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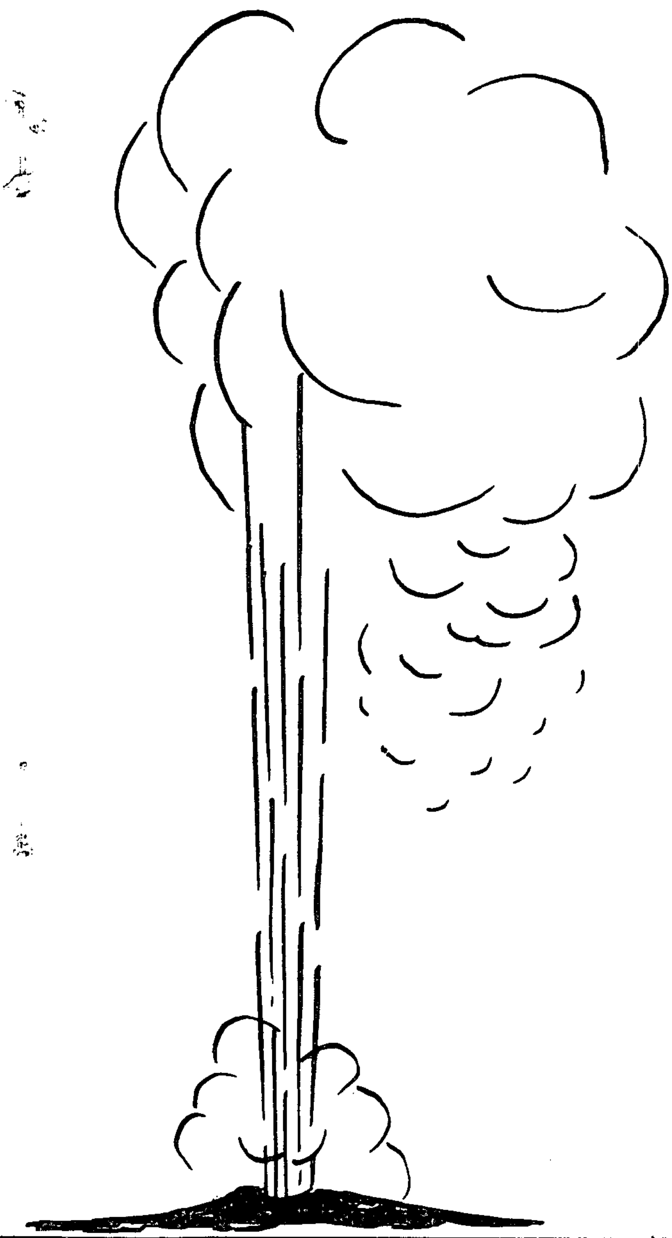

ANALYSIS OF CAMERON PARISH GEOPRESSURED AQUIFER

Final Report

By
C. O. Durham, Jr.

September 1978

Work Performed Under Contract No. ET-78-C-08-1561

Magma Gulf Company
Baton Rouge, Louisiana

MASTER

U. S. DEPARTMENT OF ENERGY
Geothermal Energy

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analysis of cameron parish geopressured aquifer

C. O. Durham, Jr.

September 1978

Prepared for

U.S. DEPARARTMENT OF ENERGY
DIVISION OF ENERGY TECHNOLOGY
Under Contract No. ET-78-C-08-1561
By

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I ABSTRACT

The Sweet Lake geopressured-geothermal prospect is located in northern Cameron Parish, Louisiana in T.12 S., R. 7 W. and T. 12 S., R. 8 W. approximately 10-15 miles south of Lake Charles.

The region is characterized by Cenozoic sand and clay deposits of geosynclinal thickness and differentially uplifted salt structures. The primary geopressured-geothermal aquifer is the "Miogyp" sand of the Camerina zone (Upper Frio formation of Oligocene-Miocene age).

The main prospect is located in a basin on the north flank of the Hackberry-Big Lake-Sweet Lake salt ridge. Interpretation of 27 miles of seismic lines and 17 deep well logs localizes the prospect in a basin with northwesterly dip in a graben between east-west faults converging eastward.

Aquifer depth ranges from 14,000 to 18,000 feet. Net sand thickness exceeds 400 feet with 22% porosity. Temperatures range from 280°F. (corrected) at 14,000 feet to 350°F. at 18,000 feet. Geopressures occur below 9,000 feet with mud weight equivalents in the sand from 12 to 13 pounds per gallon. Net sand volume of one cubic mile is estimated in the area mapped.

II INTRODUCTION

The Sweet Lake geopressured-geothermal prospect is situated mainly in T.12S., R.7 and 8W in northern Cameron Parish in Southwestern Louisiana. The proposed drillsite, in the eastern portion of the prospect, is 15 miles south-southeast of Lake Charles and 18 miles north-northeast of Cameron. Fig. 1 is a regional map depicting the study area.

