flushed water saturations represents the change in water saturation due to core invasion. Using this assumption, Fig. 33 shows moderate filtrate invasion effects as donut water saturations are only slightly higher than plug water saturations. Furthermore, the porosities of the plugs are slightly higher than those of the donuts. These data were used with tracer measurements to estimate the effectiveness of the low-invasion fluid.

The pore water extracted from the plugs and donuts was sent to Teledyne Isotope Laboratories for determination of its tritium content. Mud filtrate collected during the drilling operations was similarly analyzed. A total activity of 5×10^{11} picocuries (0.5 curie) was used to tag the initial mud mixture. Figure 34 is a plot of the Teledyne results for the plug and donut pore-water samples. Generally, the tritium activity of the donut was greater than that of the plug. Furthermore, the mud filtrate tritium activity was greater than both the plug and donut pore water activities, indicating incomplete mud filtrate invasion.

The low-invasion fluid was tagged with sodium nitrate ($NaNO_3$) at a concentration of 1395 mg/l for the filtrate. Measured concentrations of $NaNO_3$ in the plug and donut pore water are in some some cases greater than the low-invasion filtrate concentration; this probably resulted from poor mixing of the chemical tracer with the high-viscosity polymer-based fluid. The data are plotted in Fig. 35; in cases where the plug value was greater than the donut value, the higher measurement was plotted. Core Labs has had very limited success with sodium nitrate in the past, and major oil companies have been using radioactive tracers more frequently than chemical tracers.

The contamination by mud filtrate was determined from the ratio of the tritium activity of the pore water to the tritium activity of the mud filtrate. Results for the donut samples are plotted in Fig. 35. Intervals cored using low-invasion fluid showed significantly lower mud filtrate contamination, although appreciable flushing by the low-invasion-gel filtrate did occur. Figure 36 is a plot of chloride concentration for the full-diameter core samples compared with the percentage of mud filtrate invasion determined by tritium analysis. The mud filtrate concentration indicates that the First Porosity zone (above 5,260 ft) has a greater degree of mud filtrate invasion than the Main Pay.

The percentage of total invasion was determined from the differences in water saturations of the plugs and donuts. The tritium data were then used to determine whether the invading fluid was mud fitrate, low-invasion fluid, or a combination of the two. Table 12 presents the results of this analysis. The table entries for depths less than 5,257 ft, taken from cored intervals without low-invasion fluid in the core barrel, had an average total filtrate invasion of 17 percent. The remaining intervals, representing core data with low-invasion fluid in the core barrel, had an

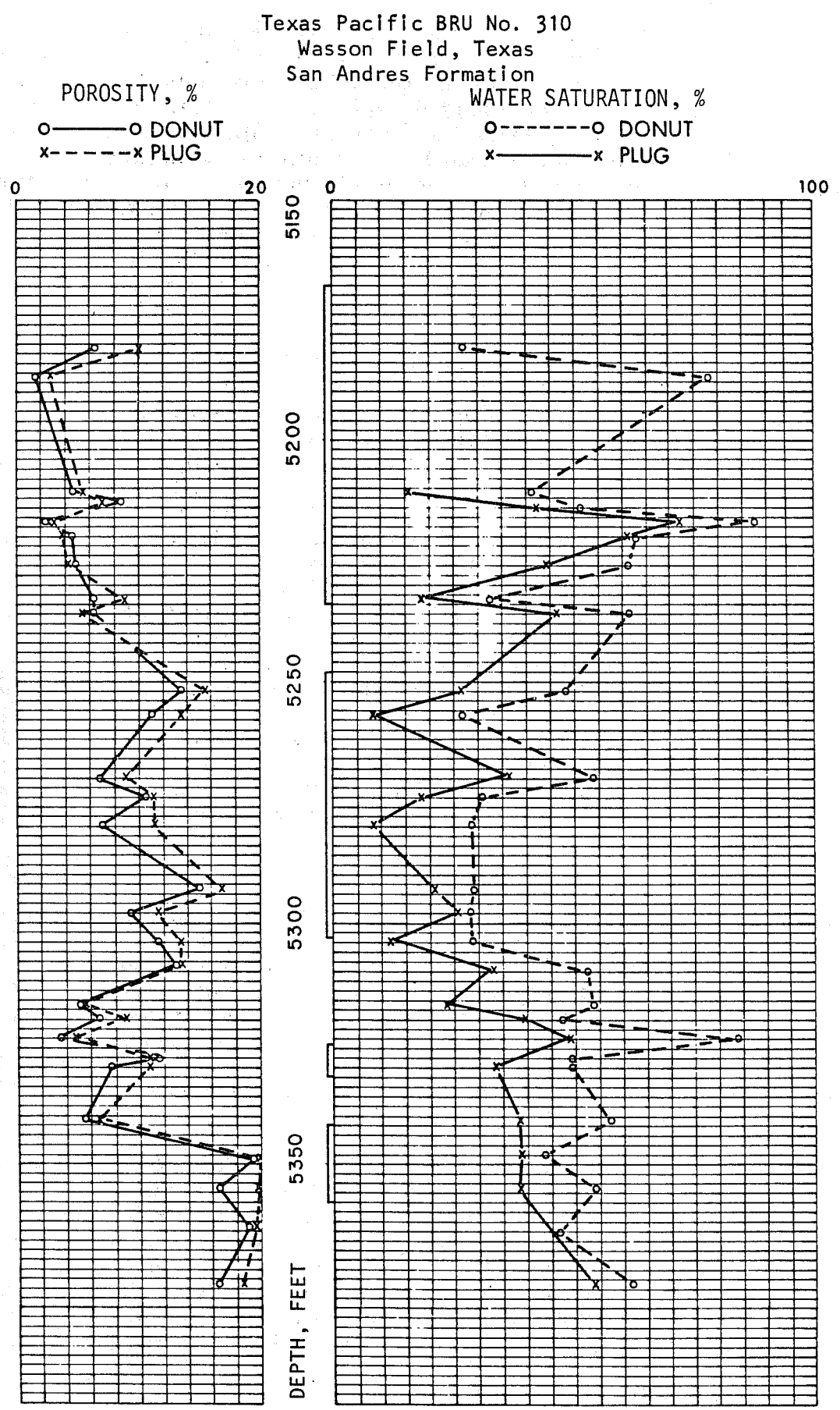


Figure 33.--Porosity and water saturation of plug and donut core samples.

Texas Pacific BRU No. 310
Wasson Field, Texas
San Andres Formation

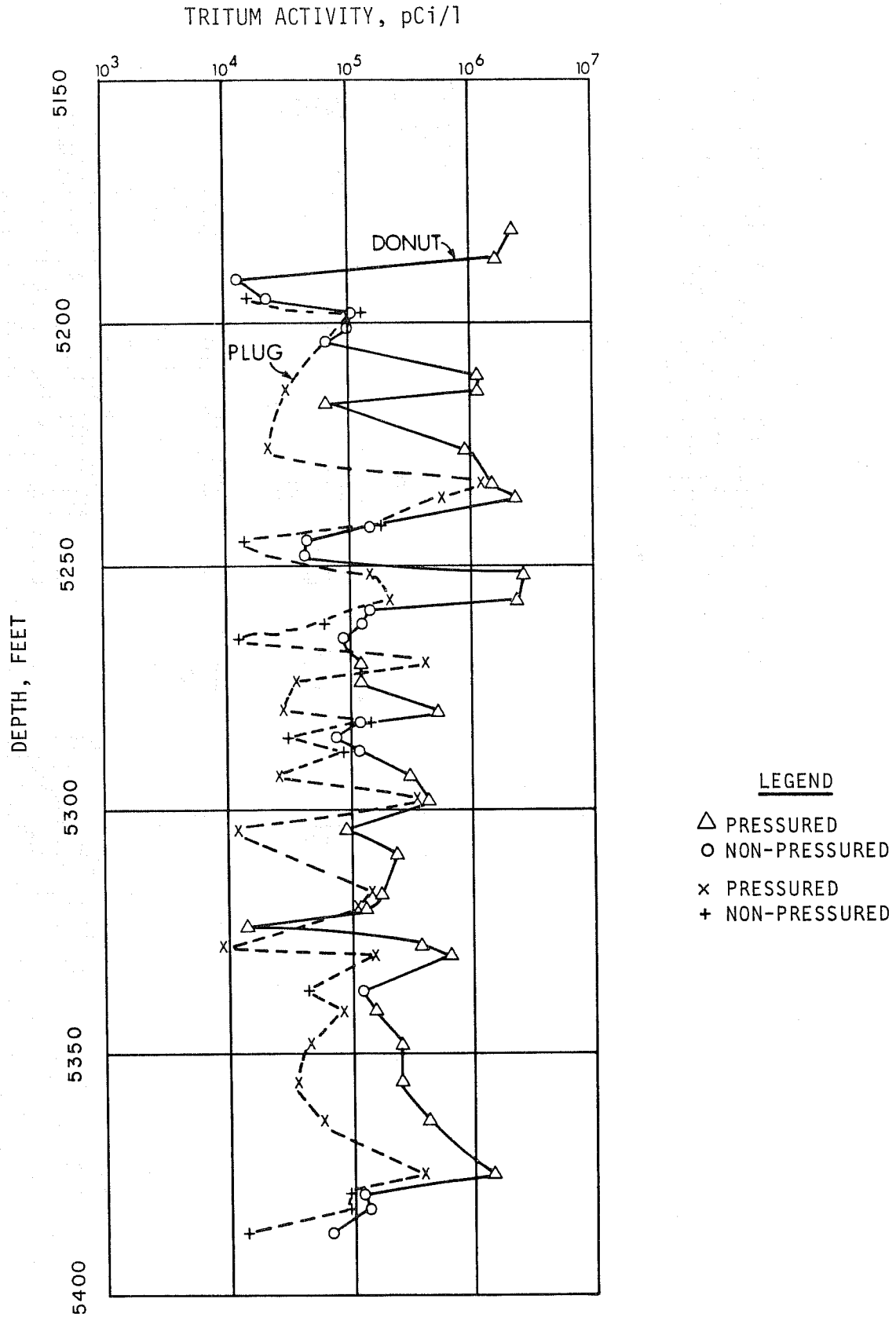


Figure 34.--Tritium activity of plug and donut pore water.

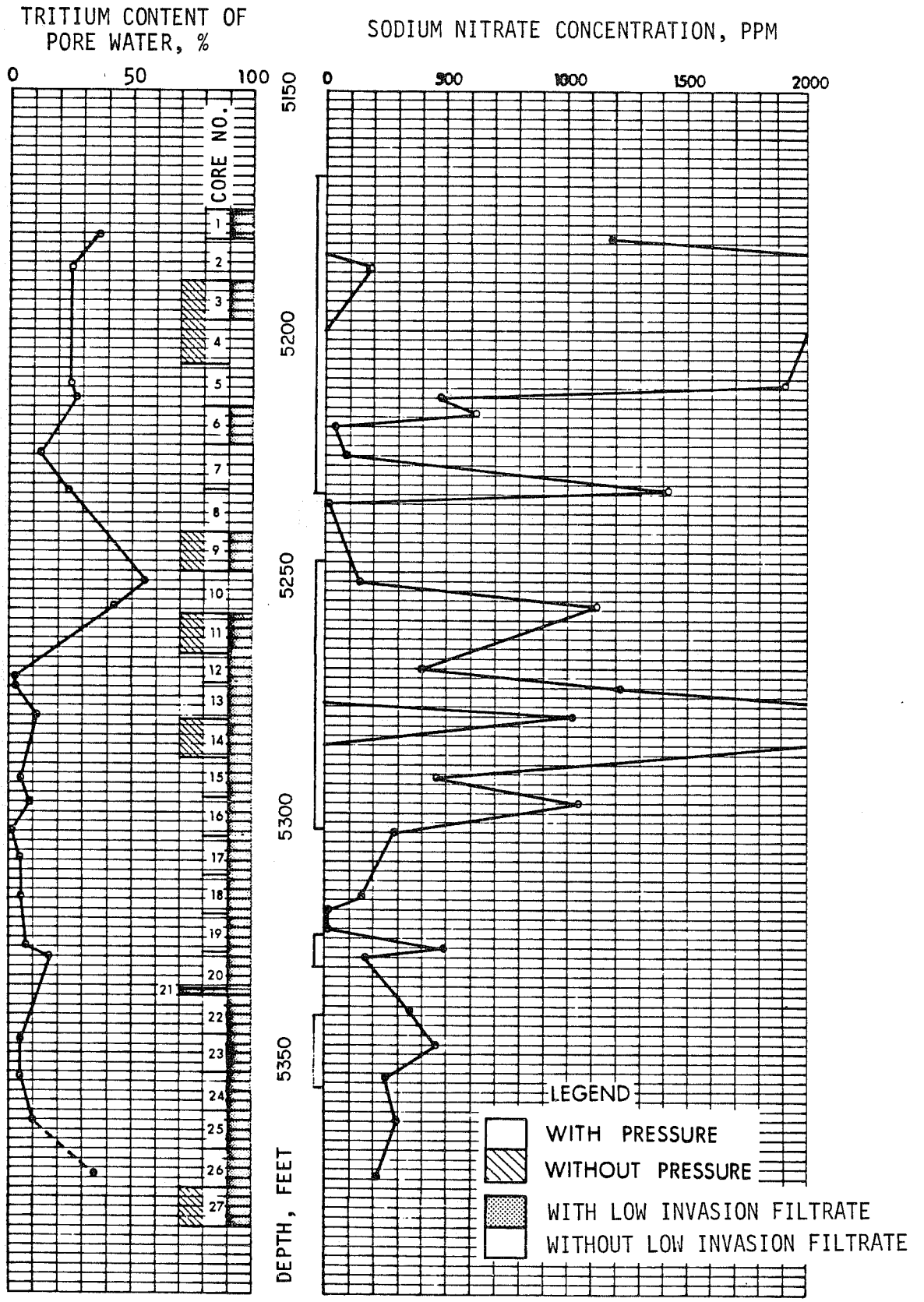


Figure 35.--Sodium nitrate (tracer) concentration in core pore water.

Texas Pacific BRU No.310
Wasson Field, Texas
San Andres Formation

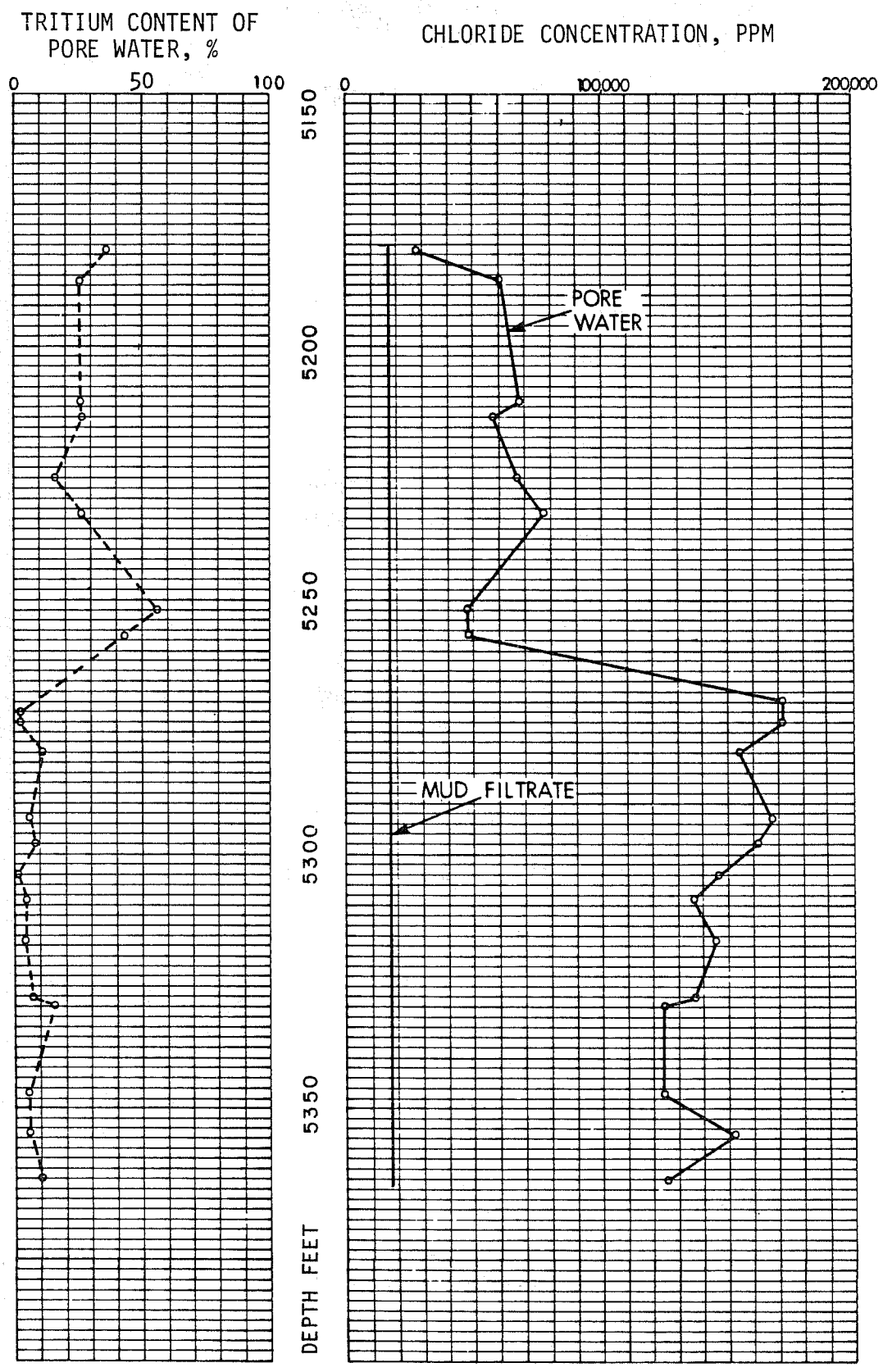


Figure 36.--Pore water tritium and chloride concentration.

TABLE 12

INVASION ANALYSIS

Depth, ft	% Total Flushing*	% Mud Filtrate**
5211	25	25
5214	10	10
5217	15	15
5226	16	16
5233	15	15
5236	14	14
5252	21	21
5257	18	18
5270	19	2
5274	13	2
5280	20	10
5293	9	6
5298	3	3
5304	16	2
5309	19	5
5320	8	3
5328	10	8
5330	16	15
5341	19	4
5348	6	6
5355	16	6
5364	0	0
5375	7	7

*Determined from plug and donut water saturations.

**Determined from plug and donut tritium measurements.

average total filtrate invasion of 11 percent. This indicates that the low-invasion fluid reduced the total flushing of the core.

Many factors can influence the degree of filtrate invasion, making comparisons unreliable.[19] For example, a slight pressure overbalance between the mud column and the formation can create severe invasion problems. Some other influencing factors are mud circulation, rate and amount of filtrate loss, bit penetration rate, and interfacial tension between the reservoir oil and the filtrate. Furthermore, it should be recognized that changes in porosity and permeability also affect the degree of invasion.

Gas Liberation. The validity of the fluid saturation measurements from pressure core analysis can be checked by computing the summation of core fluids, the gas-to-oil ratio, and the oil formation volume factor. The fluid measurements for gas, oil, and water determined by Core Labs were corrected to reservoir conditions. All gas was assumed to have evolved from the oil. The corrected oil and water volumes were then compared to the total pore volume to determine whether all pore fluids had been accounted for. Table 13 shows that in most cases 95% of the original fluids were obtained. The gas liberation data were used to determine the gas-to-oil ratio (scf/STB) for the cores recovered with pressure. Figure 37 is a plot of the gas-to-oil ratio (GOR) and the non-hydrocarbon gas composition. Generally, a low GOR correlated well with low permeability and high mol percentages of nitrogen and carbon dioxide in the liberated gas. Low porosity intervals showed low GORs, reflecting the fact that low-porosity intervals have a higher percentage of pore water and yield a lower volume of extracted oil. This small volume of oil is subject to a larger relative error in measurement than a larger volume of oil extracted from a more porous interval.

A statistical analysis of the GOR values gave a mean value of 451 scf/STB. The average oil volume factor was 1.36 RB/STB. Shell engineers measured an average GOR of about 530 scf/STB from Wasson field cores recovered with pressure.[29] Formation oil volume factor correlations for west Texas crudes predict an oil volume factor of 1.27 when applied to the Bennett Ranch unit data.

Electrical Resistivity Core Analysis

Special core analysis was performed by Core Labs to determine the formation factors and saturation exponents for selected rock samples. Initial formation resistivity factor measurements did not fall within the expected range. It was discovered that dissolution of anhydrite had occurred, which invalidated the first test results. A second set of formation resistivity factor measurements was conducted, using core samples that were pressure-saturated with a brine containing 80,000 ppm sodium chloride and 20,000 ppm calcium sulfate to inhibit mineral dissolution. The report submitted by Core Labs is included as Appendix E.

These measurements were obtained to provide experimental data for evaluation of unknowns a, m, and n in the basic log analysis equations*:

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*See equations 7, 8, and 9, p. 85, for definitions of a, m, and n.

TABLE 13

SUMMATION OF CORE FLUID SATURATION

Depth (ft.)	Oil Saturation At Stock Tank Conditions	Water Saturation	Gas/Oil* Ratio	Oil Formation** Volume Factor	Oil Saturation At Reservoir Conditions	Sum of Reservoir Oil & Water Saturation	Core Porosity
5182	.645	.160	400	1.17	.755	.915	.069
5183	.490	.307	420	1.17	.573	.880	.054
5184	.073	.621	150	1.065	.078	.699	.035
5185	.176	.713	400	1.17	.206	.919	.047
5186	.585	.341	70	1.04	.608	.949	.063
5187	.321	.359	450	1.18	.379	.738	.025
5188	.124	.611	570	1.22	.151	.762	.033
5189	.241	.531	60	1.03	.248	.779	.035
--	--	--	--	--	--	--	--
5209	.366	.442	80	1.04	.381	.823	.039
5210	.186	.749	250	1.12	.208	.957	.071
5211	.479	.482	360	1.15	.551	1.033	.090
5212	.530	.439	350	1.15	.610	1.049	.087
5214	.569	.297	--	--	--	--	--
5215	.607	.248	--	--	--	--	--
5216	.336	.452	--	--	--	--	--
5217	.336	.452	--	--	--	--	--
5218	.124	.638	100	1.05	.130	.768	.031
5219	.191	.602	100	1.05	.201	.803	.016
5220	.232	.553	100	1.05	.244	.797	.029
5221	.194	.655	75	1.04	.202	.857	.027
5222	.182	.693	50	1.03	.187	.880	.017
5224	.337	.483	150	1.065	.359	.842	.035
5225	.596	.325	500	1.19	.709	1.034	.067
5227	.631	.274	460	1.18	.745	1.019	.085
5228	.629	.255	465	1.18	.742	.997	.085
5229	.629	.255	480	1.19	.749	1.004	.070
5230	.469	.242	400	1.17	.549	.791	.050
5231	.642	.307	470	1.19	.764	1.071	.050
5232	.652	.187	550	1.21	.789	.976	.081
5233	.531	.307	450	1.18	.627	.934	.064
5234	.490	.420	520	1.19	.583	1.003	.071
--	--	--	--	--	--	--	--
5239	.549	.415	520	1.19	.653	1.068	.105
5240	.539	.321	550	1.21	.652	.973	.094
5241	.490	.377	550	1.21	.593	.970	.091
--	--	--	--	--	--	--	--
5251	.543	.344	150	1.065	.578	.922	.121
5252	.548	.341	480	1.19	.652	.993	.128
5253	.513	.410	400	1.17	.600	1.010	.113
5254	.639	.314	400	1.17	.748	1.062	.040
5255	.636	.253	480	1.18	.750	1.003	.087
5256	.613	.252	460	1.18	.723	.975	.088
5257	.528	.332	460	1.18	.623	.955	.112
5258	.564	.310	460	1.18	.666	.976	.090

TABLE 13 (cont.)

Depth (ft.)	Oil Saturation At Stock Tank Conditions	Water Saturation	Gas/Oil* Ratio	Oil Formation** Volume Factor	Oil Saturation At Reservoir Conditions	Sum of Reservoir Oil & Water Saturation	Core Porosity
5259	.527	.241	420	1.17	.617	.858	.059
--	--	--	--	--	--	--	--
5267	.468	.393	500	1.19	.557	.950	.103
5268	.490	.344	610	1.24	.608	.952	.125
5269	.580	.347	550	1.21	.702	1.049	.120
--	--	--	--	--	--	--	--
5272	.369	.527	400	1.17	.432	.959	.046
5273	.326	.596	500	1.19	.388	.984	.058
5274	.499	.353	500	1.19	.594	.947	.126
5275	.499	.353	500	1.19	.594	.947	.126
5276	.508	.384	450	1.18	.599	.983	.121
5277	.485	.387	400	1.17	.567	.954	.123
5278	.502	.332	350	1.15	.577	.909	.162
5279	.484	.441	500	1.19	.576	1.017	.070
5280	.595	.281	500	1.19	.708	.989	.093
5281	.486	.310	500	1.19	.578	.888	.126
--	--	--	--	--	--	--	--
5289	.481	.424	550	1.21	.582	1.006	.149
5290	.507	.368	350	1.15	.583	.951	.161
5292	.490	.402	500	1.19	.583	.985	.101
5293	.441	.378	320	1.15	.507	.885	.156
5294	.541	.317	330	1.15	.622	.939	.116
5295	.481	.379	475	1.19	.572	.951	.110
5296	.546	.372	450	1.18	.644	1.106	.139
5297	.545	.321	430	1.175	.640	.961	.155
5298	.606	.284	480	1.19	.721	1.005	.121
5299	.387	.407	300	1.135	.439	.846	.114
5300	.549	.310	510	1.19	.653	.963	.128
5301	.487	.354	335	1.15	.560	.914	.099
5302	.548	.310	500	1.19	.652	.962	.116
5303	.465	.361	350	1.15	.535	.896	.123
5304	.548	.240	450	1.18	.647	.887	.118
5305	.418	.369	540	1.21	.506	.875	.096
5306	.290	.518	400	1.17	.339	.857	.091
5307	.484	.353	420	1.175	.569	.922	.114
5308	.467	.434	450	1.18	.551	.985	.089
5309	.350	.581	530	1.21	.424	1.005	.131
5310	.336	.516	575	1.23	.413	.929	.130
5311	.332	.517	460	1.19	.395	.912	.124
5312	.384	.479	520	1.19	.457	.936	.118
5313	.322	.545	570	1.21	.390	.935	.140
5314	.294	.609	460	1.19	.350	.959	.133
5315	.357	.496	650	1.26	.450	.946	.130
5316	.251	.625	500	1.19	.299	.924	.124
5317	.421	.490	500	1.19	.501	.997	.109
5318	.246	.466	500	1.19	.293	.759	.083

TABLE 13 (cont.)

Depth (ft.)	Oil Saturation At Stock Tank Conditions	Water Saturation	Gas/Oil* Ratio	Oil Formation** Volume Factor	Oil Saturation At Reservoir Conditions	Sum of Reservoir Oil & Water Saturation	Core Porosity
5319	.276	.479	500	1.19	.328	.807	.067
5320	.307	.418	550	1.21	.371	.789	.051
5321	.407	.401	460	1.18	.480	.881	.110
5322	.464	.420	470	1.19	.552	.972	.086
5323	.106	.674	400	1.17	.124	.798	.051
5324	.211	.487	300	1.135	.239	.726	.042
5325	.146	.564	310	1.135	.166	.730	.041
5326	.375	.530	320	1.13	.424	.954	.050
5327	.371	.447	530	1.20	.445	.892	.124
5328	.401	.481	400	1.17	.469	.950	.133
5329	.405	.488	510	1.19	.482	.970	.118
5330	.398	.451	530	1.20	.478	.929	.041
5331	.344	.476	550	1.21	.416	.892	.102
5332	.437	.410	500	1.19	.520	.930	.120
5333	.411	.439	475	1.19	.489	.928	.134
5334	.463	.399	445	1.18	.546	.945	.109
5335	.480	.377	455	1.18	.566	.943	.088
5336	.442	.386	390	1.17	.452	.838	.101
--	--	--	--	--	--	--	--
5339	.428	.324	550	1.21	.518	.842	.084
--	--	--	--	--	--	--	--
5343	.351	.489	515	1.19	.418	.907	.066
5344	.321	.586	520	1.20	.385	.971	.150
5345	.334	.617	415	1.17	.391	1.008	.153
5346	.393	.491	550	1.21	.476	.967	.165
5347	.395	.511	630	1.25	.494	1.005	.188
5349	.251	.647	450	1.18	.296	.943	.178
5350	.391	.518	550	1.21	.473	.991	.163
5351	.269	.597	475	1.19	.320	.917	.175
5352	.349	.587	525	1.20	.419	1.006	.160
5353	.346	.529	540	1.21	.419	.948	.134
5354	.322	.544	450	1.18	.380	.924	.153
5356	.370	.483	450	1.18	.437	.920	.191
5357	.342	.560	640	1.26	.431	.991	.216
5358	.256	.598	630	1.26	.323	.921	.193
5359	.271	.625	610	1.245	.337	.962	.190
5360	.185	.692	590	1.24	.229	.921	.187
5361	.219	.634	550	1.21	.265	.899	.135
5363	.399	.456	275	1.130	.451	.907	.149
5364	.284	.558	210	1.10	.312	.870	.160
5365	.364	.497	500	1.19	.433	.930	.188
5366	.289	.599	540	1.21	.350	.949	.183
5367	.233	.630	550	1.21	.282	.912	.156
5368	.233	.630	620	1.245	.290	.920	.156
5369	.215	.643	550	1.21	.260	.903	.149

TABLE 13 (cont.)

Depth (ft.)	Oil Saturation At Stock Tank Conditions	Water Saturation	Gas/Oil* Ratio	Oil Formation** Volume Factor	Oil Saturation At Reservoir Conditions	Sum of Reservoir Oil & Water Saturation	Core Porosity
5370	.157	.682	525	1.20	.188	.870	.186
5371	.308	.564	480	1.19	.367	.931	.139
5372	.310	.598	480	1.19	.369	.967	.148
5373	.340	.518	725	1.295	.440	.958	.148
5374	.178	.574	650	1.260	.224	.798	.156
5375	.199	.623	575	1.22	.243	.866	.182
5376	.194	.657	500	1.19	.231	.888	.178
5377	.331	.506	500	1.19	.394	.900	.129
5378	.528	.386	500	1.19	.628	1.014	.126

* GOR (scf/STB) data obtained from GOR versus Depth plot

** Bo (RB/STB) obtained from Shell Supplemental Recovery Book I Enclosure II - 3g;2

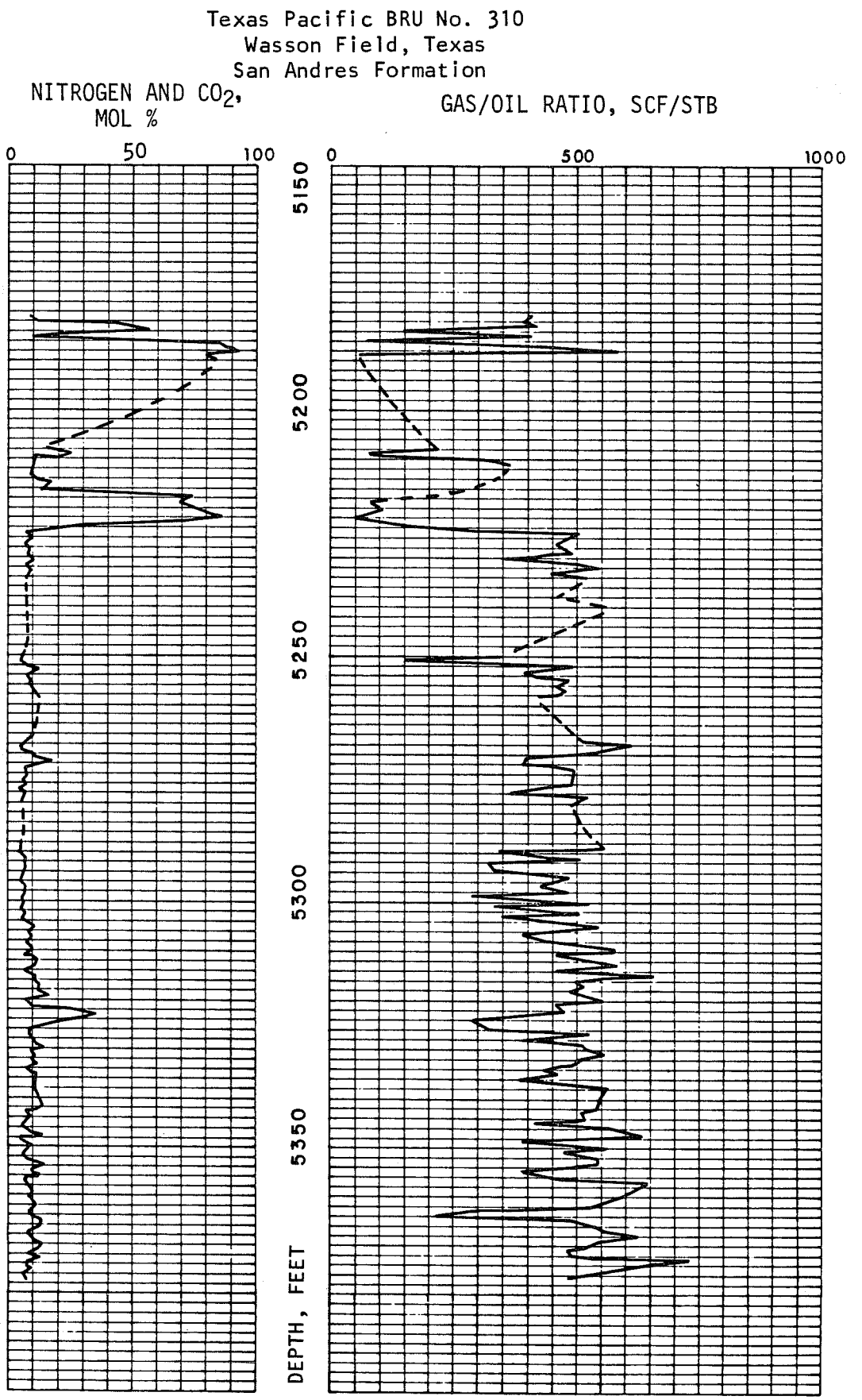

Figure 37.--N_2 and CO_2 concentration and gas/oil ratio for full-diameter cores recovered with pressure.

$$(S_w)^n = R_0/R_t$$

and $R_0 = F \cdot R_w$,

where $F = a/\phi_e^m$.

The tortuosity constant a and the cementation exponent m are interrelated and must be determined graphically. Results for measurements made on BRU 310 samples are shown in Fig. 38. An a value of 1.00 (i.e., $F = R_0/R_w = 1$ at 100 percent porosity where $\phi_e = 1.0$) appears justified from the fit of the line drawn from $F = 1.0$, $\phi_e = 1.0$ through the experimental points. This line has a slope of 2.05, which establishes the value of m. Formation resistivity index measurements as a function of brine saturation are shown in Fig. 39. The slope of the line shown is 2.08, which establishes a composite experimental value for the saturation exponent n. Individual values of the saturation exponents n found from the formation resistivity index-saturation measurements ranged from 1.81 to 3.18.

The cementation exponent and saturation exponent are consistent with values found in the literature.[30] However, the method of measurement necessarily alters the wettability of the reservoir rock, which introduces some uncertainty.[31]

Wireline Log Data

The Schlumberger logs were used for geological and petrophysical analysis. The geologic correlation with surrounding wells agreed with Texas Pacific geology for the Bennett Ranch unit. Petrophysical data and log analysis calculations agreed with the results of Core Laboratories' analyses. The results of the wireline log data analysis are presented in the following pages.

Geologic Correlation with Surrounding Wells. The BRU 310 was correlated with the BRU Nos. 311, 312, and 313. All of these wells are injectors located to the north of the BRU 310. Geologic correlations are shown in Figs. 40A and 40B. Comparison with geological maps prepared by Texas Pacific shows that the top of the Main Pay is consistent with previous correlations. The top of the Main Pay was found as follows (datum is sea level):

BRU No. 311	-1704 ft
BRU No. 312	-1710 ft
BRU No. 310	-1683 ft
BRU No. 313	-1713 ft

Log Analysis

The San Andres has a complex lithology of limestone, dolomite, anhydrite, shale, and other deposited minerals. To solve for four different mineral compositions, three porosity devices and a shale indicator are required. This log analysis method uses the responses of the density, sonic, and neutron logs to evaluate the effective porosity of the formation. The resistivity log is then used to determine water saturations based on effective porosity. The analysis assumes fluid densities in the range of the density of water and a nonlinear neutron porosity response.

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File SCAL-308-80161

Company Gruy Federal, Inc. Formation San Andres
Well Bennett Ranch Unit No. 310 County Yoakum
Field Wasson State Texas

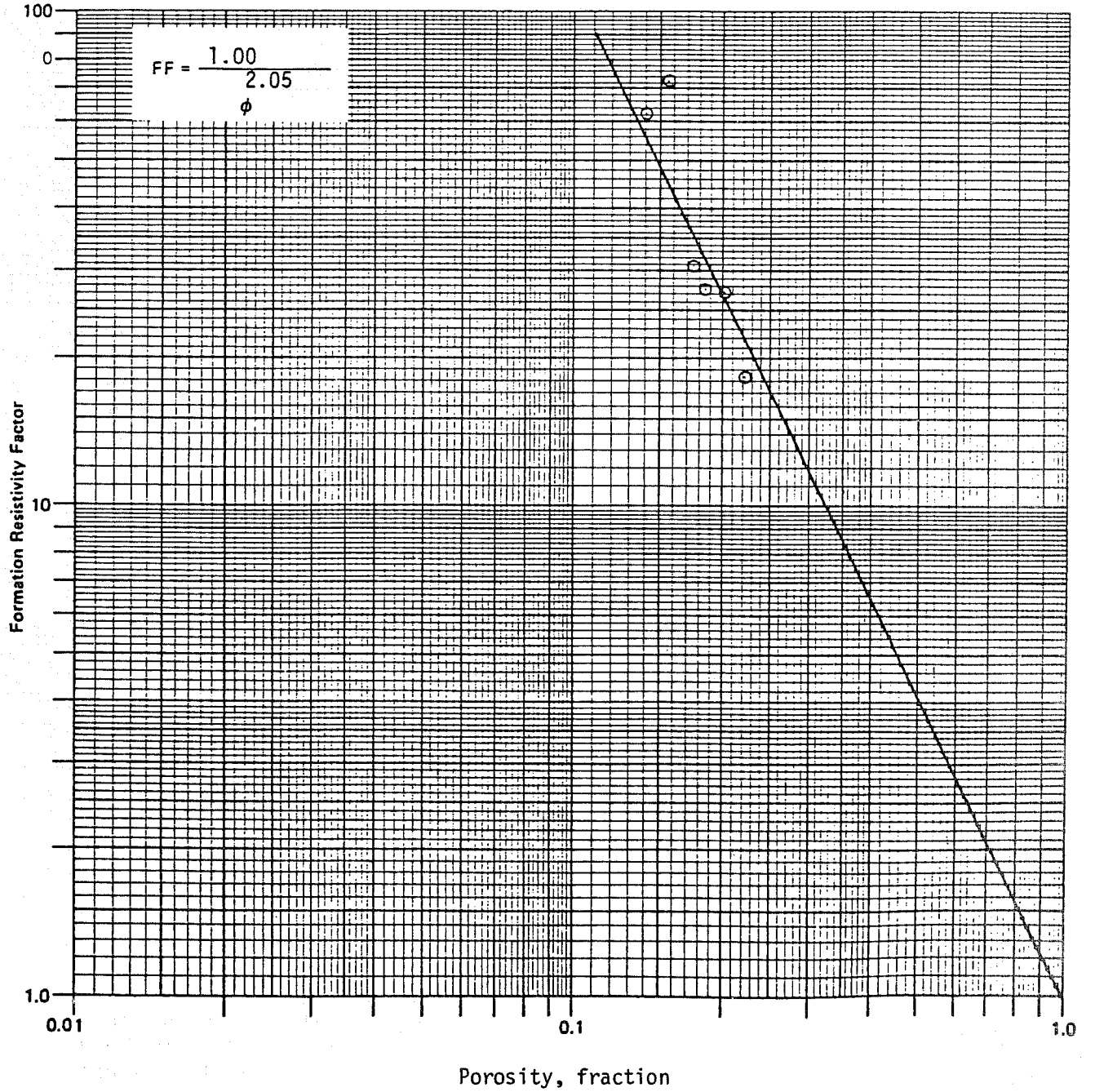

Figure 38.--Determination of cementation exponent m.

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File SCAL-308-80161

Company Gruy Federal, Inc. Formation San Andres
Well Bennett Ranch Unit No. 310 County Yoakum
Field Wasson State Texas

Composite Plot

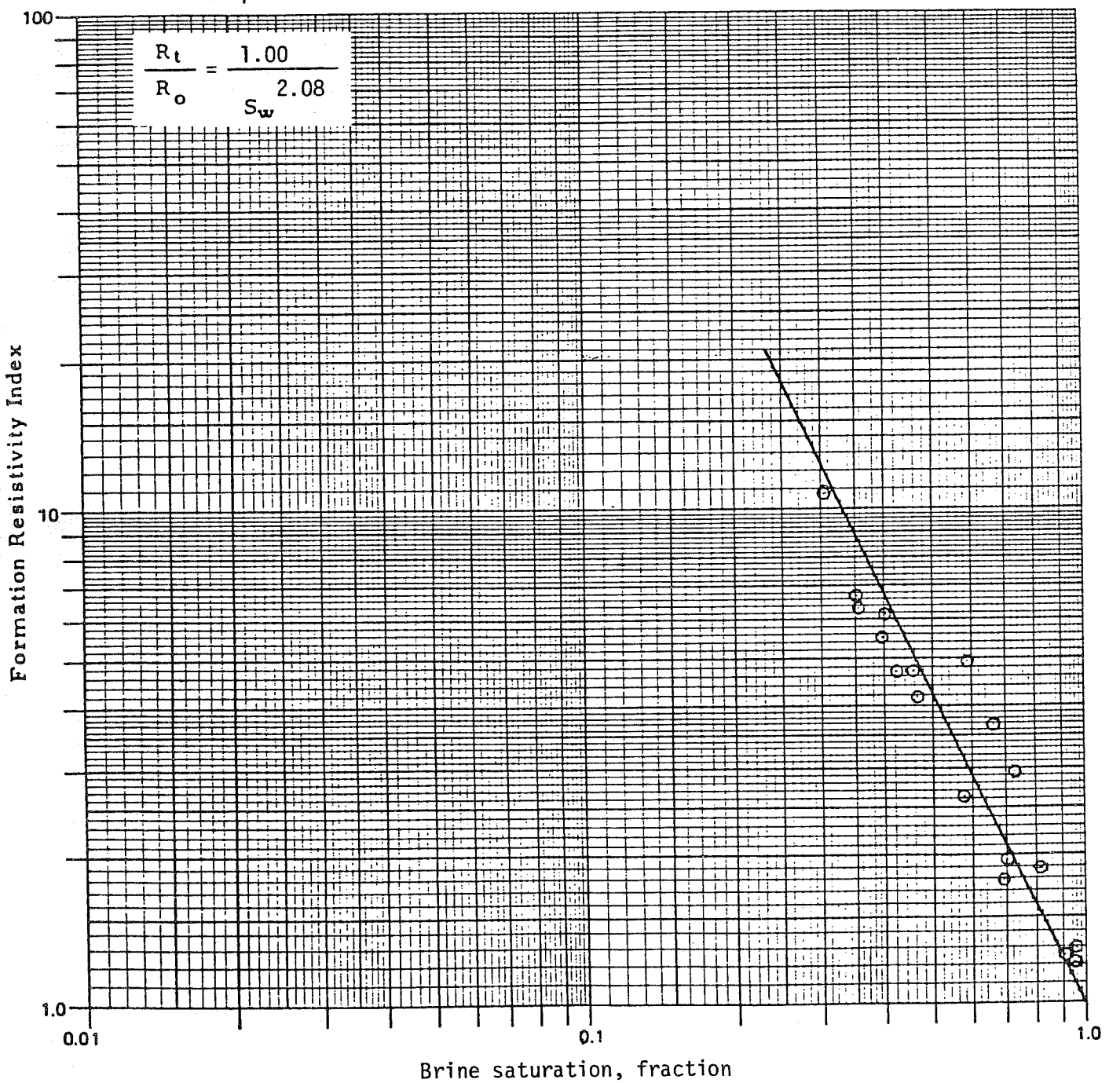
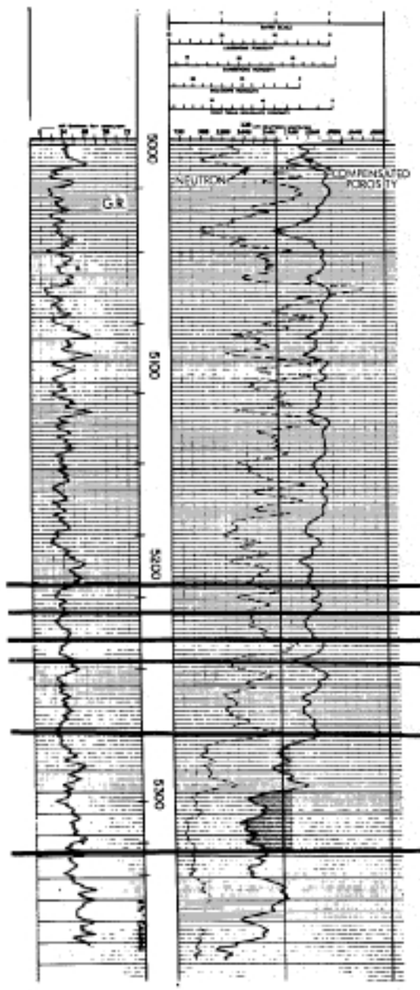


Figure 39.--Determination of saturation exponent n.

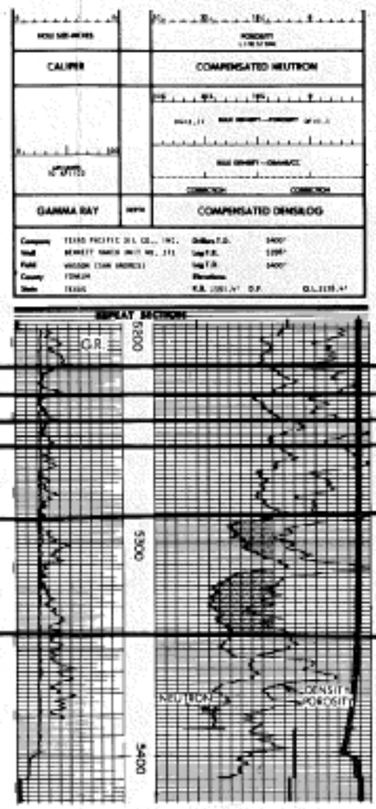
A

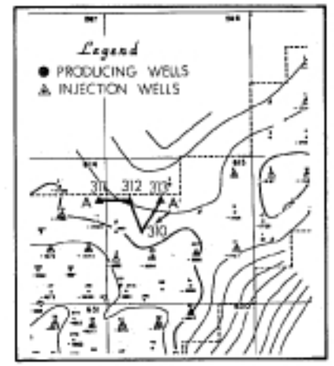
A'

TEXAS PACIFIC OIL CO.
BENNETT RANCH UNIT NO. 311
K.B. 3582' G.L. 3570'

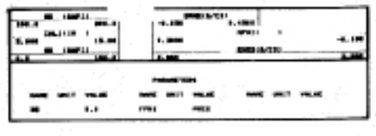


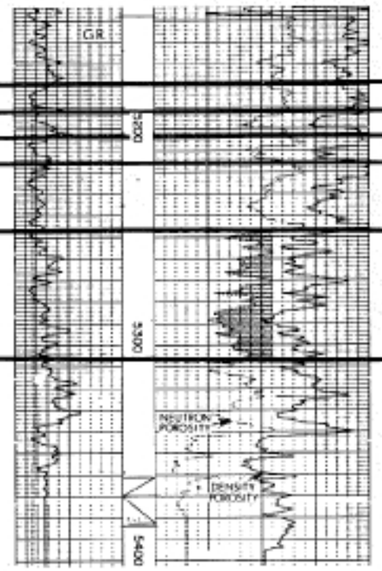
TEXAS PACIFIC OIL CO.
BENNETT RANCH UNIT NO. 312
K.B. 3591' G.L. 3578'





TEXAS PACIFIC OIL CO.
BENNETT RANCH UNIT NO. 310
K.B. 3577' G.L. 3565'



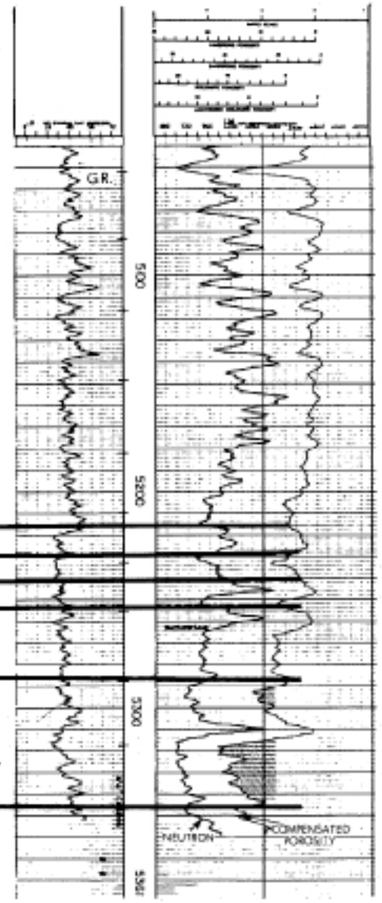


SUB SURFACE DATUM

TOP OF MAIN PAY

MAIN PAY TRANSITION MARKER

TEXAS PACIFIC OIL CO.
BENNETT RANCH UNIT NO. 313
K.B. 3588' G.L. 3575'



Legend

NEUTRON LIMESTONE POROSITY CUT OFF OF 8%

GRUY FEDERAL INC.
HOUSTON TEXAS

FIGURE 40A
WASSON FIELD
(BENNETT RANCH UNIT)
YOAKUM COUNTY TEXAS

CORRELATION THROUGH THE IMMEDIATE AREA OF THE COMPLETED BRU NO. 310

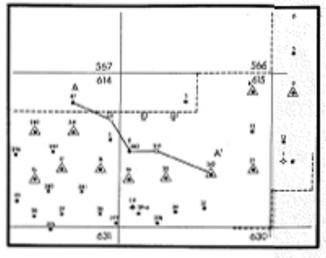
A

NORTHWEST

A'

SOUTHEAST

INDEX MAP



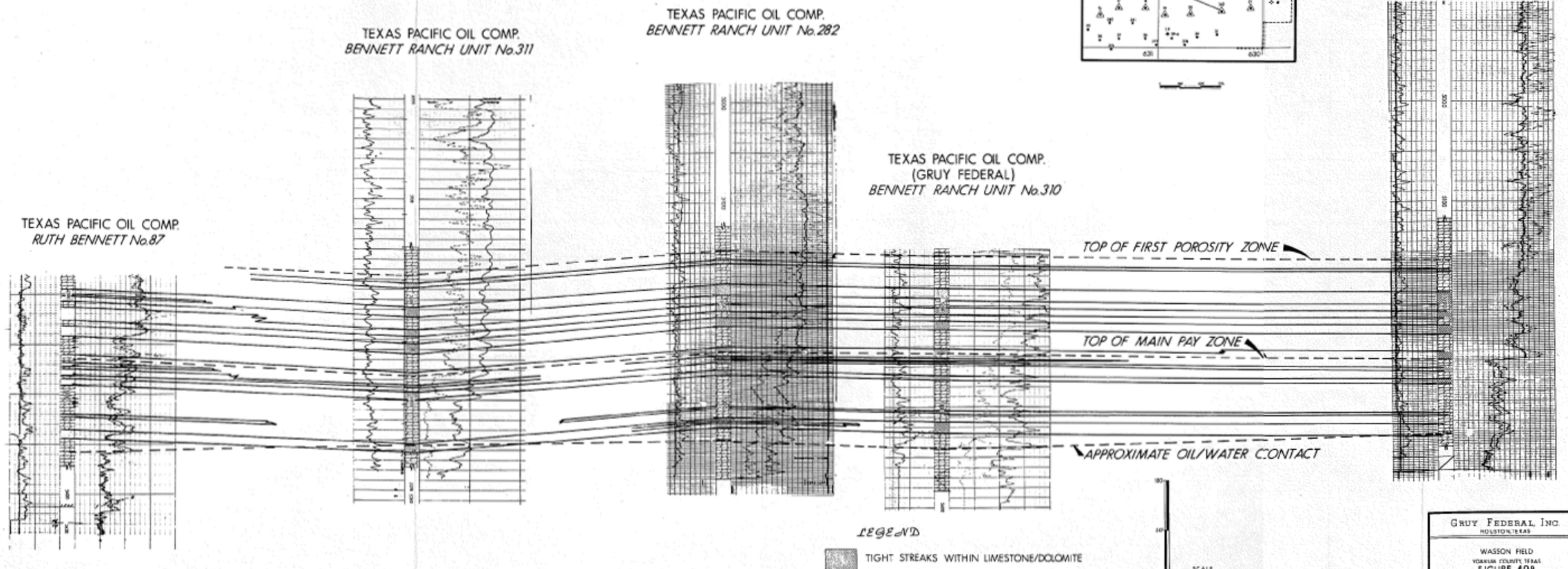
TEXAS PACIFIC OIL COMP.
RUTH BENNETT No.87

TEXAS PACIFIC OIL COMP.
BENNETT RANCH UNIT No.311

TEXAS PACIFIC OIL COMP.
BENNETT RANCH UNIT No.282

TEXAS PACIFIC OIL COMP.
(GRUY FEDERAL)
BENNETT RANCH UNIT No.310

TEXAS PACIFIC OIL COMP.
BENNETT RANCH UNIT No.242



LEGEND

TIGHT STREAKS WITHIN LIMESTONE/DOLOMITE

POROUS LIMESTONE/DOLOMITE

SCALE

GRUY FEDERAL, INC.
HOUSTON, TEXAS

WASSON FIELD
YOAKUM COUNTY, TEXAS
FIGURE 40B

CORRELATABLE TIGHT STREAKS WITHIN THE SAN ANDRES FORMATION

The basic bulk density-porosity relation is given in Eq. 1, which is simply a material balance on a given unit volume of formation.

$$\rho_b = (1 - \phi_e - V_{sh})\rho_{ma} + \phi_e\rho f + V_{sh}\rho_{sh} \quad (1)$$

where ρ_b = bulk density (gm/cc),

ϕ_e = effective porosity (decimal fraction),

V_{sh} = volume of shale (decimal fraction),

ρ_{ma} = apparent matrix density (gm/cc),

ρ_f = fluid density (gm/cc),

and ρ_{sh} = shale density (gm/cc).

The basic relation for the sonic log is given by Eq. 2, an empirical relation known as the Wyllie time-share formula:

$$\Delta t_b = (1 - \phi_e - V_{sh})\Delta t_{ma} + \phi_e\Delta t_{ma} + V_{sh}\Delta t_{sh} \quad (2)$$

where Δt_b = bulk travel time (μsec/ft),

ϕ_e = effective porosity (decimal fraction),

V_{sh} = volume of shale (decimal fraction),

Δt_{ma} = apparent matrix travel time (μsec/ft),

and Δt_{sh} = shale travel time (μsec/ft).

For most porosity ranges, porosity can be determined from the neutron log, using Eq. 3:

$$\phi N = (\phi N_{sd} - H_{ma}2 - \nabla)/(H_f - H_{ma}2) - V_{sh}\phi N_{sh} \quad (3)$$

where N_{sd} = neutron porosity in sandstone,

$H_{ma}2$ = final hydrogen index of the matrix,

H_f = final hydrogen index of the fluid,

∇ = neutron deviation function,

V_{sh} = volume of shale (decimal fraction),

and ϕN_{sh} = neutron shale porosity.

This equation was developed to obtain lithology corrections; it assumes an initial hydrogen index of 1 for the fluid.

Schlumberger has developed porosity cross-plotting techniques that allow determination of the lithology of the formation. These cross-plots are not valid if the formation contains a large volume of shale or significant free gas in the pore space, but these restrictions do not apply to the Bennett Ranch Unit. Two standard cross-plots, density-neutron and sonic-neutron, were used to aid in determining the lithology and porosity.

Figures 41 and 42 are density-neutron and sonic-neutron cross plots, respectively. From the raw data in Figs. 41 and 42, it was apparent that porosities obtained from the cross-plots would be too pessimistic if the logging measurements were not normalized. With the aid of core data, a minimum porosity of 1 percent and a maximum porosity of 22 percent were established for the San Andres formation. A shift and sensitivity equation was set up for each porosity device at the minimum and maximum porosity limits (i.e., corrected measurement = sensitivity x log measurement + shift). The six resulting equations were simultaneously solved for the six unknowns (i.e., sensitivity and shift for each porosity device). In effect, this normalization procedure corrects the data for shale and lithology. The shift and sensitivity corrections for the three porosity devices are:

Density: $$\rho b_N = 0.525 \rho b_{log} + 1.144 \quad (4)$$

Sonic: $$\Delta t_N = 1.639 \Delta t_{log} - 30.028 \quad (5)$$

Neutron: $$\phi N_N = 1.000 \phi N_{log} + 0.00 \quad \text{(no correction)} \quad (6)$$

Once normalized, the apparent true porosities taken from each chart were averaged to arrive at the effective porosity. Statistical comparisons of the two apparent true porosities showed an average deviation of less than one porosity unit. It should be noted, however, that the actual normalization constants shown above are site-specific and must be determined for each site before analysis. After obtaining a value for effective porosity, it is possible to compute an indexed volume of shale. If the apparent matrix density is assumed, Eq. 1 can be used to determine the approximate volume of shale. The volume of shale can be calculated similarly, using the sonic (Eq. 2) and neutron (Eq. 3) relationships. The most probable volume of shale is then determined using weighted averages.

Calculated shale volumes from log analysis are listed versus depth in Appendix F. It can be seen that virtually no shale was indicated over most of the interval analyzed, which is consistent with the carbonate lithology of the cored interval.