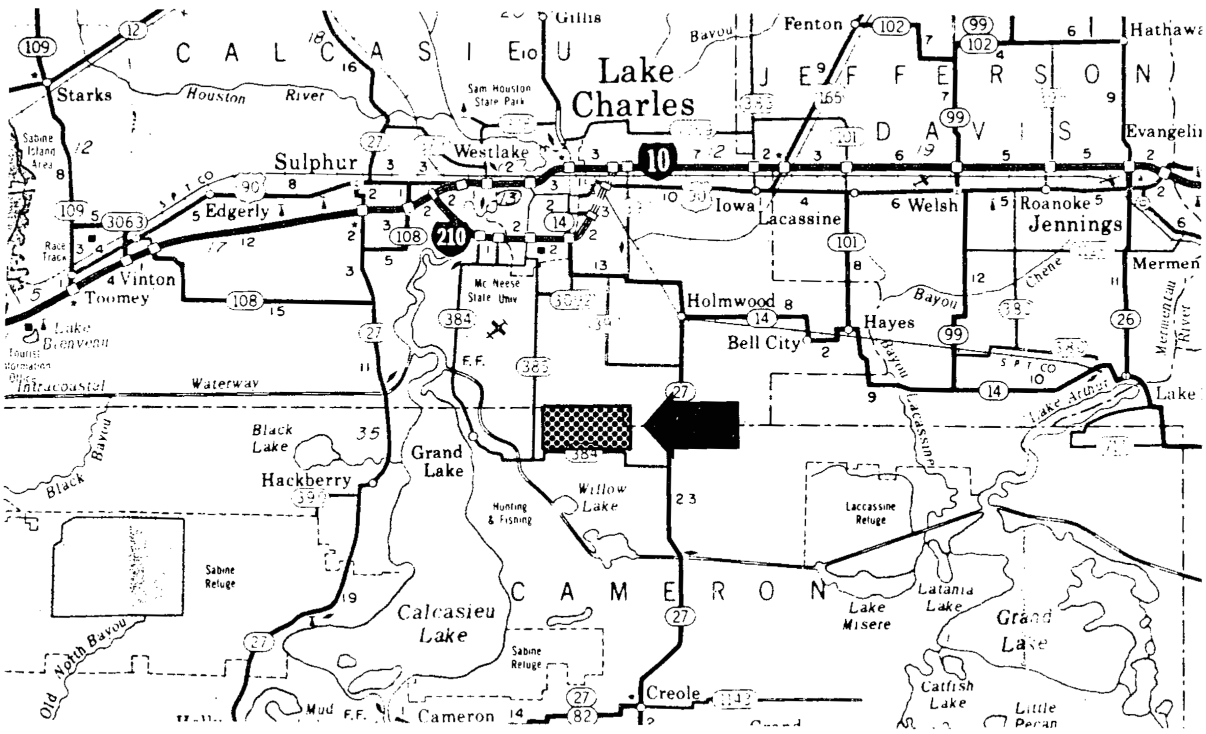


FIGURE 1: DRILLSITE LOCATION IN SW LOUISIANA

The present study, funded by the U. S. Department of Energy is designed to determine the suitability of the site for a geopressured-geothermal test well, as proposed by Magma Gulf Company in 1976.

III REGIONAL GEOLOGICAL SETTING

During the Cenozoic Era the continental margin of southwestern Louisiana has progressively built Gulfward through processes of sedimentation. The upper slope and outer shelf are normally characterized by instability with a tendency to form gigantic slumps. Simultaneous sedimentation results in contemporaneous growth faults with abnormally thick deposits of deeper water facies on the basin side contrasted to shallower water or deltaic deposits on the shoreward side. As the shelf edge moves intermittently basinward continental facies of massive sands of relatively even thickness and low dip are superposed on the earlier faulted and tilted shales and sands of variable thickness.

In Southern Louisiana these sediments of geosynclinal thickness have been superposed on the deeply buried thick Louann salt bed which has responded to differential sedimentation by lateral migration into salt ridges, massifs, and ultimately in some cases into piercement domes. Early formation of localized basins and ridges by salt migration influenced the geographical location of thicker and thinner sedimentary accumulations which in turn reinforced the continued migration of the salt. Thus, sedimentary depocenters and embayments bounded by contemporaneous growth faults have developed in areas where salt evacuation has been pronounced.