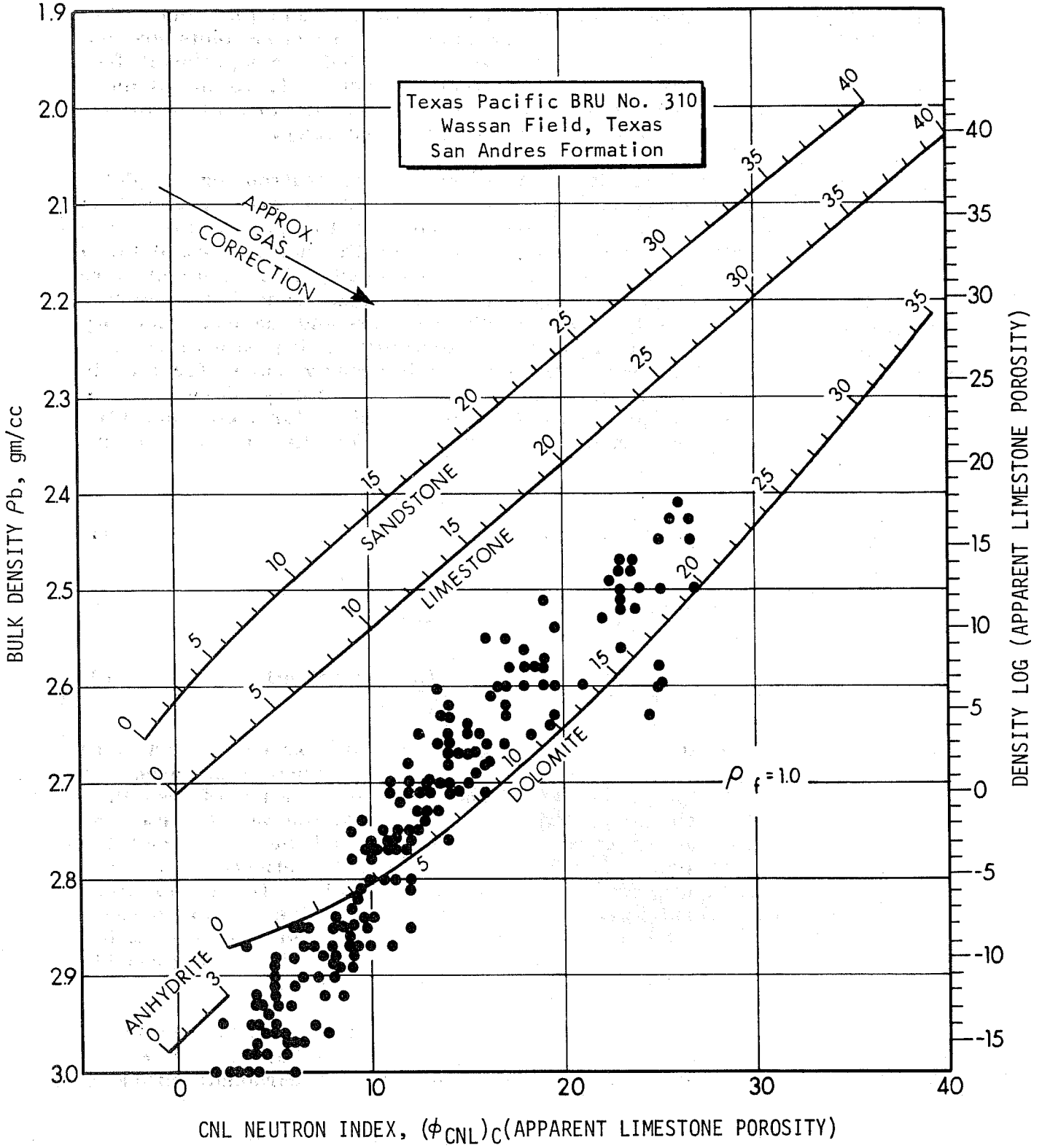


Figure 41.--Density-neutron cross plot, BRU No. 310.

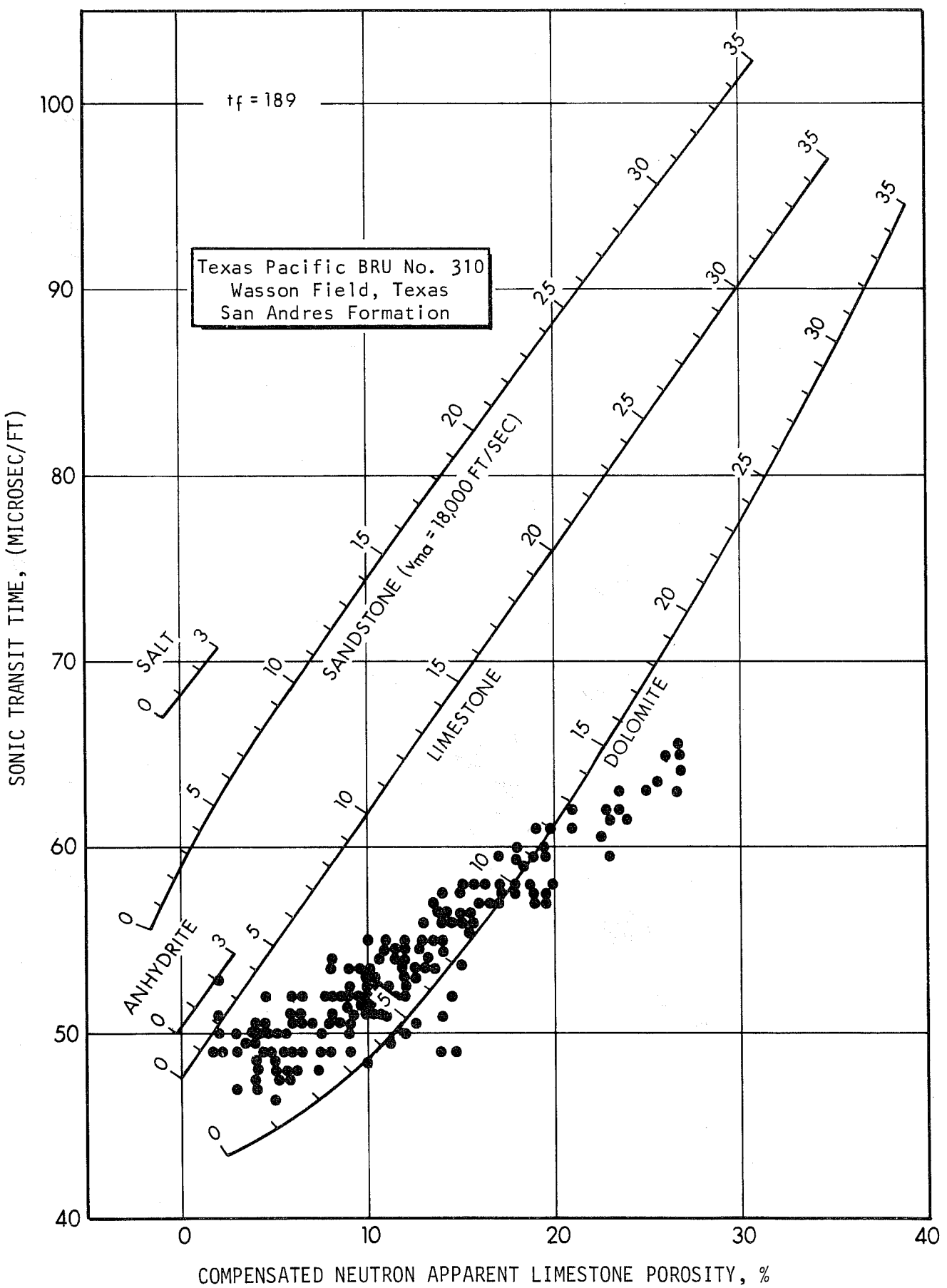


Figure 42.--Sonic-neutron cross plot, BRU No. 310.

Water saturations can be computed from the resistivity index:

$$(S_w)^n = R_0/R_t \ , \tag{7}$$

where S_w = water saturation (fraction),

n = saturation exponent,

R_0 = resistivity of water zone at 100% water saturation (ohm-m),

and R_t = true resistivity of zone being evaluated (ohm-m).

R_0 may be estimated for any core using the equation:

$$R_0 = F \cdot R_w \ , \tag{8}$$

where $F = a/\phi^m$,

a = tortuosity constant,

ϕ = porosity (fraction),

R_w = resistivity of formation water,

and m = cementation factor.

Combining Eqs. 7 and 8 yields the general expression for water saturation calculations:

$$(S_w)^n = \frac{aR_w}{\phi_e^m R_t} \ . \tag{9}$$

It is generally accepted[32] that $a = 1$ for carbonate reservoirs. The values of m and n must be determined. For consolidated and reef carbonates the value of m can range from 2.2 to 2.4. The exponent n for most formations is assumed equal to 2; for oil-wet formations n may be as high as 4.

Water saturations in the flushed zone can be computed using the equation

$$(S_{xo})^n = \frac{aR_{mf}}{\phi_e{}^m R_{xo}} \quad , \tag{10}$$

where S_{xo} = water saturation in the flushed zone (fraction),

R_{mf} = resistivity of mud filtrate (ohm-m),

and R_{xo} = shallow resistivity (ohm-m).

A final cross plotting technique was applied to approximate the value of n. Equating the cementation factor (m) and the saturation exponent (n),

$$(\phi S_w)^n = aR_w/R_t \quad . \tag{11}$$

It can be seen from Eq. 11 that a log-log plot of (ϕS_w) versus R_t has an intercept of (aR_w) and a slope of n. Cross-plots of the core bulk water (ϕS_w) versus log resistivity R_t indicated that the cementation factor m and the saturation exponent n could be equated and determined by regression. This technique resulted in a saturation exponent of 2.34 for the Main Pay. Figure 43 shows graphically the solution for the Main Pay.

Produced water from the swab tests and data from adjacent wells indicated that the formation water has a salinity of approximately 130,000 ppm NaCl, which corresponds to a formation water resistivity of 0.045 ohm-m, assuming $a = 1$. The intercept of (aR_w) was therefore set equal to 0.045 at a bulk water $(\phi_e S_w)$ fraction of 1.00. The resistivity of the invading mud filtrate was measured on location and found to be 0.16 ohm-m. Both formation and mud filtrate resistivities are corrected to the bottomhole temperature (105°F) recorded at 5,384 feet. The values of m and n were taken to be 2.34. Equation 12 was used for the true water saturation computations, Eq. 13 for the flushed zone water saturation computations.

$$S_w{}^{2.34} = \frac{0.045}{\phi_e{}^{2.34} R_t} \tag{12}$$

$$S_{xo}{}^{2.34} = \frac{0.160}{\phi_e{}^{2.34} R_{xo}} \tag{13}$$

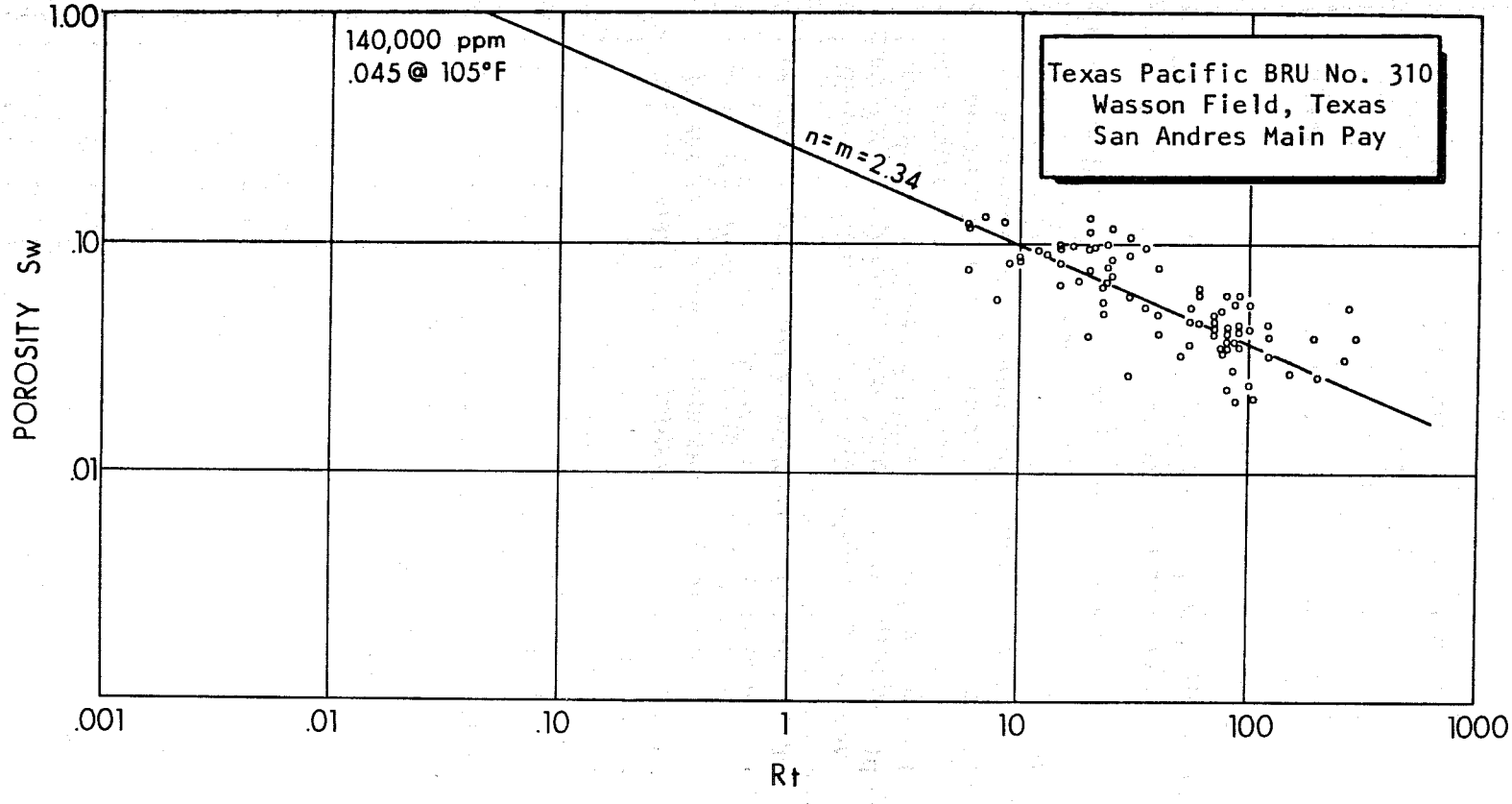


Figure 43.--Bulk core water vs. log resistivity.

The flow chart shown as Fig. 44 gives the procedure used in the log analysis. The computed effective porosities and water saturations are presented with the core data for comparison (Fig. 45).

Figure 45 shows that porosity and water saturation core data agree well with the computed log values. The nonpressured water saturations of the cores were generally lower than the computed water saturations.

The standard log analysis techniques incorporating the and values obtained from Core Labs did not agree as well as the analysis results shown in Fig. 45.

There is also generally a better match of core and log water saturation values for pressured cores than for non-pressured cores.

Standard log analysis techniques incorporating the m and n values obtained from Core Labs did not agree as well as the analysis results shown in Fig. 45. There are a number of possible reasons for this. The depth of investigation of a dual induction laterolog is approximately 5 ft. Any cementation exponents determined from log analysis would be representative average values, providing no anamolous hole conditions such as overbalance and deep invasion occurred. As cores are a much smaller formation sample for a particular depth, cementation and saturation exponents derived from them might not be representative average samples. Also, as mentioned earlier, the method of sample preparation and measurement necessarily alters the wetability of the reservoir rock, which introduces some uncertainty.

This points out out the fact that good values for R_W, m and n are requisite to obtain log calculated water saturation values comparable to pressure core water saturations as illustrated in Fig. 45.

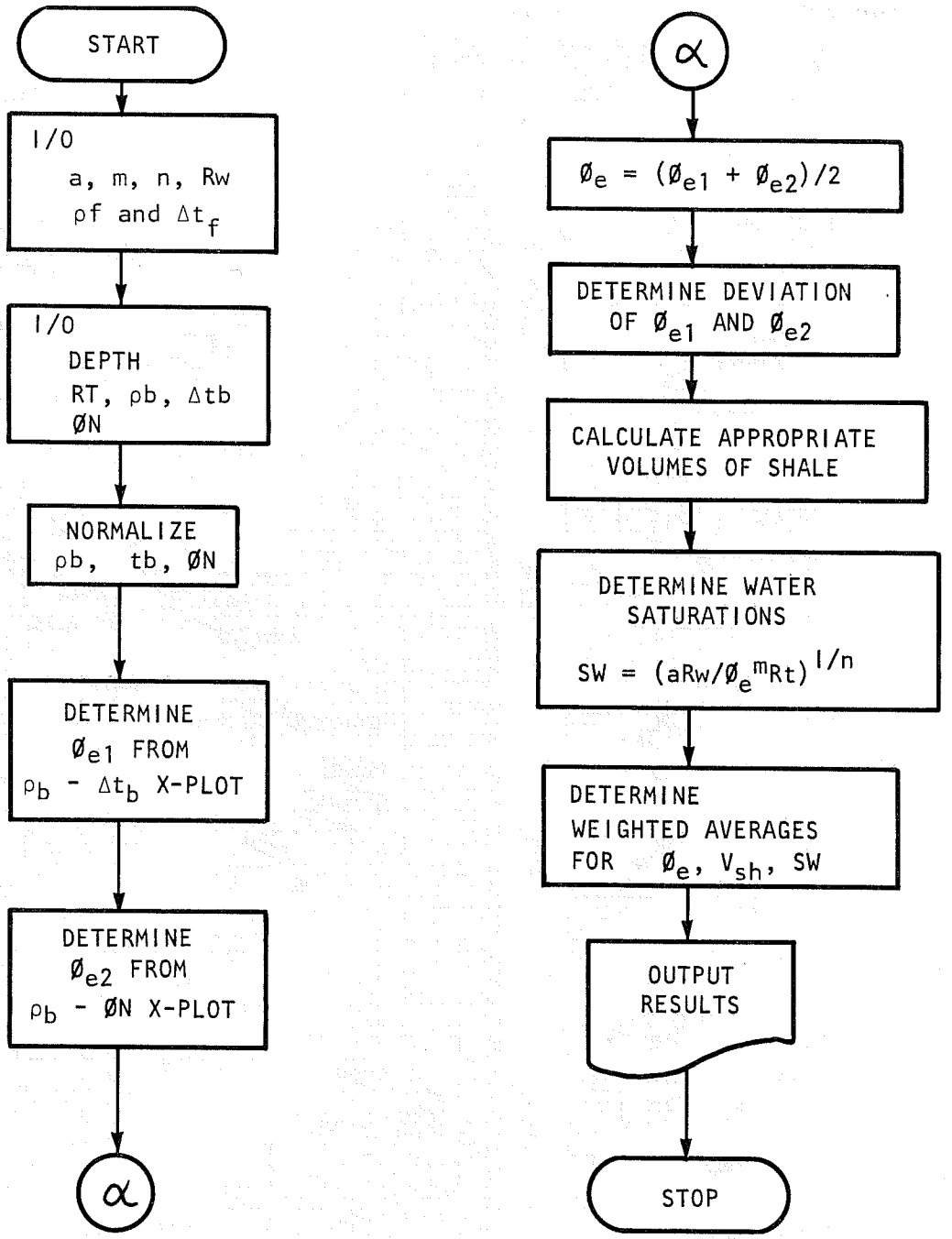


Figure 44.--Flow chart for log analysis procedure.

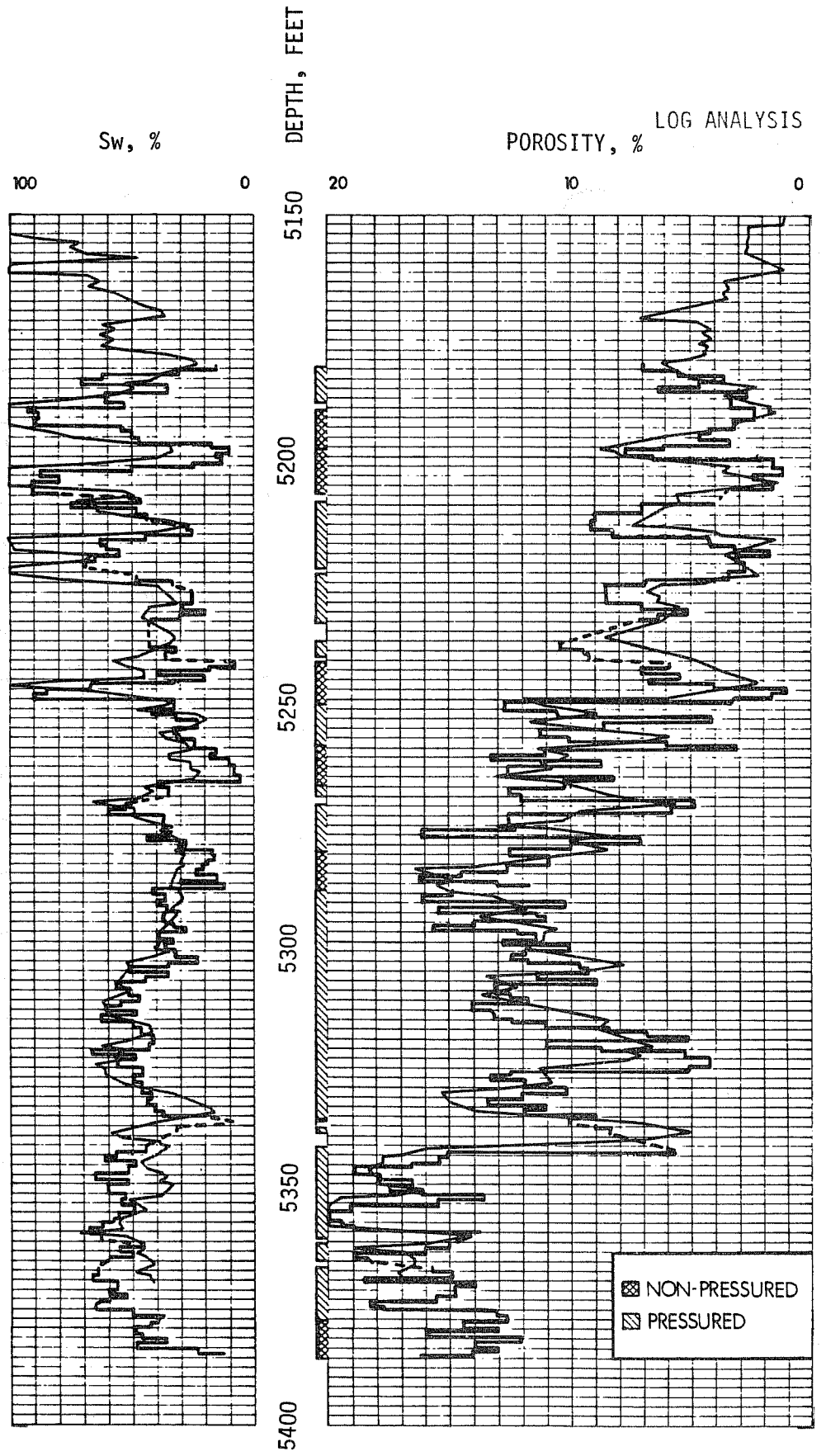


Figure 45.--Comparison of core & log analysis.

PRODUCTION TEST DATA

Production Data By Intervals

Production testing, supervised by Texas Pacific, began in April 1980 and was completed during May. Four intervals were separately swab-tested by selectively setting bridge plug and packer combinations. The individual intervals were tested sequentially from the deepest to the shallowest with results as follows:

	Interval, ft	Swab Test Results
1.	5342 - 5358	Rec. trace oil, 113 BW in 13 hours
2.	5325 - 5332	Rec. 2 BO, 105 BW in 10 hours
3.	5248 - 5302	Rec. 42 BO, 230 BW in 9 hours
4.	5168 - 5234 (overall)	Swabbed dry, gas blow

The test intervals are shown on the plot of depth versus pressure core analysis data in Fig. 46. The interval from 5,248 to 5,302 ft is the Main Pay of the San Andres reservoir in Wasson. Following the swab-testing procedures, this interval was placed on pumping production for a stabilized rate of 48 BOPD, 275 BWPD.

Detailed log analysis was performed for each interval tested. Figure 47 is a plot of average computed porosity versus average computed water saturation for the cored interval. The average porosities and water saturations for the zones tested are:

	Interval, ft	Computed Porosity	Computed Water Saturation
1.	5342-5358	0.181	0.419
2.	5325-5332	0.135	0.380
3.	5248-5302	0.111	0.338
4.	5168-5182	0.052	0.446
	5194-5200	0.066	0.523
	5209-5215	0.063	0.487
	5223-5234	0.053	0.456

A plot of porosity versus water saturation can aid in determing the type of fluid production. High volumes of bulk water ($\phi_e S_w$) are associated with water production, whereas low volumes are indicative of hydrocarbon production. Figure 48 is a plot of computed average interval porosity versus computed average interval water saturation. A hyperbolic curve for constant bulk water content (ϕS_w = constant) illustrates the expected production trends. Points falling above this curve should produce water; points falling below it should produce hydrocarbons. The hyperbolic curves represent constant bulk volume water. For a homogeneous formation at irreducible water saturation, the product of porosity and water saturation is approximately constant. Between the irreducible water section and the

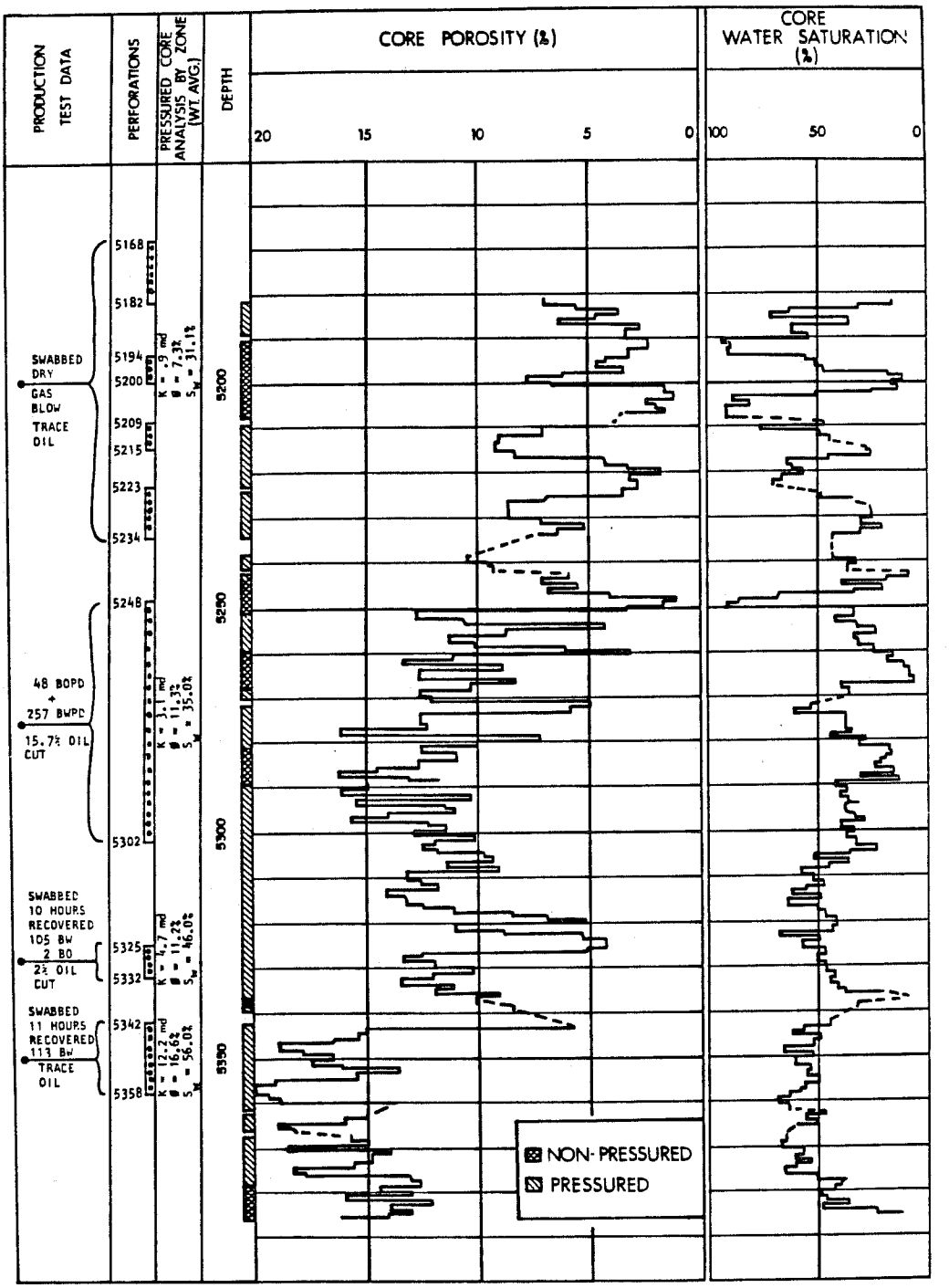


Figure 46.--Comparison of production test results and log analysis data, Bennett Ranch Unit No. 310.

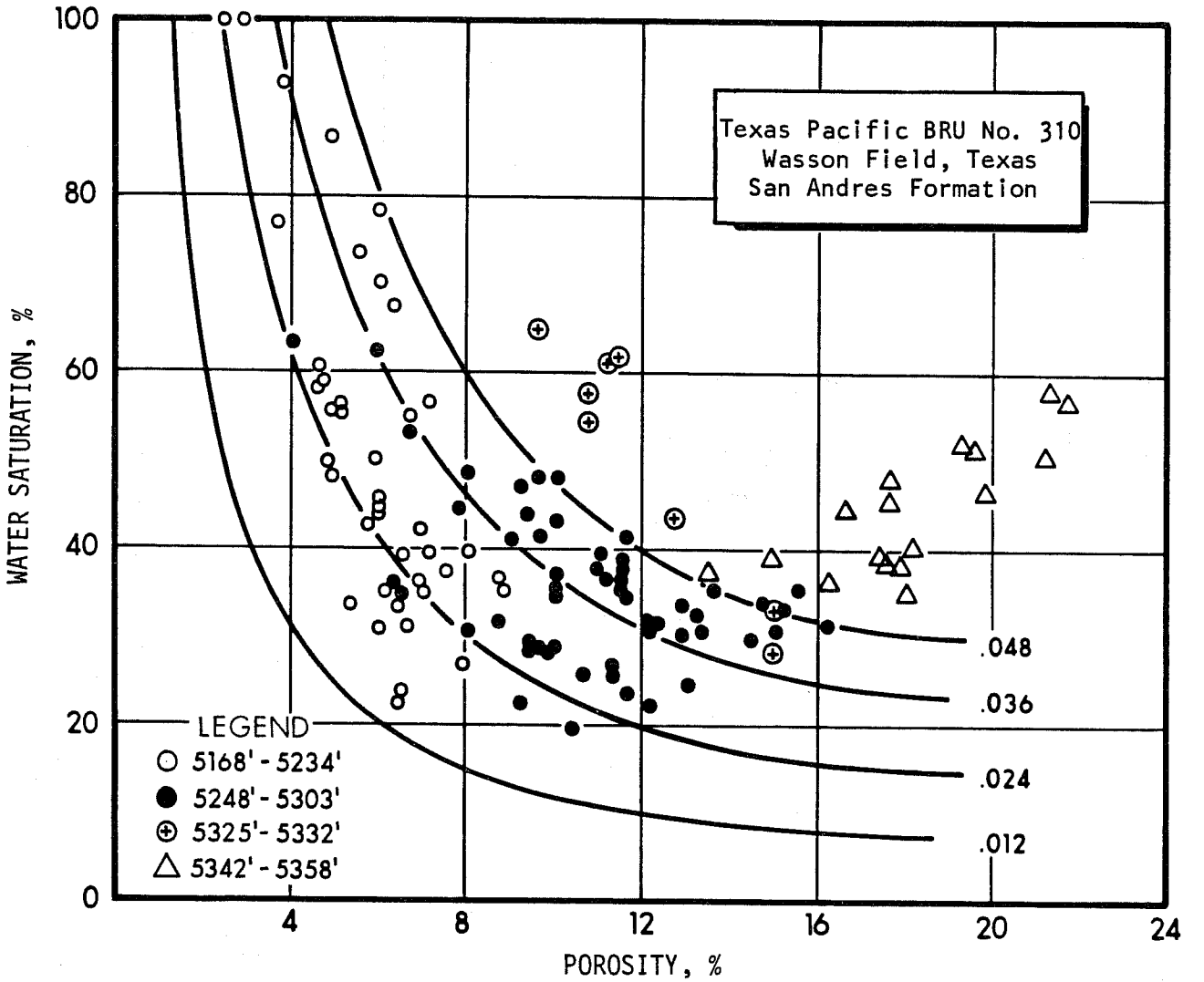


Figure 47.--Average computed porosity vs. average water saturation.

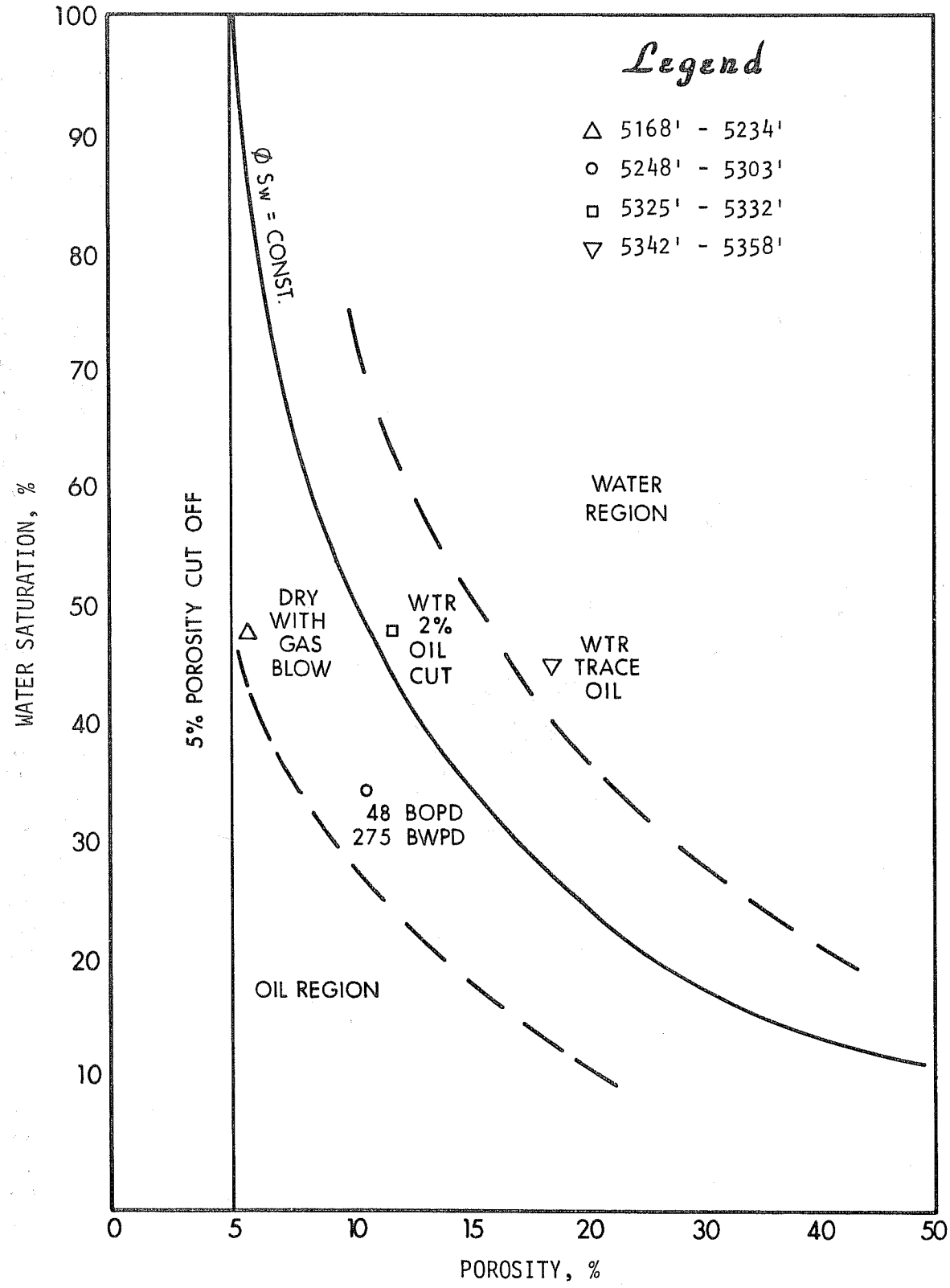


Figure 48.--Porosity vs. water saturation, from log analysis.

water zone there should exist a transition zone. On a plot of porosity versus water saturation the transition zone will deviate from the hyperbolic trend toward 100% water saturation. From Figs. 47 and 48 it is clear that the lowermost interval (5,342 to 5,348 ft) is in the transition zone. It should be noted that this zone is below the estimated oil-water contact at 5,335 ft. Further analysis of these figures indicates that the Main Pay should have a smaller water cut than the swab test results show, implying that water produced in the swab tests may have come from an adjacent interval. A description of the computer program and calculated data are presented in Appendix F.

Fluid Analysis Data

Samples of formation water recovered during the production testing procedure were analyzed for chemical and physical properties. Table 14 is a summary of these analyses; the complete results are provided in Appendix G. The analyses indicate that the low chloride content of the core water for the interval 5,168 to 5,234 ft was due to mud filtrate invasion. The chloride analyses of the produced waters indicated that original formation water was still present and that low-chloride flood waters had not swept any of the perforated intervals.

Reservoir Pressure Data

Initial and final fluid levels, recorded during the swab tests, were used to estimate the reservoir pressures for the four different zones (Table 15).

The pressures in Table 15 were calculated using a fluid column gradient of 0.433 psi/ft. Generally, static pressures recorded in the Main Pay (5,248 to 5,303 ft) are approximately 2,300 psi. The original virgin pressure was about 1,850 psi. The data in Table 15 indicate that the lowest zone (5,342 to 5,358 ft) is not repressured. Pressure in the middle two zones is close to the 2,300-psi flood pressure. The uppermost zone (5,168 to 5,234 ft) is probably not fully repressured. However, the hydrocarbon content of the fluid produced could vary enough to make the 0.433 psi/ft assumption invalid, and therefore these pressures should be considered only as rough estimates.

Summary of Core, Log, and Production Data Analysis

Analysis of pressure core data, production test data, and logs provides several insights that could not have been determined without the detailed data presented in the previous section. In the following discussion, an estimate of waterflood residual oil saturation is presented. The analysis suggests the presence of a relatively high-permeability zone that might be examined in greater detail before a CO_2 flood is initiated.

TABLE 14

CHEMICAL AND PHYSICAL PROPERTIES OF SAN ANDRES FORMATION WATER
BENNETT RANCH UNIT NO. 310

Interval, ft	Specific gravity	pH	Cl^-	Na^+	Total solids, mg/l
			(both in mg/l)		
5168-5234	------	6.2	85,000	31,240	137,700
5248-5303	1.0920	6.3	77,000	46,943	132,800
5325-5332	1.0961	6.0	85,223	51,065	146,064
5342-5358	1.0957	6.2	88,064	53,689	151,046

TABLE 15

SWAB TEST PRESSURE DATA

Interval, ft	Estimated pressure, psia
5342-5358	1758
5325-5332	2309
5248-5303	2296
5168-5234	1963

Production Test Data Summary

The analysis of produced waters obtained during the production tests indicates that the waterflood has not broken through the tested intervals. Data from tests in each zone are summarized below.

Zone 1 (5,168-5,215 ft)

1. The estimated pressure of 1,963 psia indicates that this zone is not at or near residual waterflood conditions.

2. This interval swabbed dry with a good gas blow and a trace of oil, indicating that porosity and permeability were the main factors contributing to the poor test results.

3. Two of the five core runs through this interval failed to retain pressure in the core barrel. This resulted in loss of 40 percent of in-situ saturation data.

Zone 2 (5,248-5,302 ft), Main Pay

1. The estimated pressure of 2,296 psia indicates that this zone is under active waterflood conditions.

2. This interval tested 48 BOPD and 257 BWPD (15.7 percent oil cut). Portions of this interval may be close to residual oil saturation.

Zone 3 (5,325-5,332 ft)

1. The estimated pressure of 2,309 psia indicates that this zone is under active waterflood conditions.

2. This interval tested 105 BWPD and 2 BOPD (2 percent oil cut), suggesting that the zone may be close to residual waterflood conditions.

3. This zone appears to be well isolated from the zones immediately above and below.

Zone 4 (5,342-5,348 ft)

1. The estimated pressure of 1,758 psia is below the original reservoir pressure (1,850 psia), suggesting that this zone is not under active waterflood conditions.

2. Log analysis and geologic correlations show this zone to be within the transition zone that begins at the oil-water contact (5,335 ft).

3. Residual oil saturations obtained from this zone would not be representative of Main Pay saturation values because of the influence of the capillary forces in the transition zone.

4. This zone tested 113 BW with only a trace of oil.

The analysis of the production test data and pressure core data indicates the presence of a zone from 5,308 to 5,318 ft having relatively high permeability and porosity. Tritium data indicate that this zone experienced little invasion by mud filtrate. The maximum horizontal-to-vertical permeability ratio is plotted against depth in Fig. 49. This ratio approaches 1 in the high-permeability zone, which appears to be in vertical communication with the Main Pay zone located from 5,248 to 5,302 ft. Descriptions of the cores state that fractures are found from the bottom of the Main Pay into this zone. Since the zones immediately above and below the high-permeability zone have been repressured, it is reasonable to assume that this zone is also repressured and possibly flowing water into the Main Pay. The average water saturation from pressured core data was 54.8 percent for the high-permeability zone.

The zone-by-zone production test data suggest that a basal interval from 5,325 to 5,332 ft (just above the original oil/water contact) is close to residual oil saturation and that the interval from 5,308 to 5,318 ft, immediately below the Main Pay, is at residual oil saturation. To aid in the determination of the residual oil saturation, the stock tank oil saturation produced by pressure depletion was plotted against the total stock tank oil saturation (Fig. 50). The core data were plotted only in the perforated intervals, for porosities greater than 5 percent and permeabilities greater than 1 md. The high-permeability zone located from 5,308 to 5,318 ft is also plotted in Fig. 50. Conventional cores would have plotted at zero stock tank oil saturation produced by pressure depletion (i.e., dashed line). Data from pressured cores taken deep in the transition zone (below 5,342 ft) also show zero stock tank oil saturation by pressure depletion. The Main Pay (5,248-5,302 ft) plots in the upper right-hand quadrant of Fig. 50 indicate a high percentage of pore-volume oil available for pressure depletion. However, the remaining four zones shown in Fig. 50 do not have a high percentage of pore-volume oil available for pressure depletion.

The stock tank oil produced by pressure depletion is also referred to as "blowdown oil." The percent blowdown oil versus water saturation is plotted in Fig. 51 for the three zones most likely to contain intervals at residual waterflood conditions (i.e., 5,308-5,328; 5,325-5,332; and 5,342-5,358 ft). A definite trend exists between blowdown percent and water saturation. As the percent of blowdown oil decreases, the water saturation increases. The trend line in Fig. 51 represents the trend for the zones from 5,308 to 5,318 and 5,325 to 5,332 ft (the zone from 5,342 to 5,358 ft was considered to be nonrepresentative because it is below the oil-water contact). Analysis of the Main Pay defined a minimum blowdown value of 24 percent, using the trend line in Fig. 51. Residual water saturation after waterflood is estimated at 52 percent. From Fig. 51, it is apparent that if the blowdown after waterflood is less than 24 percent the residual water saturation could be as high as 64 percent. However, the 24 percent minimum blowdown value is consistent with the zone from 5,325 to 5,332 ft that produced 2 percent oil-cut water.

It appears from Fig. 51 that the heterogeneous strata of the San Andres will have varying residual water saturations after waterflood. The average residual water saturation will depend on the efficiency of the waterflood.

Texas Pacific BRU No. 310
Wasson Field, Texas
San Andres Formation

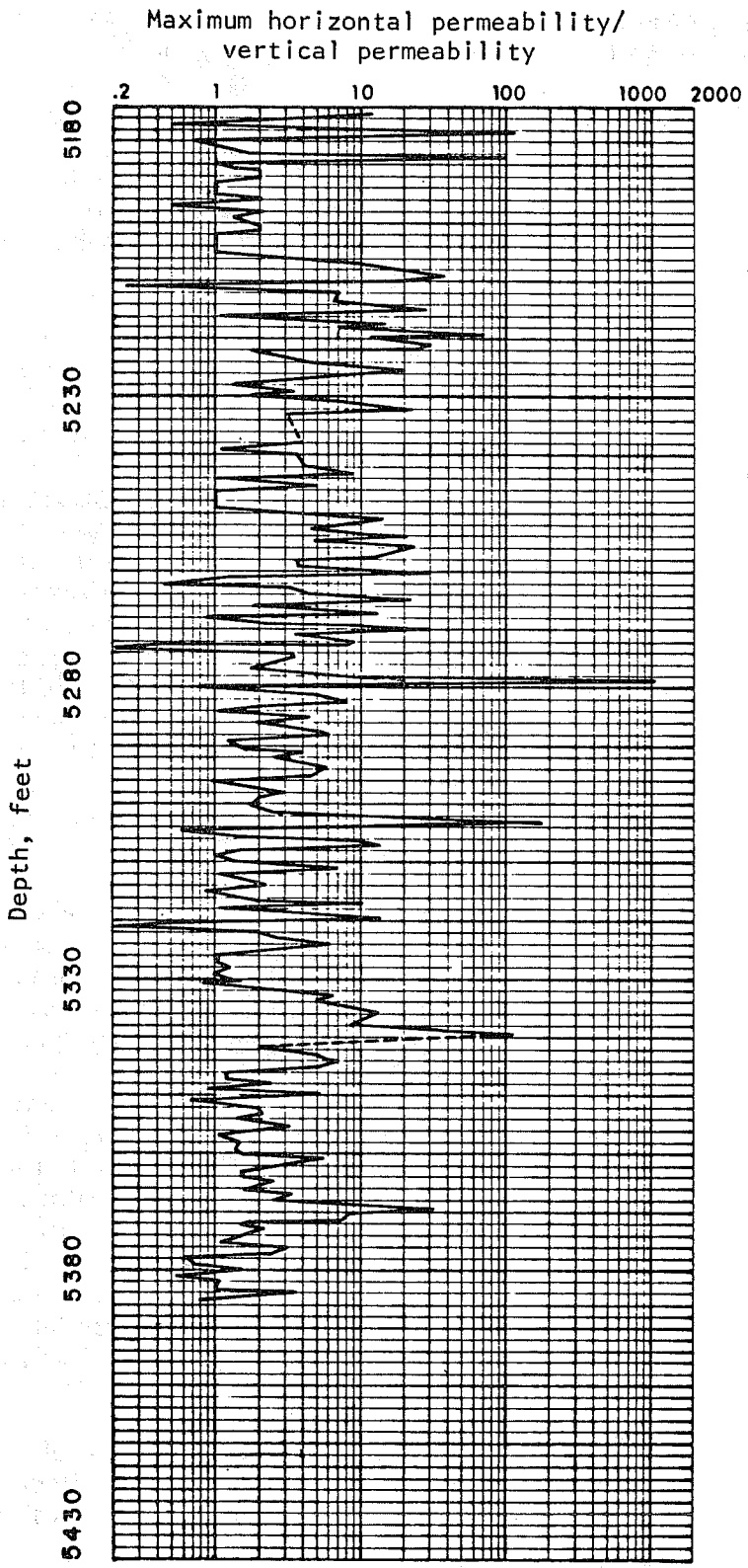


Figure 49.--Horizontal to vertical permeability ratios.

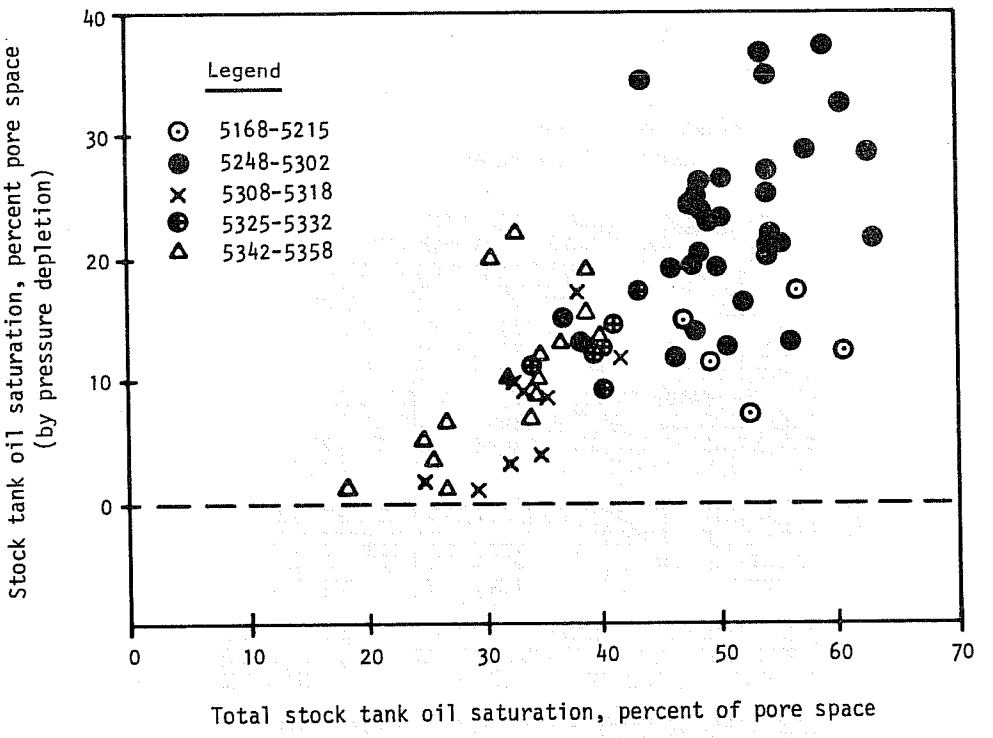


Figure 50.--Stock tank oil saturation cross-plot.

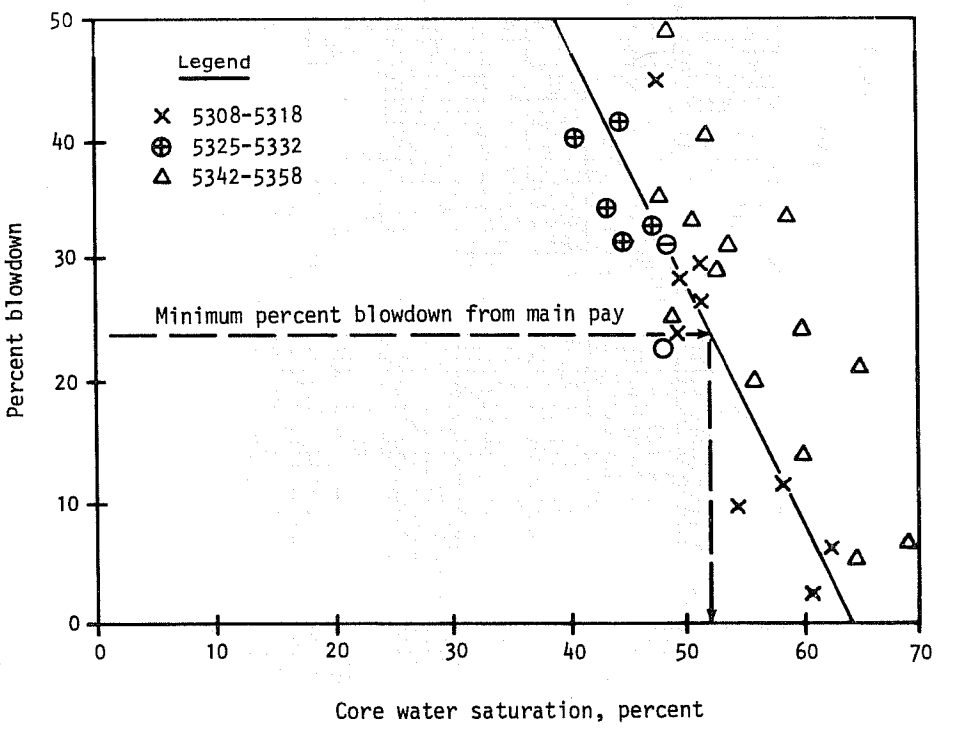


Figure 51.--Determination of residual waterflood saturation.

The following table summarizes the estimates of residual water and oil saturations for the various zones.

Zone	Depth, ft	Residual saturation, % water	oil
Main Pay	5248-5302	52.0	48.0
"Hi-Perm"	5308-5318	54.8	45.2
Basal	5325-5332	>48.8	<51.2
Transition	5342-5358	56.2	43.8

The value of 52.0 percent for the residual water saturation of the Main Pay was determined by using the minimum blowdown oil concept and the trend line in Fig. 51. For the basal zone, from 5,325 to 5,332 ft, the maximum water saturation of 48.8 percent (from core analysis) was assumed equal to or less than the final residual water saturation. The transition zone and the high-permeability zone values of residual water saturation, 56.2 and 54.8 percent respectively, were obtained from core analysis data. Residual oil saturations were calculated from $S_{or} = (1 - S_{wr})$.

Summary and Conclusions

Field operations for pressure coring required some 11.5 days, during which 27 pressure core barrel runs were made to recover 26 cores over a 210-ft San Andres interval from 5,175 to 5,385 ft. To conduct the time-consuming pressure coring operation, hole stability considerations required that the well design provide for 8-5/8 inch casing set and cemented in the San Andres at 5,150 ft, as compared to some 500 ft of casing for routine drilling and 2,500 ft of casing for conventional coring. Minor difficulties with junk in the hole were the only operational problems encountered.

An experimental program to compare coring efficiencies of a conventional diamond coring bit with newer bit designs using polycrystalline diamond compact cutters showed that the newer designs were capable of 50 to 300 percent improvements in coring rates. However, the time required for the entire coring cycle was reduced by only some 20 percent, because pipe and core-barrel handling times remained the same for all bit designs.

Twenty-six of the 27 core barrel runs recovered core material (Run 21 was aborted because of junk in the hole). Cores retained under pressure were obtained in 20 of the 26 runs, a 77 percent success ratio. Failure to obtain pressured cores in the other six runs was attributed to various causes, as follows:

- no evident reason (once),
- core slipped (too long?) in catcher, blocking ball valve (twice),
- ball valve failed to close (three times).

Measured core recoveries suggested that the two instances in which the "catcher slipped" and the core blocked the ball valve may have been compounded by cutting cores too long to be accommodated above the ball valve in the core barrel. This indicates the need for careful kelly and pipe measurements and close operational control during on-bottom coring operations.

The oil-water contact across the San Andres reservoir in the Wasson field is tilted approximately 23 feet per mile northeasterly because of hydrodynamic forces. The oil-water contact at the BRU 310 location on the northeast edge of the structure was expected at a well depth of approximately 5,335 ft (1,758 ft subsea). The top of the San Andres First Porosity was expected at a well depth of approximately 5,175 ft (1,598 ft subsea). These were encountered essentially as expected, so the core interval from 5,175 to 5,385 ft encompassed the entire San Andres "pay" interval plus approximately 50 ft of the transition zone below the oil-water contact. Four separate intervals, one in the transition zone and three in various pay intervals, were swab- or production-tested, with results as follows:

Depth, ft	Interval	Results
1. 5168-5234	First Porosity	Swabbed dry, gas flow
2. 5248-5302	Main Pay	Rec. 42 BO, 230 BW in 9 hr
3. 5325-5332	Basal Main Pay	Rec. 2 BO, 105 BW in 10 hr
4. 5342-5348	Transition zone	Rec. trace oil, 113 BW in 13 hr

These data are consistent with log and core analysis. Core and log analysis data indicate that the First Porosity intervals tested contained low porosity and permeability. High water saturations with little or no mobile oil were indicated for the transition zone and the basal Main Pay, whereas a producible (i.e., mobile) oil saturation was indicated for the main pay interval. The well was subsequently completed in the Main Pay interval for stabilized pumping production of 48 BOPD and 275 BWPD (85 percent water cut).

Pressure cores were taken in the first porosity zone, in the main pay, in the basal main pay and into the transition zone to assess the amount of immobile (to water) oil saturation present, and to assess the potential of CO_2 displacment for recovering the oil present. Residual oil saturations for the zones are 287 STB/acre-ft for the first porosity zone, 419 STB/acre-ft for the main pay, 345 STB/acre-ft for the basal main pay, to 417 STB/acre-ft for the transition zone. If residual oil saturation to carbon dioxide flooding of 10 percent is assumed, recoverable or "target" oil for the first porosity is 258 STB/acre-ft, 377 STB/acre-ft for main pay, 310 STB/acre-ft for the basal main pay and 375 STB/acre-ft for the transition zone. Oil in the transition zone was originally non-recoverable oil and, hence, represent an additional dimension to the potential for carbon dioxide flooding, in at least this area of the Wasson field.

Standard log analysis techniques were not sufficiently precise for accurate determination of residual oil saturation because of the heterogeneity and intermediate (partially oil-wet) wettability of the carbonate reservoir rocks at Wasson. Hence, data from pressure cores were required for evaluation of residual oil and to calibrate log analysis techniques.

Pressure coring offers the industry an operational and technically sound approach to tertiary recovery project evaluation. The engineering of experimental tests requires innovative thinking, but results in higher reliability of data. Determination of the residual water saturation after waterflood should be the primary objective of the experimental project. The pressure core should not be considered the sole source of data. The orderly collection of combined drilling, coring, logging, and production data allows the engineer to determine the most realistic values for evaluation of potential carbon dioxide injection projects.

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ENCLOSURE I - 1

"TARGET RESERVOIRS FOR
CARBON DIOXIDE MISCIBLE FLOODING"

Contract No. DE-AC21-79MC08341

APPENDIX A
STATEMENT OF WORK

1.0 OBJECTIVE

1.1 The objective is to build a solid engineering foundation upon which field mini and pilot tests may be conducted in both high and low oil saturation carbonate reservoirs for the purpose of extending the technology base in carbon dioxide miscible flooding.