The shelf-edge extended east-west through Beauregard Parish, 50 miles north of the study area during deposition of the Early Eocene Wilcox formation. Today it is 160 miles to the south, some 145 miles off the present coastline. The study area was occupied by unstable outer shelf and slope conditions with associated growth faults at an intermediate time during the deposition of the Upper Frio Camerina zone of upper Oligocene or Lower Miocene age. The prospective reservoir sand is a lower sand of that zone.

IV GEOLOGY OF THE SWEET LAKE AREA

A. HISTORY OF THE INVESTIGATION

In 1974 Gulf Geothermal Corporation completed a survey of the geopressured/geothermal resources of Coastal Louisiana. A deeply buried thick sand was identified as a potential reservoir in the Sweet Lake area. Geothermal leases in the area were acquired from Sweet Lake Land and Oil Company under a joint venture with Magma Power Company. With the organization of Magma Gulf Company these leases were assigned to the new company which nominated the area as a potential drillsite for a geopressured-geothermal test well to ERDA in 1976.

Because the extent of the prospective reservoir, particularly its relationship to bounding faults, was not thoroughly known by Magma Gulf at the time of the original submittal, the company proposed an initial seismic investigation prior to locating the well-site and implementing drilling. During the selecttion process Magma Gulf was asked for additional geologic data which it supplied in the form of geologic interpretation of a 9 square mile area based on nine deep wells in the area and discussion with oil operators familiar with the locality. The present study, based on 27 miles of seismic lines and 17 deep wells, extends over an area of approximately 40 square miles and defines a reservoir exceeding an area of 12 square miles and possibly with an extent twice that or more.

B. SUBSURFACE GEOLOGY

The Sweet Lake geopressured-geothermal prospect is a basin located on the north flank of an east-west salt ridge containing the Hackberry, Big Lake and Sweet Lake structures. The south side of the basin is bounded by a fault downthrown to the north. This converges eastward with a major east-west fault downthrown to the south to form the eastern termination of the basin. Dip is north-westerly into the basin which opens toward the south flank of the South Lake Charles structure several miles distant to the north.

Surface terrain is formed by Late Pleistocene deltaic deposits. Alternating massive sands and clays extend to an average depth of 9,000 feet and overlie the thick shales of the Anahuac formation. The Anahuac formation is underlain by the Frio formation, the upper member of which is called the Camerina zone. Several sands occur within this sequence, the thickest being the basal "Miogyp" sand -- for Miogypsina (Miogypsinoides), the key microfossil it contains.

Depths to the following contacts are presented on Table 1 for the seventeen wells studied:

Base of massive sands (top of Anahuac)
Top of Marginulina howei zone
Top of Camerina 1 zone (Anahuac - Frio contact)
Top of Camerina 2 zone
Top of "Miogyp" sand
Base of "Miogyp" sand

All depths cited are uncorrected log depths inasmuch as the terrain has little relief and is only a few feet above sea level. Wells are identified by number and name on Table 1. All other maps depict only the numbers. A log of the Union Oil of California Sweet Lake No. 1 (Well #3) is shown on Fig. 2.

A seismic evaluation of the geology was performed by Brian E. Parsons assisted by Lewis R. Brescoll. The Parson's report is presented as Appendix A. The geology depicted on Parson's structural map of the top of the "Miogyp" sand (his Exhibit A) resulted from the combined study of the 27 miles of seismic lines and the 17 well logs as interpreted by Parsons and Dr. C. O. Durham, Jr. Parson's map was subsequently expanded to the west by Durham utilizing the Lafayette Geological Society study of Big Lake Field prepared by Robert A. Anderson. The resultant structural map is presented as Plate A. Fault cuts in the wells are listed on Table 1.