2.0 SCOPE OF WORK

2.1 Summary of Available $C0_2$ Field Test Data

Data will be collected categorized, and interpreted from all significant past and on-going $C0_2$ field operations in order to evaluate the relative success of each test. This information will include oil gravity, reservoir pressure, depth, temperature, porosity, permeability, and net/gross pay. Also, these data must include pattern size, estimated incremental oil production due to $C0_2$ injection, $C0_2$ concentration and slug size, $C0_2$ injection rates and sequencing, $C0_2$ breakthrough and production rates, and any indications of formation damage or corrosion.

2.2 Summary of Existing Reservoir and Geological Data

The following reservoir geology will be determined on carbonate reservoirs located in west Texas, southeast New Mexico, and the Rocky Mountain states: stratigraphy, structure, mineralogy, porosity, permeability, gross and net thickness, and any other geological properties deemed significant regarding $C0_2$ injection. Reservoir data will be collected on hydrocarbon content, composition and distribution; connate water content and composition; pressure and production data from primary and/or secondary recovery operations; PVT analysis; and well test data and analysis. Guidelines for selecting reservoirs to be included are as follows:

average formation permeability	-	5 md
average current oil saturation	-	38%
oil gravity	- - - - - - - - - -	36 deg API
oil viscosity	- - - - - - - - - -	10 cp

In addition, no extremely high-permeability, stratigraphic, thief zones should exist. However, no consideration should be given to the proximity of CO_2 sources at this point. The objective here is to "characterize the resource" for possible future CO_2 injection.

ENCLOSURE I-1 (continued)

2.3 Selection of Target Reservoirs

By analyzing available reservoir and geological data, and comparing the results of various CO_2 field tests, a priority list will be developed based primarily on potential incremental oil recovery and the projected CO_2 requirements and availability. CO_2 requirements can be based on estimates from data collected in Task 1 and CO_2 supply data can be obtained from existing public documents on the subject (e.g. "The Supply of Carbon Dioxide for Enhanced Oil Recovery" by Pullman Kellogg, September, 1977).

2.4 Selection of Specific Reservoirs for CO_2 Injection Tests

A selection will be made from the priority list based on demonstrating the technology in those reservoirs with the greatest potential influence toward stimulating new projects capable of meeting the 1985 incremental oil production of 124,000 barrels per day stated in the Technical Implementation Plan for reservoirs in these target areas. For the reservoirs selected, the owners and operators will be identified. Also company officials who have the authority or influence to bring about commercialization of CO_2 recovery processes will be contacted. This is absolutely necessary since it is these companies which must eventually initiate and carry out commercial demonstrations of CO_2 injection if the full potential of the target reservoirs is realized.

2.5 Selection of Specific Sites for Test Wells (carbonate reservoirs)

Using all useful available knowledge from previous CO_2 field tests, reservoir and geological compilations, conventional production data, PVT analysis, log analysis, core analysis, and well test analysis, specific sites will be selected for drilling test wells for further delineation and substantiation of the reservoir properties prior to conducting CO_2 injection tests. These sites must be in the Rocky Mountain and west Texas-southeast New Mexico areas. A minimum of eight and a maximum of twelve sites are to be selected.

2.6 Drilling and Coring Activities

Depending on the availability of data at each site selected, test wells will be drilled, cored, logged, tested and analyzed to confirm initial oil saturation parameters and to design mini-test CO_2 injection programs. It is expected that one test well will be drilled at each site selected. However, the exact number and location of wells to be drilled will be negotiated to be consistent with the amount of additional engineering and geological information required, drilling costs in the area at the time of execution, and any other economic and engineering factors that may arise.

RECEIVED
GRUY FEDERAL, INC.
HOUSTON, TEXAS

ENCLOSURE I-2

GRUY FEDERAL, INC.
CONSULTANTS IN ENERGY SYSTEMS

May 30, 1979

JUN 1 8 1979

2500 TANGLEWILDE, SUITE 150
HOUSTON, TEXAS 77063
713/785-9200

1911 JEFFERSON DAVIS HWY., SUITE 500
ARLINGTON, VIRGINIA 22202
703/920-0113

Texas Pacific Oil Company, Inc.
P. O. Box 4067
Midland, Texas 79701

Re: Pressure Coring
Bennett Ranch Unit No. 310

Gentlemen:

This letter is a followup to the meeting held in your offices on May 17, 1979, between Messrs. Waller, Engleman and Hensley of your staff and John H. Goodrich and Rodney W. Pease of Gruy Federal, Inc. At that meeting, the participants discussed methods by which pressure cores and other data could be obtained in the Bennett Ranch Unit No. 310 well that you shortly plan to drill in the Wasson Field, west Texas. This letter is intended to outline our understanding of the results of the meeting and to solicit your approval of the terms under which Gruy Federal, Inc. will seek DOE approval to obtain pressure cores, logs, and test data from the San Andres objective of the subject well.

Gruy Federal, Inc. ("Gruy") is party to a contract with the United States Department of Energy ("DOE") under which Gruy will manage a program to locate test sites having Enhanced Oil Recovery (EOR) potential in carbonate reservoirs in the Rocky Mountain and west Texas-southeast New Mexico areas. The program will provide financial support for coring, logging and testing selected wells drilled on the identified and approved sites to evaluate the CO_2 flooding potential for possible pilot or full-scale projects. The program envisions taking cores through the reservoir intervals thought to have secondary or tertiary carbon dioxide flooding potential. The cores will be cut using a core barrel that will retain the cores under pressure for subsequent analysis in order to obtain a more direct measure of in-situ oil and water saturations as well as porosity and permeability for comparison with data obtained from a comprehensive suite of wire-line logs.

Gruy is seeking operators who plan, for their own purposes, to drill infill wells to or through reservoirs thought to have CO_2 flooding potential. These wells would be utilized to carry out the proposed coring and logging program. The Bennett Ranch Unit No. 310 well appears suitable for this program.

For chosen and agreed upon well sites, subject to DOE approval, Gruy will separately contract and pay for all coring, core analysis, and logging services and also contract to pay directly for rig time, mud services, and all other related costs during the coring and logging operations. Gruy will provide a prognosis of the work to be done but ultimate control of all operations would remain with you.

If, for your purposes, the well is to be completed in the target reservoir, Gruy would propose to conduct or monitor production tests in order to obtain further data on the CO_2 flooding potential. During the period of those tests, Gruy would contract directly for workover rig services and any perforating, stimulation, and equipment services needed to obtain satisfactory test data. Design of these tests would be done by Gruy based on data from core and log analysis, and would be subject to your approval and control for execution.

In return for, and as an incentive to you for this use by Gruy of the operator's well, Gruy will provide timely copies of all logs, core analysis, and other data obtained. Gruy's interpretation of these data will ultimately be reported to the DOE in formal reports that also will be supplied to you.

Gruy will have no interest in the well, in the leases or in any production therefrom. You are under no obligation to either Gruy or DOE to consider CO_2 flooding now or in the future.

Upon selection by Gruy, and approval by the DOE, of Bennett Ranch Unit No. 310 as a candidate well for the CO_2 target reservoir coring program, Gruy will provide experienced engineering and drilling personnel to work with your technical or operating staff in both the planning and execution phases. Gruy will designate the coring point and select the coring and logging service companies to be used on the project. Such companies will be approved by you. You will be under no obligation other than to make a good faith effort to carry out the designated coring and logging program in accordance with established oil field procedures and a plan provided by Gruy.

The Gruy Companies have been in the energy consulting business since 1950. Professional services rendered in the private sector and for governmental agencies range from energy related research and planning to estimating reserves and forecasting future production. Gruy also evaluates drilling prospect plans from the exploration phase through final development. In a management capacity, it drills and operates fields for its clients.

Gruy will stand between you and the DOE and be responsible for any and all contacts and communications with the DOE.

Attached to this letter, as Exhibit A, is a brief summary of the "Target Reservoirs for Carbon Dioxide Flooding" project, which outlines the proposed

GRUY FEDERAL, INC.

program. An objective of the program is to find ways of making carbon dioxide flooding more economically viable for application by private industry. In assisting with the program, you will receive data that perhaps may allow you to benefit in your own operations and planning. If you agree that the proposal and arrangements discussed above would be a satisfactory basis for a contract between Texas Pacific and Gruy Federal, please return a copy of this letter signed in the "concur" block provided.

Very truly yours,

John H. Goodrich

John H. Goodrich
CO_2 Project Manager
Gruy Federal, Inc.

JHG:lc
Attachment

CONCUR:

Signature

R. J. WOMACK
MIDLAND REGIONAL MANAGER

Title
Texas Pacific Oil Company, Inc.

WELL USE/OPERATOR AGREEMENT CONTRACT NO. 3027-45

TEXAS PACIFIC OIL COMPANY, INC.

This Contract is made and entered into effective the 15th day of September 1979, between GRUY FEDERAL, INC., 2500 Tanglewilde, Suite 150, Houston, Texas 77063, hereinafter called "GRUY", and TEXAS PACIFIC OIL COMPANY, INC., 1700 One Main Place, Dallas, Texas 75250, hereinafter called "TEXAS PACIFIC".

In consideration of the mutual promises hereinafter contained, both parties agree that this Contract will be performed in accordance with the following conditions:

I. SCOPE OF WORK

GRUY is a party to a Contract, No. DE-AC21-79MC08341, with the United States Department of Energy, to pressure core, log, and evaluate wells, at various sites, having potential for CO_2 flooding and enhanced oil recovery. As TEXAS PACIFIC is drilling a well, Bennett Ranch Unit 310 in Wasson Field, Yoakum County, Texas which exhibits such a potential, TEXAS PACIFIC agrees to cooperate with GRUY in the drilling, pressure coring, logging and evaluation of said well. TEXAS PACIFIC shall remain the "Operator", and have sole control, direction, and responsibility during the required operations. GRUY shall have the right to have engineers, drilling supervisors, and geologists on site to observe and to consult with TEXAS PACIFIC on the various operations, to select the coring point; and GRUY shall select, contract, and pay for the coring and logging services and other required services and materials during the coring and logging operations.

TEXAS PACIFIC agrees to start the actual drilling of the well, on or about 15 September 1979, and thereafter to continue drilling of said well with due diligence, dispatch and in a workmanlike manner in accordance with the below:

A. Drill additional 12-1/4 in hole from 2,500± feet to 5,165± feet (top of San Andres formation).

B. Set and cement to surface an additional 2,665' of 8-5/8" casing from 2,500± feet to 5,165± feet.

C. Act as Operator and provide field supervision to accomplish the logging and coring programs as established by GRUY.

D. Consult with GRUY on all operations.

E. Carry out the coring and logging programs, as set forth by GRUY, in accordance with established oil field procedures.

F. Accept all responsibility and liability for the operations and well.

G. Provide living and office space for two (2) GRUY employees.

H. Cease operation, for GRUY account, when advised by GRUY.

I. Transfer the drilling contract to and from GRUY in accordance with TEXAS PACIFIC'S, and GRUY's contracts with SITTON DRILLING CO., which by this reference are made a part hereof.

II. CONSIDERATION

In consideration for the above, and to reimburse TEXAS PACIFIC for the additional cost of the well, above those planned under it's original well plan, from 2,500± feet to 5,165± feet, GRUY will pay TEXAS PACIFIC in accordance with the below schedule, however all costs must be documented (copies of invoices, drilling time curve, etc.):

A. SCHEDULE

1.	Additional required sitework	Est.	$ 5,000
2.	Additional rig costs	Est.	20,000
3.	Additional 8-5/8" casing from 2,500± feet to 5,165± feet - Est. 2,665 ft. @ 8.51/ft.		22,679
4.	Additional cementing	Est.	7,000
5.	Miscellaneous other additional costs		5,000
6.	Additional mud pump, with fuel, Est. 20 days @ 375.00/day		7,500
	TOTAL ESTIMATED COST		$ 67,179

7. GRUY further agrees to provide TEXAS PACIFIC with all logs, core analysis, and other data obtained.

B. FUNDING LIMITATION

TEXAS PACIFIC shall not incur, for GRUY'S account, expenditures in excess of $68,000, without prior approval of GRUY and modification to this contract.

III. OTHER PROVISIONS

A. INSURANCE

1. TEXAS PACIFIC shall maintain insurance, by reliable and responsible insurance companies licensed to do business in the state of Texas, in the amounts as set forth in GRUY'S General Provisions.

2. GRUY shall maintain general liability insurance in the amounts of $20,000,000.

B. GENERAL PROVISIONS

1. GRUY'S General Provisions are attached hereto and by this reference made a part hereof, with the exceptions of clauses No. 10 "Disputes", No. 17, "Key Personnel", and No. 22, "Payment of Interest on Contractor's Claims" which are hereby deleted.

C. ADDITIONAL PROVISIONS

1. GRUY'S Additional Provision "SP", Safety Policy, is attached hereto and by this reference made a part hereof.

D. INTEREST

1. Neither GRUY nor DOE shall have any interest in the well, or in the oil and gas lease, minerals, production, or energy recovered from the well, or in any surface or subsurface equipment therein or thereon.

ACCEPTED AND AGREED:

GRUY FEDERAL, INC.

by_____

Purchasing Agent
Title

_____
Date

TEXAS PACIFIC OIL COMPANY, INC.

by_____

_____
Title

_____
Date

APPENDIX B

Coring Operations

The pressure-coring operations for the Bennett Ranch Unit No. 310, Wasson field, are illustrated on the following pages.

The pressure-coring system is shown in Fig. 1. The system has an outer barrel and an inner barrel suspended on a swivel so that it does not rotate during coring. As the core bit rotates, the core gradually enters the core tube. After drilling 8 ft the driller breaks off the core, which is held in the core tube by the core shoe. While the core barrel is under full mud column pressure, a steel ball is dropped from the surface to unlatch the outer barrel. Simultaneously, the ball valve closes and the pressure-maintenance system is activated.

The experimental procedure required different bits to be used in cutting the first 10 cores. Figures 2 through 5 show the diamond core bit and different views of the STRATAPAX® cutter equipped DOWDCO core bit. Figure 6 shows the drilling rig used throughout the drilling operations.

Standard procedures require that the pressure-coring crew prepare the pressure core barrel in a field lab and transfer it to the rig floor (Fig. 7). The drilling assembly is completed by placing the core bit on the barrel (Fig. 8).

The drilling crew runs the drilling assembly to the bottom of the hole (Fig. 9). The DOWDCO driller then drills out 8 to 9 ft, filling the core barrel. The core is then broken and the pressure-retaining system is activated. The drilling crew then brings the core to the surface. The DOWDCO crew removes the core bit and barrel from the drill string (Fig. 10), immediately places the core barrel in dry ice (Fig. 11) and checks the recovery

pressure (Fig. 12). Additional dry ice is used to freeze the core (Fig. 13).

Figure 14 shows the inner core barrels (core tubes) used by DOWDCO.

After six hours in dry ice, the frozen core is removed from the outer core barrel (Fig. 15), cut, and identified (Figs. 16, 17). Each section of core is marked with its top and bottom depth (Fig. 18). Cores are packed in fiberglass-lined shipping boxes filled with dry ice (Fig. 19) and shipped by truck to Core Laboratories.

Figures 20 and 21 are interior and exterior views of the DOWDCO pressure-coring field lab.

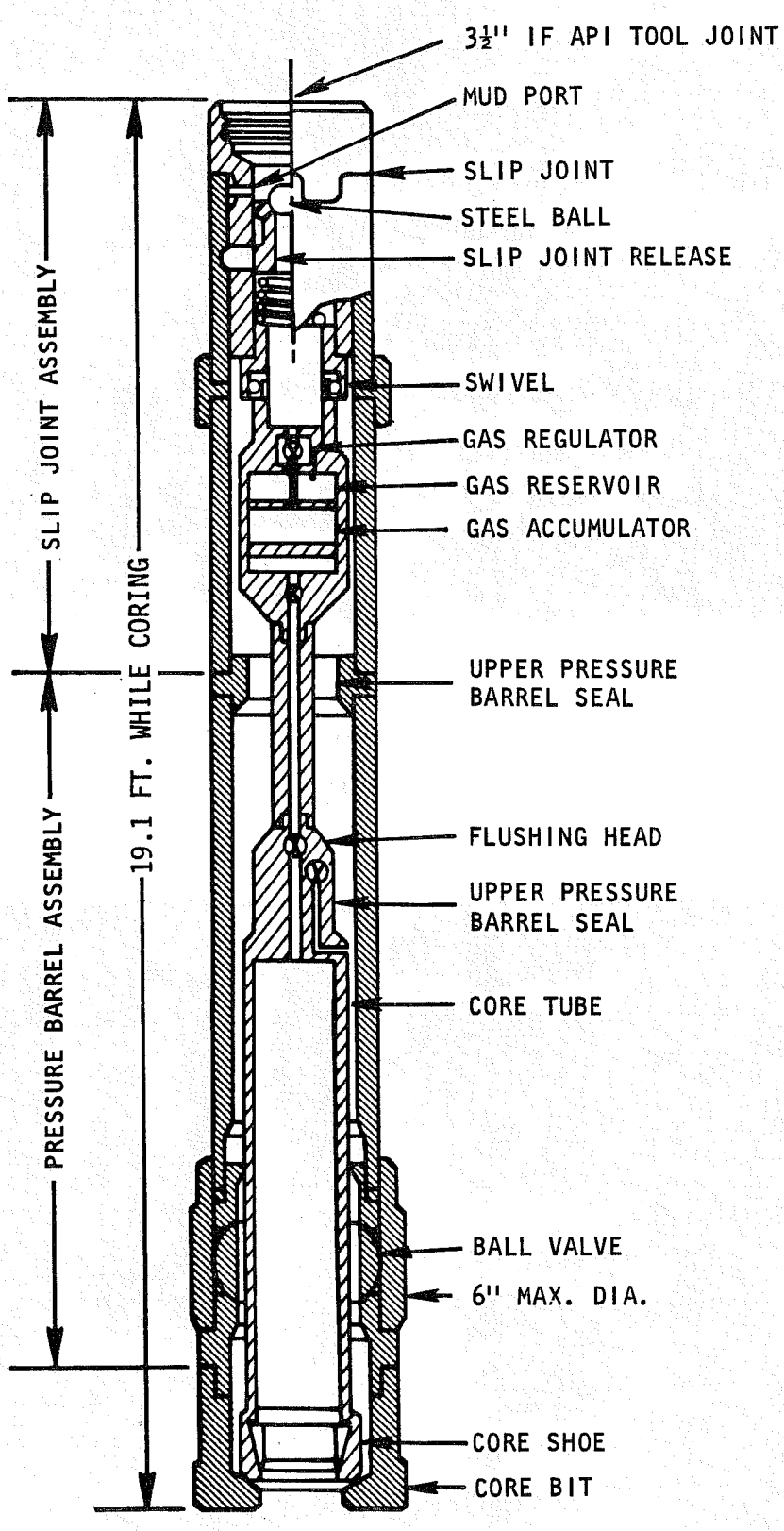

FIGURE 1

PRESSURE CORE BARREL

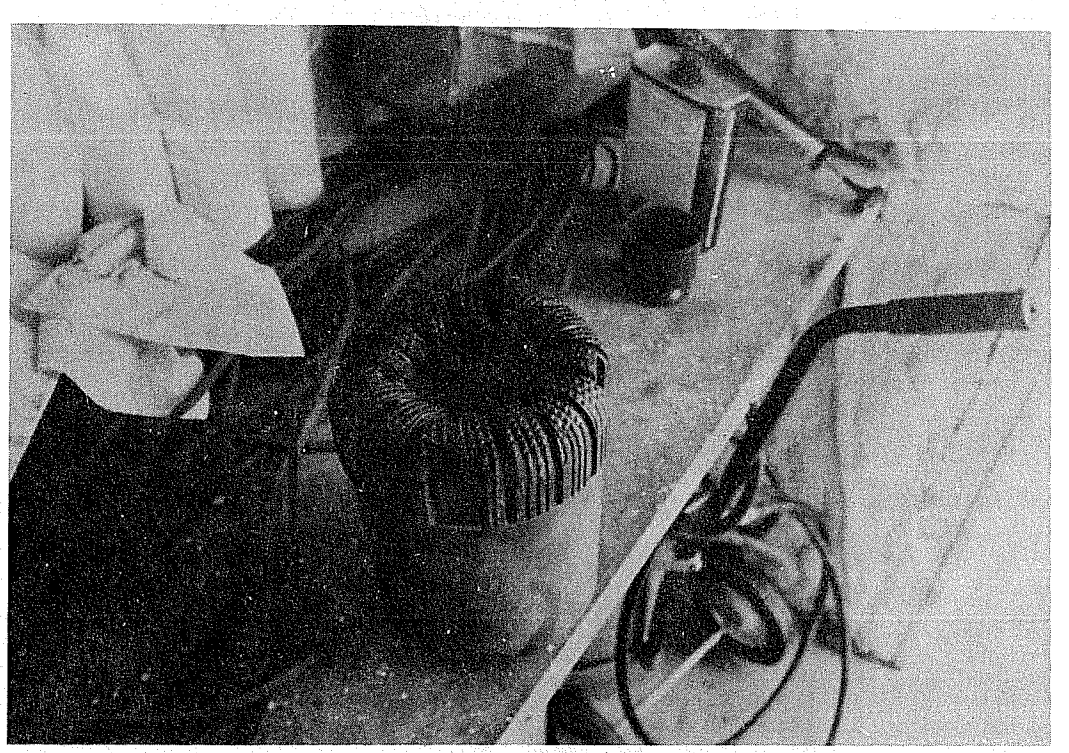

FIGURE 2
DIAMOND CORE BIT

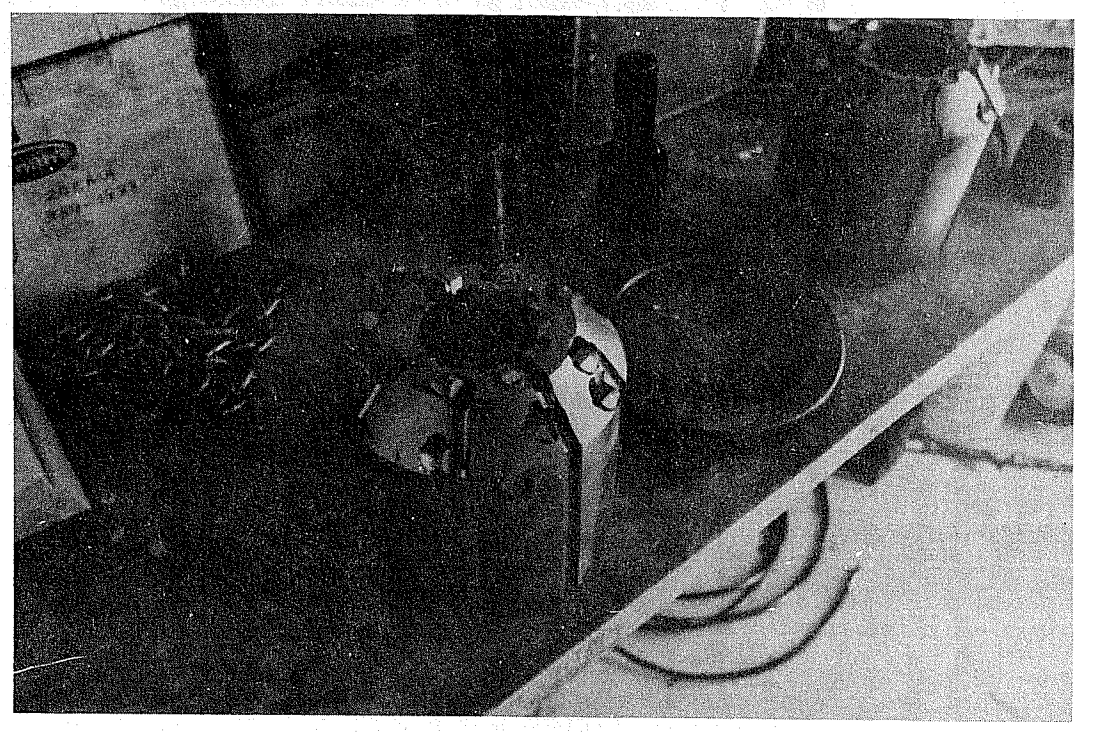

FIGURE 3
STRATAPAX CORE BIT

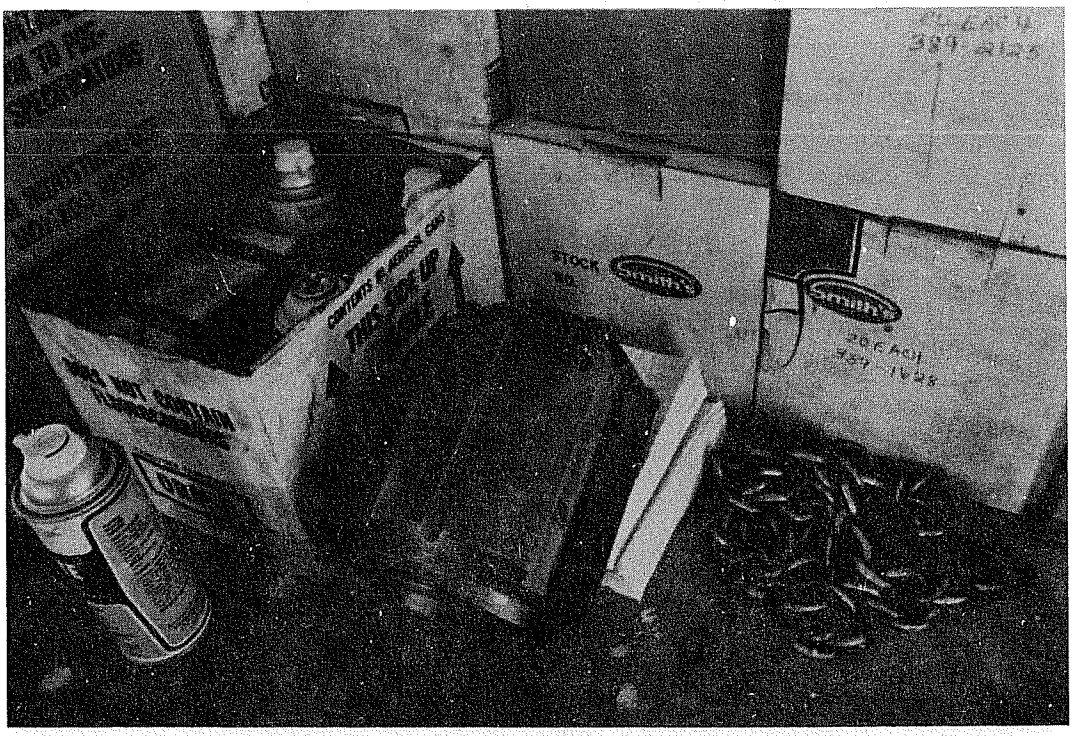

FIGURE 4
STRATAPAX CORE BIT (SIDEVIEW)

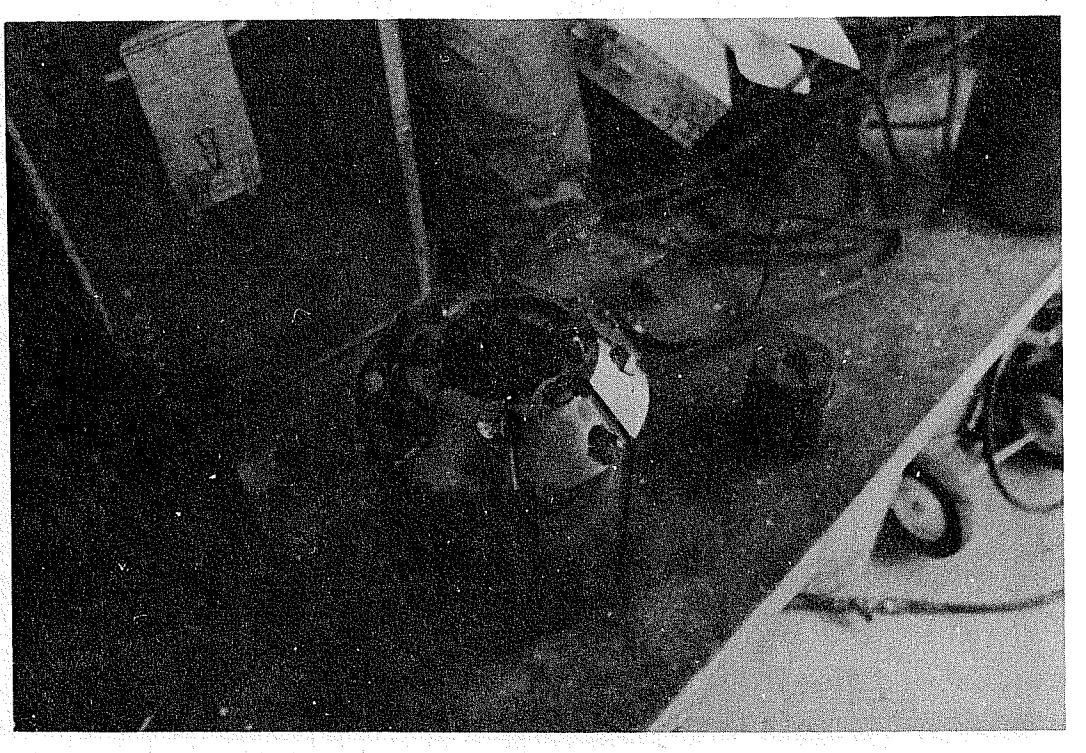

FIGURE 5
STRATAPAX CORE BIT USED WITH LOW INVASION FLUID

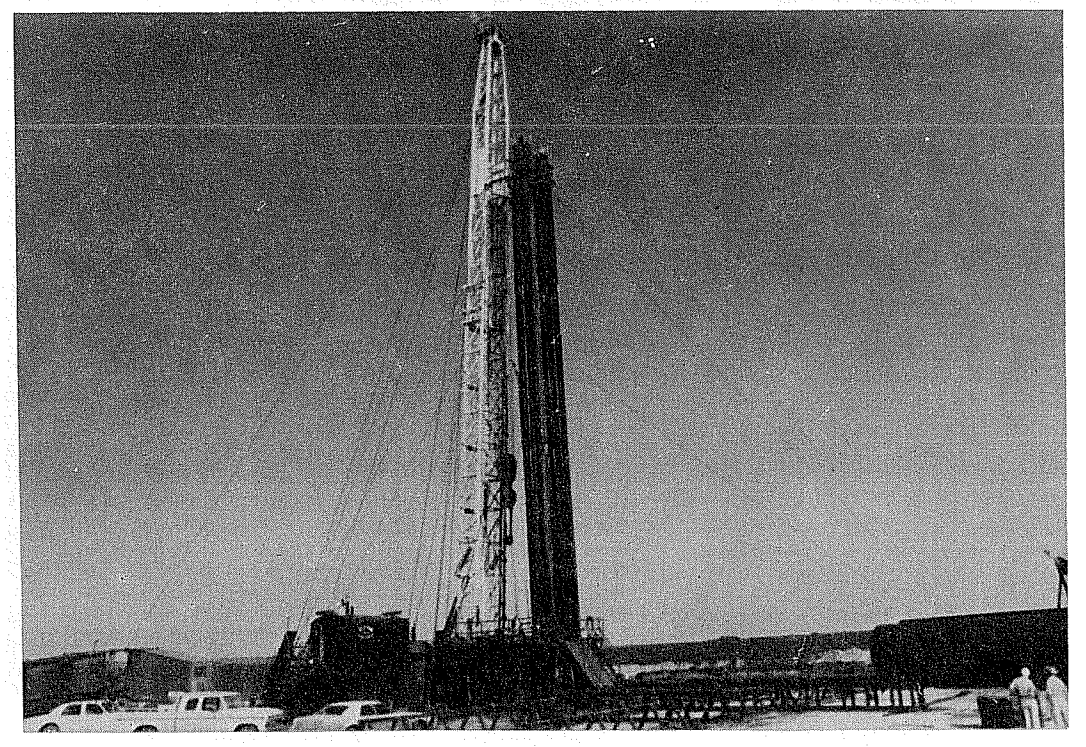

FIGURE 6

DRILLING RIG-DENVER CITY, TEXAS-WASSON FIELD

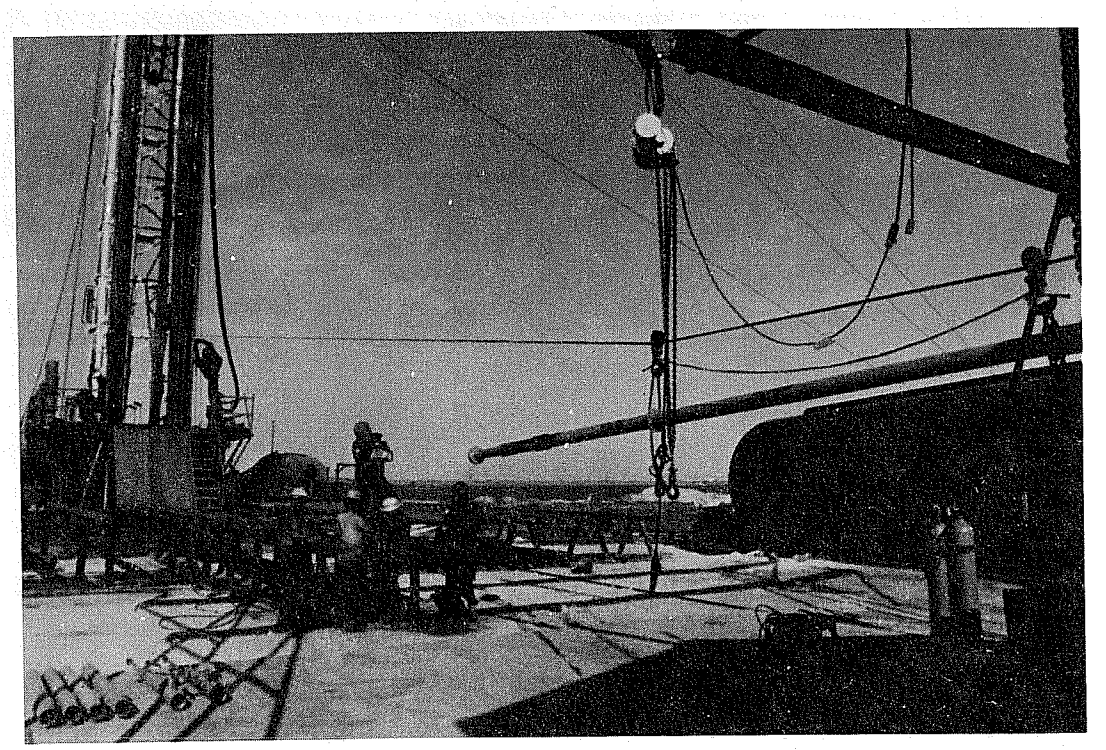

FIGURE 7

TRANSFERRING CORE BARREL FROM FIELD LAB TO RIG

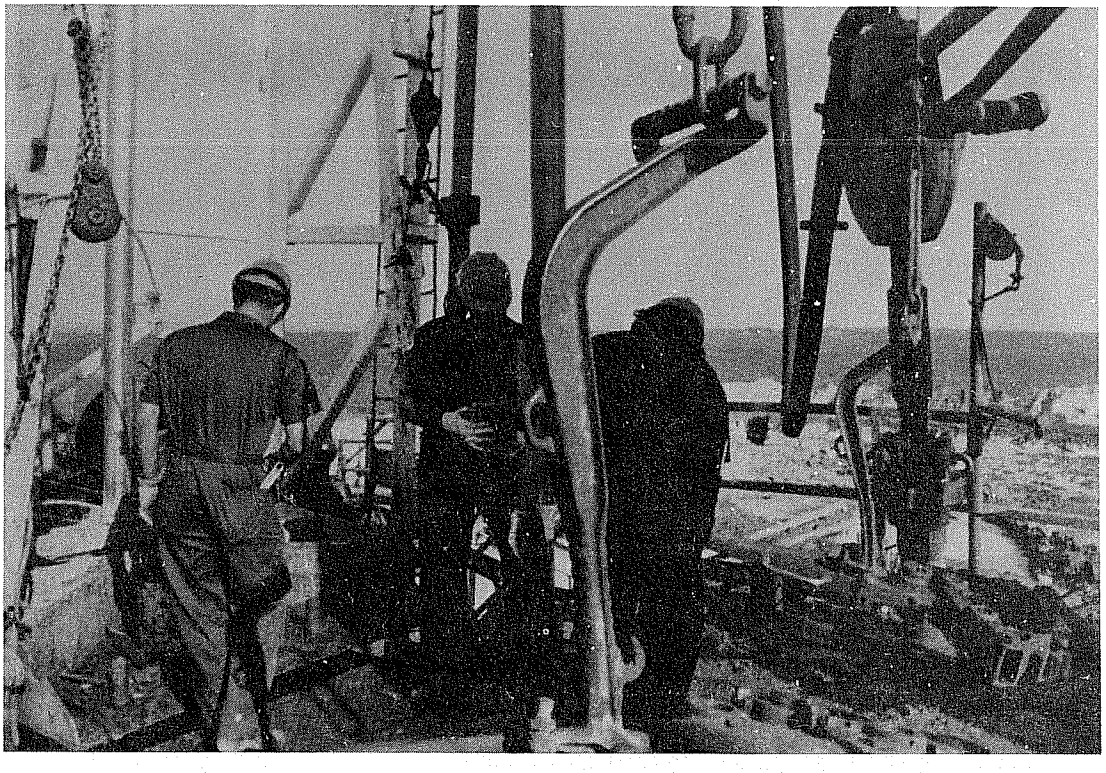

FIGURE 8
CORING BIT IS INSERTED TO LOWER SUB OF CORE BARREL

FIGURE 9
TRIPPING INTO HOLE

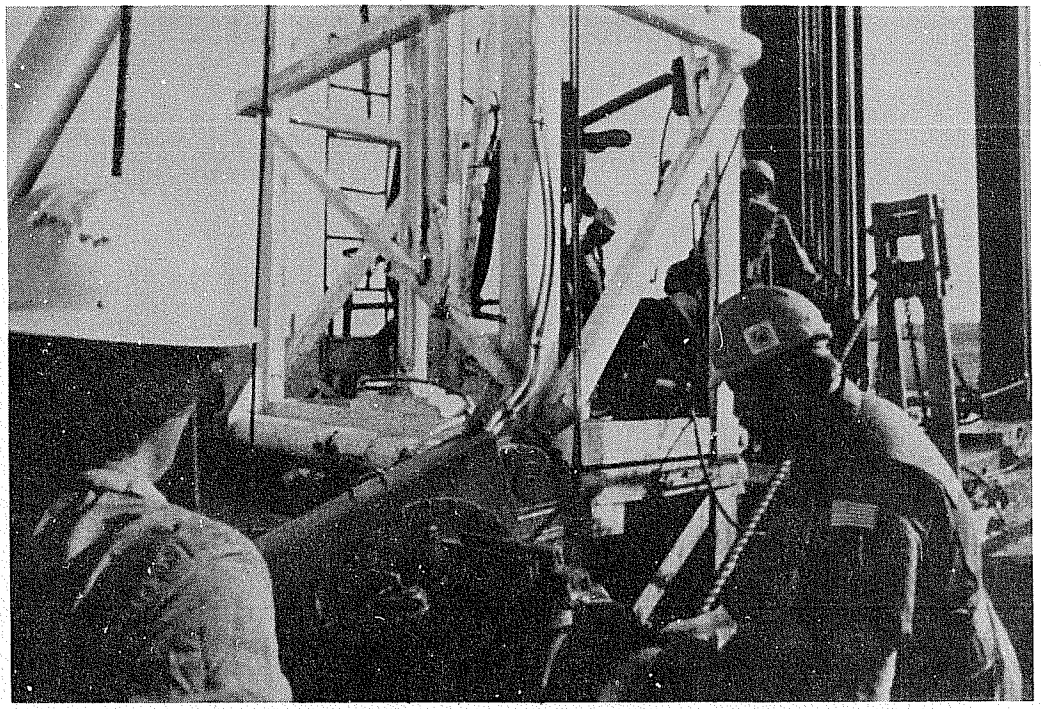

FIGURE 10

DOWDCO PERSONNEL REMOVING CORE BARREL AFTER TRIP OUT

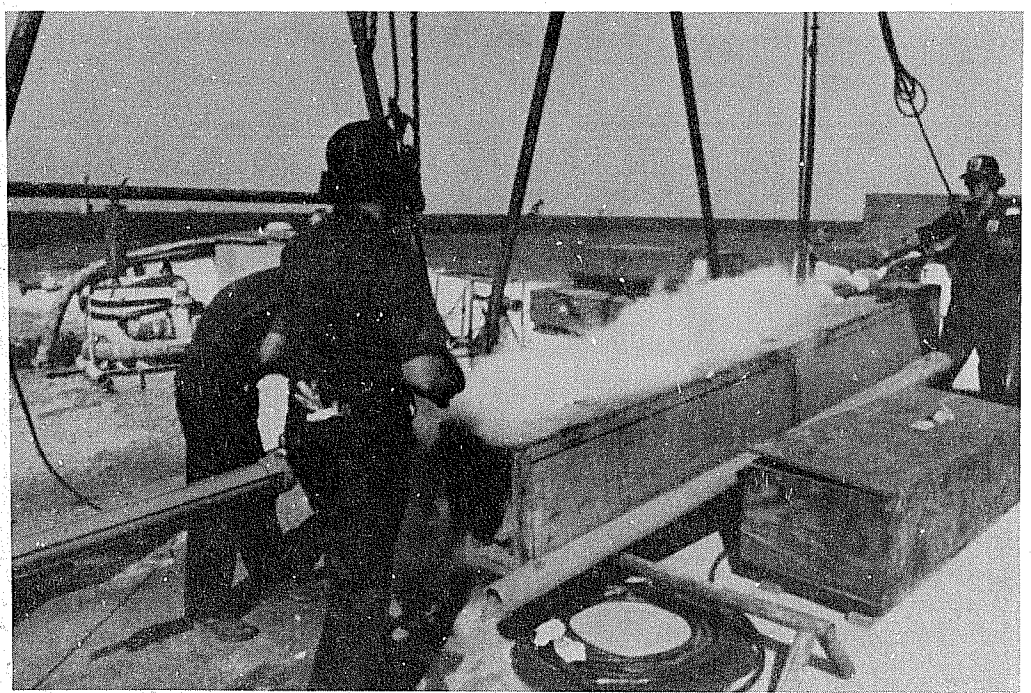

FIGURE 11

PRESSURE CORE BARREL IS LOWERED INTO BOX WITH DRY ICE.
CORE BARREL IS FROZEN FOR SIX HOURS.

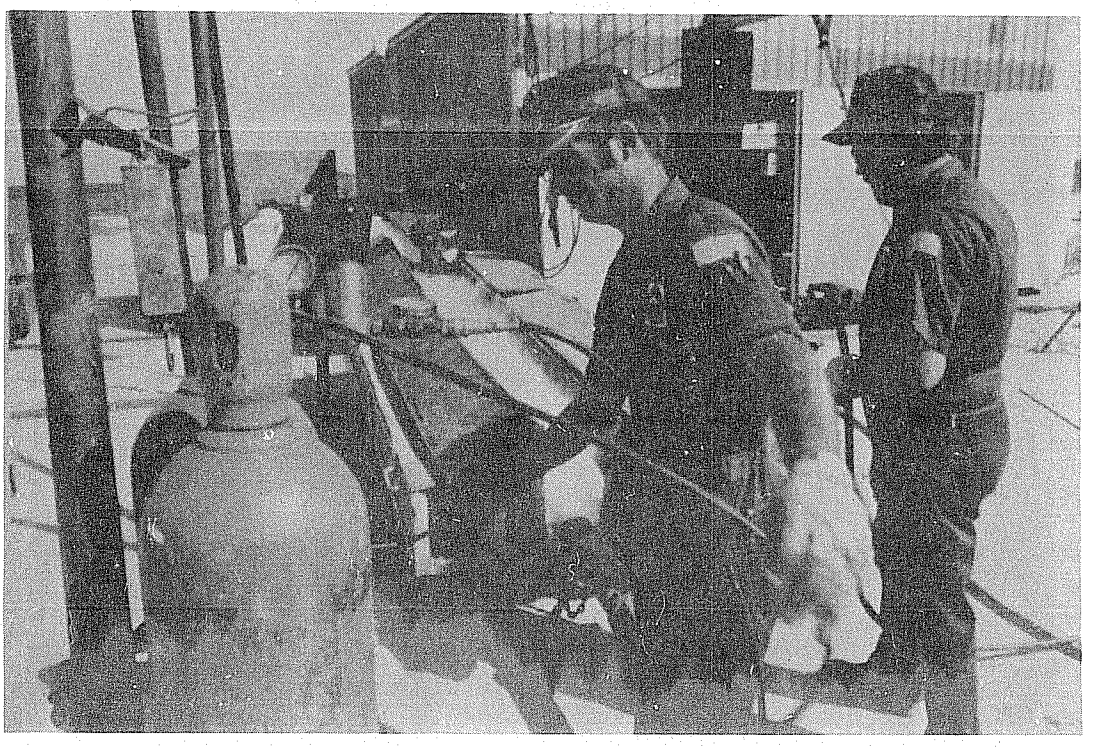

FIGURE 12
PRESSURE IN CORE BARREL IS CHECKED

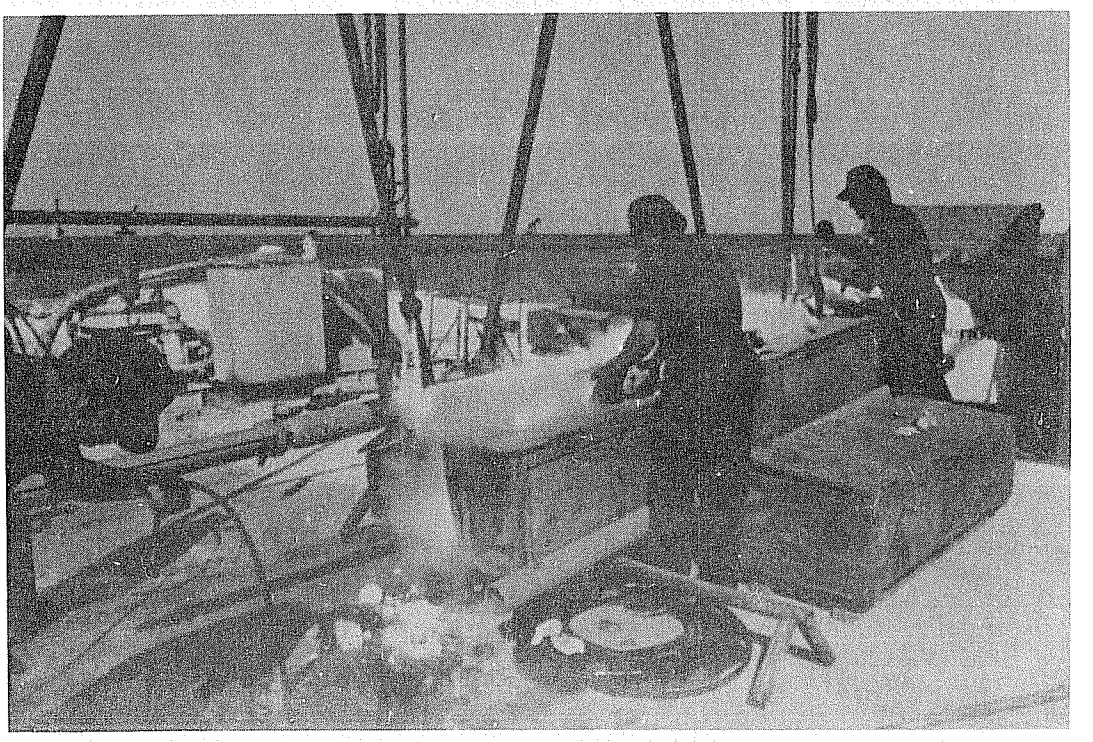

FIGURE 13
CORE BARREL IS COVERED WITH DRY ICE.

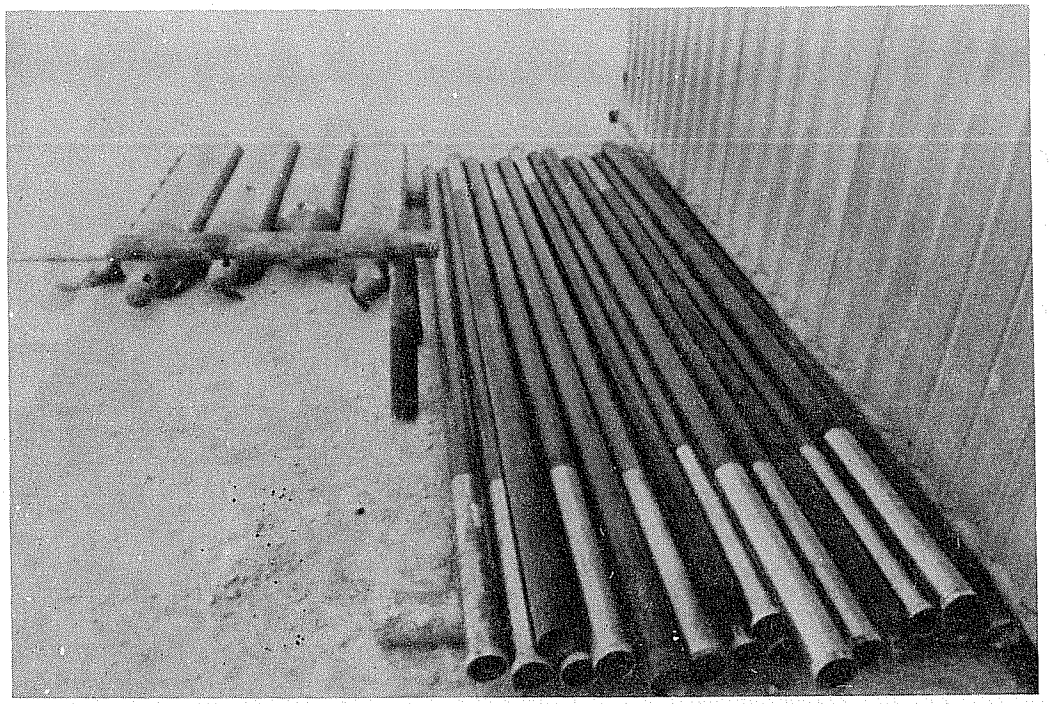

FIGURE 14

INNER CORE BARRELS BEFORE USE

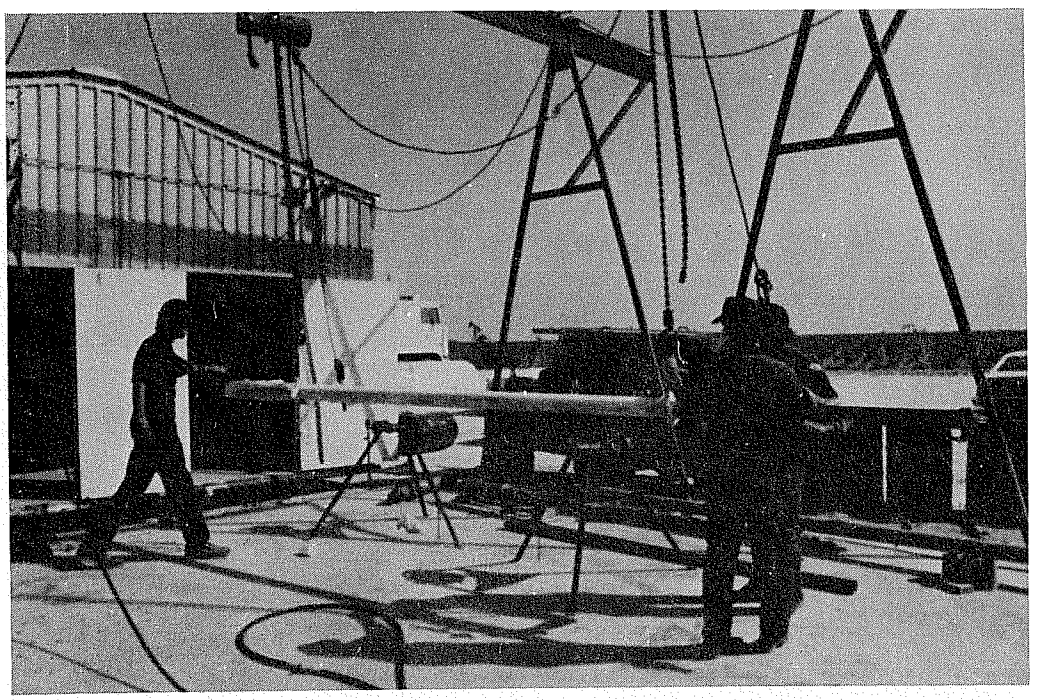

FIGURE 15

FROZEN CORE BARREL IS TRANSFERRED FROM DRY ICE AND OUTER BARREL REMOVED

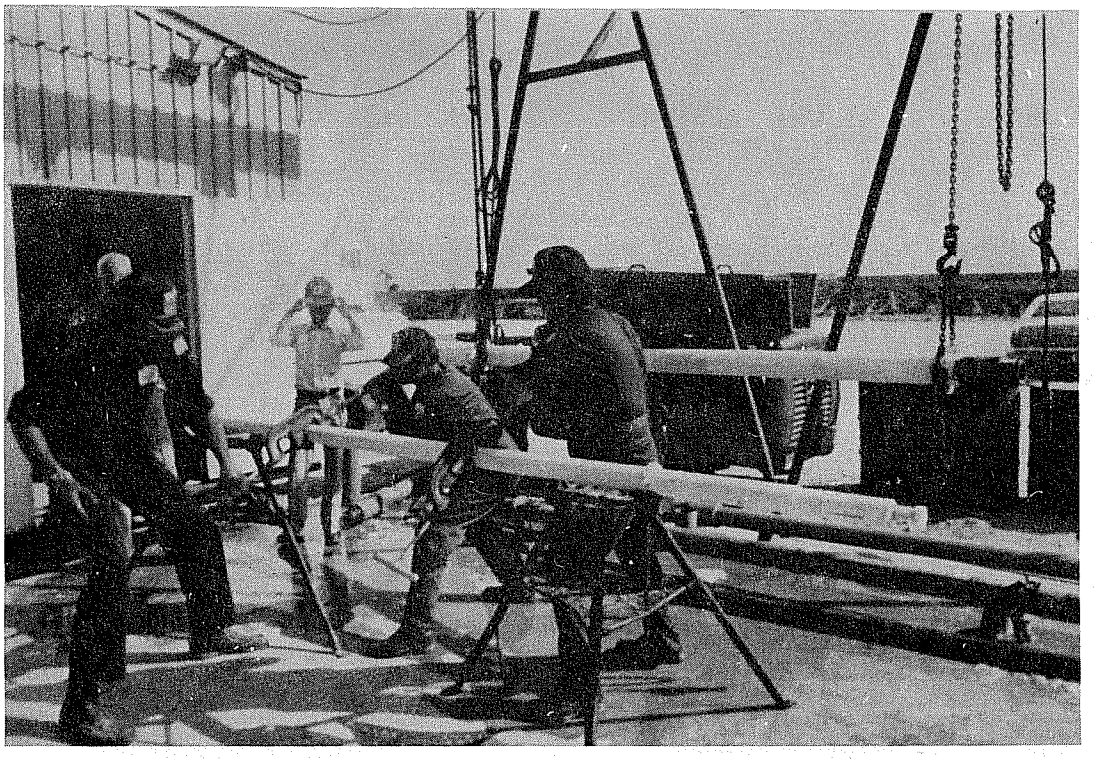

FIGURE 16

INNER CORE BARREL IS CUT INTO THREE EQUAL PARTS.

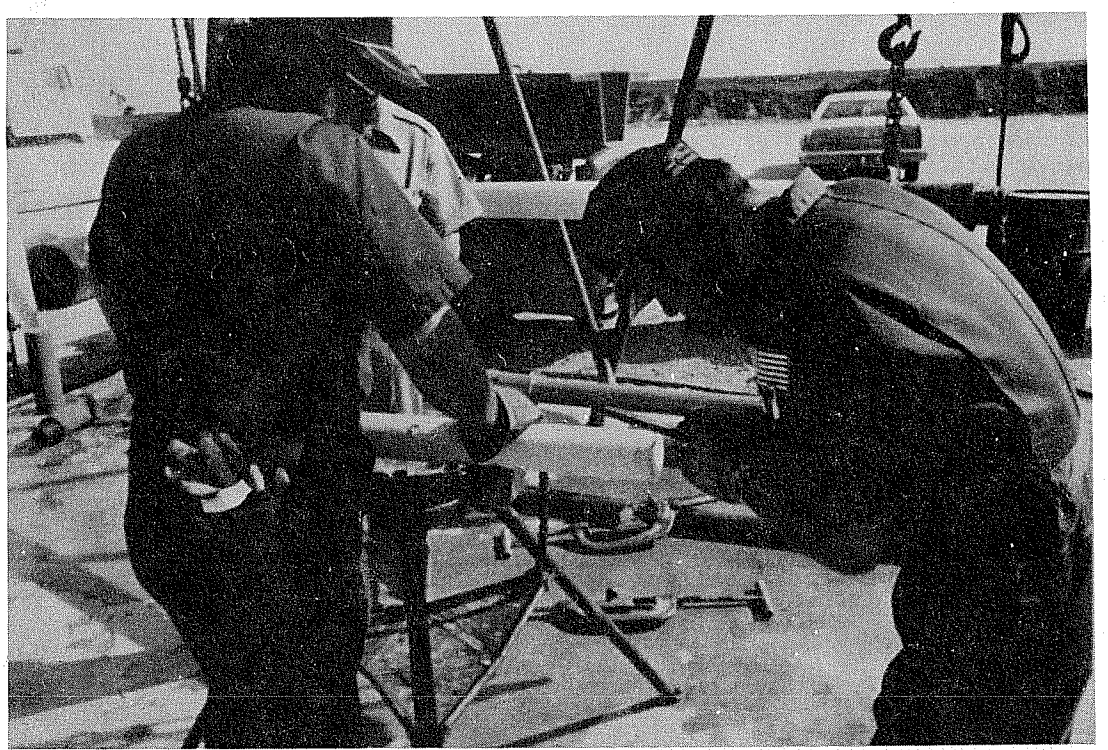

FIGURE 17

FROZEN CORE IS MARKED WITH A FILE.