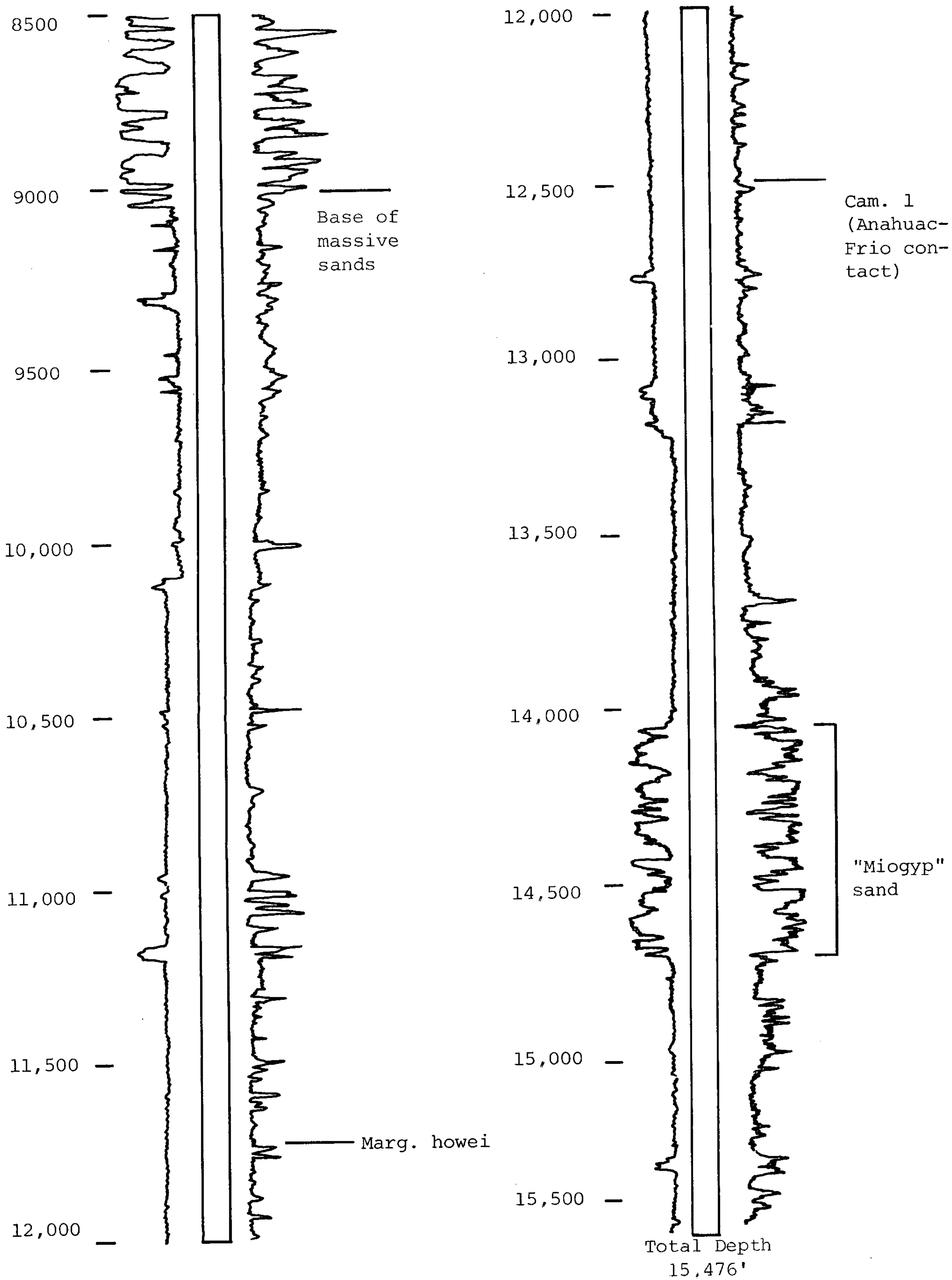
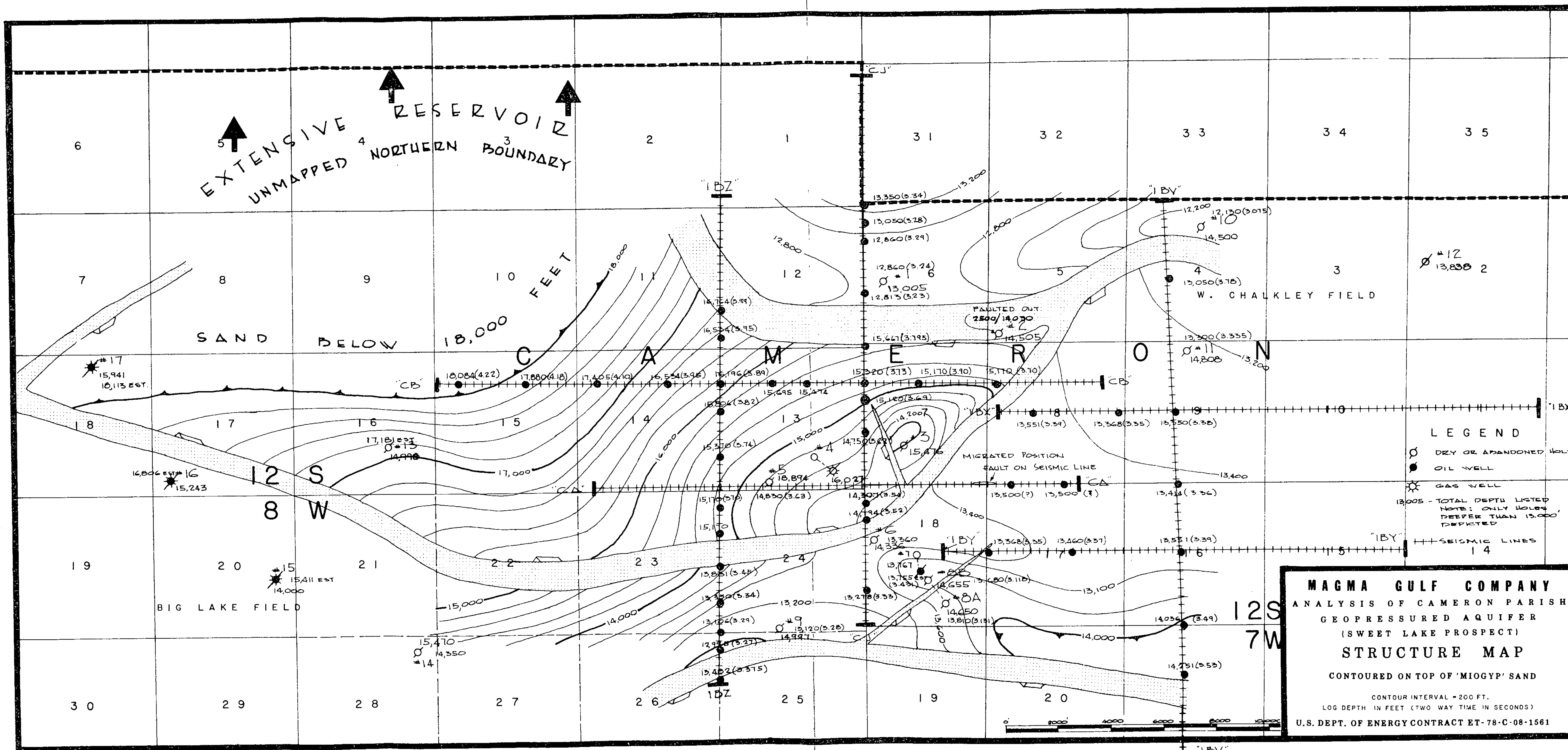