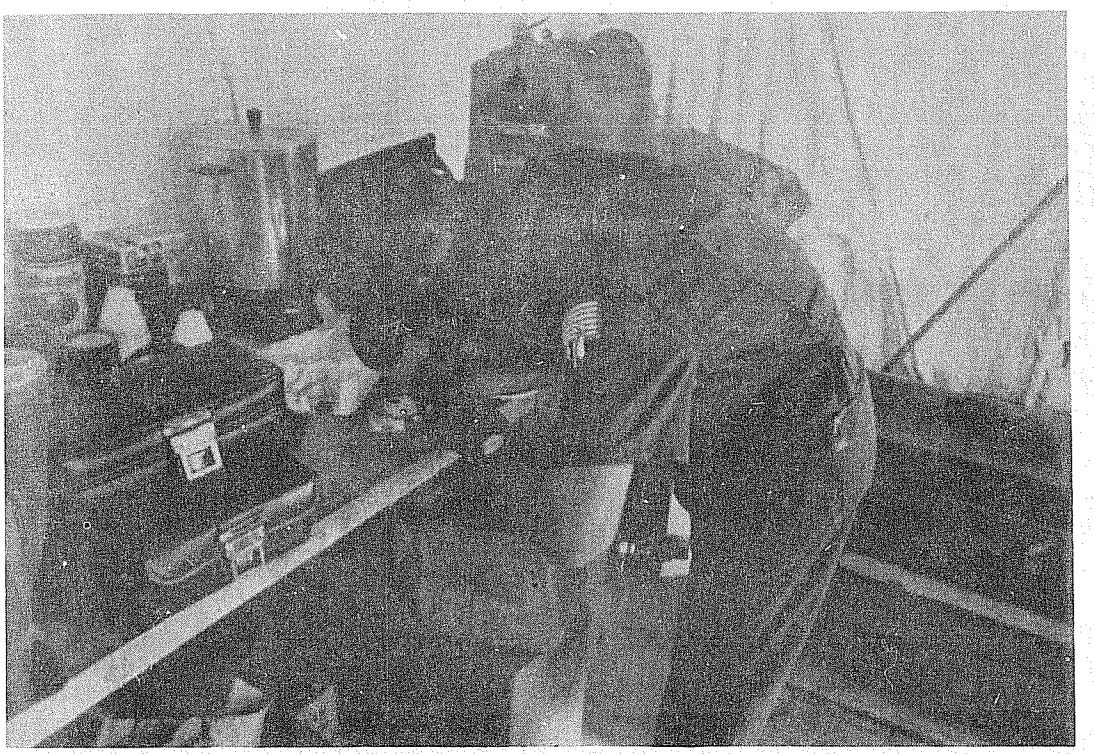

FIGURE 18

EACH SECTION OF CORE IS LABELED.

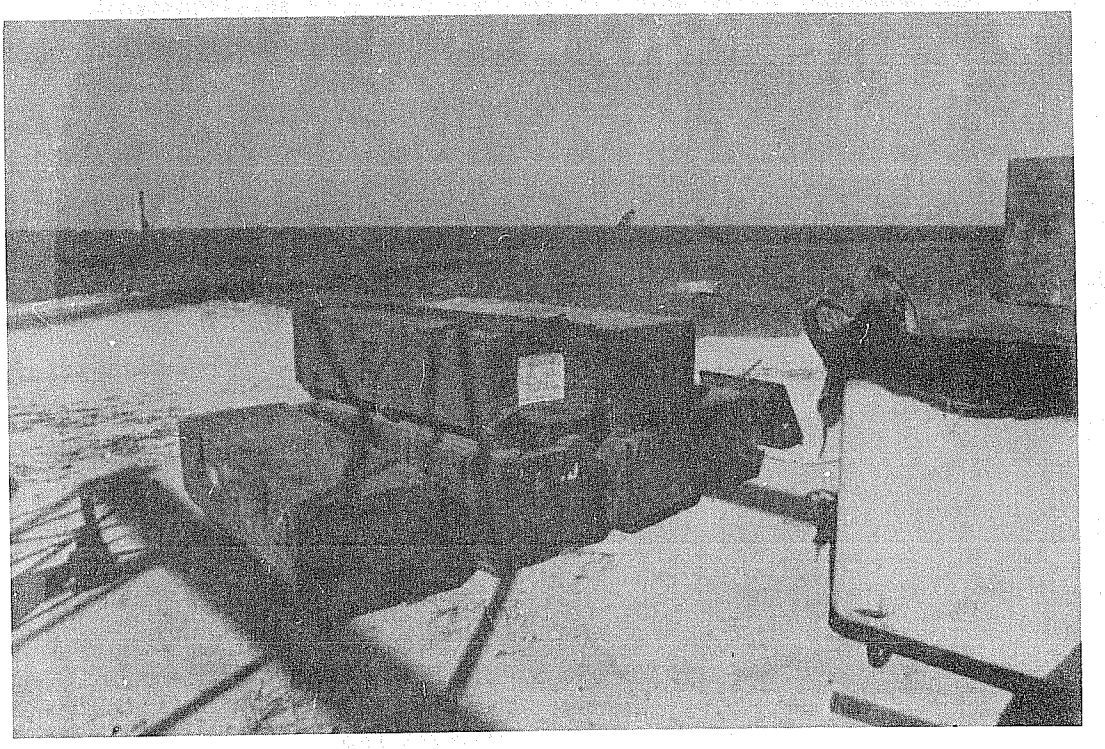

FIGURE 19

FIBERGLASS LINED PRESSURE CORE SHIPPING BOXES.

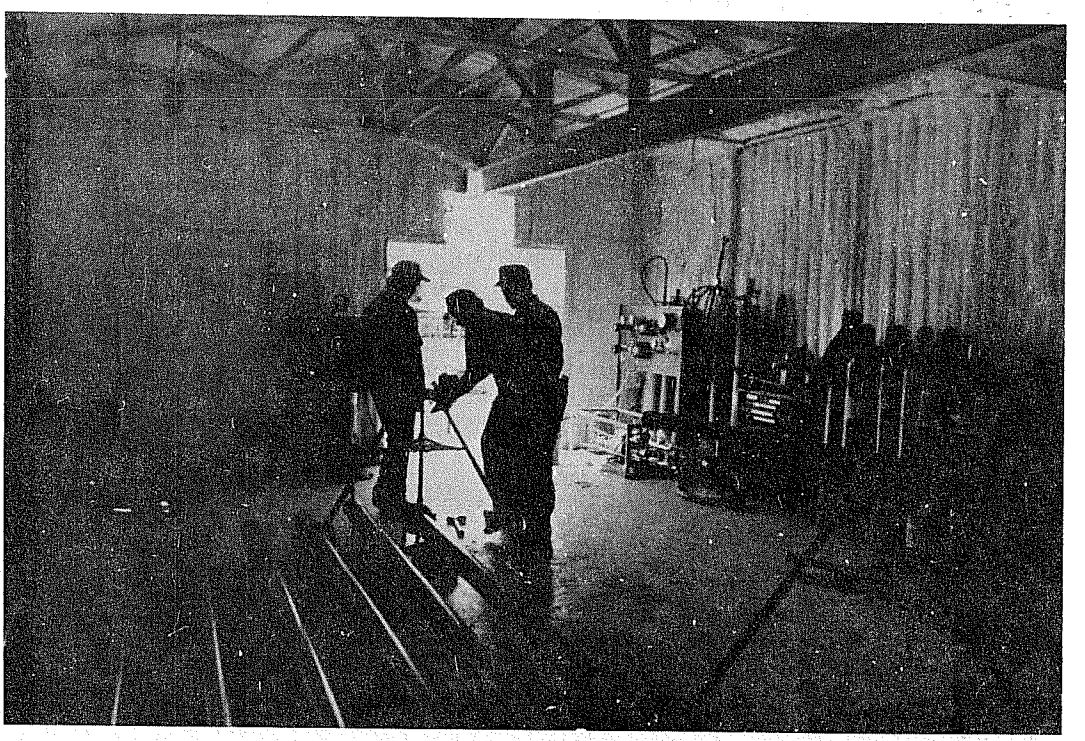

FIGURE 20
INSIDE FIELD CORE LAB

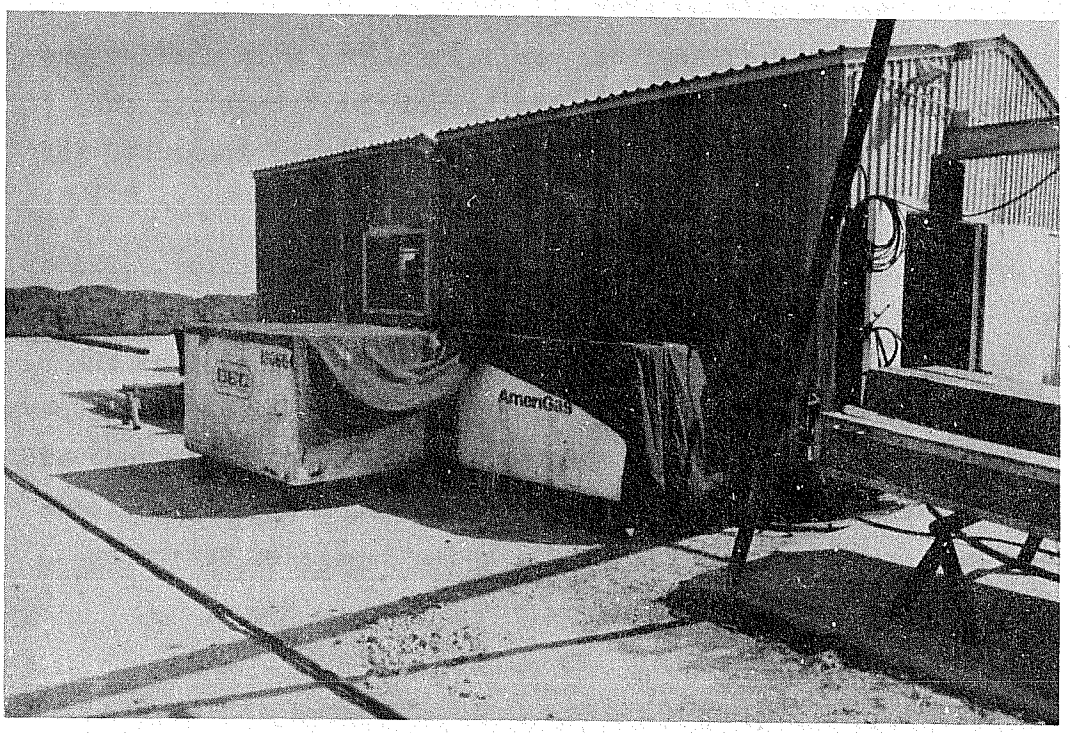

FIGURE 21
FIELD CORE LAB WITH DRY ICE CONTAINERS

APPENDIX C

EXTRACT FROM
DIAMOND OIL WELL DRILLING COMPANY
POST-ANALYSIS REPORT ON BENNETT RANCH UNIT NO. 310

Descriptions of Core Runs

Run # 1: This was a dummy run to aquaint all personnel in operations of the pressure coring system. The drilling rate was 1.9 ft./hr. with indications of wear due to drilling on aluminum junk. The barrel was brought to the surface. The pressure was bled off (2,750 psi), and the core inspected for quality. It was a good core.

Run # 2: The drilling rate was improved on this run to 5.93 ft./hr. Pieces of aluminum were found on the bit. This junk damaged 10 of the Stratapax$_{(R)}$* cutting edges slightly. The aluminum was suspected to have come from the casing shoe. (See Figure 7 which shows drilled up aluminum cuttings.) Pressure on the barrel was 2,550 psi. Went into the hole with a 6-7/8 mill tooth bit and junk basket to clean the hole; several pieces of aluminum and one tooth of a mill tooth bit were retrieved. Figure 7a shows damage to Stratapax$_{(R)}$ and bit body by junk in the hole.

* Stratapax$_{(R)}$ as used by Diamond Oil Well Drilling Company: STRATAPAX®, (correct trade name).

Run # 3: A volume gain was noticed in the mud pits and an increase in the chlorides in the mud (changed from 8,500 to 15,000 ppm). Coring was slow. Barite settled out of the mud, and settled around the lower ball seal keeping it from closing. There was no pressure on this core. Recommended an increase in the yield point of the mud to eliminate settling of the barite in the mud. Cored very slowly -- more junk?

Run # 4: Ran regular diamond core bit into the hole. This requires 80-100 gallons per minute pump flow to operate properly. 143 gallons per minute was as slow as the large displacement mud pump would pump. The core was brought to the surface without pressure. It was found that the inner barrel spring tension was weak.

Run # 5: This test was drilled with Shell's Stratapax$_{(R)}$ bit to determine if the formation was hard or if the bit had been damaged appreciably by junk. The drilling rate was 3.46 ft./hr., somewhat faster. The pressure was 2,600 psi on the barrel.

Run # 6: Used Shell's Stratapax$_{(R)}$ bit. This run was much slower, 1.74 ft./hr. The pump pressure gauge on the rig did not work. The pressure on this barrel was 1,600 psi.

Run # 7: Used the standard diamond bit again and the drilling rate was about the same, 1.96 ft./hr. The mud flow rate was much too fast, 143 gal./min. The barrel pressure was 2,800 psi.

Run # 8: A 6-1/2 stabilizer was placed at 20 feet up on the bottom hole assembly. Started using 9,000 lbs. on bit. This bit drilled slower because of damage to Stratapax$_{(R)}$ by junk. The drilling rate was 2.56 ft./hr. The pressure on the barrel was 3,600 psi.

Run # 9: This barrel had zero pressure because the core broke off long, which did not allow closing of the ball valve. This is a very unusual occurence. The drilling rate was 2.56 ft./hr.

Run #10: This core was drilled again with the standard diamond bit. The pressure on the barrel was 1,600 psi. The reduction in pressure was due to a leak in the regulator.

Run #11: This barrel drilled fine but had no pressure on it. The drilling

rate was 6.23 ft./hr.

Run #12: This barrel contained only 6 feet of core, however, this core was drilled very well. The drilling rate was 4.09 ft./hr. The pressure on the barrel was 3,300 psi. The high pressure was due to malfunction of Tescom regulator.

Run #13: This was a good run. The pressure on the barrel was 2,600 psi. The drilling rate was 3.13 ft./hr.

Run #14: Again core in ball restricted the closing of the ball. Again this penomena that has been seldom seen before occurred. The drilling rate was 3.13 ft./hr.

Run #15: This core drilled well at 6 ft./hr. The pressure on core was 2,900 psi.

Run #16: Due to a leak in the Tescom regulator, this core had a pressure of 1,500 psi. The drilling rate was 6 ft./hr.

Run #17: The drilling rate was 4.48 ft./hr. This was a good run taken at 2,600 psi.

Run #18: This was a good run. The rock was considerably harder. The drilling rate was 3.6 ft./hr. The pressure on the barrel was 2,600 psi.

Run #19: The drilling rate was 5.45 ft./hr. This was a good run. The pressure on the barrel was 2,700 psi.

Run #20: The drilling rate was 6.66 ft./hr. This was a good run. Pressure on the barrel was 2,400 psi.

Run #21: Tong dies were found in the hole. Pulled drill string from the hole, and ran a junk basket. Two tong dies were retrieved (See Figure 8). Substantial damage was done to the bit. (See Figure 7a to see damage to bit.)

Run #22: Drilling indicated that junk was still in the hole. Cored only 8 feet because of hole problems. The drilling rate was substantially slower, 3.05 ft./hr., dut to bit damage. Pressure was 3,600 psi due to tescom regulator malfunction.

Run #23: Still appeared to be running on junk. Lifted bit from the bottom of the hole and continued to drill. This appeared to displace junk up the hole. Inspection of the bit indicated additional bit damage had occurred. Barrel

pressure was 3,100 psi. The drilling rate was 3.66 ft./hr.

Run #24: Slow drilling indicated that junk was still in the hole. A piece of tong die was found in the junk slot of the bit. Pressure on core was 2,700 psi. The drilling rate was 4.40 ft./hr.

Run #25: Junk still in the hole. Two pieces of wire, probably the keys to the tong dies, were found on the bit. The pressure on the core was 3,300 psi. The drilling rate was 3.40 ft./hr.

Run #26: Junk still in the hole. Found hexagonal head of bolt on bit. The drilling rate was 3.09 ft./hr. The pressure on the core barrel was 2,900 psi.

Run #27: Stratapax$_{(R)}$ bit badly worn because of junk. The drilling rate reduced to 2.79 ft./hr. The barrel had no pressure due to swelling of sliding sleeve adapter. The daily drilling records are available. (See Figure 9.)

APPENDIX D

DIAMOND OIL WELL DRILLING COMPANY

POST OFFICE BOX 6358 / MIDLAND, TEXAS 79701 / 915 563-0775

DOWDCO RUN REPORT

A. Date 9-30-79 Job No. 22 Bit No. CS106 Well No. 310TP Run No. 1

COMPANY Texas Pacific Location: Denver City

Starting Depth 5,175 Ending Depth 5,181

B. Time - Through Table 10:30 a.m. On Surface 8:45 p.m.

Tag Bottom 2:46 p.m. Drilling Time 63 minutes

Drop Ball 4:09 p.m. Ball Time 6 minutes Close yes

C. Reaming Yes/(No)

D. String weight start 96,000

E. Feathered in (Yes)/No

F. Tag Bottom a. right depth (Yes)/No (If no, remarks) _____

G. Starting RPM 80 Drilling RPM 80

H. Average weight on Bit 7,000

I. Maximum weight on Bit 7,000

J. String weight end 96,000

K. Tool Trip (Yes)/No – if no, spudded _____

L. (Ball caused) Pressure Increase 25 lbs.

M. Extension 17 1/2 In _____

N. Ball closed (Yes)/No

O. Pressure on Dome (expected) 2,600

P. Pressure on Core 2,750

Q. Good Flush Yes/No – If no, remarks: Dummy run

R. Mud Weight 9.7

S. Mud Viscosity 46

T. Any change Yes/(No) – If no, remarks: _____

U. Pump PSI 700 (Drilling)

V. G P M 140 (Drilling)

W. P V 18 Y P 12

X. Extraction time none

Y. Core cut and transferred (Yes)/No

Z. All records up-to-date (Yes)/No

REMARKS: Stratapax bit with low invasion gel -- (L. I. G.)

DIAMOND OIL WELL DRILLING COMPANY
POST OFFICE BOX 6358 / MIDLAND, TEXAS 79701 / 915 563-0775

DOWDCO RUN REPORT

A. Date 9-30-79 Job No. 22 Bit No. CS103 Well No. 310TP Run No. 2

COMPANY Texas Pacific Location: Denver City

Starting Depth 5,181 Ending Depth 5,190

B. Time - Through Table 9:55 p.m. On Surface 8:10 a.m.

Tag Bottom 1:20 a.m. Drilling Time 169 minutes

Drop Ball 5:03 a.m. Ball Time 8.5 minutes Close yes

C. Reaming Yes/(No)

D. String weight start 95,000

E. Feathered in (Yes)/No

F. Tag Bottom a. right depth (Yes)/No (If no, remarks) _____

G. Starting RPM 80 Drilling RPM 78

H. Average weight on Bit 6,000

I. Maximum weight on Bit 7,000

J. String weight end 95,000

K. Tool Trip (Yes)/No – if no, spudded _____

L. (Ball caused) Pressure Increase not seen

M. Extension 17 1/2 In _____

N. Ball closed (Yes)/No

O. Pressure on Dome (expected) 2,600

P. Pressure on Core 2,550

Q. Good Flush (Yes)/No – If no, remarks: _____

R. Mud Weight 9.7

S. Mud Viscosity 46

T. Any change Yes/(No) – If no, remarks: _____

U. Pump PSI 700 (Drilling)

V. G P M 120 (Drilling)

W. P V 18 Y P 12

X. Extraction time 15 minutes

Y. Core cut and transferred (Yes)/No

Z. All records up-to-date (Yes)/No

REMARKS: Aluminum cuttings in barrel and bit. Used Stratapax without low invasion gel.

Core weight: Top--36lbs., Middle--37 lbs, and Bottom--34 lbs.

DIAMOND OIL WELL DRILLING COMPANY
POST OFFICE BOX 6358 / MIDLAND, TEXAS 79701 / 915 563-0775

DOWDCO RUN REPORT

A. Date 10-1-79 Job No. 22 Bit No. CS106 Well No. 310 TP Run No. 3

COMPANY Texas Pacific Location: Denver City

Starting Depth 5,190 Ending Depth 5,198

B. Time - Through Table 11:25 p.m. On Surface 10:05 a.m.

Tag Bottom 2:35 a.m. Drilling Time 235 minutes

Drop Ball 7:02 a.m. Ball Time 9 minutes Close yes

C. Reaming Yes (No)

D. String weight start 95,000

E. Feathered in (Yes) / No

F. Tag Bottom a. right depth (Yes) / No (If no, remarks) _____

G. Starting RPM 80 Drilling RPM 78

H. Average weight on Bit 7,000

I. Maximum weight on Bit 8,000

J. String weight end 95,000

K. Tool Trip (Yes) / No – if no, spudded _____

L. (Ball caused) Pressure Increase 25 lbs.

M. Extension 17 1/2 In _____

N. Ball closed Yes (No)

O. Pressure on Dome (expected) 2,600

P. Pressure on Core -0-

Q. Good Flush Yes (No) – If no, remarks: No flush

R. Mud Weight 9.7

S. Mud Viscosity 45

T. Any change (Yes) / No – If no, remarks: _____

U. Pump PSI 650 (Drilling)

V. G P M 140 (Drilling)

W. P V 17 Y P 10

X. Extraction time -0-

Y. Core cut and transferred (Yes) / No

Z. All records up-to-date (Yes) / No

REMARKS: Barite packed to run ball. Ball not completely closed. Used Stratapax bit with low invasion gel. Core dumped, not weighed.

DIAMOND OIL WELL DRILLING COMPANY
POST OFFICE BOX 6358 / MIDLAND, TEXAS 79701 / 915 563-0775

DOWDCO RUN REPORT

A. Date 10-2-79 Job No. 22 Bit No. C7048 Well No. 310 TP Run No. 4

COMPANY Texas Pacific Location: Denver City

Starting Depth 5,198 Ending Depth 5,207

B. Time - Through Table 12:15 p.m. On Surface 10:30 p.m.

Tag Bottom 2:35 p.m. Drilling Time 275 minutes

Drop Ball 8:10 p.m. Ball Time 12 minutes Close yes

C. Reaming Yes/(No)

D. String weight start 95,000

E. Feathered in (Yes)/No

F. Tag Bottom a. right depth (Yes)/No (If no, remarks)

G. Starting RPM 45 Drilling RPM 72

H. Average weight on Bit 7,000

I. Maximum weight on Bit 8,000

J. String weight end 95,000

K. Tool Trip (Yes)/No – if no, spudded

L. (Ball caused) Pressure Increase 50 lbs.

M. Extension 17 1/2 In

N. Ball closed Yes/(No)

O. Pressure on Dome (expected) 2,600

P. Pressure on Core -0-

Q. Good Flush Yes/(No) – If no, remarks:

R. Mud Weight 9.75

S. Mud Viscosity 55

T. Any change (Yes)/No – If no, remarks:

U. Pump PSI 400 to 500 (Drilling)

V. G P M 140 (Drilling)

W. P V 25 Y P 17

X. Extraction time -0-

Y. Core cut and transferred (Yes)/No

Z. All records up-to-date (Yes)/No

REMARKS: Weak tension spring caused ball not to fully close. Diamond bit used without low invasion gel. Core dumped, not weighed.

DIAMOND OIL WELL DRILLING COMPANY
POST OFFICE BOX 6358 / MIDLAND, TEXAS 79701 / 915 563-0775

DOWDCO RUN REPORT

A. Date 10-3-79 Job No. 22 Bit No. CS100 Well No. 310TP Run No. 5

COMPANY Texas Pacific Location: Denver City

Starting Depth 5,207 Ending Depth 5,216

B. Time - Through Table 11:40 p.m. On Surface 8:00 a.m.

Tag Bottom 1:40 a.m. Drilling Time 156 minutes

Drop Ball 5:00 a.m. Ball Time 7 minutes Close yes

C. Reaming Yes (No)

D. String weight start 95,000

E. Feathered in (Yes)/No

F. Tag Bottom a. right depth (Yes)/No (If no, remarks) _____

G. Starting RPM 68 Drilling RPM 80

H. Average weight on Bit 6,000

I. Maximum weight on Bit 7,000

J. String weight end 95,000

K. Tool Trip (Yes)/No – if no, spudded _____

L. (Ball caused) Pressure Increase not seen

M. Extension 17 1/2 In _____

N. Ball closed (Yes)/No

O. Pressure on Dome (expected) 2,600

P. Pressure on Core 2,600

Q. Good Flush (Yes)/No – If no, remarks: _____

R. Mud Weight 9.75

S. Mud Viscosity 55

T. Any change (Yes)/No – If no, remarks: _____

U. Pump PSI 450 (Drilling)

V. G P M 140 (Drilling)

W. P V 25 Y P 17

X. Extraction time 15 minutes

Y. Core cut and transferred (Yes)/No

Z. All records up-to-date (Yes)/No

REMARKS: Used Stratapax bit without low invasion gel. Core weight: Top--38 lbs., Middle--34 lbs., and Bottom--32 lbs.

DIAMOND OIL WELL DRILLING COMPANY
POST OFFICE BOX 6358 / MIDLAND, TEXAS 79701 / 915 563-0775

DOWDCO RUN REPORT

A. Date 10-3-79 Job No. 22 Bit No. CS 100 Well No. 310TP Run No. 6

COMPANY Texas Pacific Location: Denver City

Starting Depth 5,216 Ending Depth 5,224

B. Time - Through Table 9:00 a.m. On Surface 5:45 p.m.

Tag Bottom 11:25 a.m. Drilling Time 176 minutes

Drop Ball 3:15 p.m. Ball Time 9 minutes Close yes

C. Reaming (Yes)/No

D. String weight start 95,000

E. Feathered in (Yes)/No

F. Tag Bottom a. right depth (Yes)/No (If no, remarks) _____

G. Starting RPM 60 Drilling RPM 80

H. Average weight on Bit 7,000

I. Maximum weight on Bit 8,000

J. String weight end 95,000

K. Tool Trip (Yes)/No – if no, spudded _____

L. (Ball caused) Pressure Increase 25 lbs.

M. Extension 17 1/2 In _____

N. Ball closed (Yes)/No

O. Pressure on Dome (expected) 2,600

P. Pressure on Core 1,600

Q. Good Flush (Yes)/No – If no, remarks: _____

R. Mud Weight 9.75

S. Mud Viscosity 62

T. Any change Yes/(No) – If no, remarks: _____

U. Pump PSI 450 (Drilling)

V. G P M 140 (Drilling)

W. P V 32 Y P 24

X. Extraction time 15 minutes

Y. Core cut and transferred (Yes)/No

Z. All records up-to-date (Yes)/No

REMARKS: Used Stratapax with low invasion gel. Core weight: Top--22 lbs., Middle--40 lbs, and Bottom--34 lbs.

DIAMOND OIL WELL DRILLING COMPANY
POST OFFICE BOX 6358 / MIDLAND, TEXAS 79701 / 915 563-0775

DOWDCO RUN REPORT

A. Date 10-3-79 Job No. 22 Bit No. C7048 Well No. 310TP Run No. 7

COMPANY Texas Pacific Location: Denver City

Starting Depth 5,224 Ending Depth 5,233

B. Time - Through Table 6:45 p.m. On Surface 10:00 a.m.

Tag Bottom 2:10 a.m. Drilling Time 271 minutes

Drop Ball 7:36 a.m. Ball Time 9 minutes Close yes

C. Reaming (Yes)/No

D. String weight start 95,000

E. Feathered in (Yes)/No

F. Tag Bottom a. right depth (Yes)/No (If no, remarks) _____

G. Starting RPM 50 Drilling RPM 70

H. Average weight on Bit 8,000

I. Maximum weight on Bit 8,000

J. String weight end 95,000

K. Tool Trip (Yes)/No – if no, spudded _____

L. (Ball caused) Pressure Increase 25 lbs.

M. Extension 17 1/2 In _____

N. Ball closed (Yes)/No

O. Pressure on Dome (expected) 2,600

P. Pressure on Core 2,800

Q. Good Flush (Yes)/No – If no, remarks: _____

R. Mud Weight 9.75

S. Mud Viscosity 62

T. Any change Yes/(No) – If no, remarks: _____

U. Pump PSI 650 (Drilling)

V. G P M 140 (Drilling)

W. P V 32 Y P 24

X. Extraction time 15 minutes

Y. Core cut and transferred (Yes)/No

Z. All records up-to-date (Yes)/No

REMARKS: Diamond bit used without L. I. G. (Low Invasion Gel)

DIAMOND OIL WELL DRILLING COMPANY
POST OFFICE BOX 6358 / MIDLAND, TEXAS 79701 / 915 563-0775

DOWDCO RUN REPORT

A. Date 10-4-79 Job No. 22 Bit No. CS 103 Well No. 310TP Run No. 8

COMPANY Texas Pacific Location: Denver City

Starting Depth 5,233 Ending Depth 5,242

B. Time - Through Table 11:15 a.m. On Surface 7:30 p.m.

Tag Bottom 3:30 p.m. Drilling Time 91 minutes

Drop Ball 5:50 p.m. Ball Time 7 minutes Close yes

C. Reaming (Yes)/No

D. String weight start 95,000

E. Feathered in (Yes)/No

F. Tag Bottom a. right depth (Yes)/No (If no, remarks) _____

G. Starting RPM 60 Drilling RPM 80

H. Average weight on Bit 9,000

I. Maximum weight on Bit 9,000

J String weight end 95,000

K. Tool Trip (Yes)/No – if no, spudded _____

L. (Ball caused) Pressure Increase 25 lbs.

M. Extension 17 1/2 in _____

N. Ball closed (Yes)/No

O. Pressure on Dome (expected) 2,600

P. Pressure on Core 3,600

Q. Good Flush (Yes)/No – If no, remarks: _____

R. Mud Weight 9.8

S. Mud Viscosity 66

T. Any change (Yes)/No – If no, remarks: _____

U. Pump PSI 650 (Drilling)

V. G P M 140 (Drilling)

W. P V 35 Y P 23

X. Extraction time 15 minutes

Y. Core cut and transferred (Yes)/No

Z. All records up-to-date (Yes)/No

REMARKS: Stratapax without low invasion gel. Core weight: Top--32 lbs., Middle-- 34 lbs., Bottom--32 lbs.

DIAMOND OIL WELL DRILLING COMPANY
POST OFFICE BOX 6358 / MIDLAND, TEXAS 79701 / 915 563-0775

DOWDCO RUN REPORT

A. Date 10-4-79 Job No. 22 Bit No. CS106 Well No. 310TP Run No. 9

COMPANY Texas Pacific Location: Denver City

Starting Depth 5,242 Ending Depth 5,250

B. Time - Through Table 9:05 p.m. On Surface 8:00 a.m.

Tag Bottom 1:30 a.m. Drilling Time 187 minutes

Drop Ball 5:20 a.m. Ball Time 6 minutes Close 5:26 a.m.

C. Reaming Yes/(No)

D. String weight start 95,000

E. Feathered in (Yes)/No

F. Tag Bottom a. right depth (Yes)/No (If no, remarks) _____

G. Starting RPM 60 Drilling RPM 80

H. Average weight on Bit 9,000

I. Maximum weight on Bit 9,000

String weight end 95,000

K. Tool Trip (Yes)/No – if no, spudded _____

L. (Ball caused) Pressure Increase not seen

M. Extension 17 In _____

N. Ball closed Yes/(No)

O. Pressure on Dome (expected) 2,600

P. Pressure on Core -0-

Q. Good Flush Yes/(No) – If no, remarks: _____

R. Mud Weight 9.7

S. Mud Viscosity 66

T. Any change Yes/(No) – If no, remarks: _____

U. Pump PSI 650 (Drilling)

V. G P M 140 (Drilling)

W. P V 35 Y P 24

X. Extraction time -0-

Y. Core cut and transferred (Yes)/No

Z. All records up-to-date (Yes)/No

REMARKS: Stratapax with low invasion gel. Core dumped and not weighed. Core kept ball from closing.

DIAMOND OIL WELL DRILLING COMPANY
POST OFFICE BOX 6358 / MIDLAND, TEXAS 79701 / 915 563-0775

DOWDCO RUN REPORT

A. Date 10-5-79 Job No. 22 Bit No. C7048 Well No. 310TP Run No. 10

COMPANY Texas Pacific Location: Denver City

Starting Depth 5,250 Ending Depth 5,259

B. Time - Through Table 9:45 a.m. On Surface 6:45 p.m.

Tag Bottom 11:15 a.m. Drilling Time 243 minutes

Drop Ball 3:55 p.m. Ball Time 6 minutes Close yes

C. Reaming Yes/(No)

D. String weight start 96,000

E. Feathered in (Yes)/No

F. Tag Bottom a. right depth (Yes)/No (If no, remarks) _____

G. Starting RPM 45 Drilling RPM 60

H. Average weight on Bit 9,000

I. Maximum weight on Bit 9,000

J. String weight end 96,000

K. Tool Trip (Yes)/No – if no, spudded spudded twice

L. (Ball caused) Pressure Increase 25 lbs.

M. Extension 17 3/4 In _____

N. Ball closed (Yes)/No

O. Pressure on Dome (expected) 2,600

P. Pressure on Core 1,600

Q. Good Flush (Yes)/No – If no, remarks: _____

R. Mud Weight 9.7

S. Mud Viscosity 66

T. Any change Yes/(No) – If no, remarks: _____

U. Pump PSI 650 (Drilling)

V. G P M 140 (Drilling)

W. P V 35 Y P 24

X. Extraction time 25 minutes

Y. Core cut and transferred (Yes)/No

Z. All records up-to-date (Yes)/No

REMARKS: Diamond bit used without low invasion gel. Core weight: Top-- 38 lbs., Middle-- 38 lbs., and Bottom-- 34 lbs.

DIAMOND OIL WELL DRILLING COMPANY
POST OFFICE BOX 6358 / MIDLAND, TEXAS 79701 / 915 563-0775

DOWDCO RUN REPORT

A. Date 10-5-79 Job No. 22 Bit No. CS103 Well No. 310TP Run No. 11

COMPANY Texas Pacific Location: Denver City

Starting Depth 5,259 Ending Depth 5,267

B. Time - Through Table 7:30 p.m. On Surface 2:45 a.m.

Tag Bottom 11:00 p.m. Drilling Time 77 minutes

Drop Ball 12:40 a.m. Ball Time 7 minutes Close yes

C. Reaming (Yes)/No

D. String weight start 95,000

E. Feathered in (Yes)/No

F. Tag Bottom a. right depth (Yes)/No (If no, remarks) _____

G. Starting RPM 60 Drilling RPM 80

H. Average weight on Bit 9,000

I. Maximum weight on Bit 9,000

J. String weight end 95,000

K. Tool Trip (Yes)/No – if no, spudded _____

L. (Ball caused) Pressure Increase not seen

M. Extension 16 3/4 In _____

N. Ball closed (Yes)/No

O. Pressure on Dome (expected) 2,600

P. Pressure on Core -0-

Q. Good Flush Yes/(No) - If no, remarks: No flush

R. Mud Weight 9.7

S. Mud Viscosity 66

T. Any change Yes/(No) - If no, remarks: _____

U. Pump PSI 600 (Drilling)

V. G P M 140 (Drilling)

W. P V 35 Y P 24

X. Extraction time not applicable

Y. Core cut and transferred (Yes)/No

Z. All records up-to-date (Yes)/No

REMARKS: Stratapax with low invasion gel-- 7 foot, 9 inch core-- No reason found for leak.

DIAMOND OIL WELL DRILLING COMPANY
POST OFFICE BOX 6358 / MIDLAND, TEXAS 79701 / 915 563-0775

DOWDCO RUN REPORT

A. Date 10-6-79 Job No. 22 Bit No. CS 103 Well No. 310TP Run No. 12

COMPANY Texas Pacific Location: Denver City

Starting Depth 5,267 Ending Depth 5,273

B. Time - Through Table 4:10 a.m. On Surface 11:00 a.m.

Tag Bottom 6:50 a.m. Drilling Time 88 minutes

Drop Ball 8:45 a.m. Ball Time 6 minutes Close yes

C. Reaming Yes/(No)

D. String weight start 95,000

E. Feathered in (Yes)/No

F. Tag Bottom a. right depth (Yes)/No (If no, remarks) _____

G. Starting RPM 50 Drilling RPM 80

H. Average weight on Bit 9,000

I. Maximum weight on Bit 9,000

J. String weight end 95,000

Tool Trip (Yes)/No – if no, spudded _____

L. (Ball caused) Pressure Increase 25 lbs.

M. Extension 17 1/2 In _____

N. Ball closed (Yes)/No

O. Pressure on Dome (expected) 2,600

P. Pressure on Core 3,300

Q. Good Flush (Yes)/No – If no, remarks: _____

R. Mud Weight 9.7

S. Mud Viscosity 65

T. Any change Yes/(No) – If no, remarks: _____

U. Pump PSI 650 (Drilling)

V. G P M 140 (Drilling)

W. P V 35 Y P 24

X. Extraction time 25 minutes

Y. Core cut and transferred (Yes)/No

Z. All records up-to-date (Yes)/No

REMARKS: Stratapax bit used with low invasion gel-- 6 foot core-- No pup sub on location--

Core weight: Top-- 38 lbs., Bottom-- 34 lbs.

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POST OFFICE BOX 6358 / MIDLAND, TEXAS 79701 / 915 563-0775

DOWDCO RUN REPORT

A. Date 10-6-79 Job No. 22 Bit No. CS103 Well No. 310TP Run No. 13

COMPANY Texas Pacific Location: Denver City

Starting Depth 5,273 Ending Depth 5,281

B. Time - Through Table 11:45 a.m. On Surface 8:00 p.m.

Tag Bottom 2:35 p.m. Drilling Time 153 minutes

Drop Ball 5:33 p.m. Ball Time 7 minutes Close yes

C. Reaming Yes/(No)

D. String weight start 95,000

E. Feathered in (Yes)/No

F. Tag Bottom a. right depth (Yes)/No (If no, remarks) _____

G. Starting RPM 60 Drilling RPM 80

H. Average weight on Bit 9,000

I. Maximum weight on Bit 9,000

J. String weight end 95,000

K. Tool Trip (Yes)/No – if no, spudded _____

L. (Ball caused) Pressure Increase 25 lbs.

M. Extension 17 1/2 In _____

N. Ball closed (Yes)/No

O. Pressure on Dome (expected) 2,600

P. Pressure on Core 2,600

Q. Good Flush (Yes)/No – If no, remarks: _____

R. Mud Weight 9.7

S. Mud Viscosity 65

T. Any change Yes/(No) – If no, remarks: _____

U. Pump PSI 650 (Drilling)

V. G P M 140 (Drilling)

W. P V 35 Y P 24

X. Extraction time 25 minutes

Y. Core cut and transferred (Yes)/No

Z. All records up-to-date (Yes)/No

REMARKS: Stratapax bit used with low invasion gel. Core weight: Top--50 lbs., Bottom--40 lbs.

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DOWDCO RUN REPORT

A. Date 10-7-79 Job No. 22 Bit No. CS103 Well No. 310TP Run No. 14

COMPANY Texas Pacific Location: Denver City

Starting Depth 5,281 Ending Depth 5,289

B. Time - Through Table 8:30 p.m. On Surface 3:50 a.m.

Tag Bottom 11:50 p.m. Drilling Time 99 minutes

Drop Ball 2:00 a.m. Ball Time 7 minutes Close yes

C. Reaming Yes/(No)

D. String weight start 95,000

E. Feathered in (Yes)/No

F. Tag Bottom a. right depth (Yes)/No (If no, remarks) _____

G. Starting RPM 60 Drilling RPM 80

H. Average weight on Bit 9,000

I. Maximum weight on Bit 9,000

J. String weight end 95,000

Tool Trip (Yes)/No – if no, spudded _____

L. (Ball caused) Pressure Increase not seen

M. Extension 16 1/2 In _____

N. Ball closed Yes/(No)

O. Pressure on Dome (expected) 2,600

P. Pressure on Core -0-

Q. Good Flush Yes/(No) – If no, remarks: No flush

R. Mud Weight 9.7

S. Mud Viscosity 65

T. Any change Yes/(No) – If no, remarks: _____

U. Pump PSI 600 (Drilling)

V. G P M 140 (Drilling)

W. P V 32 Y P 21

X. Extraction time -0-

Y. Core cut and transferred (Yes)/No

Z. All records up-to-date (Yes)/No

REMARKS: Stratapax bit used with low invasion gel--Core in ball valve--Ball valve could not close.

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DOWDCO RUN REPORT

A. Date 10-7-79 Job No. 22 Bit No. CS 103 Well No. 310TP Run No. 15

COMPANY Texas Pacific Location: Denver City

Starting Depth 5,289 Ending Depth 5,297

B. Time - Through Table 4:40 a.m. On Surface 11:00 a.m.

Tag Bottom 7:10 a.m. Drilling Time 80 minutes

Drop Ball 8:52 a.m. Ball Time 8 minutes Close yes

C. Reaming Yes/(No)

D. String weight start 95,000

E. Feathered in (Yes)/No

F. Tag Bottom a. right depth (Yes)/No (If no, remarks)

G. Starting RPM 60 Drilling RPM 80

H. Average weight on Bit 8,000

I. Maximum weight on Bit 9,000

J. String weight end 95,000

Tool Trip (Yes)/No – if no, spudded Spudded once

L. (Ball caused) Pressure Increase 25 lbs.

M. Extension 17 1/2 In

N. Ball closed (Yes)/No

O. Pressure on Dome (expected) 2,600

P. Pressure on Core 2,900

Q. Good Flush (Yes)/No – If no, remarks:

R. Mud Weight 9.6

S. Mud Viscosity 66

T. Any change Yes/(No) – If no, remarks:

U. Pump PSI 650 (Drilling)

V. G P M 140 (Drilling)

W. P V 33 Y P 22

X. Extraction time 20 minutes

Y. Core cut and transferred (Yes)/No

Z. All records up-to-date (Yes)/No

REMARKS: Stratapax bit used with low invasion gel. Core weight: Top--42 lbs., Bottom--48 lbs.

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DOWDCO RUN REPORT

A. Date 10-7-79 Job No. 22 Bit No. CS103 Well No. 310TP Run No. 16

COMPANY Texas Pacific Location: Denver City

Starting Depth 5,297 Ending Depth 5,305

B. Time - Through Table 1:15 p.m. On Surface 7:50 p.m.

Tag Bottom 3:20 p.m. Drilling Time 80 minutes

Drop Ball 5:08 p.m. Ball Time 8 minutes Close yes

C. Reaming Yes/(No)

D. String weight start 95,000

E. Feathered in (Yes)/No

F. Tag Bottom a. right depth (Yes)/No (If no, remarks) _____

G. Starting RPM 60 Drilling RPM 80

H. Average weight on Bit 8,000

I. Maximum weight on Bit 9,000

J. String weight end 95,000

Tool Trip (Yes)/No – if no, spudded Spudded once

L. (Ball caused) Pressure Increase 25 lbs.

M. Extension 17 1/2 In _____

N. Ball closed (Yes)/No

O. Pressure on Dome (expected) 2,600

P. Pressure on Core 1,500

Q. Good Flush (Yes)/No – If no, remarks: _____

R. Mud Weight 9.6

S. Mud Viscosity 66

T. Any change Yes/(No) – If no, remarks: _____

U. Pump PSI 600 (Drilling)

V. G P M 140 (Drilling)

W. P V 33 Y P 22

X. Extraction time 25 minutes

Y. Core cut and transferred (Yes)/No

Z. All records up-to-date (Yes)/No

REMARKS: Stratapax with low invasion gel. Core weight: Top--40 lbs, Bottom-- 44 lbs.

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DOWDCO RUN REPORT

A. Date 10-7-79 Job No. 22 Bit No. CS103 Well No. 310TP Run No. 17

COMPANY Texas Pacific Location: Denver City

Starting Depth 5,305' Ending Depth 5,313'

B. Time - Through Table 8:40 p.m. On Surface 4:30 a.m.

Tag Bottom 11:03 p.m. Drilling Time 107 minutes

Drop Ball 1:20 a.m. Ball Time 8 minutes Close yes

C. Reaming Yes/(No)

D. String weight start 97,000

E. Feathered in (Yes)/No

F. Tag Bottom a. right depth (Yes)/No (If no, remarks) _____

G. Starting RPM 60 Drilling RPM 80

H. Average weight on Bit 9,000

I. Maximum weight on Bit 9,000

J. String weight end 97,000

Tool Trip (Yes)/No – if no, spudded Spudded once

L. (Ball caused) Pressure Increase not seen

M. Extension 17 1/2 In _____

N. Ball closed (Yes)/No

O. Pressure on Dome (expected) 2,600

P. Pressure on Core 2,600

Q. Good Flush (Yes)/No – If no, remarks: _____

R. Mud Weight 9.6

S. Mud Viscosity 66

T. Any change Yes/(No) – If no, remarks: _____

U. Pump PSI 600 (Drilling)

V. G P M 140 (Drilling)

W. P V 33 Y P 22

X. Extraction time 15 minutes

Y. Core cut and transferred (Yes)/No

Z. All records up-to-date (Yes)/No

REMARKS: Used Stratapax bit with low invasion gel. Core weight: Top-- 34 lbs., Middle-- 36 lbs., and Bottom-- 22 lbs.

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DOWDCO RUN REPORT

A. Date 10-8-79 Job No. 22 Bit No. CS103 Well No. 310TP Run No. 18

COMPANY Texas Pacific Location: Denver City

Starting Depth 5,313' Ending Depth 5,321'

B. Time - Through Table 4:35 a.m. On Surface 12:01 p.m.

Tag Bottom 6:23 a.m. Drilling Time 133 minutes

Drop Ball 9:00 a.m. Ball Time 5 minutes Close yes

C. Reaming Yes/(No)

D. String weight start 95,000

E. Feathered in (Yes)/No

F. Tag Bottom a. right depth (Yes)/No (If no, remarks) _____

G. Starting RPM 60 Drilling RPM 80

H. Average weight on Bit 8,000

I. Maximum weight on Bit 9,000

J. String weight end 95,000

Tool Trip (Yes)/No – if no, spudded Spudded once

L. (Ball caused) Pressure Increase 25 lbs.

M. Extension 17 1/2 In _____

N. Ball closed (Yes)/No

O. Pressure on Dome (expected) 2,600

P. Pressure on Core 2,600

Q. Good Flush (Yes)/No – If no, remarks: _____

R. Mud Weight 9.6

S. Mud Viscosity 66

T. Any change Yes/(No) – If no, remarks: _____

U. Pump PSI 650 (Drilling)

V. G P M 140 (Drilling)

W. P V 33 Y P 22

X. Extraction time 25 minutes

Y. Core cut and transferred (Yes)/No

Z. All records up-to-date (Yes)/No

REMARKS: Stratapax bit used with low invasion gel. Core weight:, Top-- 40 lbs., Bottom-- 40 lbs.

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DOWDCO RUN REPORT

A. Date 10-8-79 Job No. 22 Bit No. CS103 Well No. 310TP Run No. 19

COMPANY Texas Pacific Location: Denver City

Starting Depth 5,321' Ending Depth 5,329'

B. Time - Through Table 1:30 p.m. On Surface 7:30 p.m.

Tag Bottom 3:33 p.m. Drilling Time 88 minutes

Drop Ball 5:29 p.m. Ball Time 6 1/2 minutes Close yes

C. Reaming Yes/(No)

D. String weight start 96,000

E. Feathered in (Yes)/No

F. Tag Bottom a. right depth (Yes)/No (If no, remarks) _____

G. Starting RPM 45 Drilling RPM 80

H. Average weight on Bit 8,000

I. Maximum weight on Bit 9,000

J. String weight end 96,000

Tool Trip (Yes)/No – if no, spudded _____

L. (Ball caused) Pressure Increase 100

M. Extension 17 3/4 In _____

N. Ball closed (Yes)/No

O. Pressure on Dome (expected) 2,600

P. Pressure on Core 2,700

Q. Good Flush (Yes)/No – If no, remarks: _____

R. Mud Weight 9.6

S. Mud Viscosity 66

T. Any change Yes/(No) – If no, remarks: _____

U. Pump PSI 650 (Drilling)

V. G P M 140 (Drilling)

W. P V 33 Y P 22

X. Extraction time 25 minutes

Y. Core cut and transferred (Yes)/No

Z. All records up-to-date (Yes)/No

REMARKS: Stratapax bit used with low invasion gel. Core weight: Top-- 48 lbs., Bottom-- 40 lbs.

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DOWDCO RUN REPORT

A. Date 10-9-79 Job No. 22 Bit No. CS103 Well No. 310TP Run No. 20

COMPANY Texas Pacific Location: Denver City

Starting Depth 5,329' Ending Depth 5,337'

B. Time - Through Table 8:30 p.m. On Surface 2:30 a.m.

Tag Bottom 11:00 p.m. Drilling Time 72 minutes

Drop Ball 12:50 a.m. Ball Time 9 minutes Close yes

C. Reaming Yes/(No)

D. String weight start 96,000

E. Feathered in (Yes)/No

F. Tag Bottom a. right depth (Yes)/No (If no, remarks)

G. Starting RPM 60 Drilling RPM 80

H. Average weight on Bit 7,000

I. Maximum weight on Bit 9,000

J String weight end 96,000

Tool Trip (Yes)/No – if no, spudded

L. (Ball caused) Pressure Increase 25

M. Extension 17 3/8 In

N. Ball closed (Yes)/No

O. Pressure on Dome (expected) 2,600

P. Pressure on Core 2,400

Q. Good Flush (Yes)/No – If no, remarks:

R. Mud Weight 9.6

S. Mud Viscosity 66

T. Any change Yes/(No) – If no, remarks:

U. Pump PSI 650 (Drilling)

V. G P M 140 (Drilling)

W. P V 33 Y P 22

X. Extraction time 20 minutes

Y. Core cut and transferred (Yes)/No

Z. All records up-to-date (Yes)/No

REMARKS: Used Stratapax bit with low invasion gel. Core weight: Top-- 36 lbs., Bottom-- 40 lbs

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DOWDCO RUN REPORT

A. Date 10-9-79 Job No. 22 Bit No. CS103 Well No. 310TP Run No. 21

COMPANY Texas Pacific Location: Denver City

Starting Depth 5,337' Ending Depth 5,337'

B. Time - Through Table 3:30 a.m. On Surface 11:30 a.m.

Tag Bottom 8:05 a.m. Drilling Time 90 minutes

Drop Ball no Ball Time -- Close no

C. Reaming Yes/No

D. String weight start 95,000

E. Feathered in Yes/No

F. Tag Bottom a. right depth Yes/No (If no, remarks) _____

G. Starting RPM 60 Drilling RPM 80

H. Average weight on Bit 8,000

I. Maximum weight on Bit 10,000

J. String weight end 95,000

* Tool Trip Yes/No – if no, spudded _____

L. (Ball caused) Pressure Increase _____

M. Extension _____ In _____

N. Ball closed Yes/No

O. Pressure on Dome (expected) _____

P. Pressure on Core _____

Q. Good Flush Yes/No – If no, remarks: _____

R. Mud Weight _____

S. Mud Viscosity _____

T. Any change Yes/No – If no, remarks: _____

U. Pump PSI _____ (Drilling)

V. G P M _____ (Drilling)

W. P V _____ Y P _____

X. Extraction time _____

Y. Core cut and transferred Yes/No

Z. All records up-to-date Yes/No

REMARKS: * Attempted to core 1 1/2 hours. No hole made. Pulled out of the hole. Made a bit run with junk basket and retrieved 1/2 of a tong die.

DOWDCO

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DOWDCO RUN REPORT

A. Date 10-9-79 Job No. 22 Bit No. CS103 Well No. 310TP Run No. 22

COMPANY Texas Pacific Location: Denver City

Starting Depth 5,338' Ending Depth 5,346'

B. Time - Through Table 11:00 p.m. On Surface 7:45 a.m.

Tag Bottom 1:30 a.m. Drilling Time 157 minutes

Drop Ball 4:36 a.m. Ball Time 8 minutes Close yes

C. Reaming Yes/(No)

D. String weight start 96,000

E. Feathered in (Yes)/No

F. Tag Bottom a. right depth (Yes)/No (If no, remarks) _____

G. Starting RPM 60 Drilling RPM 80

H. Average weight on Bit 9,000

I. Maximum weight on Bit 9,000

J. String weight end 96,000

K. Tool Trip (Yes)/No – if no, spudded _____

L. (Ball caused) Pressure Increase not seen

M. Extension 17 1/2 In _____

N. Ball closed (Yes)/No

O. Pressure on Dome (expected) 2,600

P. Pressure on Core 3,600

Q. Good Flush (Yes)/No – If no, remarks: _____

R. Mud Weight 9.5

S. Mud Viscosity 76

T. Any change Yes/(No) – If no, remarks: _____

U. Pump PSI 650 (Drilling)

V. G P M 140 (Drilling)

W. P V 39 Y P 26

X. Extraction time 20 minutes

Y. Core cut and transferred (Yes)/No

Z. All records up-to-date (Yes)/No

REMARKS: Stratapax bit used with low invasion gel. Core weight: Top-- 42 lbs.

Bottom-- 52 lbs.

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DOWDCO RUN REPORT

A. Date 10-10-79 Job No. 22 Bit No. CS103 Well No. 310TP Run No. 23

COMPANY Texas Pacific Location: Denver City

Starting Depth 5,346' Ending Depth 5,354'

B. Time - Through Table 8:00 a.m. On Surface 3:15 p.m.

Tag Bottom 10:10 a.m. Drilling Time 131 minutes

Drop Ball 1:00 p.m. Ball Time 6 minutes Close yes

C. Reaming Yes/(No)

D. String weight start 95,000

E. Feathered in (Yes)/No

F. Tag Bottom a. right depth (Yes)/No (If no, remarks) _____

G. Starting RPM 60 Drilling RPM 80

H. Average weight on Bit 9,000

I. Maximum weight on Bit 9,000

J. String weight end 95,000

Tool Trip (Yes)/No – if no, spudded _____

L. (Ball caused) Pressure Increase 25 lbs.

M. Extension 17 1/2 In _____

N. Ball closed (Yes)/No

O. Pressure on Dome (expected) 2,600

P. Pressure on Core 3,100

Q. Good Flush (Yes)/No – If no, remarks: _____

R. Mud Weight 9.5

S. Mud Viscosity 76

T. Any change Yes/(No) – If no, remarks: _____

U. Pump PSI 600 (Drilling)

V. G P M 140 (Drilling)

W. P V 39 Y P 29

X. Extraction time 25 minutes

Y. Core cut and transferred (Yes)/No

Z. All records up-to-date (Yes)/No

REMARKS: Stratapax bit used with low invasion gel. Core weight: Top--46 lbs.

Bottom--36 lbs.

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DOWDCO RUN REPORT

A. Date 10-10-79 Job No. 22 Bit No. CS103 Well No. 310TP Run No. 24

COMPANY Texas Pacific Location: Denver City

Starting Depth 5,354' Ending Depth 5,362'

B. Time - Through Table 3:30 p.m. On Surface 11:00 p.m.

Tag Bottom 6:00 p.m. Drilling Time 109 minutes

Drop Ball 8:00 p.m. Ball Time 9 minutes Close yes

C. Reaming Yes/(No)

D. String weight start 97,000

E. Feathered in (Yes)/No

F. Tag Bottom a. right depth (Yes)/No (If no, remarks) _____

G. Starting RPM 60 Drilling RPM 78

H. Average weight on Bit 9,000

I. Maximum weight on Bit 9,000

J. String weight end 97,000

Tool Trip (Yes)/No – if no, spudded _____

L. (Ball caused) Pressure Increase not seen

M. Extension 17 1/2 In _____

N. Ball closed (Yes)/No

O. Pressure on Dome (expected) 2,600

P. Pressure on Core 2,700

Q. Good Flush (Yes)/No – If no, remarks: _____

R. Mud Weight 9.6

S. Mud Viscosity 85

T. Any change Yes/(No) – If no, remarks: _____

U. Pump PSI 500 (Drilling)

V. G P M 140 (Drilling)

W. P V 37 Y P 29

X. Extraction time 20 minutes

Y. Core cut and transferred (Yes)/No

Z. All records up-to-date (Yes)/No

REMARKS: Stratapax bit used with low invasion gel. Core weight: Top--34 lbs.
Bottom--40 lbs.

DOWDCO

DIAMOND OIL WELL DRILLING COMPANY

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DOWDCO RUN REPORT

A. Date 10-11-79 Job No. 22 Bit No. CS103 Well No. 310TP Run No. 25

COMPANY Texas Pacific Location: Denver City

Starting Depth 5,362' Ending Depth 5,370'

B. Time - Through Table 11:15 p.m. On Surface 7:00 a.m.

Tag Bottom 1:45 a.m. Drilling Time 141 minutes

Drop Ball 4:45 a.m. Ball Time 8 minutes Close yes

C. Reaming Yes/No

D. String weight start 96,000

E. Feathered in Yes/No

F. Tag Bottom a. right depth Yes/No (If no, remarks) _____

G. Starting RPM 60 Drilling RPM 80

H. Average weight on Bit 9,000

I. Maximum weight on Bit 9,000

J. String weight end 96,000

Tool Trip Yes/No – if no, spudded Spudded once

L. (Ball caused) Pressure Increase not seen

M. Extension 17 1/2 In _____

N. Ball closed Yes/No

O. Pressure on Dome (expected) 2,600

P. Pressure on Core 3,300

Q. Good Flush Yes/No – If no, remarks: _____

R. Mud Weight 9.6

S. Mud Viscosity 85

T. Any change Yes/No – If no, remarks: _____

U. Pump PSI 400 (Drilling)

V. G P M 140 (Drilling)

W. P V 37 Y P 29

X. Extraction time _____

Y. Core cut and transferred Yes/No

Z. All records up-to-date Yes/No

REMARKS: Stratapax bit used with low invasion gel.

Gas pressure in barrel was pushing core out.

Wire stuck inside of bit (two pieces)

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DOWDCO RUN REPORT

A. Date 10-11-79 Job No. 22 Bit No. CS103 Well No. 310TP Run No. 26

COMPANY Texas Pacific Location: Denver City

Starting Depth 5,370' Ending Depth 5,378'

B. Time - Through Table 7:30 a.m. On Surface 3:30 p.m.

Tag Bottom 10:00 a.m. Drilling Time 155 minutes

Drop Ball 12:58 p.m. Ball Time 7 minutes Close yes

C. Reaming Yes/(No)

D. String weight start 95,000

E. Feathered in (Yes)/No

F. Tag Bottom a. right depth (Yes)/No (If no, remarks) _____

G. Starting RPM 60 Drilling RPM 80

H. Average weight on Bit 10,000

I. Maximum weight on Bit 11,000

J String weight end 95,000

K. Tool Trip (Yes)/No – if no, spudded _____

L. (Ball caused) Pressure Increase 25

M. Extension 17 1/2 In _____

N. Ball closed (Yes)/No

O. Pressure on Dome (expected) 2,600

P. Pressure on Core 2,900

Q. Good Flush (Yes)/No – If no, remarks: _____

R. Mud Weight 9.7

S. Mud Viscosity 70

T. Any change Yes/(No) – If no, remarks: _____

U. Pump PSI 500 (Drilling)

V. G P M 140 (Drilling)

W. P V 34 Y P 22

X. Extraction time 20 minutes

Y. Core cut and transferred (Yes)/No

Z. All records up-to-date (Yes)/No

REMARKS: Stratapax bit used with low invasion gel. Core weight: Top--40 lbs., Bottom--32 lbs. Junk on bit--1/2" hex bolt head.

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DOWDCO RUN REPORT

A. Date 10-11-79 Job No. 22 Bit No. CS103 Well No. 310TP Run No. 27

COMPANY Texas Pacific Location: Denver City

Starting Depth 5,378' Ending Depth 5,386'

B. Time - Through Table 3:45 p.m. On Surface 11:30 p.m.

Tag Bottom 5:40 p.m. Drilling Time 172 minutes

Drop Ball 9:13 p.m. Ball Time 8 minutes Close yes

C. Reaming Yes/(No)

D. String weight start 98,000

E. Feathered in (Yes)/No

F. Tag Bottom a. right depth (Yes)/No (If no, remarks) _____

G. Starting RPM 60 Drilling RPM 80

H. Average weight on Bit 9,000

I. Maximum weight on Bit 9,000

J. String weight end 98,000

Tool Trip (Yes)/No – if no, spudded Spudded twice

L. (Ball caused) Pressure Increase not seen

M. Extension 17 In _____

N. Ball closed Yes/(No)

O. Pressure on Dome (expected) 2,600

P. Pressure on Core - 0 -

Q. Good Flush Yes/(No) – If no, remarks: none

R. Mud Weight 9.7

S. Mud Viscosity 70

T. Any change Yes/(No) – If no, remarks: _____

U. Pump PSI 550 (Drilling)

V. G P M 140 (Drilling)

W. P V 34 Y P 22

X. Extraction time none

Y. Core cut and transferred (Yes)/No

Z. All records up-to-date (Yes)/No

REMARKS: Stratapax with low invasion gel. Core weight: Top--33 lbs., Bottom--40 lbs. Loose racks--Ball had closed about 1/4"--Sliding sleeve would not go into adapter sub fully.

CONTINUATION SHEET TP-330 [X] DRILLING WELL [ ] RECOMPLETION [ ] WORKOVER [ ] P AND A

WELL NAME AND NUMBER	FIELD	PAGE
BENNETT RANCH UNIT #310 Oil AFE 72079	Wasson/San Andres	1 OF

TPWI: 35.36%
Type Well: Oil
Location: 1340' FWL, & 2650' FNL Sec. 615, Blk "D", J. H. Gibson Survey
County & State: Yoakum County, Texas
Contractor & Rig No.: Sitton Drilling Company, Rig No. 5
PJTD: 5350'
Elevation: 3565.03'
Spud Date & Hour: 9-15-79 @ 4:00 PM
DHC/ETC: $250,600
Casing:

----------INITIAL REPORT----------

9/16/79 TCTD $8,850 Tot Dys 1/20
Rigging up to run casing @ 465' (465') Red Beds
Drilling surface hole.
MW 8.6 Vis 33 Dev 3/4 deg @ 465'

9/17/79 TCTD $27,423 Tot Dys 2/20
Drilling cement @ 445'
Ran 12 jts 13 3/8" csg. Set @ 467'. Cmtg plug down @ 11:12 AM 9-16-79. Circ 207 sx. WOC. Nippled up. Tested BOPs for ½ hr. @ 800#. OK.
Drill plug & insert float.
Csg & Cmtg Report:
Cmtd 11 jts 13 3/8" (455.13) 48#, 8R, H-40, R-3, ST&C, Lone Star, Csg set @ 467.13 w/525 sx class "C" + 2% Cacl. Pmpd 20 bbls of fresh wtr ahead of cmt. Reciprocated csg w/20 strokes for ½ hr. Bmpd plug @ 11:12 AM 9-16-79 w/500. Floats did hold. Held 500 on csg for 5 min. Circ approx 207 sx cmt. Float collar @ 411.72'.
Dowell of Levelland did cmtg. Very satisfactory job.
MW 8.6 Vis 31

9/18/79 TCTD $37,670 Tot Dys 3/20
Drilling @ 1570' (1105') Red Bed
Repairs & NU. Cut 400' off Drlg. Line.
MW 8.9 Vis 31 Dev ½ deg @ 965'; 3/4 deg @ 1,437'.

9/19/79 TCTD $42,210 Tot Dys 4/20
Drilling @ 2545' (975') Red Beds, Anhy
MW 9.3 Vis 32 Dev 1 deg @ 1931'; 3/4 deg @ 2243'.

9/20/79 TCTD $47,880 Tot Dys 5/20
Drilling @ 3260' (715') Salt & Anhy
MW 9.9 Vis 33 Dev 1 deg @ 2693'; 1¼ deg @ 3192'.

9/21/79 TCTD $52,142 Tot Dys 6/20
Drilling @ 3930' (570') Anhy
MW 10.1 Vis 34 Dev 1 deg @ 3628'.

9/22/79 TCTD $59,784 Tot Dys 7/20
Trip for new bit @ 4120' (290') Anhy
Drilling to 4120'.
MW 10.1 Vis 33 Dev 1¼ deg @ 4120'.

9/23/79 TCTD $64,009 Tot Dys 8/20
Drilling @ 4430' (310') Anhy
Finish trip for new bit @ 4120'.
MW 10.3 Vis 33 Dev 1½ deg @ 4120'.

9/24/79 TCTD $67,959 Tot Dys 9/20
Drilling @ 4750' (320') Lime
MW 10.4 Vis 33 Dev 1¼ deg @ 4620'.

9/25/79 TCTD $72,154 Tot Dys 10/20
Drilling @ 4950' (200') Lime
MW 10.5 Vis 33

9/26/79 TCTD $76,064 Tot Dys 11/20
Drilling @ 5030' (80') Lime
Trip for new bit @ 4956 (SLM no/correction)
MW 10.0 Vis 33 Dev 1 3/4 deg @ 4956'.

9/27/79 TCTD $79,994 Tot Dys 12/20
Drilling @ 5120' (170') Lime
MW 10.2 Vis 33 Dev 3/4 deg @ 5065'

9/28/79 TCTD $161,657 Tot Dys 13/20
Preparing to cmt 8 5/8" csg @ 5150' (39') Lime
Drilling. Ran 122 jts 8 5/8" csg.
MW 10.4 Vis 34 Dev 1 deg @ 5150'.

9/29/79 TCTD $161,657 Tot Dys 14/20
GIH w/BHA & bit @ 5150' (0') LE
Cmtg 8 5/8" csg. WOC & NU BOPS & tested blind rams ½ hr. to 900 psi. OK. GIH w/bit & PU BHA.
Csg & Cmtg Report:
Cmtg 122 jts 8 5/8" (5148.86) of 32# 8rd, K-55, RG-3, STC & LTC
Csg set @ 5150' w/1500 sxs class "C" w/3% Econolite & 300 sxs class "C" + 2% Cacl 2. Pmpd 20 bbls of fresh wtr ahead of cmt. Reciprocated csg w/20 strokes while circ. Bmpd plug @ 9:45 AM 9-28-79 w/1350 psi. Floats did hold. Held 1350 on csg for 5 min. Circ approx 326 sxs cmt. Float collar @ 5101'. Dowell of Levelland.

9/30/79 TCTD $165,627 Tot Dys 15/20
POOH for core #1 @ 5175' (25') Lime
PU BHA. Tested BOPS. Flange on Larkin. Head leaked. PU BOPS & tightened head. Tested BOPS. Pipe rams to 900 psi. Finish NU & GIH. Drilling float, cmt & shoe. Drilling to 5175'. Circ.
MW 9.7 Vis 46

10/1/79 TCTD $169,197 Tot Dys 16/20
POOH w/core #2 @ 5190' (15') Lime
POOH & LD 18-6¼" DCS. PU core barrel #1 & 15-4-3/4" DC. TIH. Circ on btm. Coring, cut 6' 5175-5181. Pmpg down closing ball.

10/2/79 TCTD $173,067 Tot Dys 17/20
Coring #3 @ 5197' (7') Lime
POOH w/core #2-9'. LD core bbl. Bit had marks from junk. WOO on which bit to run in hole. PU 6-6-¼" DC & 7-7/8 bit. GIH. Reaming from 5175' to 5190'. Circ & working junk basket. POOH. Recover one tooth from bit. PU core bbl & TIH. Cutting core #3 Cut 7'.
MW 9.7 Vis 45

10/3/79 TCTD $161,657 Corrected DHC/ETC $250,600 Tot Dys 18/20
POOH w/core #5 @ 5216' (19') Lm
Cutting #3 FR 5190' 5198-8'. Pmpg down closing ball valve did not close. Barite settled out around closing valve. POOH w/core #3. L/D core bbl cut drill line. PU core bbl #4 TIH w/core #4. Circ. Cut core #4 from 5198 to 5207-9'.
NOTE:
Total cost to date corrected back to when rig was released to Gruy Federal.
3 hrs - pmp down closing ball POOH & L/D core #4
2½ hrs - PU core bbl #5 TIH
¼ hrs - Circ.
3 hrs - Cutting core #5 from 5207-5216
1¼ hrs - Pmpd down closing ball & POOH
MW 9.7 Vis 55

10/4/79 TCTD $161,657 Tot Dys 19/20
Cutting core #7 @ 5231' (15') Lime
Finish POOH w/core #5. LD core bbl & PU core bbl #6. TIH w/core bbl #6. Circ on bottom. Cut core #6 from 5216-5224'. Pmpd down. Closing ball. POOH w/core #6 LD core #6 & PU core #7. TIH to bottom of csg w/core bbl #7. Repairing jack shaft on rt table. Finish TIH. Reamed 18' to btm. Cut core #7 from 5224-5231-7'. Core #1, 3 & 6 were cut w/low invasion gel. core #2, 4, 5, & 7 were cut w/low invasion gel. core #4 is the only core cut w/diamond bit. The rest stratapax. The diamond bit averaged 2' per hr. The stratapax has only averaged 2 to 3' per hr.
MW 9.7 Vis 62

10/5/79 TCTD $161,657 Tot Dys 20/20
POOH w/core #9 @ 5250' (19') Lime
Finish cutting core #7 from 5231-5233. Pmpd down. Closing ball & POOH w/core #7. LD core bbl. PU core bbl #8. TIH. Washed & reamed 30' to btm. Cutting core #8 from 5233 to 5242. Pmpd down closing ball. POOH w/core #8. PU core bbl #9 & TIH. Cutting core #9 5242 to 5250. Pmpd down closing ball. POOH w/core #9.
MW 9.2 Vis 66

10/6/79 TCTD $161,657 Tot Dys 21/20
Trip in hole for core #12 @ 5267' (17') Lime
POOH w/core #9 LD core bbl. PU core bbl #10. TIH cutting core #10 5250-5259'. 9'. Pmpd down closing ball & POOH w/core #10. PU core bbl.#11 TIH. Cutting core #11 from 5259 - 5267 8'. Pmpd down. Closing ball & POOH w/core #11. PU core bbl#12. TIH. Core #10 Stratapax w/o gel 2' per hr. core #11 Stratapax w/gel 5.33' per hr
MW 9.7 Vis 66

10/7/79 TCTD $161,657 Tot Dys 22/20
GIH for core #15 @ 5289' (22') Lime
Finish TIH for core #12. Cutting core #12 from 5267 to 5273 6'. Pmpd down. Closing ball. POOH. LD core bbl #12 & LD 3 DC w/swelled boxes. PU core bbl #13. TIH. Cutting core #13 from 5273 to 5281 -8' Pmpd down ball & POOH w/core #13. PU core bbl #14. PU 3 DC & TIH. Cutting core #14 from 5281 to 5289 - 8'. Pmpd down ball & POOH. LD core bbl. PU core bbl #15 TIH. Core #12 Stratapax w/gel 4' per hr. core #13 Stratapax w/gel 2.9 per hr. core #14 Stratapax w/gel 4.57' per hr.
MW 9.7 Vis 65

10/8/79 TCTD $161,657 Tot Dys 23/20
GIH for core #18 @ 5318' (25') Lime
Cut core #15 5289/5297'/cut core #16. 5297/5305'. Cut core #17 5205/5313'.
MW 9.7 Vis 61

10/9/79 TCTD $161,657 Tot Dys 24/20
GIH for core #21 @ 5337 (24') Lime
MW 9.7 Vis 62

10/10/79 TCTD $161,657 Tot Dys 25/20
POOH w/core #21 @ 5345' (8') Lime
GIH w/core barrel for core #21. Could not cut core. POOH. LD core bbl. GIH with junk basket & bit. Drilling on junk & circ. drilled 1" hole. POOH. Recovered $\frac{1}{2}$ of tong die. GIH w/core barrel for core #21. Core #21 5338/5345'.
MW 9.5 Vis 36

----------FINAL REPORT FROM DALLAS----------

10/11/79 TCTD $161,657 Tot Dys 26/20
POOH w/core #25 @ 5369', (34') Lime
POOH w/core #22 5338/5345'. Cut core #23 5345/5353'. Cut core #24 5353'/5361'. Cut core #25 5361/5369'.
MW 9.6 Vis 75

10/12/79 TCTD $161,657 Tot Dys 27/20
Rigging up to log @ 5385' (16') Lime
POOH w/core #25. GIH for core #26. Cut core #26 from 5369/77'.
Cut core #27 from 5377/85'. GIH with 6-1/2" Bit & Bit Sub.
MW 9.5 Vis 68 Dev 1-1/2 Deg @ 5385'.

10-16-79 CTD $ -0- TCTD $ 205,520 ETC $ 250,600
Dropped to weekly status pending completion.

10/18/79 CTD $-0- TCTD $205,520
WO completion

10/25/79 CTD $-0- TCTD $205,520
WO completion

11/1/79 CTD $-0- TCTD $205,520
Dropped to weekly 10-16-79 pending completion.

COMPLETION PROCEDURE

BENNETT RANCH UNIT NO. 310
YOAKUM COUNTY, TEXAS
AFE NO. 72079

MAY 2, 1980

Well Data

Elevation:	3565'
Datum:	3577'
Casing:	5 1/2" @ 5386' (14#/ft)
TD:	5386'
PBTD:	5372'

Procedure

PHASE I

1. MIRUPU. Install BOP.

2. GIH with 2 3/8" workstring and circulate hole clean to TD with 1% KCl water.

3. Pressure test casing to 2000 psi.

4. RU Halliburton. Spot 100 gals. of MSA acid from 5258'-5358'.

5. RU Welex. Run Cement Bond log from 5372 up to surface.

6. RU Welex. GIH with GR & CCL logs and get a correlation log of the bottom 1000' of the hole. Correlate depths with the Schlumberger CNL-Density log dated 10-12-79.

7. GIH with perforating gun and perforate with 1 JSPF from 5342'-58' (17 holes) phased at 180°. All perforating data is at the end of this procedure.

8. GIH with a 5 1/2" RBP, treating packer & SN on 2 3/8" workstring and set RBP @ ±5365' and set packer at ±5200'.

9. RU Halliburton. Acidize well with 2000 gals of 20% HCl-Fe in the following manner:

   A. Pump 150 gals. of acid followed by two ball sealers. (Note: All acid additives are at the back of this procedure).
   B. Repeat Step A until all acid is used. A total of 26 ball sealers should be used unless ballout is achieved.
   C. If ballout occurs, release pressure and let balls drop to the bottom of the well, then displace the rest of the acid into the formation.

D. Surface pressure should not exceed 2100 psi during the treatment, and the rate should be held constant at 3 BPM unless the pressure limitation is exceeded, then the rate may be reduced accordingly to stay under the 2100 psi limit.
E. Swab back approximately 100 bbls. of load water.

10. Swab test the well for one day, report the results, and a decision will be made at this point whether to continue swab testing or not.

PHASE II

11. Release packer, pick up RBP and reset RBP at ±5337'.

12. RU Halliburton. Spot 100 gals. of MSA Acetic from 5232-5332'.

13. POH with treating packer and workstring.

14. RU Welex. Get on depth and perforate from 5325-32' with 1 JSPF (8 holes).

15. GIH with 5 1/2" treating packer and SN on 2 3/8" workstring, and set packer at 5200'.

16. RU Halliburton. Acidize well with 1200 gals. of 20% HCl-Fe acid in the following manner.

A. Pump 150 gals. of 20% HCl-Fe acid followed by two ball sealers.
B. Repeat Step A until all acid is used. A total of 14 ball sealers should be used unless ballout is achieved.
C. Same as Step 9C.
D. Same as Step 9D.
E. Swab back approximately 100 bbls. of load water.

17. Same as Step 10.

PHASE III

18. Release packer, pick up RBP and reset @ ±5315'.

19. RU Halliburton. Spot 100 gals. of MSA Acetic from 5202-5302'. POH with packer and workstring.

20. RU Welex. Get on depth and perforate from 5248-5302' w/1 JSPF (55 holes).

21. GIH with 5 1/2" treating packer & SN on 2 3/8" workstring, and set packer @ ±5150'.

22. RU Halliburton. Acidize well with 6000 gals. of 20% HCl-Fe acid in the following manner:.

    A. Pump 150 gals. of 20% HCl-Fe acid followed by two ball sealers.
    B. Repeat Step A until all acid has been pumped. A total of 78 ball sealers should be used unless ball out is achieved.
    C. Same as 9C.
    D. Same as 9D
    E. Swab back approximately 200 bbls. of fluid.

PHASE IV

23. Release packer, pick up RBP and reset RBP @ ±5243'.

24. RU Halliburton. Spot 100 gals. of 20% HCl-Fe from 5138' to 5238'. POH with workstring and packer.

25. RU Welex. Get on depth and perforate from 5168'-82', 5194'-5200', 5209'-15 & 5223'-5244' with 1 JSPF (46 holes).

26. GIH with 5 1/2" treating packer & SN on 2 3/8" workstring and set packer @ ±5100'.

27. RU Halliburton. Acidize well with 4600 gals. of MSA Acetic acid in the following manner:

    A. Pump 150 gals. of 20% HCl-Fe followed by two ball sealers.
    B. Repeat Step A until all acid has been pumped. A total of 60 ball sealers should be used unless ball out is achieved.
    C. Same as 9C.
    D. Same as 9D.
    E. Swab back approximately 200 bbls. of load water.

28. Same as Step 10.

29. Release packer, pick up RBP & POH.

30. Run in production equipment and put on line.

31. Test full interval on pumping unit to get a good production test on main pay.

NOTE: All acid used in this procedure should be Halliburton's 20% HCl-Fe, containing 5 gals/1000 Losurf-259 surfactant and 1 gal/1000 HAI-50 inhibitor. Also, a 1% Protex-All scale inhibitor solution should be added to all acid. Leave acid in formation 1 hour before swabbing operations begin.

Welex will do all the perforating in this procedure, and in all instances a 4" Hollow Carrier casing gun should be used loaded with deep penetrating 19 gm. charges (.49" diameter).

CNB:lw
cc: A. M. Omar

DESCRIPTION OF ANALYSIS PROCEDURE FOR PRESSURE CORES

(From a Core Laboratories brochure)

The growing significance of evaluating a reservoir for its susceptibility to one or a combination of conventional and exotic enhanced recovery techniques, as well as the economic feasibility of a long-range commitment, magnifies the value of obtaining accurate comprehensive formation data.

No two reservoirs are alike, either in material arrangement, flow mechanics, or fluid composition. Ideally, the nearer to an in situ condition core can be brought to the surface, preserved, and delivered to a lab for analysis, the more dependable the data.

This information plays an important role in Core Lab's Special Core Analysis Department enhanced recovery services, ranging from basic bench top evaluations of mobility control agents and surfactants to tertiary oil recovery tests on reservoir cores at reservoir temperature.

With the advent of manufacturers' improved design and performance of pressure core barrels, Core Lab has established extensive modern facilities in Dallas, Texas, for performing analysis of cores taken under pressure.

Cores are received at the laboratory encased in the inner core barrel in lengths of approximately three to 4½ feet – frozen in chests of dry ice. (The concept of preserving cores through use of the "quick freeze" technique was originally introduced by Core Lab.) Each length is placed in a dry ice-filled trough attached to a milling machine. Two diametrically opposed grooves are milled down the length of the steel tubing to a depth slightly less than the maximum tubing wall thickness. Liquid nitrogen is directed to the point of milling to ensure that the temperature of the tubing and the core remain at or below that of frozen carbon dioxide. The grooved tubing lengths containing the frozen core are immediately returned to the dry ice chest. The tubing is then wedged apart into two halves and removed from the core.

Drilling mud is removed from the core by chipping and abrasive action. As before, liquid nitrogen is periodically sprayed into the chest to ensure the proper cryogenic temperature.

Cores are then visually examined for lithological characteristics and samples are selected for analysis. Each sample consists of one or more full-diameter core segments having a total length of 12 inches, or less. Both ends of each core segment are faced with a diamond saw, again using liquid nitrogen to maintain the core in a frozen state.

The segments comprising a sample are placed in thin-walled metal thimbles, quickly weighed, and placed in a low-temperature retort which is closed immediately. This retort and its attached fluid-collecting system are evacuated for 45 seconds to remove as much air as possible before gas begins to evolve from the rock. The system is then sealed and the frozen core is allowed to thaw at room temperature. Water and oil expelled by the evolving gas are collected in a graduated receiving tube, while the gas is collected in the retort void space and in an attached gas-collecting cell. This system is equipped with a gauge to allow monitoring the pressure inside both the retort and fluid-collection system.

Barometric pressure, room temperature, retort pressure, and produced liquid volumes are recorded periodically. Thawing of the core is considered complete when consecutive readings indicate no additional liquids or gas are being expelled. Portions of the gas in the retort and in the gas cell are collected separately for analysis to determine gas gravity and the mole percent of various components. Collected volumes of oil and water are also measured, as well as the chloride content of the produced water.

Upon completion of this phase of testing, the sample and its thimble are removed from the retort, weighed, and placed in a Dean-Stark (toluene distillation) apparatus. The remaining water content in the cores, as well as some additional oil are removed. When this process is completed, the volume of water recovered is measured.

The sample is removed from the Dean-Stark apparatus and placed in a vacuum oven at 240°F to dry. When drying is complete, the sample is allowed to cool in the presence of a desiccant and then reweighed. The volume of additional oil extracted is determined gravimetrically, using a stock tank oil density corrected to room temperature. The volume of water distilled is corrected to reflect the equivalent volume of water having the same salinity as the retorted water indicated by the chloride determination.

The core is taken from the thimble, all loose grains are removed from each segment of core, and the segments are encased in surgical stocking material to minimize grain loss. The cores are then subjected to further extraction, using carbon dioxide-charged toluene heated to 180°F to extract any remaining oil. When this step is completed, the cores are leached with carbon dioxide-charged methanol to remove the salt content.

(Continued)

Weight loss occurring during the extraction and leaching processes, corrected for salt content, is the weight of oil removed which is then converted into a volumetric value, using the above mentioned oil density.

Porosities and horizontal and vertical air permeabilities are determined on each core segment. Liquid saturations at stock tank conditions are calculated by using the measured total pore volume of all core segments and the total oil and water contents recovered from these segments. The volume of gas collected from the sample is determined from the known volume of the retort and fluid collection system, corrected for the grain and thimble volumes, as well as the total liquid and salt contents. This gas volume is further corrected to standard conditions.

During the course of some pressure coring operations, drilling fluid is tagged with a tracer such as tritium. This is done to afford some insight as to the degree of flushing of the core by mud filtrate. Under such circumstances, additional core samples are selected for analysis. These samples, each a full-diameter core segment about 1½ to 2 inches in length, are picked at specified depth intervals to determine the tritium content of the pore water. A cylindrical plug is drilled concentrically to the diameter of each frozen core segment, and hence along its vertical axis. Liquid nitrogen is used as a bit lubricant to sustain proper cryogenic temperature level.

Water contents in the drilled plug and in the resulting "donut" portion of the core are recovered separately by the Dean-Stark method, and both portions of the water are analyzed for the presence of tritium. These data, together with the tritium content of the mud system, are used to determine the degree of filtrate invasion which, in turn, is useful in evaluating saturations measured in the cores. Porosities of the plug and the "donut" portion are measured, as well as the vertical air permeability of the plug.

Special Core Analysis Study

for

GRUY FEDERAL, INC.

Bennett Ranch Unit No. 310 Well
Wasson Field
Yoakum County, Texas

Gruy Federal, Inc.
2500 Tanglewilde, Suite 150
Houston, Texas 77063

Attention: Mr. John H. Goodrich

Subject: Special Core Analysis Study
Bennett Ranch Unit No. 310 Well
Wasson Field
Yoakum County, Texas
File Number: SCAL-79367P

Gentlemen:

This report presents the results of core analysis measurements performed on San Andres Formation recovered from the subject well, as authorized by your Purchase Order No. 3027-41.

The cores used in this study were recovered using pressure-retaining coring equipment and water-base mud tagged with tritium as a tracer. This tracer was used as an aid to determine the degree of flushing of the core by the mud filtrate. Also, prior to coring certain depth intervals, the inner core barrel was filled with a low invasion gel treated with sodium nitrate as a tracer. This gel was used in an effort to minimize filtrate invasion of the core after it entered the barrel. The sodium nitrate tracer served to evaluate its effectiveness. This gel, however, was reported to have not been used to core the intervals 5181-5190 feet, 5207-5216 feet, and 5224-5259 feet.

All of the cores recovered under pressure at the surface were frozen at the well site. These frozen cores, which were still encased in the inner core barrel, were packed in chests of dry ice and transported to our Dallas laboratory.

Full-diameter segments of the recovered core were selected for analysis by a low temperature retort method. In addition, certain portions of the recovered core were chosen for testing to determine the concentrations of the tracers, mentioned above, in the pore water. Procedures for preparing the cores for analysis, as well as the analysis procedures, are presented on Pages 1 through 5.

The data obtained on the full-diameter samples are tabulated on Pages 6 through 22, along with the lithological descriptions. The analysis results of the gas collected from these samples during pressure depletion are given on Pages 23 through 29. Some of the components of the gas collected from certain of the cores were not measurable due to the limited volume of evolved gas. The chloride contents of the pore water expelled during pressure depletion are tabulated on Pages 30 through 32.

Permeability, porosity, and water saturation data measured on the portions of core selected for the tracer concentration determinations are given on Pages 33 through 35. As indicated, these results were obtained on "plugs" and "donuts". The plug represents the inner portion of the full-diameter core while the donut represents the outer core portion encompassing the plug. This method of core sampling was utilized to provide a means of evaluating the depth and degree of filtrate invasion into the full-diameter core.

The sodium nitrate concentrations measured on the pore water of the above samples are reported on Pages 36 through 38. The data obtained on the plugs and donuts between the depths 5181.0 feet and 5256.9 feet are questionable due to the fact that significant sodium nitrate concentrations were measured on some of these samples even though they were reportedly not exposed to the low invasion gel during coring operations.

The tracer concentration determined on the pore water of a plug is normally equal to or lower than the concentration measured on the companion donut sample. For the most part, this is evident in the data determined on the plugs and donuts analyzed below the depth of 5270.05 feet. In several instances, however, the sodium nitrate content of the plug pore water was found to be higher than in the donut. It is surmised that this may have been due to the heterogeneous pore geometry usually associated with carbonate formations. However, except for the anomalous data, the tracer concentrations measured on this lower zone, compared to the tracer content of the gel filtrate, indicates the filtrate invasion was only moderate in the peripheral portion of the core.

The samples of pore water containing the tritium were submitted to Teledyne Isotopes, Inc., for analysis. Hence, the tritium concentration data are not included in this report, but will be submitted to you by Teledyne Isotopes, Inc.

It was a pleasure working with you on this study. Should you have any questions pertaining to these test results, or if we could be of further assistance, please do not hesitate to contact us.

Very truly yours,

Core Laboratories, Inc.

C. W. Marquis
Production Research
for Duane L. Archer, Manager
Special Core Analysis

CWM:mkr
20 cc. - Addressee

Core Preparation Procedures

1. Core samples, encased in steel tubing and frozen in chests of dry ice, were submitted to our Dallas laboratory.

2. Each length of tubing-encased frozen core was placed in a dry ice filled trough attached to a milling machine. Two diametrically opposed grooves were milled down the length of the steel tubing to a depth slightly less than the wall thickness of the tubing. Liquid nitrogen was directed at the point of milling to ensure that the temperature of the tubing and core was maintained at or below that of frozen carbon dioxide.

3. The grooved tubing and encased frozen core were returned to the dry ice chest. The tubing, after being separated into two halves by wedging a tool into the milled grooves, was removed from the frozen core.

4. Drilling mud and/or low invasion gel was removed from the frozen core by chipping and abrasive action. As before, liquid nitrogen was sprayed periodically into the chest to ensure that the proper cryogenic temperature was maintained.

5. The cores were visually examined for lithological characteristics and samples were selected for analysis. One group of selected samples was specified for testing using a low-temperature retort method. The other group of cores was designated for use in determining tracer concentrations in the pore water.

6. Both ends of each selected core segments were faced with a diamond saw using liquid nitrogen to maintain the segment in a frozen state. The faced frozen core segments were stored under dry ice while awaiting testing.

Low Temperature Retort Procedures

1. The faced frozen core segments, comprising a retort sample, were placed in a thin-walled metal thimble, quickly weighed, and placed in a low temperature retort. The retort was closed immediately.

2. The retort and its attached fluid-collecting system were evacuated for 45 seconds to remove as much air as possible before gas began to evolve from the core. The system was then sealed and the frozen core allowed to thaw to room temperature.

3. Water and oil expelled by the evolving gas were collected in a graduated receiving tube.

4. The evolved gas was collected in the void space in the retort. The system is equipped with a gauge to allow monitoring of the pressure inside the retort. If the retort pressure exceeded 0 psig, an attached and previously evacuated gas-collection cell was then connected to the retort to collect additional evolved gas.

5. Barometric pressure, room temperature, retort pressure, and produced liquid volumes were recorded periodically. Thawing of the core was considered complete when consecutive readings indicated no additional liquid or gas were being produced.

6. Portions of the evolved gas were collected separately from the retort and from the gas-collection cell, if used. The gas samples were analyzed to determine gas gravity and mole percent of the various components. The volumes of oil and water collected were also measured. The chloride content of the produced water was determined.

7. Upon completion of this phase of testing, the sample and its thimble were removed from the retort, weighed, and placed in a Dean-Stark (toluene distillation) apparatus. The remaining water content of the core, as well as some additional oil, were removed by toluene distillation.

8. When distillation was complete, the volume of water recovered was measured volumetrically. The sample and the thimble were removed from the Dean-Stark apparatus and placed in a vacuum oven at 240°F to remove the toluene. When drying was complete, the sample and thimble were removed from the oven and allowed to cool in the presence of a desiccant and then reweighed.

9. The volume of additional oil extracted was determined gravimetrically using the stock tank oil density (corrected to room temperature) of 0.876 gram/cc as was indicated by analysis of retorted oil. The volume of water distilled was corrected to reflect the equivalent volume of water having the same salinity as the retorted water, as was indicated by the chloride determination.

10. The core was removed from the thimble. All loose grains were removed from each segment of core, and the segments were encased in surgical stocking material to minimize grain loss. The cores were then subjected to further extraction using carbon dioxide-charged toluene heated to 180°F to extract any oil still remaining in the core. When this extraction process was complete, the cores were leached with carbon dioxide charged methanol to remove the salt content. The weight loss occurring upon the extraction and leaching process, corrected for the salt content, was taken as the weight of oil removed which was converted into a volumetric value using the above mentioned oil density.

11. Porosities and, when possible, horizontal and vertical air permeabilities were measured on each core segment.

12. Liquid saturations at stock tank conditions were calculated using the measured total pore volume of all of the core segments comprising the retort sample and the total oil and water contents recovered from these segments. The volume of gas collected from the sample was determined from the known volume of the retort and fluid-collection system, corrected for the grain and thimble volumes as well as the total liquid and salt contents. This gas volume was further corrected to standard conditions.

Tracer Sample Analysis Procedures

1. A cylindrical plug was drilled from each frozen core segment selected for tracer concentration determinations. The plug was drilled concentrically to the circumference of the core segment and, hence, along its vertical axis. Liquid nitrogen was used as the bit lubricant to ensure the core remained at the proper cryogenic temperature level. The drilled plug and the remaining portion of the core segment, herein after referred to as the "donut," were sawed in half so as to provide a pair of plugs and a pair of donuts. Again, liquid nitrogen was used as the saw lubricant to maintain the proper cryogenic temperature level. The two sets of samples were labeled and returned to the freeze chest.

2. The sodium nitrate content in the pore water of one plug and one donut was determined separately by the Brucine method. These tracer content values were converted to parts per million concentrations on the basis of the water content of the adjacent plug and donut samples. Sodium nitrate tracer concentration determinations were preformed on filtrate obtained from submitted samples of drilling mud and low invasion gel.

3. The other plug and donut were removed from the freeze chest, quickly weighed, and immediately returned to the freeze chest for transport to the Dean-Stark (toluene distillation) apparatus. Metal extraction thimbles to be used with these samples to minimize grain loss were also weighed.

4. The plug and donut samples were removed from the freeze chest, quickly inserted into their respective thimbles, and placed in their individual Dean-Stark sample chambers. The chambers were closed immediately. Heat was applied to the toluene, and distillation of the water contents from the cores commenced.

5. When distillation was complete, the volume of water recovered from each sample of core was recorded. The heat was removed from the apparatus and the samples were allowed to cool to room temperature while inside the sample chambers. The water recovered from each sample was transferred to a glass bottle which was subsequently sealed. The bottle and its contained water were submitted to Teledyne Isotopes, Inc., for determinations of the tritium content of the recovered water.

6. The plug and the donut sample were weighed while in their thimbles to determine their individual weight loss.

7. All loose grains were removed from the plug and donut samples. The samples, after being encased in surgical stocking meterial to minimize grain loss, were subjected to further extraction and leaching using CO_2-charged toluene and methanol. The samples were dried and their porosities measured. Water saturations for the plug and donut sample were calculated from the volume of water, corrected for salinity, recovered during the toluene distillation. The air permeability of the plug was measured.

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Full-Diameter Core Analysis Data of Pressure-Retained Cores

Depth, feet	Air Permeability, md Horizontal Max.	Horizontal 90°	Vertical	Porosity, Percent	Pore Volume, cc	Grain Density, gm/cc	Stock Tank Fluid Saturations, Percent Pore Space Oil*	Oil**	Water	Description
5181.3 -82.0	0.69	0.62	0.06	6.9	42.6	2.86	25.0	64.5	10.0	Dol, brn, med xln, dns, sl/frac, sl/pp vugs, sl/anhy
5182.0 -83.05	1.1	0.72	0.49	5.4	44.9	2.85	11.6	49.0	30.7	Dol, brn, med xln, dns, sl/frac, tr/pp vugs, sl/anhy
	***	1.1	***			2.82				Dol, brn, med xln, dns, vert frac, sl/anhy
	0.15	0.04	0.38			2.85				Dol, dk brn, med xln, dns, frac, shly lam, v/anhy
5183.05-84.1	0.15	0.09	0.30	3.5	21.1	2.87	0	7.3	62.1	Dol, gry, med xln, dns, sl/frac, shly lam, anhy
	1.3	0.68	0.03			2.84				Dol, gry, med xln, dns, sl/frac, anhy
5184.1 -84.7	1.0	0.41	0.06	4.7	18.0	2.90	0	17.6	71.3	Dol, gry, med-crs xln, dns, sl/frac, v/anhy
	2.9	0.51	0.06			2.89				Dol, gry, med-crs xln, dns, v/anhy
5185.6 -86.5	2.1	1.7	0.02	6.3	15.5	2.85	28.5	58.5	34.1	Dol, gry, med xln, dns, pp vug, anhy
5186.5 -87.4	0.15	0.11	0.2	2.5	7.8	2.90	0	32.1	35.9	Dol, gry, med xln, dns, v/anhy
5188.0 -88.7	0.37	0.18	0.2	3.3	18.0	2.89	0	12.4	61.1	Dol, gry, med xln, dns, frac, anhy
5188.7 -89.55	1.1	0.2	<0.01	3.5	24.6	2.86	0	24.1	53.1	Dol, gry, med xln, dns, sl/frac sl/anhy
	0.14	0.11	<0.01			2.88				Dol, gry, med xln, dns, anhy
5208.6 -09.1	0.24	0.16	<0.01	3.9	11.2	2.92	0	36.6	44.2	Dol, gry, crs-med xln, dns, v/anhy

*By pressure depletion
**Total oil
***Open Vertical Fracture

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Full-Diameter Core Analysis Data of Pressure-Retained Cores

Depth, feet	Air Permeability, md Horizontal Max.	Horizontal 90°	Vertical	Porosity, Percent	Pore Volume, cc	Grain Density, gm/cc	Stock Tank Fluid Saturations, Percent Pore Space Oil*	Oil**	Water	Description
5209.6 -10.5	0.37	0.32	<0.01	7.1	43.6	2.88	0.3	18.6	74.9	Dol, gry, med xln, dns, anhy
	0.55	0.26	0.07			2.88				Dol, gry, med xln, dns, sl/frac anhy
5210.5 -11.6	3.2	2.8	0.36	9.0	41.7	2.85	14.9	47.9	48.2	Dol, gry-dk gry, med, xln, dns, anhy
	1.7	1.2	1.4			2.85				Dol, gry, med xln, dns, anhy
5211.6 -12.55	195	2.9	825	8.7	50.5	2.86	7.6	53.0	43.9	Dol, gry-dk gry, med xln, dns, v/frac, sl/anhy
	0.77	0.58	<0.01			2.84				Dol, gry, med xln, dns, sl/frac, tr shly lam, sl/anhy
	1.2	0.67	0.17			2.82				Dol, gry, med xln, dns, tr shly lam
5213.8 -14.55	3.9	3.7	0.56	9.2		2.86	17.7	56.9	29.7	Dol, gry, med xln, dns, frac, pp vugs, anhy
5214.75-15.45	1.7	1.2	0.06	8.3		2.82	12.4	60.7	24.8	Dol, gry, med xln, dns, frac, sl/pp vugs, sl/anhy
5216.0 -17.25	0.10	0.09	0.09	4.2		2.88	12.2	33.6	45.2	Dol, gry, med-crs xln, dns, v/anhy
5217.55-18.5	0.15	0.10	<0.01	3.1		2.84	0	12.4	63.8	Dol, gry, med xln, dns, frac, anhy
	2.9	2.9	<0.01			2.86				Dol, gry, med xln, dns, sl/anhy
5218.5 -19.2	0.05	0.05	<0.01	1.6		2.86	0	19.1	60.2	Dol, gry, med xln, dns, sl/anhy
	0.11	0.06	<0.01			2.87				Dol, gry, med xln, dns, sl/anhy
	0.07	0.07	<0.01			2.83				Dol, gry, med xln, dns, sl/anhy
5219.2 -20.2	2.10	0.09	0.03	2.9	18.0	2.88	0	23.2	55.3	Dol, gry, med-crs xln, dns, anhy

*By pressure depletion
**Total oil

Full-Diameter Core Analysis Data of Pressure-Retained Cores

Depth, feet	Air Permeability, md Horizontal Max.	Air Permeability, md Horizontal 90°	Air Permeability, md Vertical	Porosity, Percent	Pore Volume, cc	Grain Density, gm/cc	Stock Tank Fluid Saturations, Percent Pore Space Oil*	Oil**	Water	Description
						2.84				Dol, gry, med xln, dns, anhy
5219.2 -20.2	0.25	0.13	<0.01							
5220.6 -21.85	0.64	0.64	0.05	2.7	14.1	2.92	0	19.4	65.5	Dol, gry, crs-med xln, dns, v/anhy
	71	0.45	2.3			2.86				Dol, gry, med xln, dns, vert frac, anhy
	0.06	0.06	0.15			2.90				Dol, gry, med xln, dns/ v/anhy
5221.85-22.55	0.09	0.07	0.05	1.7	10.6	2.88	0	18.2	69.3	Dol, gry, med xln, dns, v/anhy
5224.0 -24.85	0.11	<0.01	0.02	3.5	19.1	2.85	0.9	33.7	48.3	Dol, gry, med xln, dns, anhy
	0.05	0.03	<0.01			2.83				Dol, gry, med xln, dns, sl/anhy
5224.85-25.8	0.20	0.19	<0.01	6.7	60.2	2.85	35.2	59.6	32.5	Dol, gry, med xln, dns, anhy
5227.05-28.15	0.27	0.27	0.07	8.5	66.5	2.83	32.8	63.1	27.4	Dol, gry, med xln, dns, frac, sl/anhy
	0.83	0.63	0.19			2.88				Dol, gry, med xln, dns, anhy
5228.7 -30.05	0.45	0.40	0.31	8.5	66.8	2.83	29.8	62.9	25.5	Dol, gry, med xln, dns, sl/anhy
	0.31	0.26	0.15			2.84				Dol, gry, med xln, dns, sl/frac, v/anhy
	0.34	0.23	<0.01			2.89				Dol, gry, med xln, dns, anhy
5230.05-30.6	0.05	0.03	0.03	7.0	31.8	2.93	23.6	46.9	24.2	Dol, gry, med xln, dns, anhy
5230.6 -31.55	0.12	0.08	<0.01	5.0	46.7	2.86	36.3	64.2	30.7	Dol, gry, med-crs xln, dns,
5231.55-32.1	0.68	0.39	0.07	8.1	37.0	2.87	38.7	65.2	18.7	Dol, gry, med xln, dns, sl/frac, sl/anhy
5232.1 -33.0	0.21	0.21	<0.01	6.4	40.0	2.87	25.8	53.1	30.7	Dol, gry, med xln, dns, tr shly lam, tr pp vugs, sl/anhy
5233.0 -33.95	0.46	0.36	0.15	7.1	45.4	2.84	25.3	49.0	42.0	Dol, gry, med xln, dns, anhy
5238.05-39.3	8.5	8.5	2.2	10.5	63.7	2.85	23.7	54.9	41.5	Dol, gry, med-crs xln, dns, anhy
	5.0	3.8	2.4			2.88				Dol, gry, med-crs xln, dns, sl/frac, anhy

*By pressure depletion
**Total oil

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Petroleum Reservoir Engineering
DALLAS, TEXAS 75247

Full-Diameter Core Analysis Data of Pressure-Retained Cores

Depth, feet	Air Permeability, md Horizontal Max.	Air Permeability, md Horizontal 90°	Air Permeability, md Vertical	Porosity, Percent	Pore Volume, cc	Grain Density, gm/cc	Stock Tank Fluid Saturations, Percent Pore Space Oil*	Oil**	Water	Description
5238.05-39.3	2.0	1.9	0.67			2.91				Dol, gry, med-crs xln, dns, v/anhy
5239.3 -40.15	0.71	0.65	0.62	9.4	63.9	2.84	31.6	53.9	32.1	Dol, gry, med-crs xln, dns, anh
	0.40	0.36	0.33			2.88				Dol, gry, med-crs xln, dns, anhy
5240.15-40.95	0.42	0.39	0.12	9.1	63.9	2.85	21.9	49.0	37.7	Dol, gry, med-crs xln, dns, anhy
	2.7	1.3	4.2			2.83				Dol, gry, med-crs xln, dns, anhy
5250.0 -51.0	1.3	1.1	0.43	12.1	99.5	2.82	20.1	54.3	34.4	Dol, gry, med xln, dns, tr anhy
	2.5	2.5	1.4			2.83				Dol, gry, med xln, dns, sl/anhy
	1.4	0.98	<0.01			2.89				Dol, gry, med xln, dns, sl/ pp vug, sl/anhy
5251.0 -51.9	2.1	1.9	0.15	12.8	103.2	2.87	21.9	54.8	34.1	Dol, gry, med xln, dns, pp vugs sl/frac, sl/anhy
5251.9 -53.0	3.9	2.4	0.62	11.3	85.3	2.82	12.2	51.3	41.0	Dol, gry, med xln, dns, pp vug, tr anhy
	0.32	0.26	0.17			2.82				Dol, gry, med xln, dns, frac, pp vugs, shly lam, anhy
5253.0 -54.0	0.27	0.27	0.06	4.0	33.9	2.78	22.0	63.9	31.4	Dol, gry, med xln, dns, frac, v/shly lam, anhy
	0.05	0.05	0.03			2.78				Dol, gry, med xln, dns, frac, v/shly lam, anhy
	0.12	0.08	0.06			2.86				Dol, gry, med xln, dns, pp vug, sl/shly lam, anhy
5254.0 -55.1	6.6	0.45	0.32	8.7	72.4	2.86	28.6	63.6	25.3	Dol, gry, med xln, dns, pp vugs anhy
	0.52	0.41	<0.01			2.86				Dol, gry, med-crs xln, dns, pp vugs, v/anhy
5255.1 -55.85	0.28	0.18	0.06	8.8	58.4	2.85	26.1	61.3	25.2	Dol, gry, med xln, dns, pp vugs, anhy

*By pressure depletion
**Total oil

Full-Diameter Core Analysis Data of Pressure-Retained Cores

Depth, feet	Air Permeability, md Horizontal Max.	Horizontal 90°	Vertical	Porosity, Percent	Pore Volume, cc	Grain Density, gm/cc	Stock Tank Fluid Saturations, Percent Pore Space Oil*	Oil**	Water	Description
5255.1 -55.85	1.3	1.2	0.70			2.84				Dol, gry, med xln, dns, sl/pp vugs, anhy
5255.85-56.7	2.7	1.6	0.12	11.2	52.8	2.83	16.3	52.8	33.2	Dol, gry, med xln, dns, sl/frac, sl/shly lam, anhy
	0.42	0.24	0.21			2.86				Dol, gry, med xln, dns, sl/frac, sl/shly lam, anhy
5256.9 -57.6	3.1	1.2	0.19	9.0	45.4	2.83	13.5	56.4	31.0	Dol, gry, med xln, dns, sl/frac sl/shly lam, anhy
5258.25-59.0	0.07	0.07	0.02	5.9	37.0	2.91	22.8	52.7	24.1	Dol, gry, med-crs xln, dns, sl/pp vugs, anhy
	0.18	0.15	0.05			2.92				Dol, gry, med xln, dns, sl/pp vugs, v/anhy
5267.0 -67.75	4.3	3.7	0.31	10.3	51.8	2.79	12.0	46.8	39.3	Dol, gry, med xln, dns, frac, shly lam, anhy
	0.52	0.46	0.21			2.86				Dol, gry, med xln, dns, vert frac, sl/anhy
5267.75-68.70	3.5	3.5	3.9	12.5	70.6	2.85	24.3	49.0	34.4	Dol, gry, med xln, dns, frac, sl/pp vugs, anhy
5268.7 -70.05	2.8	2.1	1.2	12.0	53.4	2.85	29.2	58.0	34.7	Dol, gry, med xln, dns, sl/frac anhy
	1235	0.47	43			2.83				Dol, gry, med-crs xln, dns, vert frac, anhy
5271.6 -72.35	0.1	0.1	0.03	4.6	22.6	2.90	0	36.9	52.7	Dol, gry, crs-med xln, dns, frac, v/anhy
	0.61	0.51	0.13			2.86				Dol, gry, med xln, dns, frac, v/anhy
5272.35-73.0	0.18	0.18	0.02	5.8	26.8	2.85	1.6	32.6	59.6	Dol, gry, med-crs xln, dns, frac, anhy

*By pressure depletion
**Total oil

CORE LABORATORIES, INC.
Petroleum Reservoir Engineering
DALLAS, TEXAS 75247

Full-Diameter Core Analysis Data of Pressure-Retained Cores

Depth, feet	Air Permeability, md Horizontal Max.	90°	Vertical	Porosity, Percent	Pore Volume, cc	Grain Density, gm/cc	Stock Tank Fluid Saturations, Percent Pore Space Oil*	Oil**	Water	Description
5272.35-73.0	0.56	0.43	0.37			2.84				Dol, gry, med xln, dns, sl/anhy
5273.75-75.95	3.7	2.8	1.1	12.6	73.9	2.87	23.1	49.9	35.3	Dol, gry, med xln, dns, frac, anhy
	1.02	0.51	1.9			2.85				Dol, gry, med xln, dns, frac, anhy
5275.95-76.0	3.8	3.8	0.95	12.1	55.7	2.86	26.3	50.8	38.4	Dol, gry, med xln, dns, sl/frac, anhy
	4.5	3.9	0.55			2.88				Dol, gry, med xln, dns, sl/frac, anhy
5276.0 -77.05	2.4	2.1	1.0	12.3	75.4	2.86	26.1	48.5	38.7	Dol, gry, med xln, dns, frac, anhy
	1.7	1.5	0.19			2.87				Dol, gry, med xln, dns, sl/pp vugs, anhy
5277.05-77.95	4.3	3.4	2.4	16.2	116.2	2.85	18.5	50.2	33.2	Dol, gry, med xln, dns, sl/pp vugs, anhy
	6.1	5.5	5.7			2.82				Dol, gry, med xln, dns, tr pp vugs, anhy
	4.6	4.0	1.5			2.82				Dol, gry,med xln, dns, frac, shly lam, anhy
5277.95-79.0	11	0.83	1.08	7.0	62.0	2.83	19.8	48.4	44.1	Dol, gry, med xln, dns, frac, sl/pp vugs, anhy
	4.6	0.09	0.21			2.85				Dol, gry, med xln, dns, sl/frac, pp vugs, anhy
5279.0 -80.0	733	0.46	0.75	9.3	63.2	2.83	36.8	59.5	28.1	Dol, gry, med xln, dns, v/frac, sl/pp vugs, anhy

*By pressure depletion
**Total oil

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Full-Diameter Core Analysis Data of Pressure-Retained Cores

Depth, feet	Air Permeability, md Horizontal Max.	Horizontal 90°	Vertical	Porosity, Percent	Pore Volume, cc	Grain Density, gm/cc	Stock Tank Fluid Saturations, Percent Pore Space Oil*	Oil**	Water	Description
5279.0 -80.0	2.5	2.1	3.4			2.85				Dol, gry, med xln, dns, frac, sl/pp vugs, anhy
	5	1.5	0.45			2.84				Dol, gry, med xln, dns, sl/pp vugs, anhy
5280.2 -81.0	2.8	1.8	0.68	12.6	73.9	2.86	20.1	48.6	31.0	Dol, gry, med xln, dns, frac, sl/pp vugs, tr shly lam, anhy
5289.0 -89.75	3.7	3.2	2.8	14.9	72.3	2.84	14.0	48.1	42.4	Dol, gry, med xln, dns, frac, sl/pp vugs, tr shly lam, anhy
	6.5	6.2	1.1			2.82				Dol, gry, med xln, dns, frac, sl/pp vugs, tr shly lam, anhy
5289.75-90.95	4.9	4.9	2.9	16.1	137.6	2.86	23.6	50.7	36.8	Dol, gry, med xln, dns, sl/pp vugs, anhy
	14.5	6.3	3.0			2.87				Dol, gry, med xln, dns, pp vugs, anhy
5290.95-92.0	4.7	4.6	0.22	10.1	82.0	2.86	26.2	49.0	40.2	Dol, gry, med xln, dns, frac, sl/pp vugs, anhy
	5.3	5.0	1.2			2.89				Dol, gry, med xln, dns, sl/pp vugs, anhy
5292.0 -92.85	2.4	2.3	0.89	15.6	119.8	2.91	34.3	44.1	37.8	Dol, gry, med xln, dns, frac, sl/pp vug, anhy
5293.1 -94.05	1.4	1.2	0.31	11.6	89.2	2.88	36.7	54.1	31.7	Dol, gry, med xln, dns, sl/pp vugs, anhy
5294.05-94.9	1.9	1.7	0.32	11.0	90.7	2.85	24.3	48.1	37.9	Dol, gry, med xln, dns, sl/pp vugs, tr shly lam, anhy
5294.9 -96.15	1.5	1.2	0.32	13.9	118.6	2.85	25.6	54.6	37.2	Dol, gry, med xln, dns, tr pp vugs, anhy

*By pressure depletion
**Total oil

Full-Diameter Core Analysis Data of Pressure-Retained Cores

Depth, feet	Air Permeability, md Horizontal Max.	Horizontal 90°	Vertical	Porosity, Percent	Pore Volume, cc	Grain Density, gm/cc	Stock Tank Fluid Saturations, Percent Pore Space Oil*	Oil**	Water	Description
5294.9 -96.15	10	9.2	6.9			2.84				Dol, gry, med xln, dns, sl/frac, sl/pp vugs, anhy
5296.15-96.95	8.8	7.8	9.3	15.5	110.9	2.84	21.3	54.5	32.1	Dol, gry, med xln, dns, sl/frac, sl/pp vugs, anhy
	7.0	6.7	10			2.87				Dol, gry, med xln, dns, sl/pp vugs, anhy
5297.0 -97.8	3.8	3.7	2.4	12.1	49.4	2.87	33.3	60.6	28.4	Dol, gry, med xln, dns, sl/pp vugs, anhy
5297.8 -98.95	16	11	3.7	11.4	70.6	2.92	13.3	38.7	40.7	Dol, gry, med xln, dns, frac, tr pp vugs, tr shly lam, anhy
	5.0	4.8	1.8			2.87				Dol, gry, med xln, dns, frac, tr shly lam, anhy
5298.95-5300.0	4.7	3.7	2.4	12.8	107.7	2.89	21.6	54.9	31.0	Dol, gry, med xln, dns, frac, tr pp vugs, anhy
	4.2	3.6	3.1			2.86				Dol, gry, med xln, dns, sl/frac, pp vug, anhy
5300.0 -00.9	1.9	1.7	1.1	9.9	62.0	2.85	24.7	48.7	35.4	Dol, gry, med xln, dns, sl/frac sl/pp vug, anhy
	2.1	0.84	2.6			2.85				Dol, gry, med xln, dns, sl/frac, tr pp vug, sl/anhy
5300.9 -01.85	1.5	1.5	0.61	11.6	98.4	2.82	27.3	54.8	31.0	Dol, gry, med xln, dns, frac, sl pp vug, sl/anhy
5301.85-02.95	2.9	2.1	0.73	12.3	109.5	2.85	19.3	46.5	36.1	Dol, gry, med xln, dns, frac, pp vugs, anhy
	3.3	3.2	1.2			2.86				Dol, gry, med xln, dns, sl/frac, pp vugs, anhy

*By pressure depletion
**Total oil

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Full-Diameter Core Analysis Data of Pressure-Retained Cores

Depth, feet	Air Permeability, md Horizontal Max.	90°	Vertical	Porosity, Percent	Pore Volume, cc	Grain Density, gm/cc	Stock Tank Fluid Saturations, Percent Pore Space Oil*	Oil**	Water	Description
5302.95-04.1	1.7	1.4	<0.01	11.8	89.7	2.87	35.0	54.8	24.0	Dol, gry, med xln, dns, sl/pp vugs, sl/anhy
5304.1 -04.9	1.6	0.70	0.46	9.6	62.2	2.84	25.4	41.8	36.9	Dol, gry, med xln, dns, sl/frac, pp vugs, sl/anhy
5305.0 -06.05	0.58	0.55	1.08	9.1	72.5	2.87	6.9	29.0	51.8	Dol, gry, med xln, dns, sl/frac tr pp vugs, sl/anhy
	3.7	0.76	0.27			2.87				Dol, gry, med xln, dns, frac, sl/pp vugs, shly lam, anhy
5306.05-07.05	250	0.84	88	11.4	61.7	2.91	22.6	48.4	35.3	Dol, gry, med xln, dns, frac, pp vugs, anhy
	4.8	4.4	4.2			2.92				Dol, gry, med xln, dns, sl/frac, sl/pp vugs, anhy
	5640	1.24	67			2.82				Dol, gry, med xln, dns, frac, pp vugs, anhy
5307.05-08.05	4.4	1.7	0.28	8.9	67.2	2.90	23.8	46.7	43.4	Dol, gry, med xln, dns, frac, sl/pp vugs, anhy
5308.05-09.1	3.6	3.4	2.2	13.1	104.4	2.83	4.0	35.0	58.1	Dol, gry, med xln, dns, frac, anhy
5309.45-10.15	2.8	2.6	2.7	13.0	81.3	2.86	8.8	33.6	51.6	Dol, gry, med xln, dns, sl/frac, sl/pp vugs, anhy
5310.15-11.15	3.8	3.2	2.8	12.4	88.5	2.88	9.7	33.2	51.7	Dol, gry, med xln, dns, pp vugs, anhy
	5.8	5.4	3.5			2.87				Dol, gry, med xln, dns, pp vugs, sl/anhy
5311.15-12.15	18	17	2.56	11.8	102.5	2.86	17.1	38.4	47.9	Dol, gry, med xln, dns, pp vugs, anhy