FIGURE 2: TYPE LOG -- WELL #3: Union Oil of Calif. Sweet Lake #1

TABLE 1

ANALYSIS OF DEEP WELLS IN STUDY AREA

MAP #	WELL IDENTIFICATION	LOCATION	TOTAL DEPTH	REMARKS	YEAR DRILLED	FAULTS	BASE OF MASSIVE SANDS	MARG. HOWEI	CAM.1	CAM.2	TOP MIOGYP.	BASE MIOGYP.	THICK-NESS	NET SAND	% SAND	AV. CORRECTED TEMP.(F) IN SAND	MIN. MUD WEIGHT	TOP OF SAND MIN. ACTUAL PRESSURE	TOP OF SAND MIN. EXCESS PRESSURE	SALINITY PARTS PER MILLION
1	J.P. Owen & Audas Inc. Leonard Landry #1	6-12S-7W	13,005		1966	270ft./9200	9,080	11,035	11,660	12,049	12,860	N/P	145+	120+	82.8	280	15.6	10,500	4,500	46,000
2	J.P. Owen ETAL Sweet Lake Land & Oil #1	5-12S-7W	14,505		1965	2500ft./14030	8,890	11,440	12,453	13,390	F/O	F/O	F/O	F/O		F/O	F/O	F/O	F/O	
3	Union Oil of California Sweet Lake Land & Oil #1	7-12S-7W	15,476		1973		9,013	11,725	12,510	13,050	14,045	14,708	663	428	64.6	278	12.0	8,950	2,350	100,000
4	Union Oil of California Pan Am Fee #1	13-12S-8W	16,027	Drilled Directionally Production: 15,230-38	1970		9,085	11,810	12,680	13,250	14,457	15,035	578	438	75.8	300	13.1	9,850	3,050	NA
5	Union Oil of California Pan Am Fee #2	13-12S-8W	18,894		1971		9,150	11,830	12,705	13,460	14,830	15,428	598	428	71.4	305	12.1	9,300	2,400	95,000
6	Consolidated Gas Supply Sweet Lake Land & Oil #2	18-12S-7W	14,336		1968	330ft./13060	8,905	11,415	12,160	12,750	13,360	13,860	500	350	70.9	290				60,000
7	J.M. Huber (Consol. Gas Supply (Sweet Lake Land & Oil #1	18-12S-7W	13,767	Production: 12,994-13,004	1968		8,910	11,330	12,020	13,005	N/P									
8A	J.P. Owen Sweet Lake Land & Oil #1	18-12S-7W	14,650		1969		Above LogTop	11,340	12,010	13,005	13,810	14,645	835	260	31.9	295	13.0	9,350	1,900	49,000
8B	J.P. Owen Sweet Lake Land & Oil #2	18-12S-7W	14,655	Sidetrack From #1(8A)	1970	90ft./13680	8,840	11,365	12,070	13,030	13,680	14,445	765	240	31.2	295	15.2	10,800	4,400	73,000
9	Chevron Oil Company E.B. Davis #1	24-12S-8W	14,997	Gas Shows on Log in "Miogyp" sand	1967	225ft./9220	9,020	11,155	11,958	F/O	13,120	13,790	670	170	25,4	285	12.75	8,700	2,600	55,000
10	Phillips Petroleum Co. Sweet Lake #1	4-12S-7W	14,500		1967	495ft./11150	8,840	10,790	F/O	11,305	12,132	12,480	348	243	69.8	248				
11	Natural Gas & Oil Co. Sweet Lake Land & Oil #1	9-12S-7@	14,808		1952		Above LogTop	10,090	11,950	12,560	13,290	13,500	210	155	73.8	265				
12	The British American Oil Prod. Co. Sweet Lake Land & Oil B-1	2-12S-7W	13,838	(840)	1954		8,510	10,610	11,627	11,230	12,738	13,080	342	100+	34.2	295				
13	Union Oil & Gas Corp. of La. A.B. McCain #1	16-12S-8W	14,998	(999)	1956		9,365	13,115	14,250	N.P.										
14	Amoco Production Co. McCain "8" No. 1	28-12S-8W	15,470		1972	150ft./9750	8,740	11,250	12,115	12,895	14,350	14,995	645	350	54.3	302				75,000
15	Pan American Petroleum Corp. A.B. McCain Heirs #1	20-12S-8W	14,000	Production: 9529-9600	1962	65ft./9550	8,863	11,770	12,660	13,620	N.P.									
16	Pan American Petroleum Corp. East Lake Townsite Co. #A-1	17-12S-8W	15,243	Production: 11,665-74	1961		9,045	12,150	13,310	14,530	N.P.									
17	Pan American Petroleum Corp. Clemence Klumpp #1	18-12S-8W	15,941	Production: 12,374-84	1961		9,387	12,963	14,400	N.P.										