*By pressure depletion
**Total oil

Full-Diameter Core Analysis Data of Pressure-Retained Cores

Depth, feet	Air Permeability, md Horizontal Max.	Air Permeability, md Horizontal 90°	Air Permeability, md Vertical	Porosity, Percent	Pore Volume, cc	Grain Density, gm/cc	Stock Tank Fluid Saturations, Percent Pore Space Oil*	Oil**	Water	Description
5311.15-12.15	3.4	2.7	1.3			2.88				Dol, gry, med xln, dns, pp vugs, anhy
5312.15-13.0	2.6	2.3	2.2	14.0	78.3	2.85	3.0	32.2	54.5	Dol, gry, med xln, dns, sl/frac, pp vugs, sl/anhy
5313.0 -13.95	1.5	1.2	0.96	13.3	53.1	2.85	0.7	29.4	60.9	Dol, gry, med xln, dns, sl/pp vugs, anhy
	1.9	1.7	1.6			2.82				Dol, gry, med xln, dns, tr pp vugs, anhy
5313.95-15.0	2.7	2.4	1.3	13.0	109.7	2.85	8.5	35.7	49.6	Dol, gry, med xln, dns, sl/frac, anhy
	12	4.3	5.8			2.88				Dol, gry, med xln, dns, frac, sl/pp vugs, anhy
5315.0 -16.0	3.5	3.2	4.1	12.4	57.2	2.86	1.5	25.1	62.5	Dol, gry, med xln, dns, sl/pp vugs, anhy
5316.0 -16.75	4.5	4.1	2.6	10.9	55.2	2.87	11.9	42.1	49.6	Dol, gry, med xln, dns, sl/pp vugs, anhy
	1.2	1.1	2.6			2.84				Dol, gry, med xln, dns, sl/frac, sl/pp vugs, anhy
5317.0 -18.0	0.30	0.30	0.03	8.3	67.3	2.86	9.0	24.6	46.6	Dol, gry, med xln, dns, sl/frac sl/pp vugs, anhy
5318.0 -19.0	0.45	0.45	<0.01	6.7	55.9	2.87	6.5	27.6	47.9	Dol, gry, med xln, dns, sl/frac tr pp vugs, sl/shly lam, anhy
	0.06	0.06	<0.01			2.82				Dol, gry, med xln, dns, sl/frac, shly lam, anhy
5319.0 -19.8	0.16	0.11	<0.01	5.1	30.7	2.85	0	30.7	41.8	Dol, gry, med xln, dns, shly lam, anhy

*By pressure depletion
**Total oil

Full-Diameter Core Analysis Data of Pressure-Retained Cores

Depth, feet	Air Permeability, md Horizontal Max.	90°	Vertical	Porosity, Percent	Pore Volume, cc	Grain Density, gm/cc	Stock Tank Fluid Saturations, Percent Pore Space Oil*	Oil**	Water	Description
5319.0 -19.8	0.26	0.20	0.06			2.84				Dol, gry, med xln, dns, sl/frac shly lam, sl/anhy
5320.1 -20.45	0.84	0.79	0.76	11.0	39.0	2.87	13.2	40.7	40.1	Dol, gry, med xln, dns, frac, sl/pp vugs, anhy
5321.0 -21.95	0.45	0.45	2.4	8.6	48.2	2.85	14.8	46.4	42.0	Dol, gry, med xln, dns, sl/frac tr pp vugs, sl/anhy
	0.62	0.25	0.40			2.85				Dol, gry, med xln, dns, frac, tr pp vugs, sl/anhy
5321.95-23.0	0.75	0.37	0.38	5.1	36.0	2.85	0	10.6	67.4	Dol, gry, med xln, dns, sl/frac, tr pp vugs, sl/shly lam, anhy
	3.0	0.89	0.61			2.86				Dol, gry, med xln, dns, frac, shly lam, sl/anhy
5323.0 -24.0	0.27	0.09	0.10	4.2	10.6	2.86	0	21.1	48.7	Dol, gry, med xln, dns, sl/frac shly lam, sl/anhy
5324.0 -25.0	0.68	0.27	0.11	4.1	30.9	2.86	0	14.6	56.4	Dol, gry, med xln, dns, sl/frac sl/shly lam, anhy
	0.25	0.20	0.16			2.84				Dol, gry, med xln, dns, sl/frac, anhy
5325.0 -26.0	0.10	0.10	0.04	5.0	23.9	2.82	2.9	37.5	53.0	Dol, gry, med xln, dns, tr shly lam, anhy
	0.36	0.27	0.14			2.82				Dol, gry, med xln, dns, sl/frac, tr pp vugs, anhy
5326.0 -26.9	7.3	6.3	6.7	12.4	82.7	2.86	15.3	37.1	44.7	Dol, gry, med xln, dns, frac, sl/pp vugs, anhy
5326.9 -28.0	12	12	11	13.3	50.3	2.85	9.2	40.1	48.1	Dol, gry, med xln, dns, pp vugs, anhy

*By pressure depletion
**Total oil

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Full-Diameter Core Analysis Data of Pressure-Retained Cores

Depth, feet	Air Permeability, md Horizontal Max.	90°	Vertical	Porosity, Percent	Pore Volume, cc	Grain Density, gm/cc	Stock Tank Fluid Saturations, Percent Pore Space Oil*	Oil**	Water	Description
5328.0 -29.0	4.9	4.5	3.9	11.8	72.2	2.86	12.8	40.5	48.8	Dol, gry, med xln, dns, sl/pp vugs, anhy
5329.0 -29.95	4.2	4.1	4.1	11.5	61.3	2.86	12.4	39.8	45.1	Dol, bf, med xln, dns, frac, sl/pp vugs, anhy
	2.7	2.7	2.7			2.87				Dol, bf, med xln, dns, sl/pp vugs, anhy
	***	4.5	528			2.87				Dol, bf, med xln, dns, vert frac, sl/pp vugs, anhy
5329.95-31.2	5.5	2.0	3.5	10.2	71.7	2.84	11.3	34.4	47.6	Dol, bf, med xln, dns, sl/frac, pp vugs, anhy
	0.45	0.39	<0.01			2.84				Dol, bf, med xln, dns, sl/frac, sl/pp vugs, tr shly lam, anhy
5331.6 -32.15	1.7	1.6	2.0	12.0	37.4	2.84	17.5	43.7	41.0	Dol, bf, med xln, dns, sl/pp vugs, anhy
5332.15-32.85	2.1	2.1	0.61	13.4	61.7	2.84	14.2	41.1	43.9	Dol, bf, med xln, dns, sl/pp vugs, anhy
	0.33	0.33	0.27			2.84				Dol, bf, med xln, dns, sl/frac, pp vugs, sl/shly lam, anhy
5332.85-33.65	0.84	0.78	0.13	10.9	60.6	2.82	19.4	46.3	39.9	Dol, bf, med xln, dns, sl/pp vugs, sl/shly lam, anhy
5333.85-34.35	0.90	0.85	0.45	11.8	77.4	2.83	14.0	43.5	44.0	Dol, bf, med xln, dns, frac, sl/pp vugs, sl/shly lam, anhy
5334.35-35.15	0.41	0.35	0.08	8.8	47.1	2.80	16.2	48.0	37.7	Dol, bf, med xln, dns, sl/frac, sl/pp vugs, sl/shly lam, anhy
5335.15-36.25	0.74	0.52	0.07	10.1	73.0	2.83	11.2	44.2	38.6	Dol, bf, med xln, dns, sl/frac, sl/pp vugs, sl/shly lam, anhy

*By pressure depletion
**Total oil
*** Open fracture

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Full-Diameter Core Analysis Data

Depth, feet	Air Permeability, md Horizontal Max.	Air Permeability, md Horizontal 90°	Air Permeability, md Vertical	Porosity, Percent	Pore Volume, cc	Grain Density, gm/cc	Stock Tank Fluid Saturations, Percent Pore Space Oil*	Oil**	Water	Description
5335.15-36.25	1.7	1.7	0.12			2.82				Dol, bf, med xln, dns, sl/pp vugs, shly lam, anhy
5338.0-39.15	0.64	0.50	0.07	8.4	24.6	2.88	23.1	42.8	32.4	Dol, bf, med xln, dns, sl/pp vugs, anhy
	2.7	2.3	0.03			2.88				Dol, bf, med xln, dns, sl/frac, sl/pp vugs, anhy
5342.05-42.95	2.3	1.2	1.1	6.6	46.0	2.84	8.8	35.1	48.9	Dol, bf, med xln, dns, sl/frac, sl/pp vugs, anhy
	0.32	0.16	0.03			2.81				Dol, bf, med xln, dns, sl/frac, sl/pp vugs, shly lam, anhy
5342.95-43.75	2.8	2.4	0.60	15.0	82.0	2.82	20.1	31.2	58.6	Dol, bf, med xln, dns, pp vugs, anhy
	2.5	2.5	0.13			2.86				Dol, bf, med xln, dns, sl/frac, pp vugs, anhy
5343.75-44.85	2.7	2.5	0.38	15.3	110.1	2.83	21.9	33.4	61.7	Dol, bf, med xln, dns, frac, sl/pp vugs, anhy
	6.3	6.0	3.0			2.87				Dol, bf, med xln, dns, sl/frac, sl/pp vugs, anhy
5344.85-45.7	2.8	2.8	0.56	16.5	120.7	2.82	19.3	39.3	49.1	Dol, bf, med xln, dns, sl/frac, sl/pp vugs, anhy
	5.5	5.3	2.7			2.86				Dol, bf, med xln, dns, sl/frac, sl/pp vugs, anhy
5346.0-47.55	8.9	8.7	6.7	18.8	85.7	2.83	13.1	39.5	51.1	Dol, bf, med xln, dns, frac, tr pp vugs, anhy
	11	11	4.7			2.83				Dol, bf, med xln, dns, sl/frac, tr pp vugs, anhy

*By pressure depletion
**Total oil

Full-Diameter Core Analysis Data of Pressure-Retained Cores

Depth, feet	Air Permeability, md Horizontal Max.	Horizontal 90°	Vertical	Porosity, Percent	Pore Volume, cc	Grain Density, gm/cc	Stock Tank Fluid Saturations, Percent Pore Space Oil*	Oil**	Water	Description
5347.8-49.05	9.2	8.7	3.9	17.8	102.3	2.83	5.2	25.1	64.7	Dol, bf, med xln, dns, frac, sl/pp vugs, sl/shly lam, anhy
	4.6	4.4	2.2			2.84				Dol, bf, med xln, dns, sl/pp vugs, anhy
5349.05-49.9	6.1	5.9	6.5	16.3	129.1	2.82	15.7	39.1	51.8	Dol, bf, med xln, dns, sl/frac, sl/vugs, anhy
	2.0	1.8	0.96			2.82				Dol, bf, med xln, dns, sl/frac, sl/pp vugs, anhy
5350.0-50.95	8.2	7.6	1.6	17.5	79.9	2.92	6.5	26.9	59.7	Dol, bf, med xln, dns, sl/frac, pp vugs, anhy
	10	8.8	13			2.83				Dol, bf, med xln, dns, sl/frac, pp vugs, anhy
5350.95-51.95	5.9	4.5	8.1	16.0	115.9	2.88	11.7	34.9	58.7	Dol, bf, med xln, dns, pp vugs, anhy
	5.0	2.6	5.3			2.86				Dol, bf, med xln, dns, sl/frac, sl/pp vugs, anhy
5351.95-52.95	1.9	1.8	0.99	13.4	86.2	2.87	10.0	34.6	52.9	Dol, bf, med xln, dns, tr pp vugs, anhy
	7.7	6.6	2.3			2.86				Dol, bf, med xln, dns, sl/frac, tr pp vugs, tr shly lam, anhy
	4.7	4.1	3.5			2.84				Dol, bf, med xln, dns, sl/frac, tr pp vugs, anhy
5352.95-54.0	6.1	4.2	3.0	15.3	103.3	2.84	10.0	32.2	54.4	Dol, bf, med xln, dns, sl/frac, tr pp vugs, anhy
	1.8	1.8	1.6			2.85				Dol, bf, med xln, dns, sl/pp vugs, anhy

*By pressure depletion
**Total oil

Full-Diameter Core Analysis Data of Pressure-Retained Cores

Depth, feet	Air Permeability, md Horizontal Max.	Air Permeability, md Horizontal 90°	Air Permeability, md Vertical	Porosity, Percent	Pore Volume, cc	Grain Density, gm/cc	Stock Tank Fluid Saturations, Percent Pore Space Oil*	Oil**	Water	Description
5352.95-54.0	2.7	2.1	1.8			2.84				Dol, bf, med xln, dns, tr pp vugs, anhy
5355.05-56.15	37	28	11	19.1	106.5	2.84	13.0	37.0	48.3	Dol, bf, med xln, dns, tr pp vugs, anhy
5356.15-57.0	60	52	40	21.6	121.9	2.86	6.7	34.2	56.0	Dol, bf, med xln, dns, sl/frac, tr pp vugs, anhy
	71	57	63			2.85				Dol, bf, med xln, dns, sl/frac, tr pp vugs, anhy
	52	49	32			2.84				Dol, bf, med xln, dns, sl/frac, anhy
5357.0 -58.1	19	17	16	19.3	111.9	2.83	3.6	25.6	59.8	Dol, bf, med xln, dns, anhy
	8.2	7.9	3.4			2.80				Dol, bf-gry, med xln, dns, sl/frac, anhy
5358.1 -58.9	13	13	8.2	19.0	78.5	2.83	1.3	27.1	62.5	Dol, bf, med xln, dns, sl/frac, anhy
	11	11	4.2			2.87				Dol, bf, med xln, dns, sl/frac, tr pp vugs, anhy
5358.9 -60.05	12	10	8.6	18.7	165.5	2.82	1.2	18.5	69.2	Dol, bf, med xln, dns, frac, tr shly lam, anhy
	11	11	3.0			2.80				Dol, bf-gry, med xln, dns, frac, shly stks, anhy
5358.9 -60.05	5.0	4.6	1.4			2.84				Dol, bf-gry, med xln, dns, frac shly lam, anhy
5360.05-61.1	3.7	2.6	2.4	13.5	109.7	2.87	5.1	21.9	63.4	Dol, bf-gry, med xln, dns, sl/frac, anhy

*By pressure depletion
**Total oil

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Depth, feet	Air Permeability, md Horizontal Max.	90°	Vertical	Porosity, Percent	Pore Volume, cc	Grain Density, gm/cc	Stock Tank Fluid Saturations, Percent Pore Space Oil*	Oil**	Water	Description
5360.05-61.1	2.9	2.7	0.50			2.86				Dol, bf-gry, med xln, dns, sl/frac, sl/pp vugs, anhy
5362.0 -62.8	5.0	3.5	1.4	14.9	61.2	2.84	21.5	39.9	45.6	Dol, bf, med xln, dns, sl/frac, tr pp vugs, anhy
5362.8 -63.9	5.7	4.8	3.5	16.0	121.1	2.86	10.0	28.4	55.8	Dol, bf, med xln, dns, sl/frac, tr pp vugs, anhy
	3.5	3.5	1.2			2.86				Dol, bf, med xln, dns, sl/frac, tr pp vugs, anhy
5364.2 -65.0	11	11	6.6	18.8	111.3	2.87	11.4	36.4	49.7	Dol, bf, med xln, dns, frac, tr pp vugs, anhy
5365.0 -65.8	17	15	6.9	18.3	81.2	2.82	6.3	28.9	59.9	Dol, bf, med xln, dns, sl/frac, tr pp vugs, anhy
	11	6.9	6.2			2.83				Dol, bf, med xln, dns, sl/frac, sl/pp vugs, anhy
5366.9 -67.95	16	15	5.0	15.6	81.5	2.85	0	23.3	63.0	Dol, bf, med xln, dns, tr shly lam, sl/anhy
	6.3	5.9	5.1			2.82				Dol, bf, med xln, dns, sl/frac, tr pp vugs, tr/shly lam, sl/anhy
5367.95-69.1	8.5	8.3	3.3	14.9	115.0	2.83	0.7	21.5	64.3	Dol, bf, med xln, dns, sl/frac, sl/pp vugs, tr/shly lam, sl/anhy
	3.9	3.6	1.4			2.82				Dol, gry, med xln, dns, tr/pp vugs, sl/anhy
5369.1 -70.1	6.4	5.2	0.20	18.6	152.0	2.75	0	15.7	68.2	Dol, gry, med xln, dns, frac, v/shly lam, sl/anhy
	9.6	9.6	5.7			2.85				Dol, bf, med xln, dns, frac, tr pp vugs, sl/anhy

*By pressure depletion
**Total oil

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Depth, feet	Air Permeability, md Horizontal Max.	Horizontal 90°	Vertical	Porosity, Percent	Pore Volume, cc	Grain Density, gm/cc	Stock Tank Fluid Saturations, Percent Pore Space Oil*	Oil**	Water	Description
5370.1-71.1	26	13	2.9	13.9	22.8	2.82	0	30.8	56.4	Dol, gry, med xln, dns, frac, sl/anhy
5371.1-71.9	21	20	2.9	14.8	73.1	2.85	1.1	31.0	59.8	Dol, bf, med xln, dns, sl/frac, sl/anhy
	18	16	17			2.82				Dol, bf, med xln, dns, sl/frac, sl/pp vugs, tr/shly lam, sl/anhy
5371.9-73.05	6.7	6.7	4.5	14.8	116.9	2.87	11.8	34.0	51.8	Dol, bf, med xln, dns, sl/frac, sl/pp vugs, sl/anhy
	5.9	5.3	3.5			2.81				Dol, bf, med xln, dns, tr pp vugs, tr shly lam, sl/anhy
5373.05-73.6	13	10	6.4	15.6	27.6	2.82	0	17.8	57.4	Dol, bf, med xln, dns, frac, shly lam, sl/anhy
5373.75-74.85	21	16	14	18.2	162.6	2.85	0	19.9	62.3	Dol, bf, med xln, dns, sl/frac, tr pp vugs, tr shly lam, sl/anhy
5375.2-76.1	34	28	30	17.8	137.4	2.84	0	19.4	65.7	Dol, bf, med xln, dns, sl/pp vugs, sl/anhy
	19	18	13			2.84				Dol, bf, med xln, dns, sl/pp vugs, anhy
5376.1-77.1	11	7.8	3.5	12.9	106.4	2.85	15.1	33.9	50.6	Dol, bf, med xln, dns, sl/frac, tr pp vugs, tr shly lam, sl/anhy
	1.6	1.0	0.93			2.88				Dol, bf, med xln, dns, pp vug, tr shly lam, anhy
5377.1-77.55	1.4	0.54	0.58	12.6	29.8	2.88	27.7	52.8	38.6	Dol, bf, med xln, dns, pp vug, anhy

*By pressure depletion
**Total oil

Analysis of Liberated Gas by Gas Chromatography

Depth, feet	Component Analysis, Mole Percent												Calc. Gas Gravity (Air=1.0)	Gas Volume cc @ STP
	H_2S	CO_2	N_2	C_1	C_2	C_3	IC_4	NC_4	IC_5	NC_5	C_6	C_{7+}		
5181.30-82.00	0.00	5.20	3.40	59.61	15.08	8.34	1.48	3.18	1.24	1.04	0.79	0.64	0.922	1972.8
5182.00-83.05	0.00	7.33	3.33	58.84	14.33	7.84	1.37	3.01	1.22	1.05	0.86	0.82	0.937	1552.3
5183.05-84.10	0.00	35.13	18.61	38.76	5.10	1.75	0.13	0.52	Trace	0.00	0.00	0.00	1.021	114.8
5184.10-84.70	0.00	30.74	26.11	32.96	6.10	2.69	0.40	1.00	Trace	Trace	0.00	0.00	1.035	82.1
5185.60-86.50	0.00	5.38	5.55	52.58	13.87	9.05	1.78	4.29	1.87	1.84	1.76	2.03	1.047	664.5
5186.50-87.40	0.00	29.16	55.52	13.12	1.59	0.61	0.00	0.00	0.00	0.00	0.00	0.00	1.079	31.4
5188.00-88.70	0.00	11.21	82.34	5.15	0.77	0.35	0.05	0.13	Trace	Trace	0.00	0.00	1.012	233.9
5188.70-89.55	0.00	40.34	30.51	23.64	3.44	1.48	Trace	0.59	0.00	0.00	0.00	0.00	1.109	58.4
5208.60-09.10	0.00	11.16	4.05	49.59	14.32	7.94	1.09	2.85	1.02	0.97	2.00	5.01	1.119	160.8
5209.60-10.50	0.00	19.55	6.28	48.47	12.36	6.64	0.87	2.31	0.82	0.74	1.04	0.92	1.022	218.0
5210.50-11.60	0.00	7.01	3.90	52.72	16.26	9.84	1.58	3.93	1.48	1.33	1.09	0.86	0.998	1210.3
5211.60-12.55	0.00	6.58	3.63	56.22	16.55	9.16	1.34	3.23	1.10	0.95	0.69	0.55	0.940	1753.2
5213.80-14.55	0.00	6.26	3.77	54.11	16.60	9.75	1.52	3.72	1.37	1.21	0.97	0.72	0.976	1582.6
5214.75-15.45	0.00	10.54	3.69	53.43	15.70	8.82	1.30	3.08	1.04	0.89	0.70	0.81	0.974	1531.9
5216.00-17.25	0.00	8.73	3.68	54.47	15.63	8.62	1.34	3.33	1.29	1.16	0.99	0.76	0.974	866.7
5217.55-18.50	0.00	53.88	22.07	20.37	2.76	0.92	0.00	0.00	0.00	0.00	0.00	0.00	1.188	53.2
5218.50-19.20	0.00	37.75	33.19	24.39	3.35	1.32	0.00	0.00	0.00	0.00	0.00	0.00	1.085	24.4
5219.20-20.20	0.00	51.03	27.69	19.04	1.79	0.45	0.00	0.00	0.00	0.00	0.00	0.00	1.174	63.4
5220.60-21.85	0.00	39.55	35.58	21.16	2.74	0.97	0.00	0.00	0.00	0.00	0.00	0.00	1.105	50.9
5221.85-22.55	0.00	83.29	5.50	10.14	0.92	0.15	0.00	0.00	0.00	0.00	0.00	0.00	1.387	15.7
5224.00-24.85	0.00	9.66	5.13	45.50	15.05	9.19	1.54	4.43	1.82	2.16	2.19	3.33	1.147	256.4
5224.85-25.80	0.00	5.33	3.34	49.88	17.25	11.41	1.96	5.29	1.71	1.79	1.14	0.90	1.041	1004.4
	0.00	5.43	4.61	56.01	16.67	9.61	1.40	3.53	0.96	0.96	0.52	0.30	0.929	2222.3
5227.05-28.15	0.00	5.44	3.34	48.23	18.33	12.50	1.98	5.26	1.60	1.65	0.98	0.69	1.042	1129.2
	0.12	5.38	3.72	58.65	16.62	8.87	1.22	3.01	0.78	0.77	0.50	0.36	0.903	2322.6
5228.70-30.05	0.00	5.83	2.96	47.77	18.57	12.61	1.97	5.23	1.64	1.63	1.04	0.75	1.050	1169.9
	0.14	5.93	3.38	58.36	16.63	8.80	1.20	2.99	0.79	0.79	0.55	0.44	0.910	2522.4
5230.05-30.60	0.00	6.63	3.24	49.50	17.15	11.15	1.81	4.81	1.65	1.77	1.36	0.93	1.045	1317.0
5230.60-31.55	0.16	5.45	2.45	47.43	17.54	12.32	2.08	5.70	1.91	2.06	1.51	1.39	1.090	821.3
	0.15	5.65	2.58	57.95	16.43	9.41	1.34	3.47	0.98	0.98	0.62	0.44	0.927	1903.7

Analysis of Liberated Gas by Gas Chromatography

Depth, feet	Component Analysis, Mole Percent												Calc. Gas Gravity (Air=1.0)	Gas Volume cc @ STP
	H_2S	CO_2	N_2	C_1	C_2	C_3	IC_4	NC_4	IC_5	NC_5	C_6	C_{7+}		
5231.55-32.10	0.00	5.95	3.25	51.56	17.55	11.04	1.70	4.35	1.37	1.43	0.99	0.81	1.007	2060.7
5232.10-33.00	0.01	7.78	2.97	51.59	17.64	10.48	1.61	3.95	1.23	1.26	0.86	0.62	0.996	1783.1
5233.00-33.95	0.00	5.32	3.52	51.34	17.84	11.18	1.72	4.42	1.37	1.44	1.02	0.83	1.007	2071.1
5238.05-39.30	0.00	5.06	2.58	38.56	18.58	16.21	2.65	7.15	2.41	2.67	2.10	2.03	1.213	996.4
	0.25	5.41	2.65	59.64	17.06	8.52	1.13	2.95	0.82	0.84	0.52	0.21	0.894	1850.5
5239.30-40.15	0.00	4.97	2.74	45.16	18.04	13.25	2.15	5.85	2.03	2.24	1.78	1.79	1.124	1099.3
	0.35	5.25	2.71	61.01	12.57	9.89	1.40	3.84	1.08	1.08	0.57	0.25	0.914	2129.7
5240.15-40.95	0.00	5.13	3.54	47.46	14.08	14.37	2.14	6.09	2.06	2.27	1.59	1.27	1.105	1035.3
	0.32	4.94	2.53	55.56	17.76	10.10	1.48	3.89	1.14	1.17	0.72	0.39	0.950	2055.6
5250.00-51.00	0.08	4.74	2.83	30.20	20.42	20.64	3.35	9.07	2.69	2.85	1.81	1.32	1.281	1098.5
	0.44	5.96	2.74	50.90	20.12	11.80	1.49	3.72	0.95	0.99	0.62	0.27	0.973	2229.8
5251.00-51.90	0.40	4.81	2.00	30.24	19.75	21.22	3.42	9.24	2.74	2.96	1.79	1.43	1.292	960.9
	0.00	7.49	3.65	40.36	24.52	14.58	1.78	4.49	1.12	1.13	0.54	0.34	1.059	559.6
5251.90-53.00	0.30	5.82	2.66	35.59	19.95	17.89	2.73	7.21	2.16	2.37	1.78	1.54	1.214	1201.5
	0.23	6.81	2.93	52.97	19.20	10.43	1.29	3.29	0.97	1.01	0.56	0.31	0.955	2549.9
5253.00-54.00	0.00	8.38	4.21	45.49	18.45	11.78	1.73	4.64	1.47	1.61	1.22	1.02	1.068	1528.6
5254.00-55.10	0.39	5.50	2.38	35.60	20.53	17.87	2.77	7.42	2.25	2.42	1.60	1.27	1.207	1087.2
	0.27	6.26	3.91	50.66	19.69	11.40	1.46	3.66	0.92	0.91	0.53	0.33	0.970	2248.6
5255.10-55.85	0.17	5.54	3.05	38.29	20.16	16.03	2.44	6.66	2.14	2.39	1.75	1.38	1.177	1002.1
	0.08	6.24	3.15	50.01	19.51	11.77	1.62	4.12	1.22	1.22	0.46	0.60	0.996	2072.1
5255.85-56.70	0.00	6.75	3.65	44.93	20.50	13.17	1.82	4.68	1.35	1.43	0.96	0.76	1.055	2310.4
5256.90-57.60	0.00	6.74	4.03	44.86	20.44	13.11	1.78	4.57	1.34	1.42	0.99	0.72	1.053	2178.5
5258.25-59.00	0.00	7.33	3.80	43.74	20.05	13.75	2.04	5.36	1.67	1.78	0.31	0.17	1.057	1475.9
5267.00-67.75	0.00	6.42	4.21	45.48	21.50	12.02	1.61	4.34	1.28	1.39	0.94	0.81	1.039	2189.8
5267.75-68.70	0.34	4.63	2.63	35.69	21.74	17.31	2.71	7.56	2.30	2.50	1.52	1.07	1.195	1327.9
	0.57	5.77	2.53	50.11	19.72	11.97	1.66	4.20	1.16	1.21	0.70	0.40	0.995	2449.8
5268.70-70.05	0.48	4.41	2.43	37.00	21.50	16.66	2.51	7.20	2.28	2.58	1.71	1.24	1.188	1114.8
	0.66	5.12	2.51	49.16	21.12	11.86	1.59	4.19	1.25	1.31	0.77	0.46	1.001	1935.3
5271.60-72.35	0.00	12.09	4.21	51.21	15.85	8.06	1.00	2.85	0.93	1.11	1.04	1.65	1.013	580.2
5272.35-73.00	0.00	8.79	4.35	47.18	17.51	10.35	1.43	4.00	1.38	1.61	1.58	1.82	1.071	598.5

Analysis of Liberated Gas by Gas Chromatography

Depth, feet	Component Analysis, Mole Percent												Calc. Gas Gravity (Air=1.0)	Gas Volume cc @ STP
	H_2S	CO_2	N_2	C_1	C_2	C_3	IC_4	NC_4	IC_5	NC_5	C_6	C_{7+}		
5273.75-75.95	0.46	4.81	2.04	35.62	18.92	18.10	3.04	8.39	2.62	2.83	1.84	1.33	1.234	1132.9
	0.44	6.27	2.65	52.86	19.50	11.10	1.39	3.48	0.87	0.87	0.37	0.20	0.949	2114.0
5275.95-76.00	0.52	5.68	2.36	46.34	20.00	13.61	1.94	5.04	1.42	1.48	0.96	0.65	1.050	2479.6
5276.00-77.05	0.00	4.56	4.17	35.57	18.80	17.75	2.94	8.06	2.46	2.63	1.81	1.25	1.217	1215.9
	0.00	5.85	3.56	52.12	19.35	11.32	1.44	3.71	0.95	0.95	0.52	0.23	0.959	1970.7
5277.05-77.95	0.94	4.59	1.70	29.18	20.75	21.90	3.52	9.22	2.54	2.62	1.70	1.34	1.290	1264.3
	0.63	5.33	2.51	49.15	22.70	11.85	1.45	3.68	0.91	0.91	0.52	0.36	0.977	3032.1
5277.95-79.00	0.33	5.88	3.01	43.92	22.19	13.47	1.87	4.94	1.39	1.48	0.87	0.65	1.058	1906.0
5279.00-80.00	0.49	4.83	2.68	39.25	21.09	15.33	2.38	6.84	2.20	2.40	1.48	1.03	1.155	1203.4
	0.18	5.38	3.58	50.71	19.49	11.74	1.59	4.16	1.07	1.07	0.72	0.31	0.981	2296.6
5280.20-81.00	0.48	5.29	2.51	36.37	19.36	17.64	2.74	7.45	2.26	2.52	1.84	1.54	1.214	1266.0
	0.00	6.03	3.78	53.33	19.26	10.56	1.26	3.34	0.85	0.88	0.55	0.16	0.942	2197.5
5289.00-89.75	0.29	3.97	2.92	31.34	20.91	20.67	3.21	8.86	2.32	2.65	1.64	1.22	1.255	1220.9
	0.24	2.45	4.50	56.34	19.80	9.64	1.17	3.05	0.86	0.88	0.78	0.29	0.909	2217.3
5289.75-90.95	1.20	4.51	1.59	30.55	21.26	22.07	3.37	8.72	2.30	2.38	1.26	0.79	1.248	1295.2
	0.86	6.04	2.68	49.83	20.55	12.35	1.53	3.70	0.88	0.87	0.45	0.26	0.976	2996.3
5290.95-92.00	0.08	4.91	2.29	37.24	21.37	18.29	2.63	6.84	1.99	2.10	1.33	0.93	1.169	1174.3
	0.46	7.31	2.59	51.57	18.99	10.90	1.44	3.86	1.07	1.12	0.52	0.17	0.972	2500.2
5292.00-92.85	0.67	5.60	2.33	34.57	18.32	18.24	3.22	8.90	2.58	2.69	1.62	1.26	1.242	963.3
	0.52	6.44	2.87	51.01	19.38	12.15	1.52	3.71	0.86	0.85	0.45	0.24	0.970	2105.8
5293.10-94.05	0.60	5.21	2.53	34.21	18.81	18.36	3.13	8.72	2.59	2.74	1.68	1.42	1.246	912.6
	0.61	6.17	2.64	51.93	19.54	11.78	1.43	3.58	0.83	0.82	0.41	0.26	0.959	1924.2
5294.05-94.90	0.74	4.97	2.18	35.57	22.52	17.87	2.67	7.31	2.16	2.15	1.16	0.70	1.175	969.8
	0.00	6.38	4.99	50.84	19.10	10.92	1.42	3.32	0.79	0.82	0.53	0.22	0.853	2253.1
5294.90-96.15	1.25	4.50	1.31	36.13	24.46	18.20	2.46	6.43	1.74	1.78	1.01	0.73	1.149	1674.8
	0.58	7.15	2.30	49.89	19.98	11.60	1.56	3.99	1.05	1.06	0.52	0.32	0.989	3898.1
5296.15-96.95	1.10	4.47	1.27	34.17	24.04	19.58	2.68	7.07	1.91	1.93	1.08	0.70	1.178	1635.1
	0.48	7.69	2.24	49.05	21.94	11.08	1.30	3.66	0.94	0.96	0.46	0.20	0.980	3345.3
5297.00-97.80	0.28	4.87	2.74	43.05	22.72	14.12	1.98	5.33	1.58	1.60	1.01	0.72	1.074	2284.0
5297.80-98.95	0.23	6.00	2.86	46.16	21.06	13.38	1.77	4.51	1.26	1.33	0.85	0.59	1.036	2365.9

Analysis of Liberated Gas by Gas Chromatography

Depth, feet	Component Analysis, Mole Percent												Calc. Gas Gravity (Air=1.0)	Gas Volume cc @ STP
	H_2S	CO_2	N_2	C_1	C_2	C_3	IC_4	NC_4	IC_5	NC_5	C_6	C_{7+}		
5297.80-98.95	0.23	6.00	2.86	46.16	21.06	13.38	1.77	4.51	1.26	1.33	0.85	0.59	1.036	2365.9
5298.95-00.00	1.09	4.68	1.45	28.60	20.01	22.03	3.56	9.64	2.78	2.99	1.74	1.43	1.310	960.6
	0.00	10.78	8.24	9.08	36.75	21.45	2.76	6.42	1.56	1.63	0.92	0.42	1.143	2091.3
5300.00-00.90	0.67	5.15	1.96	37.15	20.19	16.85	2.58	7.10	2.28	2.56	1.84	1.67	1.206	930.3
	0.39	5.43	2.61	53.55	19.93	10.66	1.33	3.43	0.88	0.91	0.63	0.25	0.946	1884.6
5300.90-01.85	0.92	4.64	1.66	29.43	20.91	21.78	3.43	9.11	2.57	2.71	1.68	1.16	1.283	995.0
	0.36	5.38	3.15	52.44	20.60	11.14	1.33	3.33	0.78	0.82	0.50	0.17	0.944	2173.4
5301.85-02.95	1.11	4.93	1.29	32.89	24.08	19.10	2.63	7.10	2.05	2.19	1.46	1.17	1.209	1379.3
	0.01	6.14	3.08	48.92	20.53	12.20	1.63	4.21	1.12	1.17	0.63	0.35	0.964	3253.9
5302.95-04.10	Trace	4.67	1.99	36.91	20.28	17.44	2.82	8.09	2.48	2.54	1.63	1.15	1.204	939.3
	0.45	5.83	3.15	49.97	19.70	12.40	1.63	4.09	1.01	1.01	0.47	0.29	0.984	2044.6
5304.10-04.90	0.00	5.42	3.66	43.40	21.87	13.73	1.98	5.23	1.54	1.57	0.94	0.66	1.068	2141.2
5305.00-06.05	0.00	6.72	4.71	46.02	21.69	12.03	1.52	3.97	1.11	1.12	0.70	0.41	1.012	2041.5
5306.05-07.05	0.00	5.27	4.08	44.22	22.07	13.17	1.77	4.74	1.42	1.45	1.00	0.81	1.055	2436.4
5307.05-08.05	0.00	5.84	4.23	45.52	20.02	13.58	1.89	4.84	1.34	1.40	0.77	0.57	1.043	2165.4
5308.05-09.10	Trace	5.86	3.42	38.15	20.46	16.87	2.36	6.39	1.80	1.94	1.43	1.32	1.161	934.6
	0.00	6.18	5.53	48.35	19.51	11.99	1.45	3.73	1.00	1.06	0.70	0.50	0.994	1984.7
5309.45-10.15	0.17	6.08	3.84	40.86	19.60	16.09	2.33	5.97	1.63	1.70	1.03	0.70	1.111	961.9
	0.00	6.32	5.98	53.38	17.66	10.03	1.20	3.08	0.81	0.82	0.66	0.06	0.934	1831.3
5310.15-11.15	0.32	6.43	3.27	37.58	18.63	16.66	2.59	6.94	2.09	2.34	1.63	1.52	1.192	990.3
	0.16	7.19	4.80	54.00	17.54	9.59	1.13	2.88	0.76	0.80	0.49	0.66	0.942	2025.9
5311.15-12.15	0.46	5.02	2.52	34.32	21.16	18.68	2.89	7.90	2.31	2.41	1.46	0.87	1.208	944.6
	0.25	6.01	3.87	51.45	19.71	11.42	1.38	3.42	0.85	0.86	0.57	0.21	0.958	2245.3
5312.15-13.00	0.00	8.08	4.83	45.85	19.71	12.57	1.58	3.98	1.04	1.11	0.72	0.53	1.025	2386.8
5313.00-13.95	0.00	6.13	4.78	47.07	20.27	12.60	1.54	3.87	1.03	1.14	0.83	0.74	1.016	1606.9
5313.95-15.00	1.01	5.19	2.35	32.03	20.44	20.60	3.07	8.07	2.24	2.41	1.47	1.12	1.239	982.6
	0.64	6.50	2.79	56.98	18.83	9.37	1.03	2.57	0.63	0.66	0.00	0.00	0.891	2176.2
5315.00-16.00	0.05	6.51	4.46	46.85	20.20	12.82	1.58	3.97	1.04	1.15	0.75	0.62	1.017	1686.2
5316.00-16.75	0.00	6.08	4.78	45.48	19.95	13.40	1.69	4.35	1.23	1.36	0.98	0.70	1.041	2033.7
5317.00-18.00	0.00	6.81	5.17	47.76	18.66	11.59	1.60	4.18	1.27	1.38	0.92	0.66	1.021	1526.9

Analysis of Liberated Gas by Gas Chromatography

Depth, feet	Component Analysis, Mole Percent												Calc. Gas Gravity (Air=1.0)	Gas Volume cc @ STP
	H_2S	CO_2	N_2	C_1	C_2	C_3	IC_4	NC_4	IC_5	NC_5	C_6	C_{7+}		
5318.00-19.00	0.00	6.73	4.89	47.41	18.80	12.26	1.62	4.22	1.25	1.34	0.90	0.58	1.023	1338.2
5319.00-19.80	0.00	9.44	8.05	52.37	15.36	7.77	0.91	2.45	0.72	0.90	0.93	1.10	0.963	462.2
5320.10-20.45	0.00	5.62	4.10	44.68	19.62	13.22	1.82	4.82	1.50	1.68	1.40	1.54	1.086	1567.3
5321.00-21.56	0.00	6.46	4.27	45.81	19.47	13.26	1.75	4.54	1.33	1.43	1.09	0.59	1.045	1815.9
5321.95-23.00	0.00	14.51	12.67	41.44	14.13	8.34	1.10	3.18	1.02	1.22	0.99	1.40	1.067	320.5
5323.00-24.00	0.00	24.47	14.45	45.75	10.38	4.04	0.00	0.91	0.00	0.00	0.00	0.00	0.952	91.9
5324.00-25.00	0.00	18.22	11.36	39.15	13.51	7.56	1.07	3.04	1.12	1.24	1.57	2.16	1.123	239.5
5325.00-26.00*														
5326.00-26.90	0.03	6.05	3.96	42.27	19.99	15.17	2.14	5.57	1.53	1.62	0.99	0.68	1.090	1849.0
5326.90-28.00	0.00	5.50	4.40	43.54	21.42	13.52	1.84	4.92	1.48	1.51	1.07	0.80	1.066	1915.0
5328.00-29.00	0.00	6.05	4.90	46.05	19.49	13.16	1.79	4.61	1.28	1.36	0.76	0.55	1.033	2047.2
5329.00-29.95	0.00	6.22	5.11	43.62	19.39	14.06	2.01	5.23	1.44	1.50	0.90	0.52	1.064	2204.5
5329.95-31.20	0.00	7.70	5.65	43.42	19.07	13.19	1.82	4.71	1.34	1.42	0.97	0.71	1.065	2290.7
5331.60-32.15	0.00	6.59	3.69	42.70	19.29	14.19	2.05	5.50	1.69	1.87	1.40	1.03	1.107	1628.3
5332.15-32.85	0.00	5.90	5.03	43.43	20.78	13.34	1.85	4.94	1.43	1.52	1.03	0.75	1.064	2294.1
5332.85-33.65	0.00	6.65	4.49	44.72	19.44	13.29	1.86	4.86	1.41	1.50	1.01	0.77	1.061	2465.6
5333.85-34.35	6.23	5.31	3.35	34.46	16.96	16.52	2.52	7.12	2.19	2.42	1.75	1.17	1.206	972.2
	0.31	6.78	3.08	51.27	18.18	11.21	1.49	3.89	1.16	1.23	0.80	0.60	0.992	1649.6
5334.35-35.15	0.00	6.96	5.35	45.95	18.50	12.24	1.70	4.53	1.39	1.50	1.12	0.76	1.047	1865.2
5335.15-36.25	0.46	7.42	3.84	47.96	18.80	11.80	1.58	4.07	1.18	1.27	0.91	0.71	1.022	2219.5
5338.00-39.15	0.00	5.32	5.18	40.35	17.98	14.14	2.27	6.19	2.14	2.45	2.01	1.97	1.170	1051.1
5342.05-42.95	0.00	6.94	6.02	46.18	17.23	12.49	1.70	4.54	1.38	1.49	1.13	0.90	1.051	1565.8
5342.95-43.75	0.00	6.56	3.21	40.22	18.76	15.72	2.51	6.52	1.92	2.05	1.36	1.17	1.149	948.4
	0.00	6.40	3.70	47.48	18.62	12.63	1.80	4.66	1.35	1.46	0.95	0.95	1.043	1380.3
5343.75-44.85	0.12	6.89	2.50	36.52	19.26	17.79	2.81	7.42	2.25	2.37	1.34	0.73	1.189	1278.5
	0.00	6.53	3.18	49.83	18.66	12.27	1.79	4.41	1.18	1.23	0.60	0.32	1.000	2094.6
5344.85-45.70	8.44	5.04	2.15	29.25	15.61	20.30	3.29	8.82	2.49	2.49	1.38	0.74	1.264	1345.9
	0.69	6.23	2.85	52.03	18.76	11.59	1.52	3.76	0.93	0.93	0.45	0.26	0.964	2162.6
5346.00-47.55	0.56	4.83	3.00	33.61	13.79	21.17	3.59	9.68	2.91	3.17	2.09	1.60	1.297	1222.2
	0.00	6.95	3.92	39.85	18.81	15.59	2.39	6.02	1.77	1.92	1.47	1.31	1.148	2313.9

* No gas analysis due to broken gas-collecting tube.

Analysis of Liberated Gas by Gas Chromatography

Depth, feet	Component Analysis, Mole Percent												Calc. Gas Gravity (Air=1.0)	Gas Volume cc @ STP
	H_2S	CO_2	N_2	C_1	C_2	C_3	IC_4	NC_4	IC_5	NC_5	C_6	C_{7+}		
5347.80-49.05	0.00	5.89	6.89	52.62	17.67	9.88	1.29	3.10	0.82	0.87	0.57	0.40	0.943	915.4
	0.28	6.79	5.55	53.99	16.91	9.86	1.17	2.96	0.73	0.77	0.65	0.34	0.936	1972.3
5349.05-49.90	0.45	5.32	2.69	36.45	19.57	18.58	2.87	7.32	2.05	2.18	1.38	1.14	1.191	1107.8
	0.26	5.79	3.91	50.67	18.77	12.33	1.57	3.92	0.97	0.99	0.48	0.34	0.977	2358.8
5350.00-50.95	0.18	7.17	3.85	45.42	19.34	13.45	1.83	4.59	1.27	1.33	0.91	0.66	1.049	2155.2
5350.95-51.95	0.84	5.62	2.51	41.00	16.05	18.01	2.66	6.97	1.97	2.08	1.28	1.01	1.155	1120.5
	0.56	5.55	3.59	51.03	18.48	12.08	1.54	3.80	1.04	1.05	0.69	0.59	0.985	3292.8
5351.95-52.95	0.46	6.16	3.25	42.30	16.22	16.67	2.44	6.35	1.84	1.98	1.35	0.98	1.133	954.7
	0.23	6.36	5.49	51.87	17.31	10.63	1.32	3.34	0.88	0.95	0.94	0.68	0.972	1909.3
5352.95-54.00	0.00	7.08	3.98	39.21	19.20	16.42	2.46	6.17	1.73	1.81	1.17	0.77	1.136	1099.0
5352.95-54.00	0.00	7.18	6.53	49.71	17.58	11.12	1.43	3.58	0.94	0.99	0.61	0.33	0.978	2133.2
5355.05-56.15	0.00	5.71	4.99	41.47	19.09	15.77	2.35	5.94	1.57	1.65	0.90	0.56	1.096	2509.1
5356.15-57.00	0.00	4.93	7.43	37.77	17.40	16.86	2.72	6.98	1.92	1.99	1.16	0.84	1.149	2058.0
	0.00	7.46	0.00	52.29	20.72	12.04	1.48	3.49	0.86	0.87	0.54	0.25	0.969	1369.0
5357.00-58.10	4.64	5.52	3.18	40.49	13.43	16.56	2.58	6.90	1.99	2.14	1.49	1.08	1.161	1132.4
	0.17	5.66	4.17	50.55	19.04	12.09	1.57	3.85	1.01	0.98	0.65	0.26	0.977	2181.0
5358.10-58.90	0.68	6.26	2.92	43.56	21.01	14.48	2.06	5.18	1.35	1.38	0.73	0.39	1.060	2406.9
5358.90-60.05	0.58	6.67	3.34	38.64	14.54	18.39	2.82	7.49	2.14	2.33	1.65	1.41	1.203	1035.7
	0.00	7.33	5.25	48.47	18.68	12.30	1.57	3.80	0.90	0.96	0.44	0.30	0.989	2313.3
5360.05-61.10	0.06	6.90	2.33	38.52	18.91	16.56	2.54	6.75	1.98	2.21	1.72	1.52	1.186	901.6
	0.00	6.45	9.98	44.13	18.16	11.79	1.68	4.10	1.25	1.34	0.53	0.59	1.024	1664.5
5362.00-62.80	0.00	6.35	4.28	43.41	19.05	14.54	2.17	5.44	1.55	1.56	1.00	0.65	1.080	2300.3
5362.80-63.90	0.56	6.45	3.35	41.41	19.73	16.32	2.36	5.70	1.43	1.40	0.80	0.49	1.093	2318.7
5364.20-65.00	Trace	4.43	3.87	26.24	16.31	22.87	4.37	11.58	3.37	3.44	2.10	1.42	1.370	1001.2
	Trace	6.62	3.35	52.66	18.92	11.39	1.35	3.32	0.74	0.82	0.47	0.36	0.954	485.4
5365.00-65.80	0.00	5.69	7.20	40.81	18.64	14.95	2.23	5.65	1.55	1.57	1.01	0.70	1.094	2074.4
5366.90-67.95	0.00	6.65	4.88	42.97	19.16	14.56	2.05	5.26	1.42	1.49	0.97	0.59	1.076	1872.6
5367.95-69.10	1.22	6.17	2.40	29.82	17.31	20.89	3.76	10.02	2.87	2.93	1.68	0.93	1.298	855.1
	0.00	7.63	6.04	52.38	18.62	10.13	1.09	2.51	0.54	0.55	0.31	0.20	0.928	1929.7
5369.10-70.10*														
5370.10-71.10	0.00	5.58	7.97	37.71	16.88	14.47	2.33	6.44	2.10	2.43	2.04	2.05	1.188	660.1

* No gas analysis due to broken gas-collecting tube.

CORE LABORATORIES, INC.
Petroleum Reservoir Engineering
DALLAS, TEXAS 75247

Analysis of Liberated Gas by Gas Chromatography

Depth, feet	Component Analysis, Mole Percent												Calc. Gas Gravity (Air=1.0)	Gas Volume cc @ STP
	H_2S	CO_2	N_2	C_1	C_2	C_3	IC_4	NC_4	IC_5	NC_5	C_6	C_{7+}		
5371.10-71.90	0.00	6.49	4.84	42.71	18.95	14.78	2.16	5.49	1.49	1.54	0.95	0.60	1.082	1940.2
5371.90-73.05	0.40	5.48	3.46	29.79	19.07	21.81	3.54	9.04	2.47	2.53	1.49	0.92	1.270	1128.5
	0.55	6.72	2.99	49.14	19.69	12.38	1.64	3.96	1.02	1.03	0.59	0.29	0.994	2380.0
5373.05-73.60	0.00	6.49	6.58	39.76	17.60	14.57	2.25	5.94	1.79	2.00	1.51	1.51	1.144	644.0
5373.75-74.85	0.74	6.01	2.14	30.75	17.74	21.73	3.85	9.85	2.59	2.52	1.35	0.73	1.274	1081.4
	0.00	7.04	4.18	49.39	20.23	12.38	1.54	3.29	0.68	0.65	0.38	0.24	0.969	2532.2
5375.20-76.10	0.73	7.40	2.30	26.45	15.24	21.44	4.22	11.45	3.41	3.53	2.20	1.63	1.385	780.2
	0.58	7.01	2.90	48.35	20.47	13.09	1.60	3.60	0.81	0.78	0.45	0.36	0.991	1880.3
5376.10-77.10	0.96	5.33	1.97	31.80	18.47	20.59	3.52	9.12	2.62	2.72	1.74	1.16	1.272	1002.2
	0.54	6.55	2.79	47.68	19.47	12.86	1.79	4.48	1.26	1.30	0.77	0.51	1.025	2242.2
5377.10-77.[illegible]	0.08	5.79	3.25	42.14	18.76	14.97	2.40	6.30	1.99	2.11	1.47	0.74	1.123	1337.6

Chloride Data

Depth, feet	Chloride as Cl^-, mg/L	Depth, feet	Chloride as Cl^-, mg/L
5181.3 -5182.0	28,198	5232.1-5233.0	78,150
5182.0 -5183.05	41,328	5233.0-5233.95	63,185
5183.05-5184.1	81,446	5238.05-5239.3	36,927
5184.1 -5184.7	52,324	5239.3-5240.15	49,537
5185.6 -5186.5	60,434	5240.15-5240.95	43,371
5208.6 -5209.1	*	5250.0-5251.0	52,966
5209.6 5210.5	65,088	5251.0-5251.9	41,327
5210.5 -5211.6	68,921	5251.9-5253.0	47,528
5211.6 -5212.55	60,434	5253.0-5254.0	47,424
5213.8 -5214.55	58,336	5254.0-5255.1	37,551
5214.75-5215.45	55,222	5255.1-5255.85	45,311
5216.0 -5217.25	142,202	5255.85-5256.7	59,791
5217.55-5218.5	*	5256.9-5257.6	48,913
5218.5 -5219.2	*	5258.25-5259.0	48,151
5219.2 -5220.2	*	5267.0-5267.75	156,716
5220.6 -5221.85	*	5267.75-5268.7	172,582
5221.85-5222.55	*	5268.7-5270.05	171,543
5224.0 -5224.85	37,967	5271.6-5272.35	113,900
5224.85-5225.8	66,927	5272.35-5273.0	190,873
5227.05-5228.15	54,040	5273.75-5275.95	170,850
5228.7 -5230.05	63,532	5275.95-5276.0	166,570
5230.05-5230.6	60,345	5276.0-5277.05	171,404
5230.6 -5231.55	57,089	5277.05-5277.95	183,875
5231.55-5232.1	59,998	5277.95-5279.0	133,299

*Insufficient water for analysis

Chloride Data

Depth, feet	Chloride as Cl^-, mg/L	Depth, feet	Chloride as Cl^-, mg/L
5279.0 -5280.0	154,499	5311.15-5312.15	143,137
5280.2 -5281.0	139,119	5312.15-5313.0	113,900
5289.0 -5289.75	179,025	5313.0-5313.95	139,950
5289.75-5290.95	188,770	5313.95-5315.0	135,932
5290.95-5292.0	181,381	5315.0-5316.0	132,468
5292.0 -5292.85	152,005	5316.0-5316.75	138,287
5293.1 -5294.05	167,109	5317.0-5318.0	144,938
5294.05-5294.9	165,307	5318.0-5319.0	149,095
5294.9 -5296.15	163,922	5319.0-5319.8	174,314
5296.15-5296.95	142,306	5320.1-5320.45	146,186
5297.0 -5297.8	172,651	5321.0-5321.95	145,216
5297.8 -5298.05	162,398	5321.95-5323.0	152,421
5298.95-5300.0	167,802	5324.0-5325.0	187,062
5300.0 -5300.9	173,067	5325.0-5326.0	133,299
5300.9 -5301.85	173,760	5326.0-5326.9	143,276
5301.85-5302.95	166,000	5326.9-5328.0	142,583
5302.95-5304.1	146,601	5328.0-5329.0	137,179
5304.1 -5304.9	133,022	5329.0-5329.95	147,017
5305.0 -5306.05	155,885	5329.95-5331.2	125,609
5306.05-5307.05	157,548	5331.6-5332.15	127,064
5307.05-5308.05	147,363	5332.15-5332.85	112,376
5308.05-5309.1	137,179	5332.85-5333.65	130,666
5309.15-5310.15	142,167	5333.85-5334.35	123,669
5310.15-5311.15	132,468	5334.35-5335.15	127,341

Chloride Data

Depth, feet	Chloride as Cl^-, mg/L	Depth, feet	Chloride as Cl^-, mg/L
5335.15-5336.25	108,565	5367.95-5369.1	107,387
5338.0 -5339.15	144,800	5369.1-5370.1	102,399
5342.05-5342.95	131,983	5370.1-5371.1	114,177
5342.95-5343.75	131,290	5371.1-5371.9	133,576
5343.75-5344.85	131,498	5371.9-5373.05	119,165
5344.85-5345.70	132,329	5373.05-5373.6	116,810
5346.0 -5347.55	142,583	5373.75-5374.85	110,436
5347.8 -5349.05	124,985	5375.2-5376.1	113,069
5349.05-5349.9	126,925	5376.1-5377.1	128,172
5350.0 -5350.95	132,745	5377.1-5377.55	110,020
5350.95-5351.95	123,738		
5351.95-5352.95	118,196		
5352.95-5354.0	111,267		
5355.05-5356.15	151,867		
5356.15-5357.0	149,580		
5357.0 -5358.1	138,287		
5358.1 -5358.9	140,643		
5358.9 -5360.05	130,943		
5360.05-5361.1	130,389		
5362.0 -5362.8	122,075		
5362.8 -5363.9	130,112		
5364.2 -5365.0	125,470		
5265.0 -5365.8	127,895		
5366.9 -5367.95	107,110		

CORE LABORATORIES, INC.
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DALLAS, TEXAS 75247

Vertical Plug and Donut Data

Sample Number	Sample Type	Depth, feet	Vertical Permeability, Millidarcies	Porosity, Percent	Water Saturation, Percent PV
1	Plug	5181.0 -81.3	0.55	10.0	Trace
1	Donut	5181.0 -81.3		6.3	27.0
2	Plug	5187.4 -87.65	<0.01	2.7	Trace
2	Donut	5187.4 -87.65		1.6	77.9
3	Plug	5211.05-11.3	<0.01	5.4	15.4
3	Donut	5211.05-11.3		4.7	40.4
4	Plug	5214.55-14.75	0.12	7.0	42.2
4	Donut	5214.55-14.75		8.4	51.7
5	Plug	5217.25-17.55	<0.01	2.9	72.0
5	Donut	5217.25-17.55		2.2	87.5
6	Plug	5220.2 -20.4	<0.01	4.5	61.9
6	Donut	5220.2 -20.4		3.9	62.6
7	Plug	5225.8 -26.0	0.06	4.7	44.8
7	Donut	5225.8 -26.0		4.5	60.9
8	Plug	5233.1 -33.3	0.55	8.9	17.7
8	Donut	5233.1 -33.3		6.3	32.5
9	Plug	5236.2 -36.4	*	5.3	46.6
9	Donut	5236.2 -36.4		6.3	60.1
10	Plug	5252.3 -52.5	0.81	15.5	26.8
10	Donut	5252.3 -52.5		13.6	47.9
11	Plug	5256.7 -56.9	0.55	13.5	7.8
11	Donut	5256.7 -56.9		11.1	25.6

*Unsuitable for analysis due to fracturing.

Vertical Plug and Donut Data

Sample Number	Sample Type	Depth, feet	Vertical Permeability, Millidarcies	Porosity, Percent	Water Saturation, Percent PV
12	Plug	5270.05-70.3	*	8.8	35.9
12	Donut	5270.05-70.3		6.7	54.5
13	Plug	5273.5 -73.75	0.11	11.1	17.8
13	Donut	5273.5 -73.75		10.8	30.3
14	Plug	5280.0 -80.2	0.93	11.2	8.2
14	Donut	5280.0 -80.2		7.0	28.7
15	Plug	5292.85-93.1	1.6	16.7	20.4
15	Donut	5292.85-93.1		15.1	29.0
16	Plug	5298.3 -98.6	2.9	11.5	25.2
16	Donut	5298.3 -98.6		9.6	27.9
17	Plug	5303.8 -4.1	0.29	13.5	11.9
17	Donut	5303.8 -4.1		11.5	28.3
18	Plug	5309.1 -9.45	2.0	13.5	33.8
18	Donut	5309.1 -9.45		13.2	52.5
19	Plug	5316.75-17.0	0.29	5.6	23.1
19	Donut	5316.75-17.0		5.3	54.0
20	Plug	5319.8 -20.1	4.8	8.8	39.9
20	Donut	5319.8 -20.1		6.3	47.3
21	Plug	5323.45-23.75	<0.01	4.4	48.2
21	Donut	5323.45-23.75		3.6	84.1

*Unsuitable for analysis due to fracturing.