MAGMA GULF COMPANY
ANALYSIS OF CAMERON PARISH GEOPRESSURED AQUIFER
(SWEET LAKE PROSPECT)
STRUCTURE MAP
CONTOURED ON TOP OF 'MIOGYP' SAND
CONTOUR INTERVAL = 200 FT.
LOG DEPTH IN FEET (TWO WAY TIME IN SECONDS)
U.S. DEPT. OF ENERGY CONTRACT ET-78-C-08-1561
LEGEND
DRY OR ABANDONED HOLE
OIL WELL
GAS WELL
13,005 - TOTAL DEPTH LISTED
NOTE: ONLY HOLES DEEPER THAN 13,000' DEPICTED
SEISMIC LINES
EXTENSIVE RESERVOIR
UNMAPPED NORTHERN BOUNDARY
SAND BELOW 18,000 FEET
C A M E R O N
12 S
8 W
12S
7W
W. CHALKLEY FIELD
BIG LAKE FIELD
FAULTED OUT
MIGRATED POSITION FAULT ON SEISMIC LINE
"CJ"
"1BZ"
"1BY"
"CB"
"CA"
"1BX"

Although the "Miogyp" sand is present in the entire area, it is structurally lower in the graben which widens westward from its termination at the juncture of the two bounding faults in Sec. 8, T.12S., R.7W. The three key wells drilled by Union Oil of California (#3, #4, #5) and used as a basis for the identification of the prospect are shown to be in the structurally high southeastern portion of the graben. The sand dips strongly northwestward from this area so that it occurs below 18,000 feet in depth in the northwestern portion of the map. No other wells penetrate the sand in the graben.

C. GEOTHERMAL GRADIENT AND PROSPECTIVE TEMPERATURE

Bottom-hole termperatures in the Sweet Lake area have been corrected according to the AAPG correction factor table and plotted on Fig. 3. Data are derived from the seventeen deep wells in the study area which provide over 100 data points because the wells are usually logged several times during drilling.

The solid line depicts an "average" Gulf Coast temperature gradient of 1.5^{O}F. per 100 feet of depth. Most of the data points represent temperatures 25^{O}F. cooler than this "average" at the top of the geopressured zone indicating a lower geothermal gradient in the hydrostatic zone. However, within the geopressured zone the gradient is higher than "average" and temperatures are mostly 10^{O}F. above average below a depth of 14,000 feet. It is pertinent that the target sand occurs at these depths.

The map on Plate B depicts the average corrected temperature for each well as determined from geothermal gradients prepared on each individual well at the midpoint of the sand. Such data and the composite on Fig. 3 were utilized to determine the isotherm on Map B (data in files -- see curves on wells #3, #4, #5 depicted on Fig. 4).

It should be noted that the temperature log is available in well #3. Temperatures through the proposed test sand interval range from a high of 282.7^{O}F. to a low of 273.0^{O}F. for an average

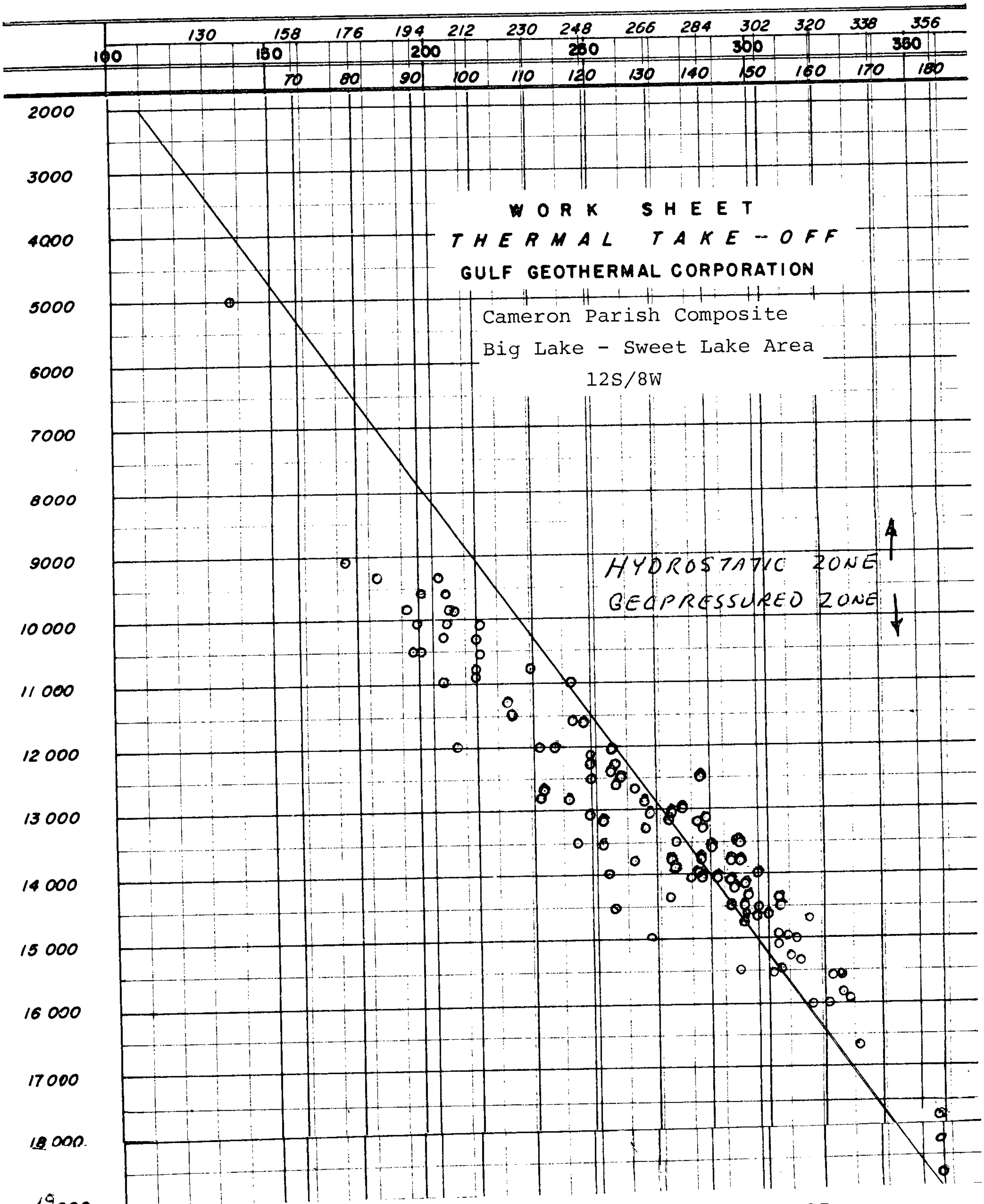
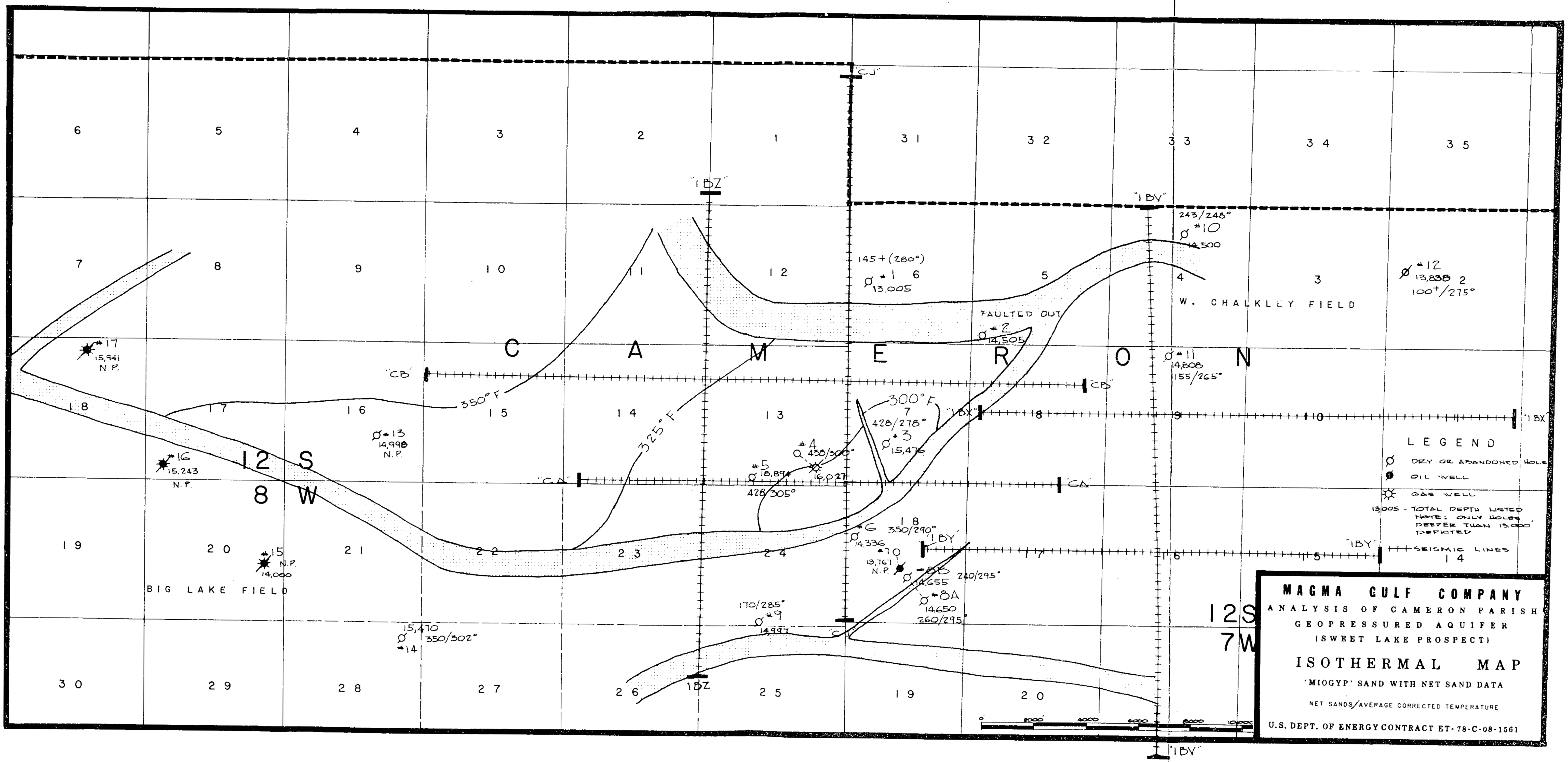