Vertical Plug and Donut Data

Sample Number	Sample Type	Depth, feet	Vertical Permeability, Millidarcies	Porosity, Percent	Water Saturation, Percent PV
22	Plug	5327.5 -27.65	2.7	10.3	39.6
22	Donut	5327.5 -27.65		11.4	49.3
23	Plug	5330.35-30.65	2.3	10.2	33.6
23	Donut	5330.35-30.65		7.5	49.5
24	Plug	5341.0 -41.25	0.07	6.3	38.3
24	Donut	5341.0 -41.25		5.6	57.2
25	Plug	5347.55-47.80	7.1	20.6	38.1
25	Donut	5347.55-47.80		19.6	43.9
26	Plug	5355.25-55.50	5.4	20.8	38.3
26	Donut	5355.25-55.50		16.5	54.0
27	Plug	5363.9 -64.2	13	19.6	46.0
27	Donut	5363.9 -64.2		18.8	46.3
28	Plug	5374.8 -75.2	45	18.4	54.4
28	Donut	5374.8 -75.2		16.4	61.3

Sodium Nitrate Data

Drilling Fluid Filtrate: 5.5 mg/L as $NaNO_3$

Low-Invasion Gel Filtrate: 1395 mg/L as $NaNO_3$

Sample Number	Sample Type	Depth, feet	µg/gm Rock	PPM Pore Water
1	Plug	5181.0 -81.3*	8.69	**
1	Donut	5181.0 -81.3*	7.78	1179
2	Plug	5187.4 -87.65*	12.78	**
2	Donut	5187.4 -87.65*	6.98	2181
3	Plug	5211.05-11.3*	6.13	1916
3	Donut	5211.05-11.3*	1.39	174
4	Plug	5214.55-14.75*	4.85	411
4	Donut	5214.55-14.75*	7.88	461
5	Plug	5217.25-17.55	5.87	605
5	Donut	5217.25-17.55	3.75	371
6	Plug	5220.2 -20.4	0.30	26
6	Donut	5220.2 -20.4	0.35	34
7	Plug	5225.8 -26.05*	<0.74	<88
7	Donut	5225.8 -26.05*	<0.21	<19
8	Plug	5233.1 -33.35*	3.48	552
8	Donut	5233.1 -33.35*	11.70	1410
9	Plug	5236.2 -36.45*	<0.22	<23
9	Donut	5236.2 -36.45*	<0.25	<17
10	Plug	5252.3 -52.5*	2.27	130
10	Donut	5252.3 -52.5*	0.48	18

*Low invasion gel not used.
**Insufficient water for ppm calculation

CORE LABORATORIES, INC.
Petroleum Reservoir Engineering
DALLAS, TEXAS 75247

Sodium Nitrate Data

Drilling Fluid Filtrate: 5.5 mg/L as $NaNO_3$

Low-Invasion Gel Filtrate: 1395 mg/L as $NaNO_3$

Sample Number	Sample Type	Depth, feet	µg/gm Rock	PPM Pore Water
11	Plug	5256.7 -56.9*	4.94	1138
11	Donut	5256.7 -56.9*	4.89	411
12	Plug	5270.05-70.3	5.73	398
12	Donut	5270.05-70.3	3.02	181
13	Plug	5273.5 -73.75	9.68	1030
13	Donut	5273.5 -73.75	18.68	1221
14	Plug	5280.0 -80.2	12.40	3024
14	Donut	5280.0 -80.2	14.04	1578
15	Plug	5292.85-93.1	<0.26	<16
15	Donut	5292.85-93.1	9.66	456
16	Plug	5298.3 -98.6	14.34	1054
16	Donut	5298.3 -98.6	1.20	96
17	Plug	5303.8 -4.1	<0.22	<30
17	Donut	5303.8 -4.1	4.54	295
18	Plug	5309.1 -9.45	<0.16	<7
18	Donut	5309.1 -9.45	8.66	254
19	Plug	5316.75-17.0	<0.28	<49
19	Donut	5316.75-17.0	2.11	161
20	Plug	5319.8 -20.1	<0.25	<15
20	Donut	5319.8 -20.1	<0.23	<15

*Low invasion gel not used.

Sodium Nitrate Data

Drilling Fluid Filtrate: 5.5 mg/L as $NaNO_3$

Low-Invasion Gel Filtrate: 1395 mg/L as $NaNO_3$

Sample Number	Sample Type	Depth, feet	µg/gm Rock	PPM Pore Water
21	Plug	5323.45-23.75	<0.25	<25
21	Donut	5323.45-23.75	<0.20	<14
22	Plug	5327.5 -27.65	1.39	73
22	Donut	5327.5 -27.65	12.63	475
23	Plug	5330.35-30.65	0.33	21
23	Donut	5330.35-30.65	2.55	154
24	Plug	5341.0 -41.25	<0.22	<20
24	Donut	5341.0 -41.25	5.09	349
25	Plug	5347.55-47.80	5.87	150
25	Donut	5347.55-47.80	19.37	447
26	Plug	5355.25-55.50	2.22	55
26	Donut	5355.25-55.50	11.29	240
27	Plug	5363.9 -64.2	12.77	290
27	Donut	5363.9 -64.2	1.82	42
28	Plug	5374.8 -75.2	4.00	83
28	Donut	5374.8 -75.2	9.81	204

Special Core Analysis Study

for

GRUY FEDERAL, INC.

Bennett Ranch Unit No. 310 Well
Yoakum County, Texas

Gruy Federal, Inc.
2500 Tanglewilde, Suite 150
Houston, Texas 77063

Attention: Mr. Terry Swift

Subject: Special Core Analysis Study
Bennett Ranch Unit No. 310 Well
Wasson Field
Yoakum County, Texas
Purchase Order Number: 3027-66
File Number: SCAL-308-80161

Gentlemen:

A purchase order dated October 12, 1979, and identified by Number 3027-66 authorized a study on core material obtained from the subject well. The Formation Resistivity Factor and Formation Resistivity Index Measurements requested in the purchase order have been performed by the Special Core Analysis Department of Core Laboratories, Inc., at Dallas, Texas, and the results are reported herein. Also reported are the results of Air Permeability and Porosity Determinations for sample selection purposes. A separate report on the remaining portion of the study has already been issued (File Number: SCAL-79366-P). The core plugs used for the electrical resistivity measurements are lithologically described and identified as to sample number and depth interval on Page 1.

Thirty-one full-diameter core segments representing depth intervals ranging from approximately 5181 feet to approximately 5377 feet were submitted for use in this study. Upon completion of the requested nitrate analyses, plug-size samples were obtained from each submitted core segment using either a diamond core drill with water as the bit coolant and lubricant, or a diamond core saw. The 28 one-inch in diameter cylindrical core samples and three shaped core samples thus obtained were extracted of any hydrocarbons present using toluene, leached of any salts present using methyl alcohol, and

dried. Air permeabilities were determined on the cylindrical core plugs, and Boyle's Law porosities were determined on all the core samples. Each shaped core sample was then mounted to the form of a right cylinder using epoxy plastic, and its air permeability was determined. The air permeability and porosity data are presented in tabular form on Page 2, and in graphical form on Page 3.

On the basis of the air permeability and porosity data, 15 samples were selected for further testing, and the selections were approved by a representative of Gruy Federal, Inc. These samples were evacuated and pressure-saturated with a brine containing 100,000 ppm sodium chloride. The electrical resistivities of the brine and the brine-saturated core plugs were measured repeatedly over a period of several days until the electrical resistivities stabilized, indicating that ionic equilibrium within the core plugs had been attained. Desaturation of the core plugs was then begun using a porous-plate cell with an air-brine system. While the formation resistivity index measurements were in progress, the results of the formation resistivity factor measurements were submitted to a representative of Gruy Federal, Inc. Although the testing procedures and data evaluation had been correctly performed, these data did not fall within the expected range. It was discovered that anhydrite was present in the samples tested, and mineral dissolution had occurred, thereby invalidating these test results.

Three samples which had not exhibited mineral dissolution during testing and three samples not previously used for testing were selected for additional electrical resistivity measurements. Air permeability and porosity were confirmed on each clean sample. The samples were then evacuated and pressure-saturated with a brine containing 80,000 ppm sodium chloride and 20,000 ppm calcium sulfate, which had ben added to inhibit mineral dissolution. The electrical resistivities of this brine and the brine-saturated core plugs were measured repeatedly over a period of several days until the electrical resistivities stabilized. The samples were desaturated using a porous-plate cell with an air-brine system, and the electrical resistivities were measured at several equilibrium saturations for each sample. The results of these formation resistivity factor and formation resistivity index measurements are presented in tabular form on Page 4, and in graphical form on Pages 5 through 12. Using Archie's equation, a cementation exponent "m" of 2.05 is calculated. The formation resistivity index-saturation relationships yield calculated saturation exponents "n" ranging from 1.81 to 3.18. For convenience, a composite plot of the formation resistivity index-saturation relationships is presented on Page 12 and yields a composite saturation exponent of 2.08.

It has been a pleasure performing this study on behalf of Gruy Federal, Inc. Should there be any questions concerning the reported test results, or if we could be of any further assistance, please do not hesitate to contact us.

Very truly yours,

Core Laboratories, Inc.

Catherine A. Dottle

Catherine A. Dottle
for Duane L. Archer, Manager
Special Core Analysis

CAD:mc
10 cc. - Addressee

CORE LABORATORIES, INC.
Petroleum Reservoir Engineering
DALLAS, TEXAS 75247

File SCAL-308-80161

Company Gruy Federal, Inc. Formation San Andres
Well Bennett Ranch Unit No. 310 County Yoakum
Field Wasson State Texas

Identification and Description of Samples

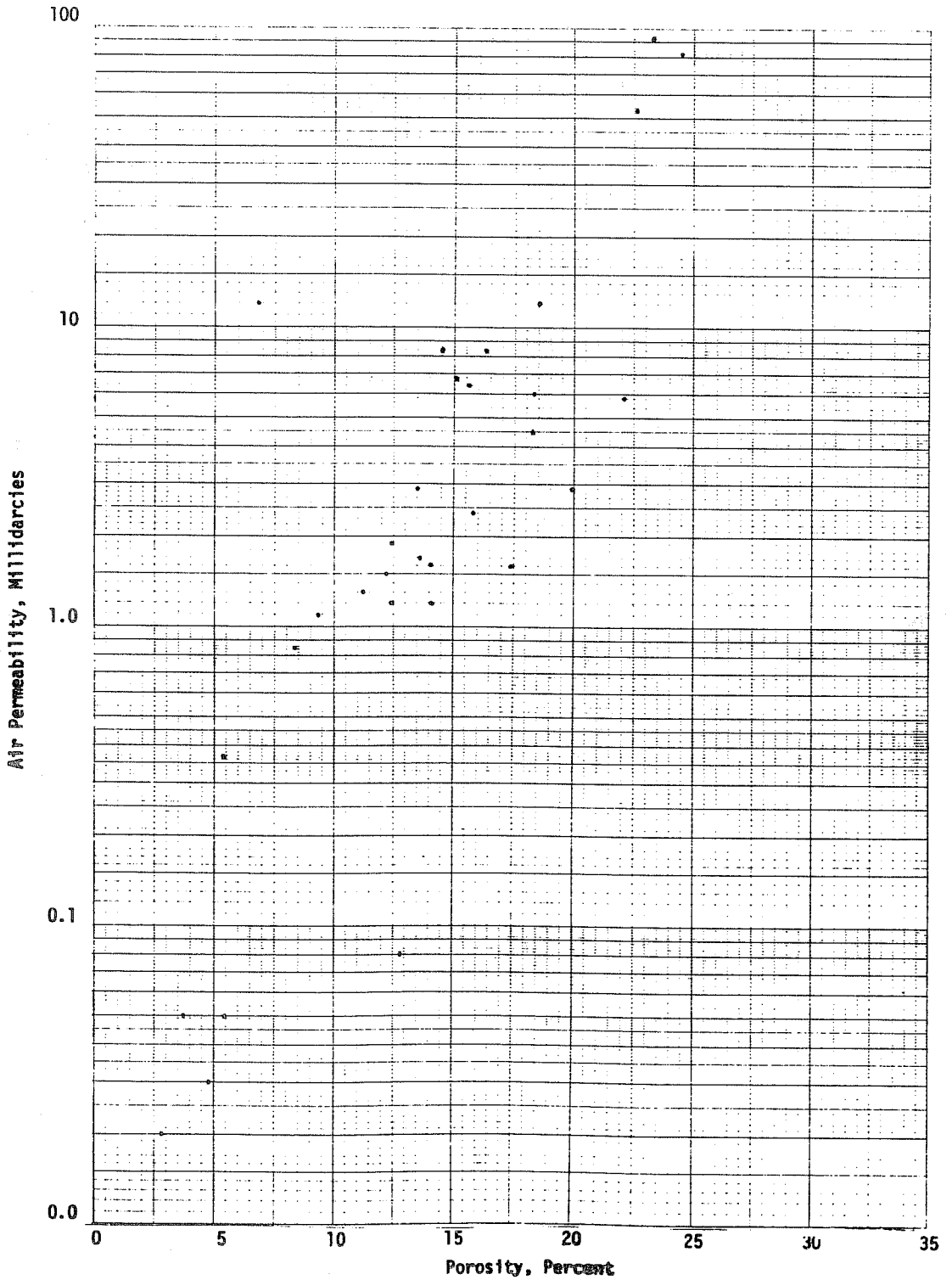
Sample Number	Depth, Feet	Lithological Description
179A	5342.95-43.75	Dol, tan, fn xln, dns, pp vugs
183A	5344.85-45.7	Dol, tan, fn xln, dns, pp vugs
191A	5350.00-50.95	Dol, tan, fn xln, dns, pp vugs
200A	5355.05-56.15	Dol, tan, fn xln, dns, pp vugs
208A	5358.9-60.05	Dol, tan, fn xln, dns, pp vugs
230A	5371.9-73.05	Dol, tan, fn xln, dns, pp vugs

CORE LABORATORIES, INC.
Petroleum Reservoir Engineering
DALLAS, TEXAS 75247

Permeability and Porosity

Sample Number	Depth, feet	Air Permeability, Millidarcies	Porosity, Percent	Remarks
1A	5181.3-2.0	12	6.8	Small vertical fracture
8A	5184.1-4.7	0.03	4.8	
21A	5211.6-2.55	0.37	5.4	
32A	5220.6-1.85	0.02	2.8	
51A	5238.05-9.3	1.1	9.3	
65A	5254.0-5.1	1.3	11.2	
69A	5255.85-6.7	2.9	13.5	
76A	5267.75-8.7	1.2	14.1	
82A	5272.35-3.0	0.05	5.4	
86A	5275.95-6.0	0.83	8.3	Epoxy-mounted shaped sample
101A	5289.75-90.95	8.4	14.5	
111A	5297.0-7.8	6.7	15.1	
119A	5301.85-2.95	1.7	13.6	
122A	5304.1-4.9	0.08	12.8	
155A	5324.0-4.5	0.05	3.7	
179A	5342.95-3.75	2.4	15.8	
183A	5344.85-5.7	1.6	17.4	
191A	5350.0-0.95	2.9	19.9	
195A	5351.95-2.95	1.5	12.2	Epoxy-mounted shaped sample
196A	5351.95-2.95	1.2	12.4	Epoxy-mounted shaped sample
200A	5355.05-6.15	6.0	18.3	
201A	5356.15-7.0	92	23.3	
202A	5356.15-7.0	82	24.5	
203A	5356.15-7.0	53	22.6	
208A	5358.9-60.05	5.8	22.1	
220A	5366.9-7.95	12	18.5	
222A	5367.95-9.1	1.9	12.4	
230A	5371.9-3.05	1.6	14.1	
234A	5375.2-6.1	4.5	18.2	
235A	5375.2-6.1	9.2	16.3	
236A	5376.1-7.1	6.4	15.6	

Company Gruy Federal, Inc. Formation San Andres
Well Bennett Ranch Unit No. 310 County Yoakum
Field Wasson State Texas



Formation Factor and Resistivity Index Data

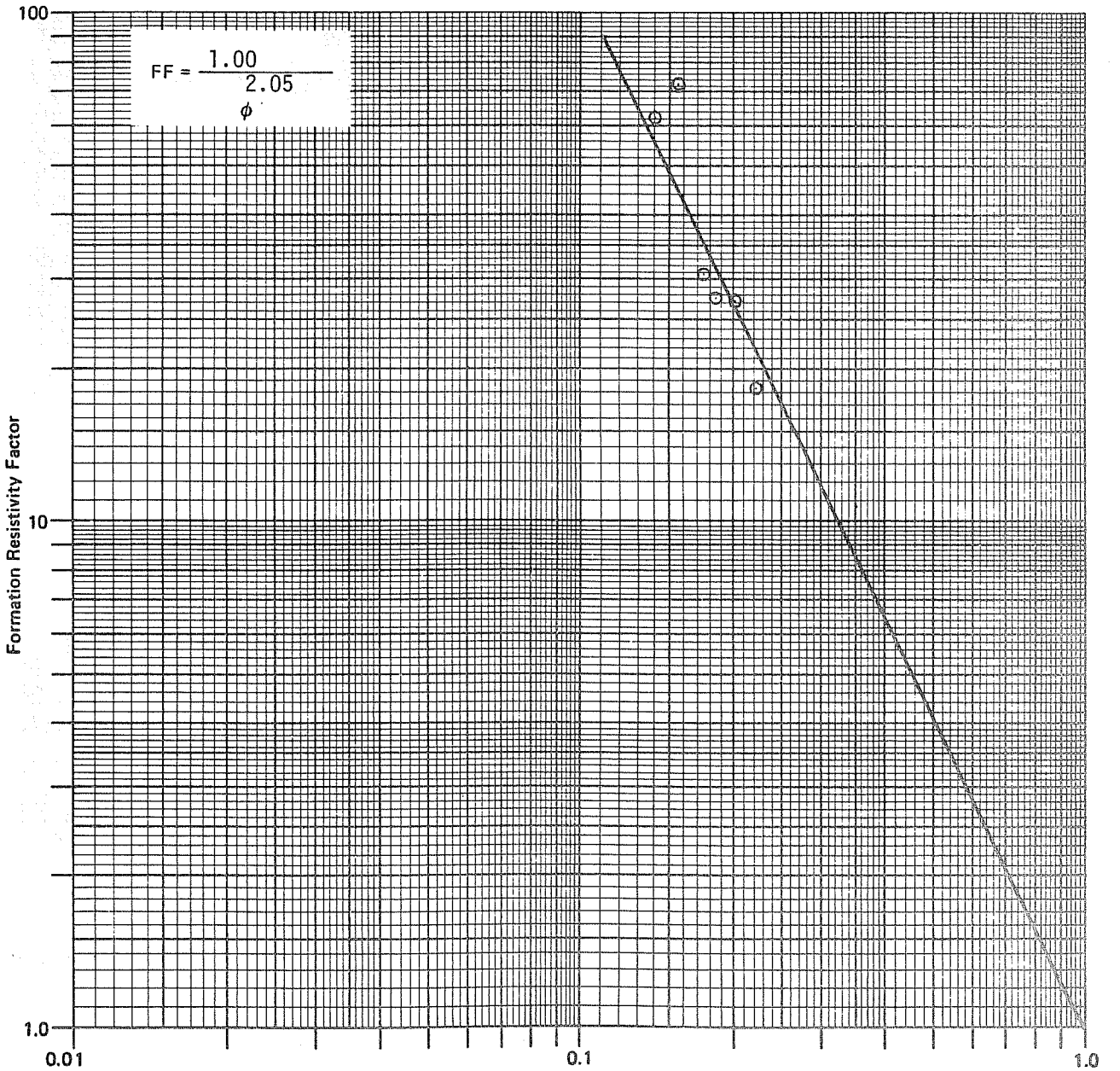
Resistivity of Saturating Brine, Ohm-Meters: 0.109 @ 72.5°F.

Sample Number	Air Permeability, Millidarcies	Porosity, Percent	Formation Factor	Brine Saturation, Percent Pore Space	Resistivity Index
179A	2.6	15.6	72.6	100.0	1.00
				72.9	2.95
				66.3	3.68
				59.2	4.94
183A	1.6	17.5	30.9	100.0	1.00
				70.0	1.96
				45.9	4.70
				39.7	5.50
191A	3.2	20.1	27.3	100.0	1.00
				90.3	1.24
				57.6	2.61
				35.7	6.35
200A	6.5	18.5	27.8	100.0	1.00
				95.6	1.29
				46.5	4.08
				30.5	10.7
208A	5.3	22.3	18.4	100.0	1.00
				94.5	1.21
				69.0	1.78
				40.0	6.18
230A	1.7	14.0	62.5	100.0	1.00
				80.9	1.87
				42.1	4.70
				35.1	6.70

CORE LABORATORIES, INC.
Petroleum Reservoir Engineering
DALLAS, TEXAS

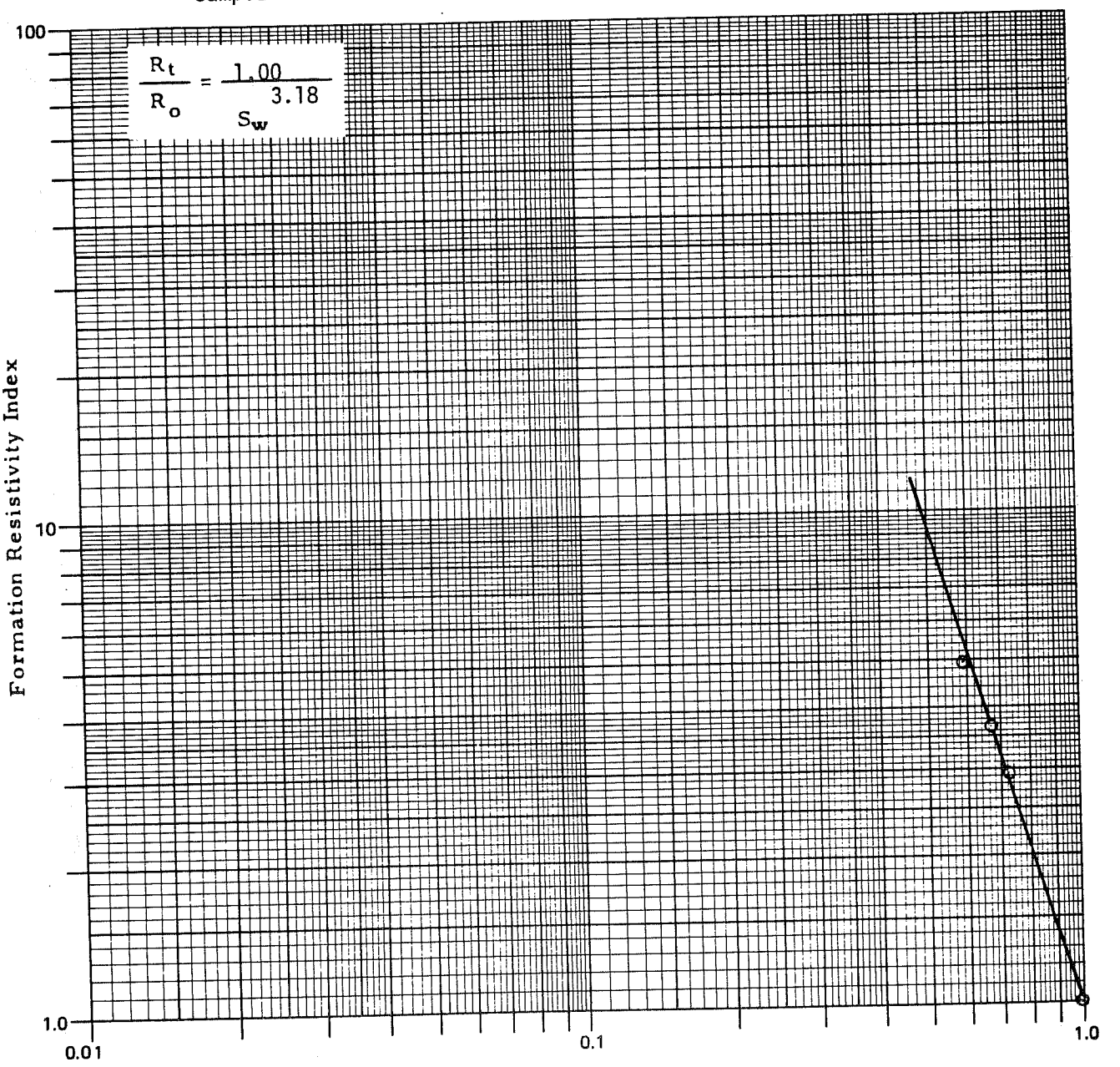
File SCAL-308-80161

Company Gruy Federal, Inc. Formation San Andres
Well Bennett Ranch Unit No. 310 County Yoakum
Field Wasson State Texas



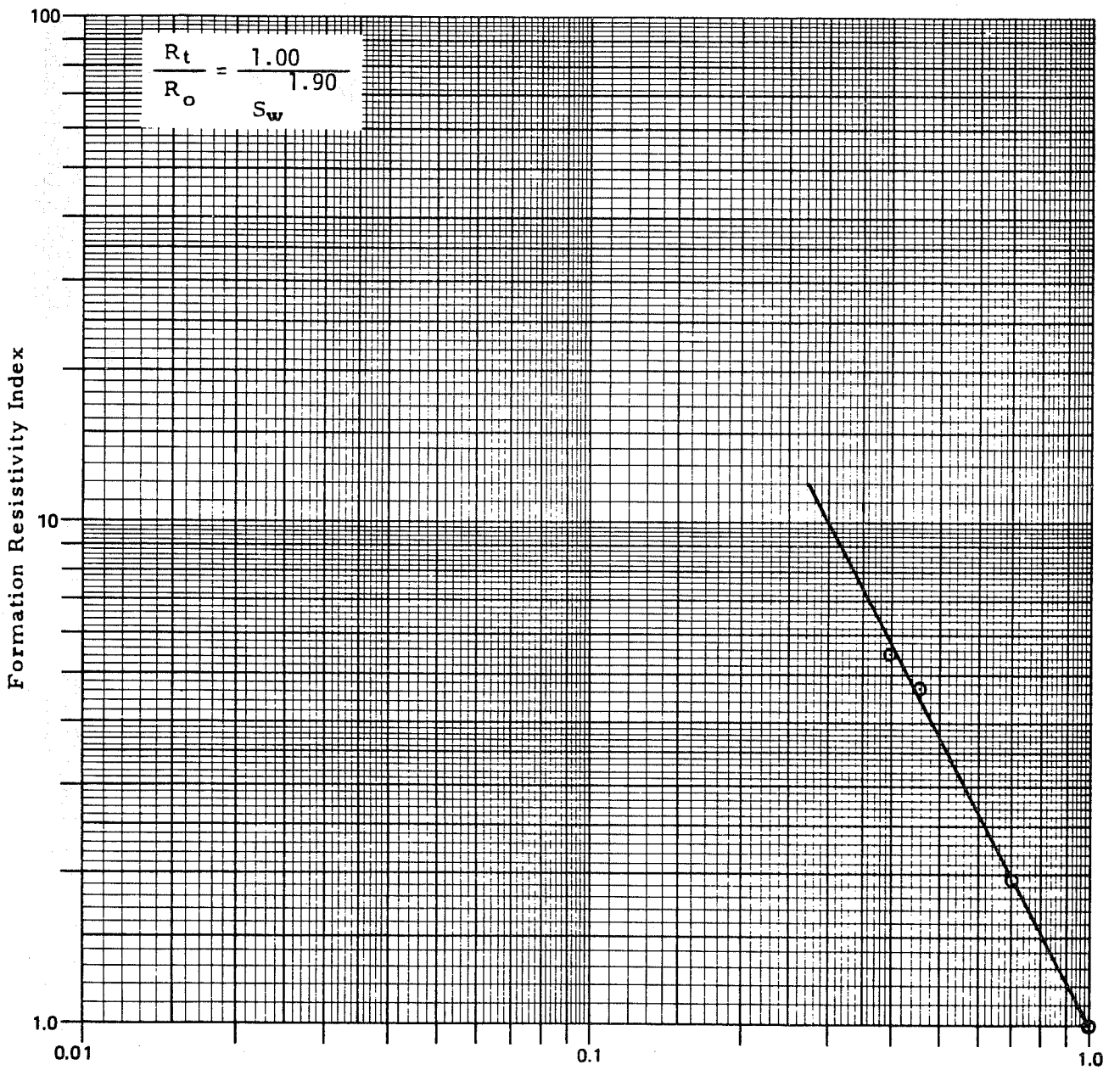
Company Gruy Federal, Inc. Formation San Andres
Well Bennett Ranch Unit No. 310 County Yoakum
Field Wasson State Texas

Sample Number: 179A



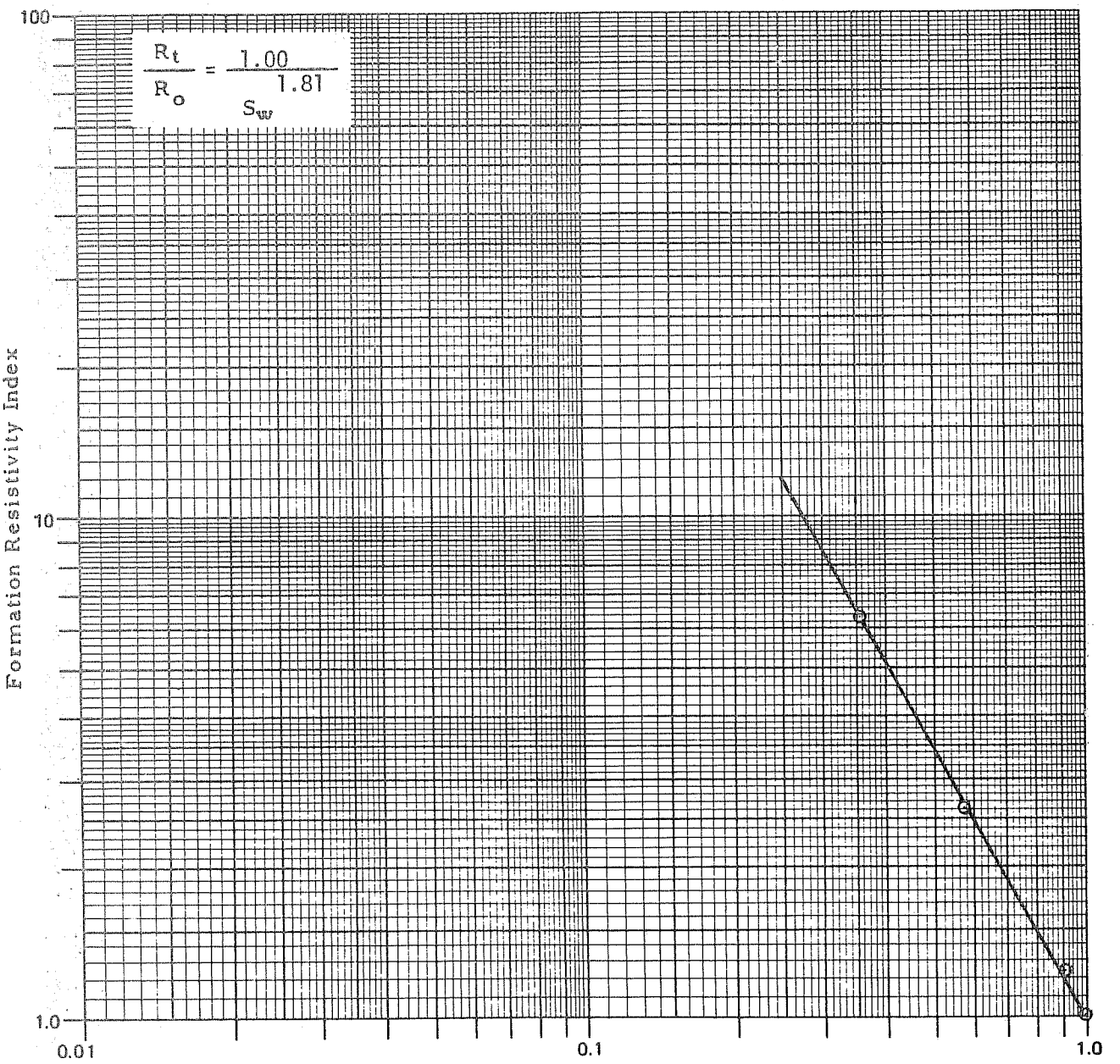
Company Gruy Federal, Inc. Formation San Andres
Well Bennett Ranch Unit No. 310 County Yoakum
Field Wasson State Texas

Sample Number: 183A



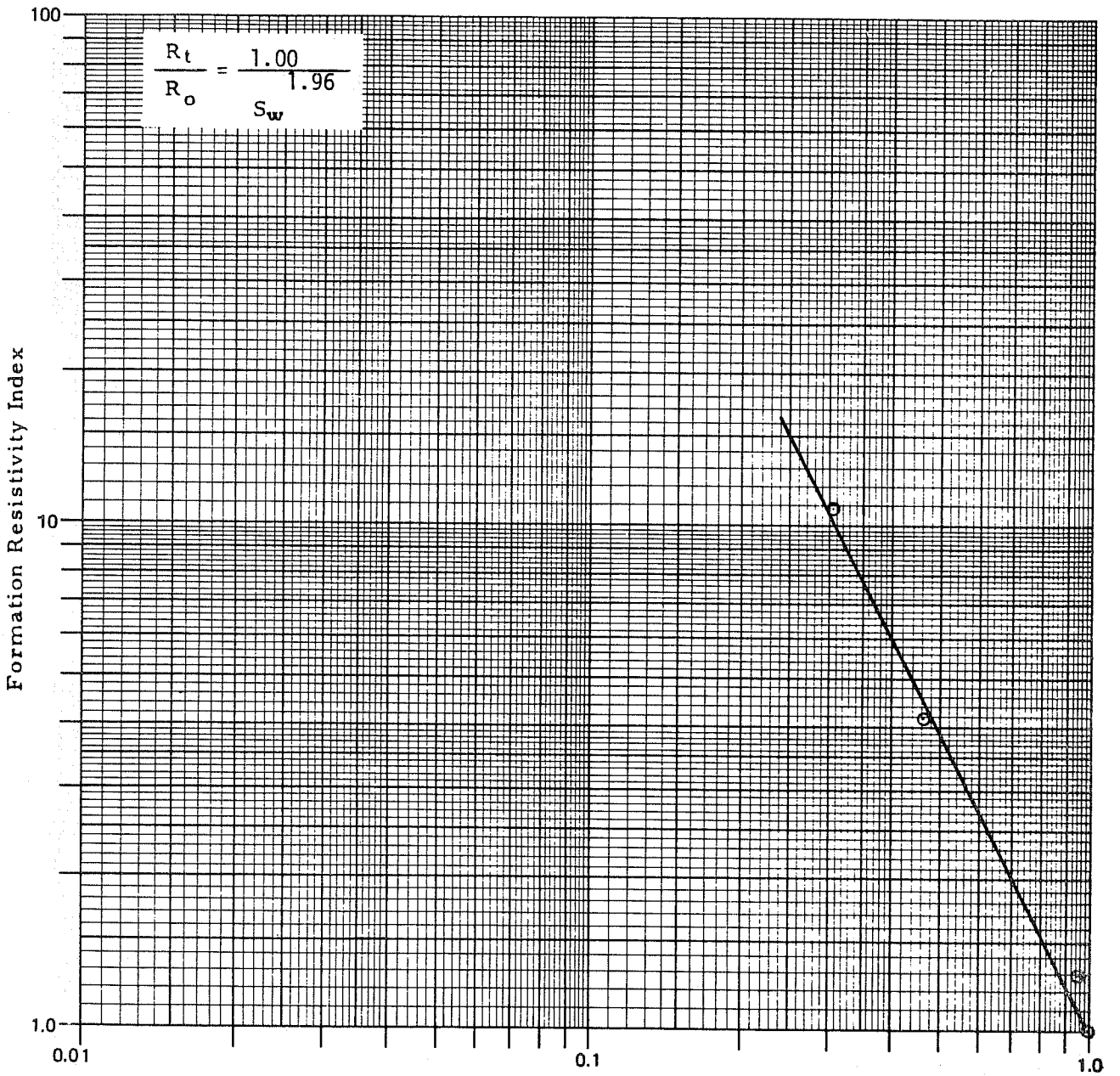
Company Gruy Federal, Inc. Formation San Andres
Well Bennett Ranch Unit No. 310 County Yoakum
Field Wasson State Texas

Sample Number: 191A



Company Gruy Federal, Inc. Formation San Andres
Well Bennett Ranch Unit No. 310 County Yoakum
Field Wasson State Texas

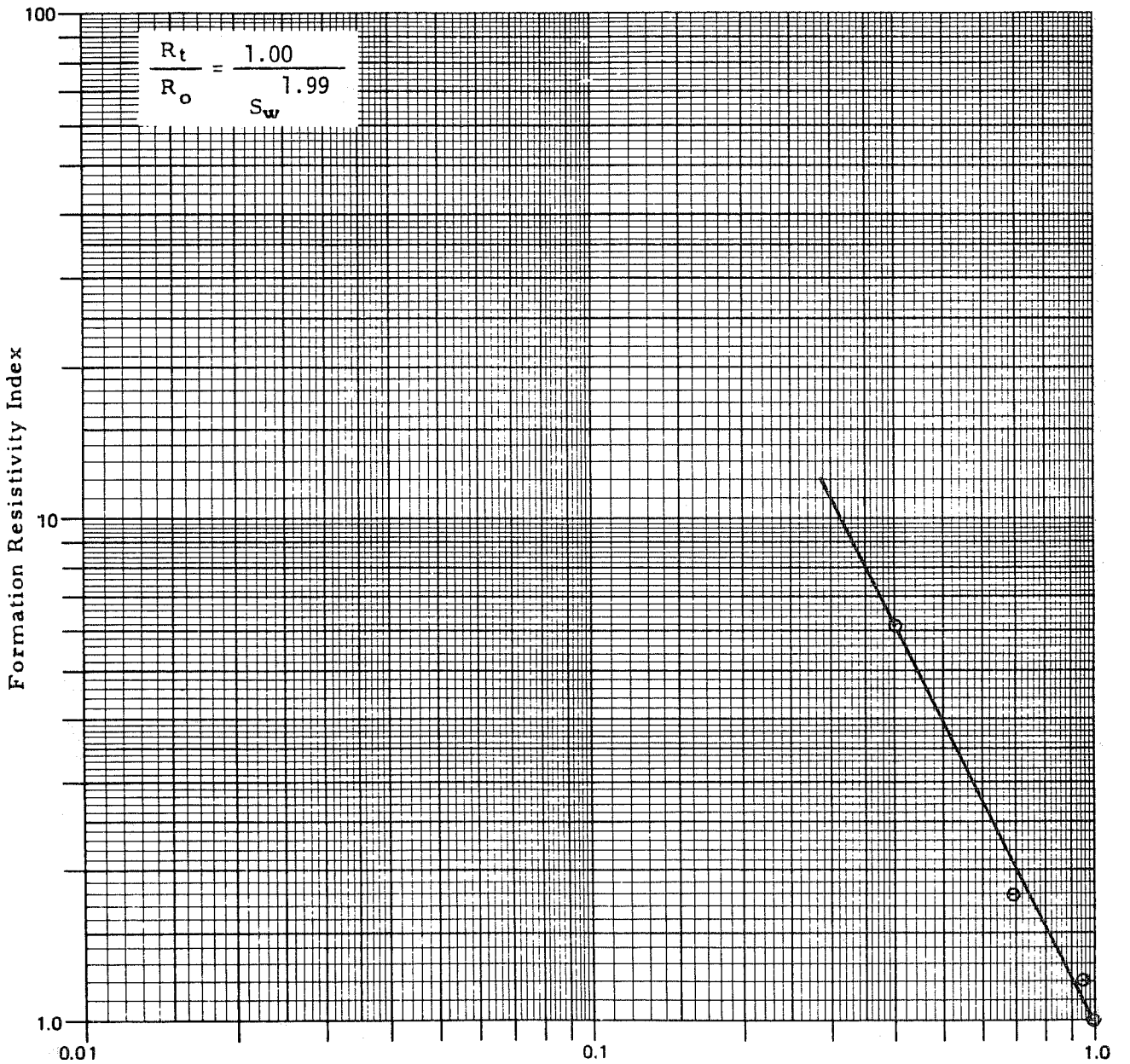
Sample Number: 200A



CL 847/SCAL 4006

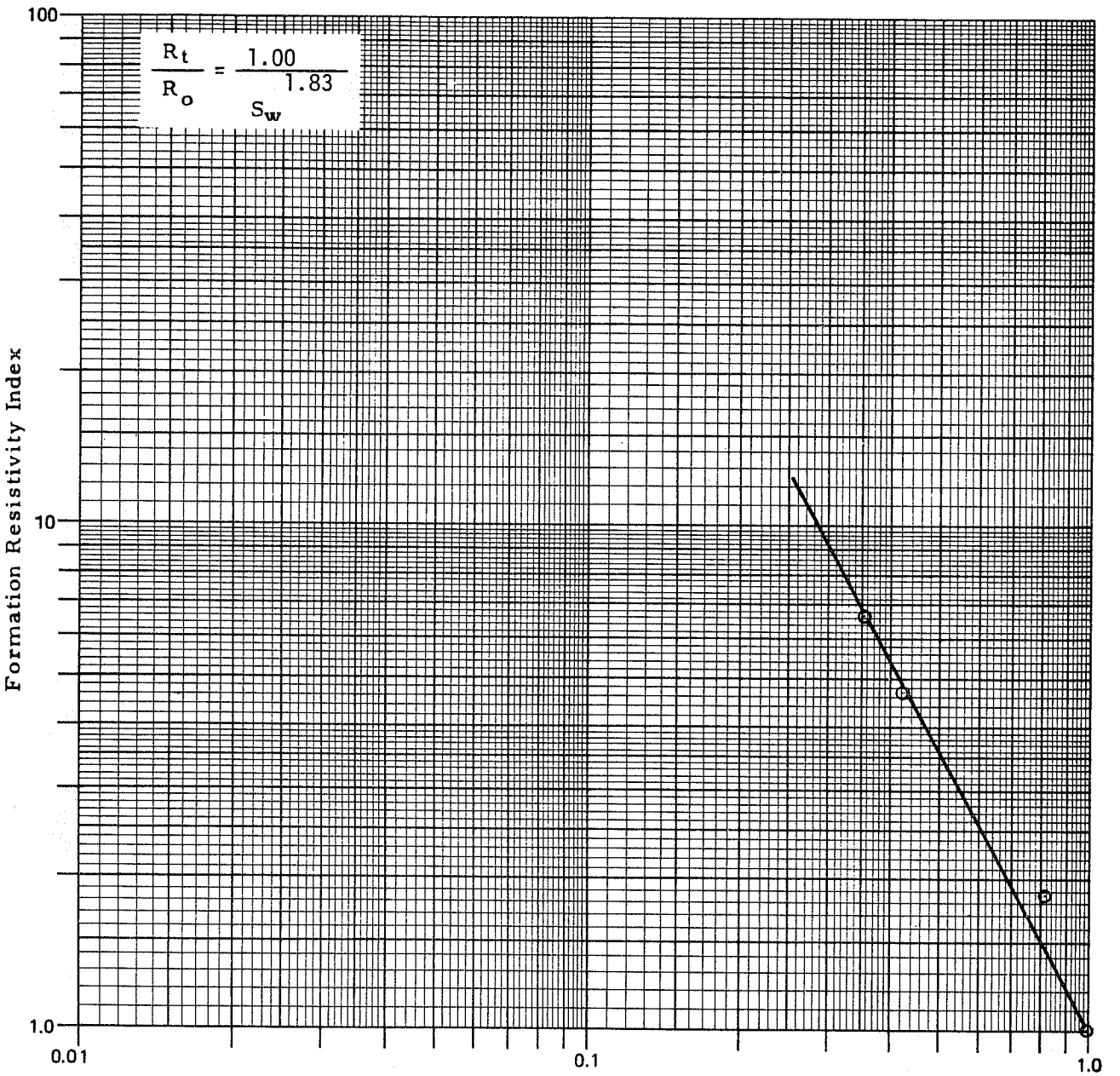
Company Gruy Federal, Inc. Formation San Andres
Well Bennett Ranch Unit No. 310 County Yoakum
Field Wasson State Texas

Sample Number: 208A



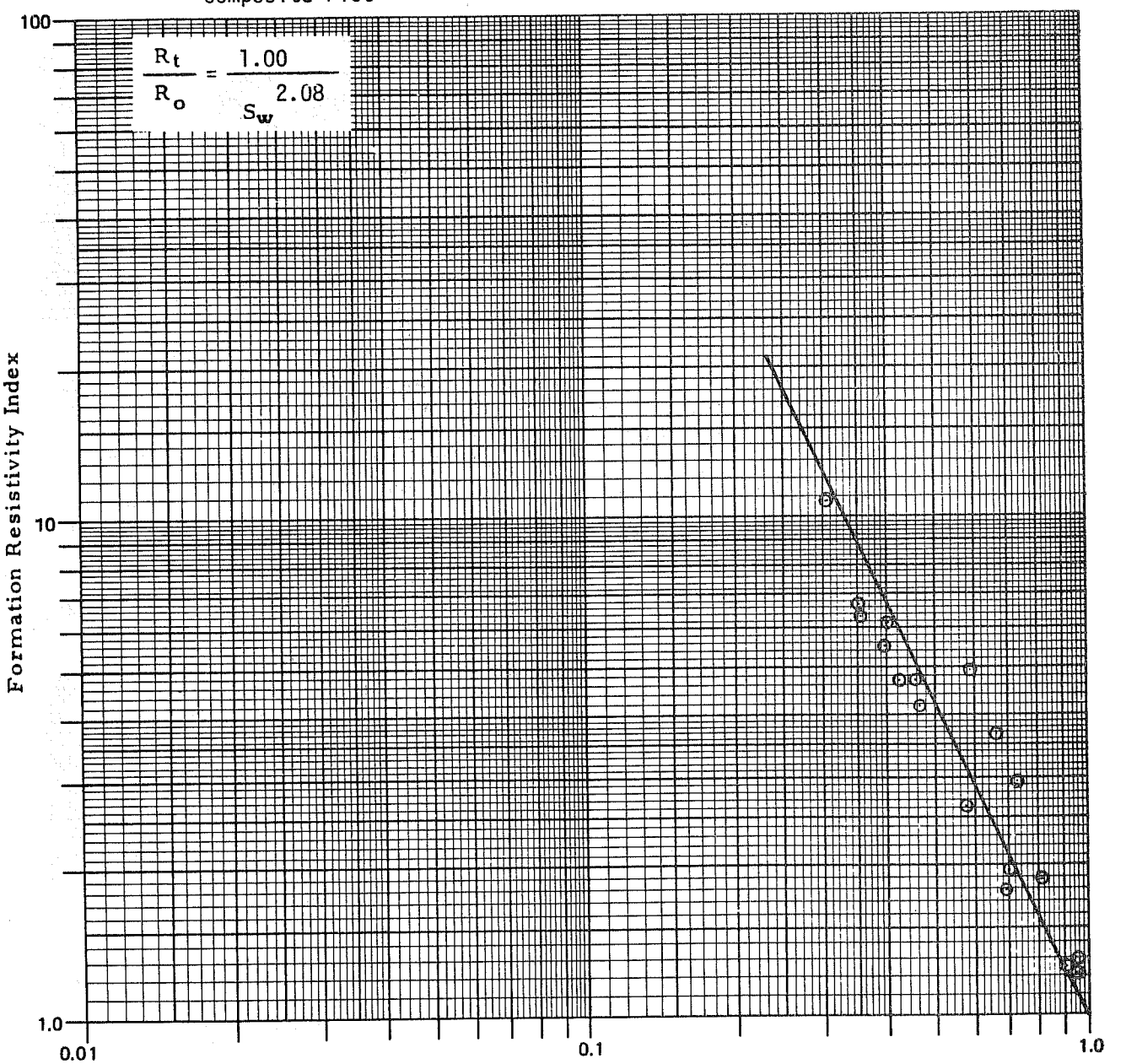
Company Gruy Federal, Inc. Formation San Andres
Well Bennett Ranch Unit No. 310 County Yoakum
Field Wasson State Texas

Sample Number: 230A



Company Gruy Federal, Inc. Formation San Andres
Well Bennett Ranch Unit No. 310 County Yoakum
Field Wasson State Texas

Composite Plot



CL 847/SCAL 4006

TELEDYNE
ISOTOPES
50 VAN BUREN AVENUE
WESTWOOD, NEW JERSEY 07675
(201) 664-7070
TELEX 134474 TDYISOT WTWD

13 November 1979

Mr. John Goodrich
Gruy Federal Inc.
2500 Tanglewilde
Suite 150
Houston, TX 77063

Re: W. O. No. 3-0295

Dear Mr. Goodrich:

Enclosed is the Report of Analysis for the above referenced work order. This comprises the tritium results from the first set of mud filtrate samples which have previously been reported to you by telephone.

The units of tritium (H-3) measurement are picocuries per liter (pCi/ℓ) of filtered liquid. All are reported with a statistical counting error ± 10%, and all from this set are in the activity range of E 06 (millions).

A picocurie is $1x10^{-12}$ of a curie. It is an environmental level of radiation measurement. A total activity of $5x10^{11}$ picocuries (0.5 Ci) was used to tag the initial mud mixture, and represents $\sim\frac{5x10^{6}\ pCi\ (\text{Average Filtrate Activity})}{5x10^{11}pCi\ (\text{Total Tracer Injected})}$ $\sim 1x10^{-5}$ of the average sample activity listed on the Report of Analysis.

Should you have additional questions please feel free to call.

Yours truly,

Andrew Carmichael

Andrew Carmichael
TeleTrace Project Coordinator

AC:hp
enclosure

cc: Mr. T. Calhoun, Petroleum Tracers w/encl.
Mr. Tommy C. Wilson, Texas Pacific Oil Co. w/encl.

TELEDYNE ISOTOPES

REPORT OF ANALYSIS

RUN DATE 11/08/79

WORK ORDER NUMBER	CUSTOMER P.O. NUMBER	DATE RECEIVED	DELIVERY DATE	PAGE
3-0295	3027-72	10/25/79	11/23/79	1

MR JOHN GOODRICH
GRUY FEDERAL INC
2500 TANGLEWILDE
SUITE 150
HOUSTON TX 77063

W A T E R

TELEDYNE SAMPLE NUMBER	CUSTOMER'S IDENTIFICATION	STA NUM	COLLECTION-DATE START DATE	START TIME	STOP DATE	STOP TIME	NUCLIDE	ACTIVITY (pCi/liter)	NUCL-UNIT-% U/M *	MID-COUNT TIME DATE	MID-COUNT TIME TIME	VOLUME - UNITS ASH-WGHT-% *	LAB.
77560	MUD FLTRT AT 5251 FT		10/05				H-3	5.40+-0.54E 06		11/04			5
77561	MUD FLTRT AT 5272 FT		10/06				H-3	5.09+-0.51E 06		11/04			5
77562	MUD FLTRT AT 5292 FT		10/07				H-3	4.79+-0.48E 06		11/04			5
77563	MUD FLTRT AT 5321 FT		10/08				H-3	4.55+-0.46E 06		11/04			5
77564	MUD FLTRT AT 5337 FT		10/09				H-3	4.72+-0.47E 06		11/04			5
77565	MUD FLTRT AT 5348 FT		10/10				H-3	4.18+-0.42E 06		11/04			5
77566	MUD FLTRT AT 5371 FT		10/11				H-3	4.13+-0.41E 06		11/04			5

226

LAST PAGE OF REPORT

APPROVED BY K. ROACH 11/08/79

SEND 1 COPIES TO GR830S MR JOHN GOODRICH
SEND 1 COPIES TO PE850N MR T CALHOUN

2 - GAS LAB. 3 - RADIO CHEMISTRY LAB. 4 - Ge(Li) GAMMA SPEC LAB. 5 - TRITIUM GAS/L.S. LAB.

TELEDYNE
ISOTOPES
50 VAN BUREN AVENUE
WESTWOOD, NEW JERSEY 07675
(201) 664-7070
TELEX 134474 TDYISOT WTWD

14 December 1979

FORWARD
GRUY FEDERAL INC.
HOUSTON, TEXAS

Mr. John Goodrich
Gruy Federal Inc.
2500 Tanglewilde
Suite 150
Houston, TX 77063

Re: W. O. No. 3-0573 DEC 19 1979

Dear Mr. Goodrich:

Enclosed is the Report of Analysis for the above referenced work order. As I mentioned to you over the telephone Thrusday, there were two samples that contained insufficient water for analysis. Also there were several samples that contained much less than one milliliter of water and, therefore, their data shows a larger uncertainty.

Yours truly,

Andrew Carmichael

Andrew Carmichael
TeleTrace Project Coordinator

AC:hp
enclosures

cc: Mr. T. Calhoun w/encl.

TELEDYNE ISOTOPES

REPORT OF ANALYSIS

RUN DATE 12/11/79

WORK ORDER NUMBER	CUSTOMER P.O. NUMBER	DATE RECEIVED	DELIVERY DATE	PAGE
3-0573	3027-72	11/30/79	12/14/79	1

MR JOHN GOODRICH
GRUY FEDERAL INC
2500 TANGLEWILDE
SUITE 150
HOUSTON TX 77063

WATER - GROUND

TELEDYNE SAMPLE NUMBER	CUSTOMER'S IDENTIFICATION	STA NUM	COLLECTION-DATE START DATE	START TIME	STOP DATE	STOP TIME	NUCLIDE	ACTIVITY (pCi/liter)	NUCL-UNIT-% U/M *		MID-COUNT TIME DATE	MID-COUNT TIME TIME	VOLUME - UNITS ASH-WGHT-% *	LAB.
79505	BENNETT RH U310 P5191		11/0R				H-3	L.T. 2.2 E 05			12/07			5
79506	BENNETT RH U310 B5191		11/0R				H-3	1.57+-0.15E 04			12/05			5
79507	BENNETT RH U310 P5195		11/0R				H-3	1.55+-1.07E 04			12/05			5
79508	BENNETT RH U310 B5195		11/0R				H-3	2.10+-0.21E 04			12/05			5
79509	BENNETT RH U310 P5198		11/0R				H-3	1.32+-0.40E 05			12/07			5
79510	BENNETT RH U310 B5198		11/0R				H-3	1.15+-0.12E 05			12/05			5
79511	BENNETT RH U310 P5201		11/0R				H-3	NOT ANALYZED	NONE	*				5
79512	BENNETT RH U310 B5201		11/0R				H-3	9.84+-0.98E 04			12/05			5
79513	BENNETT RH U310 P5204		11/0R				H-3	NOT ANALYZED	NONE	*				5
79514	BENNETT RH U310 B5204		11/0R				H-3	6.47+-0.65E 04			12/05			5
79515	BENNETT RH U310 P5242		11/0R				H-3	1.80+-0.21E 05			12/07			5
79516	BENNETT RH U310 B5242		11/0R				H-3	1.54+-0.16E 05			12/05			5
79517	BENNETT RH U310 P5245		11/0R				H-3	1.45+-1.23E 04			12/07			5
79518	BENNETT RH U310 B5245		11/0R				H-3	4.88+-0.49E 04			12/05			5

TELEDYNE ISOTOPES

REPORT OF ANALYSIS

RUN DATE 12/11/79

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MR JOHN GOODRICH
GRUY FEDERAL INC
2500 TANGLEWILDE
SUITE 150
HOUSTON TX 77063

WATER - GROUND

TELEDYNE SAMPLE NUMBER	CUSTOMER'S IDENTIFICATION	STA NUM	COLLECTION-DATE START DATE	START TIME	STOP DATE	STOP TIME	NUCLIDE	ACTIVITY (pCi/liter)	NUCL-UNIT-% U/M *	MID-COUNT TIME DATE	MID-COUNT TIME TIME	VOLUME - UNITS ASH-WGHT-% *	LAB.
79519	BENNETT RH U310 P5248		11/0R				H-3	L.T. 5. E 04		12/07			5
79520	BENNETT RH U310 B5248		11/0R				H-3	4.42+-0.44E 04		12/05			5
79521	BENNETT RH U310 P5259		11/0R				H-3	L.T. 1.4 E 05		12/07			5
79522	BENNETT RH U310 B5259		11/0R				H-3	1.47+-0.15E 05		12/05			5
79523	BENNETT RH U310 P5262		11/0R				H-3	6.52+-1.13E 04		12/07			5
79524	BENNETT RH U310 B5262		11/0R				H-3	1.27+-0.13E 05		12/05			5
79525	BENNETT RH U310 P5265		11/0R				H-3	1.25+-1.06E 04		12/06			5
79526	BENNETT RH U310 B5265		11/0R				H-3	8.72+-0.87E 04		12/06			5
79527	BENNETT RH U310 P5282		11/0R				H-3	1.35+-0.14E 05		12/05			5
79528	BENNETT RH U310 B5282		11/0R				H-3	1.24+-0.12E 05		12/06			5
79529	BENNETT RH U310 P5285		11/0R				H-3	3.11+-0.45E 04		12/05			5
79530	BENNETT RH U310 B5285		11/0R				H-3	7.68+-0.77E 04		12/05			5
79531	BENNETT RH U310 P5288		11/0R				H-3	8.56+-0.85E 04		12/05			5
79532	BENNETT RH U310 B5288		11/0R				H-3	1.14+-0.11E 05		12/06			5

TELEDYNE ISOTOPES

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WATER - GROUND

TELEDYNE SAMPLE NUMBER	CUSTOMER'S IDENTIFICATION	STA NUM	COLLECTION-DATE START DATE	START TIME	STOP DATE	STOP TIME	NUCLIDE	ACTIVITY (pCi/liter)	NUCL-UNIT-% U/M *	MID-COUNT TIME DATE	MID-COUNT TIME TIME	VOLUME - UNITS ASH-WGHT-% *	LAB.
79533	BENNETT RH U310 P5337		11/0R				H-3	4.25+-0.66E 04		12/06			5
79534	BENNETT RH U310 B5337		11/0R				H-3	1.27+-0.13E 05		12/06			5
79535	BENNETT RH U310 P5379		11/0R				H-3	9.91+-0.99E 04		12/06			5
79536	BENNETT RH U310 B5379		11/0R				H-3	1.19+-0.12E 05		12/06			5
79537	BENNETT RH U310 P5382		11/0R				H-3	9.16+-0.92E 04		12/06			5
79538	BENNETT RH U310 B5382		11/0R				H-3	1.52+-0.15E 05		12/07			5
79539	BENNETT RH U310 P5385		11/0R				H-3	1.37+-0.38E 04		12/07			5
79540	BENNETT RH U310 B5385		11/0R				H-3	6.82+-0.68E 04		12/07			5

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SEND 1 COPIES TO PE850N MR F CALHOUN

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TELEDYNE
ISOTOPES
50 VAN BUREN AVENUE
WESTWOOD, NEW JERSEY 07675
(201) 664-7070
TELEX 134474 TDYISOT WTWD

14 January 1980

JAN 21 1980

Mr. John Goodrich
Gruy Federal Inc.
2500 Tanglewilde
Suite 150
Houston, TX 77063

Re: W. O. Nos. 3-0787, 0788

Dear Mr. Goodrich:

Enclosed are the Reports of Analysis for the above referenced work orders.

Four samples specified on your paper work were not received by us. Two reported less than values were greater than our usual $2x10^3$ pCi/ℓ MLD due to low initial sample volume. Also, five positive tritium values carried greater than ± 10% 1σ uncertainties due to low sample volumes.

Yours truly,

Andrew Carmichael

Andrew Carmichael
TeleTrace Project Coordinator

AC:hp
enclosures

cc: Mr. T. Calhoun w/encl.
Mr. T. C. Wilson, Tex. Pacific Oil Co., w/encl.

TELEDYNE ISOTOPES

REPORT OF ANALYSIS

RUN DATE 01/08/80

WORK ORDER NUMBER	CUSTOMER P.O. NUMBER	DATE RECEIVED	DELIVERY DATE	PAGE 1
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MR JOHN GOODRICH
GRUY FEDERAL INC
2500 TANGLEWILDE
SUITE 150
HOUSTON TX 77063

WATER - GROUND

TELEDYNE SAMPLE NUMBER	CUSTOMER'S IDENTIFICATION	STA NUM	COLLECTION-DATE START DATE	START TIME	STOP DATE	STOP TIME	NUCLIDE	ACTIVITY (pCi/liter)	NUCL-UNIT-% U/M *	MID-COUNT TIME DATE	MID-COUNT TIME TIME	VOLUME - UNITS ASH-WGHT-% *	LAB.
81110	NO 1 D 5181		11/12				H-3	2.34+-0.23E 06		01/03			5
81111	NO 1 P NONE RECEIVED		11/12				SAMPLE	NOT C OLLECTED	NONE *				3
81112	NO 2 D 5187		11/12				H-3	1.68+-0.17E 05		01/03			5
81113	NO 2 P NONE RECEIVED		11/12				SAMPLE	NOT C OLLECTED	NONE *				3
81114	NO 3 D 5211		11/12				H-3	1.55+-0.16E 05		01/03			5
81115	NO 3 P		11/12				H-3	NOT ANALYZED					5
81116	NO 4 D 5214		11/12				H-3	1.58+-0.16E 06		01/03			5
81117	NO 4 P		11/12				H-3	3.24+-0.62E 04		01/03			5
81118	NO 5 D 5217		11/12				H-3	6.54+-0.65E 04		01/03			5
81119	NO 5 P		11/12				H-3	L.T. 1.5 E 04		01/03			5
81120	NO 6 D 5220		11/12				H-3	NOT ANALYZED					5
81121	NO 6 P		11/28				H-3	L.T. 1.5 E 04		01/04			5
81122	NO 7 D 5226		11/28				H-3	9.40+-0.94E 05		01/04			5
81123	NO 7 P		11/28				H-3	2.18+-1.10E 04		01/04			5

TELEDYNE ISOTOPES

REPORT OF ANALYSIS

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MR JOHN GOODRICH
GRUY FEDERAL INC
2500 TANGLEWILDE
SUITE 150
HOUSTON TX 77063

WATER - GROUND

TELEDYNE SAMPLE NUMBER	CUSTOMER'S IDENTIFICATION	STA NUM	COLLECTION-DATE START DATE	START TIME	STOP DATE	STOP TIME	NUCLIDE	ACTIVITY (pCi/liter)	NUCL-UNIT-% U/M *	MID-COUNT TIME DATE	MID-COUNT TIME TIME	VOLUME - UNITS ASH-WGHT-% *	LAB.
81124	NO 8 D 5233		11/28				H-3	1.47+-0.15E 06		01/04			5
81125	NO 8 P		11/28				H-3	1.16+-0.12E 06		01/04			5
81126	NO 9 D 5236		11/28				H-3	2.32+-0.23E 06		01/04			5
81127	NO 9 P		11/28				H-3	5.75+-0.58E 05		01/04			5
81128	NO 10 D 5252		12/03				H-3	2.97+-0.30E 05		01/04			5
81129	NO 10 P		12/03				H-3	1.46+-0.15E 05		01/04			5
81130	NO 11 D 5257		12/03				H-3	2.27+-0.23E 06		01/04			5
81131	NO 11 P		12/03				H-3	2.12+-0.21E 05		01/04			5
81132	NO 12 D 5270		12/03				H-3	1.26+-0.13E 05		01/04			5
81133	NO 12 P		12/03				H-3	4.16+-0.42E 05		01/05			5
81134	NO 13 D 5274		12/03				H-3	1.21+-0.12E 05		01/05			5
81135	NO 13 P		12/03				H-3	3.54+-0.39E 04		01/05			5
81136	NO 14 D 5278		12/03				H-3	5.23+-0.52E 05		01/05			5
81137	NO 14 P		12/03				H-3	2.83+-1.11E 04		01/05			5

TELEDYNE ISOTOPES

REPORT OF ANALYSIS

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MR JOHN GOODRICH
GRUY FEDERAL INC
2500 TANGLEWILDE
SUITE 150
HOUSTON TX 77063

WATER - GROUND

TELEDYNE SAMPLE NUMBER	CUSTOMER'S IDENTIFICATION	STA NUM	COLLECTION-DATE START DATE	START TIME	STOP DATE	STOP TIME	NUCLIDE	ACTIVITY (pCi/liter)	NUCL-UNIT-% U/M *	MID-COUNT TIME DATE	MID-COUNT TIME TIME	VOLUME - UNITS ASH-WGHT-% *	LAB.
81138	NO 15 D 5293		12/07				H-3	3.16+-0.32E 05		01/05			5
81139	NO 15 P		12/07				H-3	2.34+-0.26E 04		01/05			5
81140	NO 16 D 5298		12/07				H-3	4.31+-0.43E 05		01/05			5
81141	NO 16 P		12/07				H-3	3.77+-0.38E 05		01/05			5
81142	NO 17 D 5304		12/07				H-3	9.09+-0.91E 04		01/05			5
81143	NO 17 P		12/07				H-3	1.22+-0.55E 04		01/05			5
81144	NO 18 D 5311		12/07				H-3	2.31+-0.23E 05		01/05			5
81145	NO 18 P		12/07				H-3	L.T. 2. E 03		01/05			5
81146	NO 19 D 5317		12/07				H-3	1.86+-0.19E 05		01/05			5
81147	NO 19 P		12/07				H-3	1.73+-0.18E 05		01/06			5
81148	NO 22 D 5328		12/11				H-3	3.58+-0.36E 05		01/05			5
81149	NO 22 P NONE RECEIVED		12/11				SAMPLE	NOT C OLLECTED	NONE *				3
81150	NO 23 D 5336		12/11				H-3	6.76+-0.68E 05		01/05			5
81151	NO 23 P		12/11				H-3	1.79+-0.18E 05		01/06			5

TELEDYNE ISOTOPES

REPORT OF ANALYSIS

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MR JOHN GOODRICH
GRUY FEDERAL INC
2500 TANGLEWILDE
SUITE 150
HOUSTON TX 77063

WATER - GROUND

TELEDYNE SAMPLE NUMBER	CUSTOMER'S IDENTIFICATION	STA NUM	COLLECTION-DATE START DATE	START TIME	STOP DATE	STOP TIME	NUCLIDE	ACTIVITY (pCi/liter)	NUCL-UNIT-% U/M *	MID-COUNT TIME DATE	MID-COUNT TIME TIME	VOLUME - UNITS ASH-WGHT-% *	LAB.
81162	NO 20 D 5319.8 - 20.1		12/11				H-3	1.39+-0.14E 05		01/03			5
81163	NO 20 P		12/11				H-3	1.30+-0.13E 05		01/03			5
81164	NO 21 D 5323.45 - 23.75		12/11				H-3	1.58+-0.16E 04		01/03			5
81165	NO 21 P		12/11				H-3	L.T. 5. E 03		01/03			5
81166	NO 22 D NONE RECEIVED 5327.5 - 5327.65		12/11				SAMPLE	NOT C OLLECTED	NONE *				3
81167	NO 22 P		12/11				H-3	8.7 +-1.6 E 03		01/03			5

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TELEDYNE ISOTOPES

REPORT OF ANALYSIS

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MR JOHN GOODRICH
GRUY FEDERAL INC
2500 TANGLEWILDE
SUITE 150
HOUSTON TX 77063

WATER - GROUND

TELEDYNE SAMPLE NUMBER	CUSTOMER'S IDENTIFICATION	STA NUM	COLLECTION-DATE START DATE	START TIME	STOP DATE	STOP TIME	NUCLIDE	ACTIVITY (pCi/liter)	NUCL-UNIF-% U/M *	MID-COUNT TIME DATE	MID-COUNT TIME TIME	VOLUME - UNITS ASH-WGHT-% *	LAB.
81152	NO 24 D	5341.0 - 41.25	12/08				H-3	1.52+-0.15E 05		01/06			5
81153	NO 24 P		12/08				H-3	8.91+-0.89E 04		01/05			5
81154	NO 25 D	5347.55 - 5347.8	12/14				H-3	2.57+-0.26E 05		01/06			5
81155	NO 25 P		12/14				H-3	4.65+-0.47E 04		01/05			5
81156	NO 26 D	5355.25 - 5355.5	12/14				H-3	2.63+-0.25E 05		01/06			5
81157	NO 26 P		12/14				H-3	3.39+-0.34E 04		01/06			5
81158	NO 27 D	5363.9 - 5364.2	12/14				H-3	4.16+-0.42E 05		01/06			5
81159	NO 27 P		12/14				H-3	5.38+-0.54E 04		01/06			5
81160	NO 28 D	5374.85 - 5375.2	12/14				H-3	1.40+-0.14E 06		01/07			5
81161	NO 28 P		12/14				H-3	3.86+-0.39E 05		01/07			5

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OPERATOR AND PROGRAMMER MANUAL FOR CORE AND LOG ANALYSIS MODELING SYSTEM

by

Terry E. Swift

and

Raj M. Kumar

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III. CLAMS Options

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Introduction

The Gruy Federal Core and Log Analysis Modeling System was developed to aid in the log analysis of open hole well logs through cored intervals. Core data, though extremely valuable in the interpretation, is not required to run the model, hereafter referred to as CLAMS. CLAMS is comprehensive and allows the analyst complete versatility. Log corrections, such as bed thickness and invasion, should be made prior to data entry. However, volume of shale, lithology, normalization, and hydrocarbon corrections can be made internally. Furthermore, a variety of option combinations allows the analyst to use core data results to arrive at an appropriate log analysis technique. The model is very simple to use. The operator selects the desired options and inputs log and core data. CLAMS performs the desired computations and presents the average values. If requested, CLAMS compares the log calculations to the core analysis. Finally, CLAMS reproduces all input data to verify the computations.

Technical Discussion

The Core and Log Analysis Modeling System (CLAMS) has incorporated a wide range of equations and assumptions. Many of these equations have severe limitations and should be used with great care. The equations and assumptions are presented in this document in the same order as they appear in the computer program. Sub-routines, involving cross plot equations, are discussed following the main program equations.

Normalization Equations

Density:

$$pbn = A1 * pb + B1$$

where,

pbn = normalized bulk density (gm/cc)
pb = bulk density (gm/cc)
A1 = slope
B1 = intercept

Sonic:

$$\Delta tb_n = A2 * \Delta t_b + B2$$

where,

Δtb_n = normalized travel time (m-sec/ft)
Δt_b = travel time (m-sec/ft)
A2 = slope
B2 = intercept

Neutron:

$$\text{ØN}_n = A3 * \text{ØN} + B3$$

where,

ØNn = normalized neutron porosity (dec.)
ØN = neutron porosity (dec.)
A3 = slope
B3 = intercept

Resistivity: (deep and shallow)

$$1/Rt_n = A4/Rt + B4/1000$$

$$(1/R_{xon} = A4/Rxo + B4/1000)$$

where,

Rtn = normalized deep resistivity (ohm-m)
Rxon= normalized shallow resistivity (ohm-m)
Rt = deep resistivity (ohm-m)
Rxo = shallow resistivity (ohm-m)
A4 = slope
B4 = intercept

Note: the preceeding equations are based on conductivity response, i.e.,

$$C_n = A4 * C + B4$$

where,

C_n = normalized conductivity (millimho)
C = conductivity (millimho)
and C = 1000/Rt

Density and Sonic Lithology and Fluid Corrections

Density:

$$\phi D = (Pbn - Pma)/(Pf - Pma)$$

where,

ϕD = density porosity (dec.)
Pma = density of matrix (gm/cc)
Pf = density of fluid (gm/cc)

Sonic:

$$\phi S = (\Delta tb_n - \Delta tma)/(\Delta t_f - \Delta tma)$$

where,

ϕS = sonic porosity (dec.)
Δtma = travel time of matrix (m-sec/ft)
Δt_f = travel time of fluid (m-sec/ft)

Neutron Matrix Correction

$$\phi N_2 = (\phi Nsd - Hma_2 - \nabla) / (H_f - Hma_2)$$

and

$$\phi Nsd = f(\phi N_1, Hma_1)$$

where,

ϕN_2 = final neutron porosity (dec.)
ϕNsd = neutron porosity in sandstone (dec.)
Hma_2 = final hydrocarbon index of matrix
Hf = hydrocarbon index of fluid
Hma_1 = initial hydrogen index of matrix
ϕN_1 = initial neutron porosity (dec.)

The hydrogen index of the fluid is generally assumed to be 1. The following table illustrates the various matrix values for this correlation.

Density of Matrix	Hydrogen Index of Matrix
2.65	0.000
2.71	.026
2.87	.065

Volume of Shale Calculations

Gamma Ray Index:

$$GRI = (GR - GRsd) / (GRsh - GRsd)$$

where,

GRI = gamma ray index
GR = gamma ray of formation
GRsd = gamma ray in clean sand
GRsh = gamma ray in shale

Straight Gamma Volume of Shale:

$$Vsh = GRI$$

where,

Vsh = volume of shale (dec.)

Older rocks (Dresser):

$$Vsh = 1.777 - (3.781 - (GRI + .806)^2)^{\frac{1}{2}}$$

Tertiary Rocks (Dresser):

$$Vsh = 2. - (4.-GRI*(GRI^2 + GRI + 1.))^{\frac{1}{2}}$$

Basic 'q' shale relation:

$$Vsh = (\phi S - \phi D) / \phi S$$

Cross Plot Volume of Shale Calculations

Density-Neutron:

$$V1 = (\phi D - \phi e)$$
$$V2 = (\phi N - \phi e)$$
$$Vsh = (V1 + V2)/(\phi Nsh + \phi Dsh)$$

where,

ϕe = effective porosity (dec.)
ϕDsh = density shale porosity (dec.)
ϕNsh = neutron shale porosity (dec.)

Density-Sonic:

$$V3 = (\phi S - \phi e)$$
$$Vsh = (V1 + V3) / (\phi Dsh + \phi Ssh)$$

where,

ϕSh = sonic shale porosity (dec.)

Density-Neutron-Sonic:

$$Vsh = (V1 + V2 + V3)/(\phi Nsh + \phi Dsh + \phi Ssh)$$

Porosity Shale Corrections

Density-Sonic-Neutron:

$$\phi Dsc = \phi D - Vsh\phi Dsh$$
$$\phi Nsc = \phi N - Vsh\phi Nsh$$
$$\phi Ssc = \phi S - Vsh\phi Ssh$$

where,

ϕDsc = porosity density shale corrected
ϕNsc = porosity neutron shale corrected
ϕSsc = porosity sonic shale corrected

Bulk Shale Corrections

$$pbsc = (1. - \emptyset Dsc) * Pma + \emptyset Dsc * Pf$$

$$\Delta tbsc = (1. - \emptyset Ssc) * \Delta tma + \emptyset Ssc * \Delta tf$$

where,

pbsc = bulk density shale corrected

Δtbsc = bulk travel time shale corrected

Temperature Calculations

$$\nabla T = (BHT - TSC)/TD$$

where,

∇T = temperature gradient (^{o}F/ft)

BHT = bottom hole temperature (^{o}F)

TSC = surface temperature (^{o}F)

TD = total depth (ft.)

$$Tf = \nabla T * DEPTH + TSC$$

where,

Tf = formation temperature (^{o}F)

DEPTH = depth of formation (ft.)

Fluid Resistivity Temperature Corrections

$$Rwf = Rwi\ (Twi + 7.6) / (Tf + 7.6)$$

where,

Rwf = resistivity of formation water (ohm-m) at formation temperature

Rwi = resistivity of formation water (ohm-m) at reference temperature

Twi = reference temperature (^{o}F)

$$Rmf = Rmfi\ (Tmfi + 7.6) / (Tf + 7.6)$$

where,

Rmf = resistivity of mud filtrate (ohm-m) at formation temperature
Rmfi = resistivity of mud filtrate (omh-m) at reference temperature
Tmfi = reference temperature (^{O}F)

Cross Plot True Porosities

Density-Neutron:

$$Ø1 = g\ (ØDsc, ØNsc)$$

Density-Sonic:

$$Ø2 = h\ (ØDsc, ØSsc)$$

Density-Neutron-Sonic:

$$Ø3 = (Ø1 + Ø2) / 2$$

(see appendix for algorithims)

Hydrocarbon Corrections

2/3 Density-Neutron Relation:

$$Øe = 2/3\ ØDsc + 1/3\ ØNsc$$

where,

Øe = effective porosity

Square-Root relation:

$$Øe = (ØD^2_{sc} + ØN^2_{sc})/2)^{½}$$

Saturation Equations:

Archie:

$$SW = (aRwf/\phi e^{m}Rt)^{1/n}$$

where,

SW = water saturation (dec.)
a = tortuosity factor
m = cementation exponent
n = saturation exponent

Basic Simendeaux Relation

$$SW = (aRwfRcl/((X + Y + 2\sqrt{XY})Rt))^{1/n}$$
$$X = aRwf\ GRI\ (2-GRI)$$
$$Y = \phi e^{m}\ Rcl$$

where,

Rcl = resistivity of clay (ohm-m)

Basic q relation

$$SW = \frac{\left(\frac{aRw}{\phi SmRt} + \frac{q^2(Rcl-Rw)^2}{4Rcl2} - \frac{q(Rcl + Rw)}{2Rcl}\right)}{(1 - q)}$$

where,

$q = (\phi S-\phi D)/\phi S$

Laminar Model

$$SW = (AB)^{1/n}$$
$$A = (1/Rt - Vsh/Rcl)$$
$$B = ((1-Vsh) * a * Rwf)/\phi e^{m}$$

Parameter Averaging

Net Sand:

$$\bar{h} = \sum_{i=1}^{N} (hi)$$

where,

$\bar{h}$ = net sand thickness (ft)

N = total number of intervals which meet volume of shale, porosity and salt water saturation requirements

hi = the individual sand thicknesses (ft)

Average Volume of Sand:

$$\overline{Vsh} = \{ \sum_{i=1}^{N} (Vshi\ hi) \} / \bar{h}$$

where,

$\overline{Vsh}$ = average volume of shale

Vshi = individual volumes of shale

Average Porosity:

$$\bar{\phi} = \{ \sum_{i=1}^{N} (\phi i\ hi) \} / \bar{h}$$

where,

$\bar{\phi}$ = average porosity

ϕi = individual porosities

Average Saltwater Saturation:

$$\overline{SW} = \{ \sum_{i=1}^{N} (SWi)(\phi i hi) \} / (\overline{\phi h})$$

where,

$\overline{SW}$ = average water saturation (dec.)

CLAMS Options

Volume of Shale Option:

- Ø.Ø = no correction
- 1.Ø = gamma ray index
- 2.Ø = older rocks
- 3.Ø = tertiary rocks
- 4.Ø = "q" equation
- 5.Ø = cross-plot calculation

Hydrocarbon Correction Option:

- Ø.Ø = no correction
- 1.Ø = 2/3 density + 1/3 neutron
- 2.Ø = square root relation for density-neutron

Porosity Option:

- 1.Ø = density porosity
- 2.Ø = sonic porosity
- 3.Ø = density-neutron cross-plot
- 4.Ø = density-sonic cross-plot
- 5.Ø = average of options 3 and 4
- 6.Ø = neutron porosity

Water Saturation Option for SW and/or Sxo:

- Ø.Ø = no calculation (Sxo only)
- 1.Ø = Archie
- 2.Ø = Simendeaux (dispersed shale)
- 3.Ø = Q equation (dispersed shale)
- 4.Ø = Laminar shale model

Core Analysis Option:

- Ø.Ø = no core analysis
- 1.Ø = core analysis using SW
- 2.Ø = core analysis using Sxo

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DATA

FORMATING

DATA INPUT FOR
FIGURE ____

CARD	COLUMNS	FORMAT	VARIABLE	DESCRIPTION	EXAMPLES
1	1-5	I5	NZONE	No. of Zones	4
2	1-10	F10.3	FLGCHK	Echo data flag No = 0.0 yes = 1.0	1.0
2	11-20	F10.3	VSHLE	Constant Volume of Shale	0.0
3	1-40	10A4	TITLE1	Alpha - title	BRU NO. 1
3	41-80	10A4	TITLE2	Alpha - title	WASSON
4	1-10	F10.3	BHT	Bottom hole temp.	105.
4	11-20	F10.3	TSC	Surface temp.	60.
4	21-30	F10.3	TD	Total Depth	5386.
4	31-40	F10.3	RWI	Water Resistivity @ TWI	.042
4	41-50	F10.3	TWI	Reference temp.	105.
4	51-60	F10.3	RMFI	Mud filtrate Resistivity @ TMFI	.16
4	61-70	F10.3	TMFI	Reference temp.	105.
5	1-10	F10.3	SLOPE	SONIC - DENSITY X-PLOT LIME-DOLOMITE (See Appendix)	-.039
5	11-20	F10.3	BB	SONIC - DENSITY X-PLOT LIME-DOLOMITE (See Appendix)	4.5676
5	21-30	F10.3	GRSD	Gamma Ray Sand	0.0

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DATA INPUT FOR
FIGURE ___

CARD	COLUMNS	FORMAT	VARIABLE	DESCRIPTION	EXAMPLES
5	31-40	F10.3	GRSH	Gamma Ray Shale	100.0
5	41-50	F10.3	RCL	Resistivity of Clay	10.0
5	51-60	F10.3	PORSHD	Density Shale Porosity	.10
5	61-70	F10.3	PORSHS	Sonic Shale Porosity	.10
5	71-80	F10.3	PORSHN	Neutron Shale Porosity	.30
6	1-10	F10.3	FLGVSH	Shale Option	5.
6	11-20	F10.3	FLGGAS	Hydrocarbon Option	- BLANK -
6	21-30	F10.3	FLGSAT	SW Option	1.
6	31-40	F10.3	FLGCORE	Core Analysis Option	2.0
6	41-50	F10.3	FLGSXO	SXO Option	1.0
6	51-60	F10.3	FLGPOR	Porosity Option	5.0
7	1-10	F10.3	AC	tortuosity factor	1.00
7	11-20	F10.3	CE	cementation exponent	2.00
7	21-30	F10.3	SE	saturation exponent	2.00
7	31-40	F10.3	DENM	Density of Matrix	2.71

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DATA INPUT FOR FIGURE ____

CARD	COLUMNS	FORMAT	VARIABLE	DESCRIPTION	EXAMPLES
7	41-50	F10.3	DENF	Density of Fluid	1.09
7	51-60	F10.3	DELTF	Travel-time of Fluid	189.
7	61-70	F10.3	DELTM	Travel-time of Matrix	47.5

DATA INPUT FOR
FIGURE ___

CARD	COLUMNS	FORMAT	VARIABLE	DESCRIPTION	EXAMPLES
8	1-10	F10.3	HIMAI	initial hydrogen index (see Appendix)	.026
8	11-20	F10.3	HIMAT	true hydrogen index	.026
9	1-10	F10.3	A1	Density slope	.525
9	11-20	F10.3	B1	Density intercept	1.144
9	21-30	F10.3	A2	Sonic slope	1.639
9	31-40	F10.3	B2	Sonic intercept	-30.028
9	41-50	F10.3	A3	Neutron slope	1.0
9	51-60	F10.3	B3	Neutron intercept	- BLANK -
9	61-70	F10.3	A4	Conductivity slope	1.0
9	71-80	F10.3	B4	Conductivity intercept	- BLANK -
10	1-10	F10.3	VSHC	Volume of Shale Cut off	.30
10	11-20	F10.3	TRUEC	Porosity Cut off	.05
10	21-30	F10.3	SWC	Water Saturation Cut off	.50
10	31-40	F10.3	SXO	SXO cut off depth	1.00
11	1-6	F6.2	DEPTH	depth	5150.
11	6-12	F6.2	THK	Thickness	- BLANK -

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DATA INPUT FOR
FIGURE ___

CARD	COLUMNS	FORMAT	VARIABLE	DESCRIPTION	EXAMPLES
11	13-18	F6.2	RT	Deep Resistivity	2ØØ.
11	19-24	F6.2	RXO	Shallow Resistivity	3ØØ.
11	25-30	F6.2	GR	Gamma Ray	35.
11	31-36	F6.2	DENB	Bulk Density	2.6Ø
11	37-42	F6.2	DELTB	Bulk Travel Time	61.5Ø
11	43-48	F6.2	TRON	Compensated Neutron	.155
11	49-54	F6.2	PORCOR	Porosity of Core	.2Ø6
11	55-60	F6.2	SATCOR	Water Saturation of Core	.455
11	61-66	F6.2	PERMAX	Permeability of Core	5.ØØ
N	1-8Ø	11 F6.2	DEPTH thru PERMAX	Last Data Card (N)	—
N+1	1-8Ø	11F6.2	"BLANK"	INDICATES END OF ZONE (NOT REQ. FOR Last ZONE)	—
←			REPEAT CARDS 2-10 DEFINING NEXT ZONE'S PARAMETERS		→
←			REPEAT CARD 11 UNTIL ZONE IS COMPLETE		→

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Sample
INPUT
FORMS

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CARD	COLUMNS	FORMAT	VARIABLE	DESCRIPTION	VALUE
1	1-5	I5	NZONE	No. of Zones	
2	1-10	F10.3	FLGCHK	Echo data flag (No = 0.0, yes = 1.0)	
2	11-20	F10.3	VSHLE	Constant Volume of Shale	
3	1-40	10A4	TITLE1	Alpha - title	
3	41-80	10A4	TITLE2	Alpha - title	
4	1-10	F10.3	BHT	Bottom hole temp.	
4	11-20	F10.3	TSC	Surface temp.	
4	21-30	F10.3	TD	Total Depth	
4	31-40	F10.3	RWI	Water Resistivity @ TWI	
4	41-50	F10.3	TWI	Reference temp.	
4	51-60	F10.3	RMFI	Mud filtrate Resistivity @ TMFI	
4	61-70	F10.3	TMFI	Reference temp.	
5	1-10	F10.3	SLOPE	SONIC-DENSITY X-PLOT LIME-DOLOMITE (See Appendix)	
5	11-20	F10.3	BB	SONIC-DENSITY X-PLOT LIME-DOLOMITE (see Appendix)	
5	21-30	F10.3	GRSD	Gamma Ray Sand	

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DATA INPUT FOR
FIGURE

CARD	COLUMNS	FORMAT	VARIABLE	DESCRIPTION	VALUE
5	31-40	F10.3	GRSH	Gamma Ray Shale	
5	41-50	F10.3	RCL	Resistivity of Clay	
5	51-60	F10.3	PORSHD	Density Shale Porosity	
5	61-70	F10.3	PORSHS	Sonic Shale Porosity	
5	71-80	F10.3	PORSHN	Neutron Shale Porosity	
6	1-10	F10.3	FLGVSH	Shale Option	
6	11-20	F10.3	FLGGAS	Hydrocarbon Option	
6	21-30	F10.3	FLGSAT	SW Option	
6	31-40	F10.3	FLGCORE	Core Analysis Option	
6	41-50	F10.3	FLGSXO	SXO Option	
6	51-60	F10.3	FLGPOR	Porosity Option	
7	1-10	F10.3	AC	tortuosity factor	
7	11-20	F10.3	CE	cementation exponent	
7	21-30	F10.3	SE	saturation exponent	
7	31-40	F10.3	DENM	Density of Matrix	

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DATA INPUT FOR
FIGURE ___

CARD	COLUMNS	FORMAT	VARIABLE	DESCRIPTION	VALUE
7	41-50	F10.3	DENF	Density of Fluid	
7	51-60	F10.3	DELTF	Travel-time of Fluid	
7	61-70	F10.3	DELTM	Travel-time of Matrix	

DATA INPUT FOR
FIGURE ___

CARD	COLUMNS	FORMAT	VARIABLE	DESCRIPTION	VALUE
8	1-10	F10.3	HIMAI	initial hydrogen index (see Appendix)	
8	11-20	F10.3	HIMAT	true hydrogen index	
9	1-10	F10.3	A1	Density slope	
9	11-20	F10.3	B1	Density intercept	
9	21-30	F10.3	A2	Sonic slope	
9	31-40	F10.3	B2	Sonic intercept	
9	41-50	F10.3	A3	Neutron slope	
9	51-60	F10.3	B3	Neutron intercept	
9	61-70	F10.3	A4	Conductivity slope	
9	71-80	F10.3	B4	Conductivity intercept	
10	1-10	F10.3	VSHC	Volume of Shale Cutoff	
10	11-20	F10.3	TRUEC	Porosity Cut off	
10	21-30	F10.3	SWC	Water Saturation Cut off	
10 11	31-40 1-6	F10.3 F6.2	SXO DEPTH	SXO cut off depth	
11	6-12	F6.2	THK	Thickness	

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SAMPLE
RUN

LOG ANALYSIS

BRU NO. 310 WASSON FIELD

FIRST INTERVAL

(GENERAL DATA)

TD(FT.)=	5386.00
BHT(DEG F)=	105.00
TSC(DEG F)=	60.00
RMFI(OHM-MM/M)=	.048
TMFI(DEG F)=	105.00
RWI(OHM-MM/M)=	.045
TWI(DEG F)=	105.00
DENF(G/CC)=	1.09
DENM(G/CC)=	2.71
DELTF(U-SEC/FT)=	189.00
DELTM(U-SEC/FT)=	47.50
SLOPE=	-.039
BB=	4.568
PORSHD=	.100
PORSHS=	.100
PORSHN=	.300
RCL=	10.00
HIMAI=	.026
HIMAT=	.026
GRSD=	0.00
GRSH=	100.00
VSHLE=	0.000
A=	1.00
M=	2.34
N=	2.34
FLGVSH=	5.
FLGGAS=	0.
FLGSAT=	1.
FLGSXO=	1.
FLGPOR=	5.
FLGCORE=	1.
FLGCHK=	1.
A1=	.525
B1=	1.144
A2=	1.639
B2=	-30.028
A3=	1.000
B3=	0.000
A4=	1.000
B4=	0.000

LOG ANALYSIS

	DEPTH (FT) DEPTH	THICK (FT) THK	FORMATION RESISTIVITY (OHM-MM/M) RT	RXO	VOL. SH. (DEC.) VSH	POROSITY (DEC.) TRUEP	WATER SATURATION (DEC.) SW	SXO	SW1	SW2	SW3	SW4
**	5168.00	1.00	320.00	360.00	0.000	.046	.494	.483	.494	.494	.494	.494
	5169.00	1.00	240.00	250.00	.015	.058	.441	.446	.441	.441	.440	.360
	5170.00	1.00	220.00	180.00	0.000	.069	.387	.434	.387	.387	.387	.387
	5171.00	1.00	220.00	200.00	0.000	.072	.371	.397	.371	.371	.371	.371
**	5172.00	1.00	220.00	200.00	0.000	.047	.566	.606	.566	.566	.566	.566
**	5173.00	1.00	240.00	320.00	0.000	.043	.602	.548	.602	.602	.602	.602
**	5174.00	1.00	240.00	160.00	0.000	.045	.572	.699	.572	.572	.572	.572
**	5175.00	1.00	220.00	200.00	0.000	.043	.621	.665	.621	.621	.621	.621
**	5176.00	1.00	210.00	150.00	0.000	.048	.571	.678	.571	.571	.571	.571
**	5177.00	1.00	230.00	250.00	0.000	.044	.601	.596	.601	.601	.601	.601
**	5178.00	1.00	320.00	300.00	0.000	.044	.516	.545	.516	.516	.516	.516
**	5179.00	1.00	600.00	350.00	0.000	.050	.347	.449	.347	.347	.347	.347
	5180.00	1.00	800.00	400.00	0.000	.062	.247	.341	.247	.247	.247	.247
	5181.00	1.00	1000.00	500.00	0.000	.060	.232	.321	.232	.232	.232	.232
	5182.00	1.00	550.00	175.00	0.000	.056	.320	.537	.320	.320	.320	.320
**	5183.00	1.00	420.00	250.00	0.000	.054	.375	.481	.375	.375	.375	.375
**	5184.00	1.00	600.00	300.00	0.000	.043	.406	.562	.406	.406	.406	.406
**	5185.00	1.00	1000.00	400.00	0.000	.026	.529	.805	.529	.529	.529	.529
**	5186.00	1.00	800.00	400.00	0.000	.031	.496	.686	.496	.496	.496	.496
**	5187.00	1.00	340.00	160.00	0.000	.041	.544	.771	.544	.544	.544	.544
**	5188.00	1.00	250.00	160.00	0.000	.032	.778	.968	.778	.778	.778	.778
**	5189.00	1.00	240.00	15.00	0.000	.019	1.000	1.000	1.369	1.369	1.369	1.369
**	5190.00	1.00	240.00	200.00	0.000	.017	1.000	1.000	1.477	1.477	1.477	1.477
**	5191.00	1.00	140.00	60.00	0.000	.021	1.000	1.000	1.511	1.511	1.511	1.511
**	5192.00	1.00	105.00	130.00	0.000	.031	1.000	1.000	1.182	1.182	1.182	1.182
**	5193.00	1.00	110.00	70.00	0.000	.034	1.000	1.000	1.064	1.064	1.064	1.064
**	5194.00	1.00	130.00	150.00	.010	.036	.925	.894	.925	.925	.929	.865
**	5195.00	1.00	90.00	30.00	.084	.047	.824	1.000	.824	.824	.855	.432
**	5196.00	1.00	70.00	40.00	.053	.059	.736	.961	.736	.736	.749	.591
	5197.00	1.00	100.00	100.00	.041	.070	.533	.548	.533	.533	.535	.417
	5198.00	1.00	170.00	100.00	.027	.086	.346	.446	.346	.346	.342	.262
	5199.00	1.00	180.00	90.00	0.000	.087	.336	.464	.336	.336	.336	.336
	5200.00	1.00	170.00	200.00	0.000	.076	.391	.375	.391	.391	.391	.391
**	5201.00	1.00	120.00	45.00	0.000	.056	.619	.968	.619	.619	.619	.619
**	5202.00	1.00	105.00	400.00	0.000	.034	1.000	.616	1.062	1.062	1.062	1.062
**	5203.00	1.00	100.00	100.00	0.000	.037	1.000	1.000	1.022	1.022	1.022	1.022
**	5204.00	1.00	130.00	80.00	0.000	.033	1.000	1.000	1.015	1.015	1.015	1.015
**	5205.00	1.00	100.00	60.00	0.000	.017	1.000	1.000	2.261	2.261	2.261	2.261
**	5206.00	1.00	85.00	30.00	0.000	.026	1.000	1.000	1.527	1.527	1.527	1.527
	5207.00	1.00	150.00	740.00	0.000	.059	.532	.276	.532	.532	.532	.532
	5208.00	1.00	180.00	200.00	0.000	.059	.491	.482	.491	.491	.491	.491
**	5209.00	1.00	100.00	80.00	.048	.053	.701	.792	.701	.701	.711	.517
**	5210.00	1.00	90.00	100.00	.093	.060	.655	.644	.655	.655	.673	.290
**	5211.00	1.00	90.00	100.00	.035	.061	.640	.629	.640	.640	.645	.537
	5212.00	1.00	120.00	150.00	0.000	.065	.534	.499	.534	.534	.534	.534
	5213.00	1.00	300.00	300.00	.011	.068	.342	.351	.342	.342	.340	.285
	5214.00	1.00	400.00	400.00	0.000	.077	.268	.275	.268	.268	.268	.268
	5215.00	1.00	400.00	400.00	0.000	.058	.358	.368	.358	.358	.358	.358
**	5216.00	1.00	200.00	100.00	0.000	.041	.681	.942	.681	.681	.681	.681
**	5217.00	1.00	230.00	400.00	0.000	.018	1.000	1.000	1.449	1.449	1.449	1.449
**	5218.00	1.00	140.00	40.00	0.000	.021	1.000	1.000	1.527	1.527	1.527	1.527
**	5219.00	1.00	110.00	1000.00	0.000	.037	.978	.391	.978	.978	.978	.978
**	5220.00	1.00	280.00	300.00	0.000	.043	.564	.563	.564	.564	.564	.564

** 5221.00	1.00	250.00	150.00	0.000	.037	.679	.868	.679	.679	.679	.679
** 5222.00	1.00	180.00	100.00	0.000	.035	.840	1.000	.840	.840	.840	.840
** 5223.00	1.00	180.00	240.00	0.000	.025	1.000	1.000	1.140	1.140	1.140	1.140
** 5224.00	1.00	180.00	100.00	.023	.022	1.000	1.000	1.326	1.326	1.346	1.044
** 5225.00	1.00	210.00	200.00	0.000	.034	.800	.840	.800	.800	.800	.800
5226.00	1.00	250.00	500.00	0.000	.057	.443	.339	.443	.443	.443	.443
5227.00	1.00	270.00	170.00	.036	.064	.382	.478	.382	.382	.378	.088
5228.00	1.00	290.00	200.00	.012	.067	.354	.426	.354	.354	.352	.293
5229.00	1.00	400.00	700.00	0.000	.061	.337	.273	.337	.337	.337	.337
5230.00	1.00	440.00	450.00	0.000	.063	.314	.320	.314	.314	.314	.314
** 5231.00	1.00	300.00	140.00	0.000	.055	.428	.609	.428	.428	.428	.428
5232.00	1.00	250.00	200.00	0.000	.056	.448	.507	.448	.448	.448	.448
5233.00	1.00	230.00	200.00	.014	.058	.452	.493	.452	.452	.451	.378
5234.00	1.00	210.00	230.00	.027	.068	.402	.398	.402	.402	.400	.278

AVERAGE VALUES:

TOT.FEET=	24.00
TRUEP=	.066
VSH=	.008
SW=	.383
SXO=	.408
RW USED=	.046
RMF USED=	.049
TF=	103.73

CUTOFF VALUES:

VOL. SH.=	.300
POROSITY=	.055
WAT. SAT.=	.550

CORE VERSUS LOG ANALYSIS

DEPTH	LOG POR	CORE POR	DIFF1	SW	SWC	DIFF2	PERM
5168.000	.046	0.000	.046	.494	0.000	.494	0.000
5169.000	.058	0.000	.058	.441	0.000	.441	0.000
5170.000	.069	0.000	.069	.387	0.000	.387	0.000
5171.000	.072	0.000	.072	.371	0.000	.371	0.000
5172.000	.047	0.000	.047	.566	0.000	.566	0.000
5173.000	.043	0.000	.043	.602	0.000	.602	0.000
5174.000	.045	0.000	.045	.572	0.000	.572	0.000
5175.000	.043	0.000	.043	.621	0.000	.621	0.000
5176.000	.048	0.000	.048	.571	0.000	.571	0.000
5177.000	.044	0.000	.044	.601	0.000	.601	0.000
5178.000	.044	0.000	.044	.516	0.000	.516	0.000
5179.000	.050	0.000	.050	.347	0.000	.347	0.000
5180.000	.062	.069	-.007	.247	.160	.087	.690
5181.000	.060	.069	-.009	.232	.160	.072	.690
5182.000	.056	.054	.002	.320	.307	.013	1.100
5183.000	.054	.035	.019	.375	.621	-.246	.150
5184.000	.043	.047	-.004	.406	.713	-.307	1.000
5185.000	.026	.063	-.037	.529	.341	.188	2.100
5186.000	.031	.025	.006	.496	.359	.137	.150
5187.000	.041	.025	.016	.544	.359	.185	.150
5188.000	.032	.033	-.001	.778	.611	.167	.370
5189.000	.019	.035	-.016	1.000	.531	.469	1.100
5190.000	.017	.022	-.005	1.000	.929	.071	.100
5191.000	.021	.024	-.003	1.000	.875	.125	.200
5192.000	.031	.031	-.000	1.000	.900	.100	.200
5193.000	.034	.030	.004	1.000	.875	.125	.100
5194.000	.036	.042	-.006	.925	.510	.415	.100
5195.000	.047	.046	.001	.824	.497	.327	.100
5196.000	.059	.033	.026	.736	.469	.267	.200
5197.000	.070	.060	.010	.533	.159	.374	.100
5198.000	.086	.077	.009	.346	.096	.250	.200
5199.000	.087	.065	.022	.336	.149	.187	.300
5200.000	.076	.021	.055	.391	.138	.253	.200
5201.000	.056	.018	.038	.619	.250	.369	.200
5202.000	.034	.011	.023	1.000	.500	.500	.100
5203.000	.037	.024	.013	1.000	.875	.125	.100
5204.000	.033	.020	.013	1.000	.800	.200	.100
5205.000	.017	.015	.002	1.000	.909	.091	.100
5206.000	.026	.033	-.007	1.000	.909	.091	.300
5207.000	.059	.033	.026	.532	.909	-.377	.300
5208.000	.059	.039	.020	.491	.442	.049	.240
5209.000	.053	.039	.014	.701	.442	.259	.240
5210.000	.060	.090	-.030	.655	.482	.173	3.200
5211.000	.061	.087	-.026	.640	.439	.201	0.000
5212.000	.065	.087	-.022	.534	.439	.095	0.000
5213.000	.068	.092	-.024	.342	.297	.045	3.900
5214.000	.077	.083	-.006	.268	.248	.020	1.700
5215.000	.058	.083	-.025	.358	.248	.110	1.700
5216.000	.041	.042	-.001	.681	.452	.229	.100
5217.000	.018	.031	-.013	1.000	.638	.362	.150
5218.000	.021	.016	.005	1.000	.602	.398	.050
5219.000	.037	.029	.008	.978	.553	.425	2.100
5220.000	.043	.027	.016	.564	.655	-.091	.640
5221.000	.037	.017	.020	.679	.693	-.014	.090

5222.000	.035	.017	.018	.840	.693	.147	.090	
5223.000	.025	0.000	.025	1.000	0.000	1.000	0.000	
5224.000	.022	.035	-.013	1.000	.483	.517	.110	
5225.000	.034	.067	-.033	.800	.325	.475	.200	
5226.000	.057	0.000	.057	.443	0.000	.443	0.000	
5227.000	.064	.085	-.021	.382	.274	.108	.270	
5228.000	.067	.085	-.018	.354	.255	.099	.450	
5229.000	.061	.085	-.024	.337	.255	.082	.450	
5230.000	.063	.070	-.007	.314	.242	.072	.050	
5231.000	.055	.081	-.026	.428	.187	.241	.680	
5232.000	.056	.064	-.008	.448	.307	.141	.210	
5233.000	.058	.071	-.013	.452	.420	.032	.460	
5234.000	.068	0.000	.068	.402	0.000	.402	0.000	

STATISTICS:

AVGPOR=	.062
AVGCPOR=	.077
AVGDIF1=	-.015
AVGSAT=	.410
AVGCSAT=	.279
AVGDIF2=	.153
PPDA=	24.567
PSDA=	70.732

5168.000	1.000	320.000	360.000	0.000	3.013	50.000	.090	0.000	0.000	0.000	0.000	
5169.000	1.000	240.000	250.000	0.000	2.882	51.000	.107	0.000	0.000	0.000	0.000	
5170.000	1.000	220.000	180.000	0.000	2.882	52.500	.100	0.000	0.000	0.000	0.000	
5171.000	1.000	220.000	200.000	0.000	2.940	53.500	.080	0.000	0.000	0.000	0.000	
5172.000	1.000	220.000	200.000	0.000	2.955	51.000	.063	0.000	0.000	0.000	0.000	
5173.000	1.000	240.000	320.000	0.000	2.999	50.500	.060	0.000	0.000	0.000	0.000	
5174.000	1.000	240.000	160.000	0.000	2.984	50.500	.070	0.000	0.000	0.000	0.000	
5175.000	1.000	220.000	200.000	0.000	3.057	50.000	.075	0.000	0.000	0.000	0.000	
5176.000	1.000	210.000	150.000	0.000	3.013	50.500	.080	0.000	0.000	0.000	0.000	
5177.000	1.000	230.000	250.000	0.000	2.955	50.500	.065	0.000	0.000	0.000	0.000	
5178.000	1.000	320.000	300.000	0.000	2.984	50.500	.066	0.000	0.000	0.000	0.000	
5179.000	1.000	600.000	350.000	0.000	2.999	50.500	.090	0.000	0.000	0.000	0.000	
5180.000	1.000	800.000	400.000	0.000	2.969	52.000	.090	.069	.160	.690		
5181.000	1.000	1000.000	500.000	0.000	2.999	52.000	.081	.069	.160	.620		
5182.000	1.000	550.000	175.000	0.000	3.028	52.000	.064	.054	.307	1.100		
5183.000	1.000	420.000	250.000	0.000	3.115	52.000	.045	.035	.621	.150		
5184.000	1.000	600.000	300.000	0.000	3.145	50.500	.045	.047	.713	1.000		
5185.000	1.000	1000.000	400.000	0.000	3.115	48.500	.050	.063	.341	2.100		
5186.000	1.000	800.000	400.000	0.000	3.042	49.000	.060	.025	.359	.150		
5187.000	1.000	340.000	160.000	0.000	3.145	50.000	.055	.025	.359	.150		
5188.000	1.000	250.000	160.000	0.000	3.130	49.000	.057	.033	.611	.370		
5189.000	1.000	240.000	15.000	0.000	3.072	47.500	.058	.035	.531	1.100		
5190.000	1.000	240.000	200.000	0.000	3.072	47.500	.052	.022	.929	.100		
5191.000	1.000	140.000	60.000	0.000	2.999	48.000	.057	.024	.875	.200		
5192.000	1.000	105.000	130.000	0.000	3.042	49.000	.060	.031	.900	.200		
5193.000	1.000	110.000	70.000	0.000	3.130	49.000	.063	.030	.875	.100		
5194.000	1.000	130.000	150.000	0.000	2.984	48.500	.100	.042	.510	.100		
5195.000	1.000	90.000	30.000	0.000	2.838	49.500	.112	.046	.497	.100		
5196.000	1.000	70.000	40.000	0.000	2.823	51.000	.109	.033	.469	.200		
5197.000	1.000	100.000	100.000	0.000	2.808	52.000	.120	.060	.159	.100		
5198.000	1.000	170.000	100.000	0.000	2.779	53.500	.134	.077	.096	.200		
5199.000	1.000	180.000	90.000	0.000	2.808	54.000	.120	.065	.149	.300		
5200.000	1.000	170.000	200.000	0.000	2.955	54.000	.080	.021	.138	.200		
5201.000	1.000	120.000	45.000	0.000	3.115	52.000	.053	.018	.250	.200		
5202.000	1.000	105.000	400.000	0.000	3.101	49.000	.070	.011	.500	.100		
5203.000	1.000	100.000	100.000	0.000	3.115	49.000	.078	.024	.875	.100		
5204.000	1.000	130.000	80.000	0.000	3.130	49.000	.059	.020	.800	.100		
5205.000	1.000	100.000	60.000	0.000	3.130	47.500	.040	.015	.909	.100		
5206.000	1.000	85.000	30.000	0.000	3.174	49.000	.020	.033	.909	.300		
5207.000	1.000	150.000	740.000	0.000	3.174	53.000	.020	.033	.909	.300		
5208.000	1.000	180.000	200.000	0.000	3.174	52.000	.060	.039	.442	.240		
5209.000	1.000	100.000	80.000	0.000	2.882	50.000	.120	.039	.442	.240		
5210.000	1.000	90.000	100.000	0.000	2.794	50.500	.127	.090	.482	3.200		
5211.000	1.000	90.000	100.000	0.000	2.823	51.500	.100	.087	.439	0.000		
5212.000	1.000	120.000	150.000	0.000	2.940	52.000	.100	.087	.439	0.000		
5213.000	1.000	300.000	300.000	0.000	2.852	52.000	.114	.092	.297	3.900		
5214.000	1.000	400.000	400.000	0.000	2.882	53.500	.100	.083	.248	1.700		
5215.000	1.000	400.000	400.000	0.000	3.130	52.000	.060	.083	.248	1.700		
5216.000	1.000	200.000	100.000	0.000	3.145	50.000	.055	.042	.452	.100		
5217.000	1.000	230.000	400.000	0.000	3.174	47.500	.039	.031	.638	.150		
5218.000	1.000	140.000	40.000	0.000	3.145	48.000	.040	.016	.602	.050		
5219.000	1.000	110.000	1000.000	0.000	3.174	50.000	.030	.029	.553	2.100		
5220.000	1.000	280.000	300.000	0.000	3.174	51.000	.020	.027	.655	.640		
5221.000	1.000	250.000	150.000	0.000	3.145	50.000	.038	.017	.693	.090		
5222.000	1.000	180.000	100.000	0.000	3.174	49.000	.060	.017	.693	.090		
5223.000	1.000	180.000	240.000	0.000	3.028	48.000	.072	0.000	0.000	0.000		
5224.000	1.000	180.000	100.000	0.000	2.955	48.000	.060	.035	.483	.110		
5225.000	1.000	210.000	200.000	0.000	2.999	49.000	.075	.067	.325	.200		
5226.000	1.000	250.000	500.000	0.000	2.955	51.500	.085	0.000	0.000	0.000		

5227.000	1.000	270.000	170.000	0.000	2.794	52.000	.094	.085	.274	.270	
5228.000	1.000	290.000	200.000	0.000	2.808	52.500	.090	.085	.255	.450	
5229.000	1.000	400.000	700.000	0.000	2.955	52.000	.086	.085	.255	.450	
5230.000	1.000	440.000	450.000	0.000	2.984	52.000	.093	.070	.242	.050	
5231.000	1.000	300.000	140.000	0.000	2.911	51.000	.092	.081	.187	.680	
5232.000	1.000	250.000	200.000	0.000	2.955	51.000	.099	.064	.307	.210	
5233.000	1.000	230.000	200.000	0.000	2.882	51.000	.105	.071	.420	.460	
5234.000	1.000	210.000	230.000	0.000	2.823	52.000	.110	0.000	0.000	0.000	

P. O. BOX 1468
MONAHANS, TEXAS 79756
PHONE 943-3234 OR 563-1040

Martin Water Laboratories, Inc

709 W. INDIANA
MIDLAND, TEXAS 79701
PHONE 683-4521

RESULT OF WATER ANALYSES

LABORATORY NO. 58082

TO: Mr. Cary Billingsley
P. O. Box 4067, Midland, TX

SAMPLE RECEIVED As Listed

RESULTS REPORTED 5-14-80

COMPANY Texas Pacific Oil Co. LEASE Bennett Ranch Unit

FIELD OR POOL Wasson

SECTION ____ BLOCK ____ SURVEY ____ COUNTY Yoakum STATE TX

SOURCE OF SAMPLE AND DATE TAKEN:

NO. 1 Recovered water - taken from Bennett Ranch Unit #310 @ 10:30 a.m. (Zone IV). 5-8-80

NO. 2 Recovered water - taken from Bennett Ranch Unit #310 (Zone III-Phase II). 5-12-80

NO. 3

NO. 4

REMARKS: San Andres

CHEMICAL AND PHYSICAL PROPERTIES

	NO. 1	NO. 2	NO. 3	NO. 4
Specific Gravity at 60° F.	1.0957	1.0961		
pH When Sampled				
pH When Received	6.2	6.0		
Bicarbonate as HCO_3	1,190	1,275		
Supersaturation as $CaCO_3$				
Undersaturation as $CaCO_3$				
Total Hardness as $CaCO_3$	12,400	14,000		
Calcium as Ca	3,240	3,680		
Magnesium as Mg	1,045	1,156		
Sodium and/or Potassium	53,689	51,065		
Sulfate as SO_4	3,819	3,655		
Chloride as Cl	88,064	85,223		
Iron as Fe	46.8	9.6		
Barium as Ba				
Turbidity, Electric				
Color as Pt				
Total Solids, Calculated	151,046	146,064		
Temperature °F.				
Carbon Dioxide, Calculated				
Dissolved Oxygen, Winkler				
Hydrogen Sulfide	23.0	37.5		
Resistivity, ohms/m at 77° F.	0.070	0.072		
Suspended Oil				
Filtrable Solids as mg/l				
Volume Filtered, ml				
	Phase I	Phase II		

Results Reported As Milligrams Per Liter

Additional Determinations And Remarks: The above results show characteristics reasonably comparable to what we have recorded as water from the composite San Andres interval.

Form No. 3

268

Waylan C. Martin, M. A.

TEXAS PACIFIC OIL COMPANY, INC.
REGIONAL OFFICE
MIDLAND, TEXAS 79701

P. O. BOX 4067
1509 WEST WALL STREET

TEL. 915-684-5584
TWX. 910-895-5324

APPENDIX G

July 17, 1980

Gruy Federal, Inc.
2500 Tanglewilde
Suite 150
Houston, Texas 77063

Attention: Mr. Terry Swift

RE: Bennett Ranch Unit Well No. 310
Wasson Field
Yoakum County, Texas

Gentlemen:

As requested in your telephone conversation with Mr. Cary Billingsley on July 17, 1980, I have enclosed copies of the water analyses on the four zones tested in the above referenced well. Also enclosed are well test curves on offsetting producers.

If additional information is required, please let me know.

Yours very truly,

TEXAS PACIFIC OIL COMPANY, INC.

A. R. Hensley
Regional Engineer

SW:lw

Enclosures

WATER TECHNOLOGISTS, INC. 705 WEST INDIANA AVENUE • MIDLAND, TEXAS 79701 • (915) 682-5751

CLIENT: Texas Pacific Oil Company PROJECT: Bennett Ranch Un

Sample No.		WM04			
Date Sampled		5-12-80			
Time Sampled					
Location:		#310 Zone II			
FIELD DATA					
pH					
Temperature					
Dissolved Oxygen	O_2				
Hydrogen Sulfide	H_2S				
LABORATORY DATA					
pH		6.3			
Specific Gravity		1.092			
Conductivity	Mmhos				
Carbon Dioxide	CO_2				
Dissolved Oxygen	O_2				
Total Sulfides					
Carbonate Alkalinity	CO_3				
Bicarbonate Alkalinity	HCO_3	1,130			
Chlorides	Cl	77,000			
Total Hardness	$CaCO_3$	11,200			
Calcium	Ca	3,275			
Magnesium (Calc.)	Mg	730			
Sulfates	SO_4	3,700			
Total Iron	Fe				
Dissolved Iron	Fe				
Total Dissolved Solids		132,800			
Total Suspended Solids					
Suspended Solids					
Suspended Organic					
Oil Extraction					
Sodium		46,943			

Chemical Results Expressed in mg/l

Stability Indices:

Calcium Carbonate

Calcium Sulfate

Note: Results from sample brought to our laboratory by Shelly Wigzell, re request by Mr. Billingsl

John V. Slyker

cc: Mr. Art Stevenson

Main part
Plant III

CALGON CORPORATION

SUBSIDIARY OF MERCK & CO., INC.

CALGON ANALYTICAL LABORATORIES
WATER ANALYSIS RESULTS

WATER MANAGEMENT DIVISION CALGON CORPORATION 705 WEST INDIANA AVE. MIDLAND, TEXAS 79701 (915) 682-575

CLIENT: Texas Pacific Oil Company PROJECT: Bennett Ranch Unit

Sample No.		A6-01			
Date Sampled		5-19-80			
Time Sampled		12:00 PM			
Location:		Bennett Ranch Unit #310 (Zone I)			
FIELD DATA					
pH		6.2			
Temperature					
Dissolved Oxygen	O_2				
Hydrogen Sulfide	H_2S				
LABORATORY DATA					
pH					
Specific Gravity					
Conductivity	Mmhos				
Carbon Dioxide	CO_2				
Dissolved Oxygen	O_2				
Total Sulfides					
Carbonate Alkalinity	CO_3				
Bicarbonate Alkalinity	HCO_3	1,240			
Chlorides	Cl	85,000			
Total Hardness	$CaCO_3$	55,000			
Calcium	Ca	12,000			
Magnesium (Calc.)	Mg	6,100			
Sulfates	SO_4	2,100			
Total Iron	Fe				
Dissolved Iron	Fe				
Total Dissolved Solids		137,700			
Total Suspended Solids					
Suspended Solids					
Suspended Organic					
Oil Extraction					
Sodium (calc)		31,240			

Chemical Results Expressed in mg/l

Stability Indices:

Calcium Carbonate

Calcium Sulfate

Oilfield Products

Phase IV

WATER TECHNOLOGISTS, INC.

CALGON OILFIELD CHEMICALS — SALES AND TECHNICAL SERVICES

705 WEST INDIANA AVENUE MIDLAND, TEXAS 79701 (915) 682-5751

CLIENT: Texas Pacific Oil Company **PROJECT:** Bennett Ranch 21

Sample No.		A-5-207			
Date Sampled		5-12-80			
Time Sampled		4:00 P.M.			
Location:		20 NC III	2 plus III		
FIELD DATA					
pH					
Temperature					
Dissolved Oxygen	O_2				
Hydrogen Sulfide	H_2S				
LABORATORY DATA					
pH		6.6			
Specific Gravity					
Conductivity	Mmhos				
Carbon Dioxide	CO_2				
Dissolved Oxygen	O_2				
Total Sulfides					
Carbonate Alkalinity	CO_3				
Bicarbonate Alkalinity	HCO_3	1,090			
Chlorides	Cl	79,000			
Total Hardness	$CaCO_3$	13,500			
Calcium	Ca	3,750			
Magnesium (Calc.)	Mg	1,020			
Sulfates	SO_4	3,600			
Total Iron	Fe				
Dissolved Iron	Fe				
Total Dissolved Solids		103,100			
Total Suspended Solids					
Suspended Solids					
Suspended Organic					
Oil Extraction					
Sodium		47,080			

Chemical Results Expressed in mg/l

Stability Indices:

Calcium Carbonate

Calcium Sulfate

☆U.S. GOVERNMENT PRINTING OFFICE: 1982-546-085/3095