FIGURE 3: SUBSURFACE TEMPERATURES FROM WELLS 1 - 17


MAGMA GULF COMPANY
ANALYSIS OF CAMERON PARISH
GEOPRESSURED AQUIFER
(SWEET LAKE PROSPECT)
ISOTHERMAL MAP
'MIOGYP' SAND WITH NET SAND DATA
NET SANDS/AVERAGE CORRECTED TEMPERATURE
U.S. DEPT. OF ENERGY CONTRACT ET-78-C-08-1561
LEGEND
DRY OR ABANDONED HOLE
OIL WELL
GAS WELL
13,005 - TOTAL DEPTH LISTED
NOTE: ONLY HOLES DEEPER THAN 13,000' DEPICTED
SEISMIC LINES
C A M E R O N
12 S
8 W
12S
7W
W. CHALKLEY FIELD
BIG LAKE FIELD
FAULTED OUT
350° F
325° F
300° F
"CJ"
"1BZ"
"1BY"
"1BX"
"CB"
"CA"
243/248°
#10
14,500
145+(280°)
#1
13,005
#12
13,838
100+/275°
#2
14,505
#11
14,808
155/265°
#17
15,941
N.P.
#16
15,243
N.P.
#13
14,998
N.P.
#15
N.P.
14,000
428/278°
#3
15,476
#4
430/300°
16,027
#5
18,894
428/305°
#6
14,336
350/290°
#7
13,767
N.P.
14,655
240/295°
#8A
14,650
260/295°
170/285°
#9
14,997
15,470
#14
350/302°

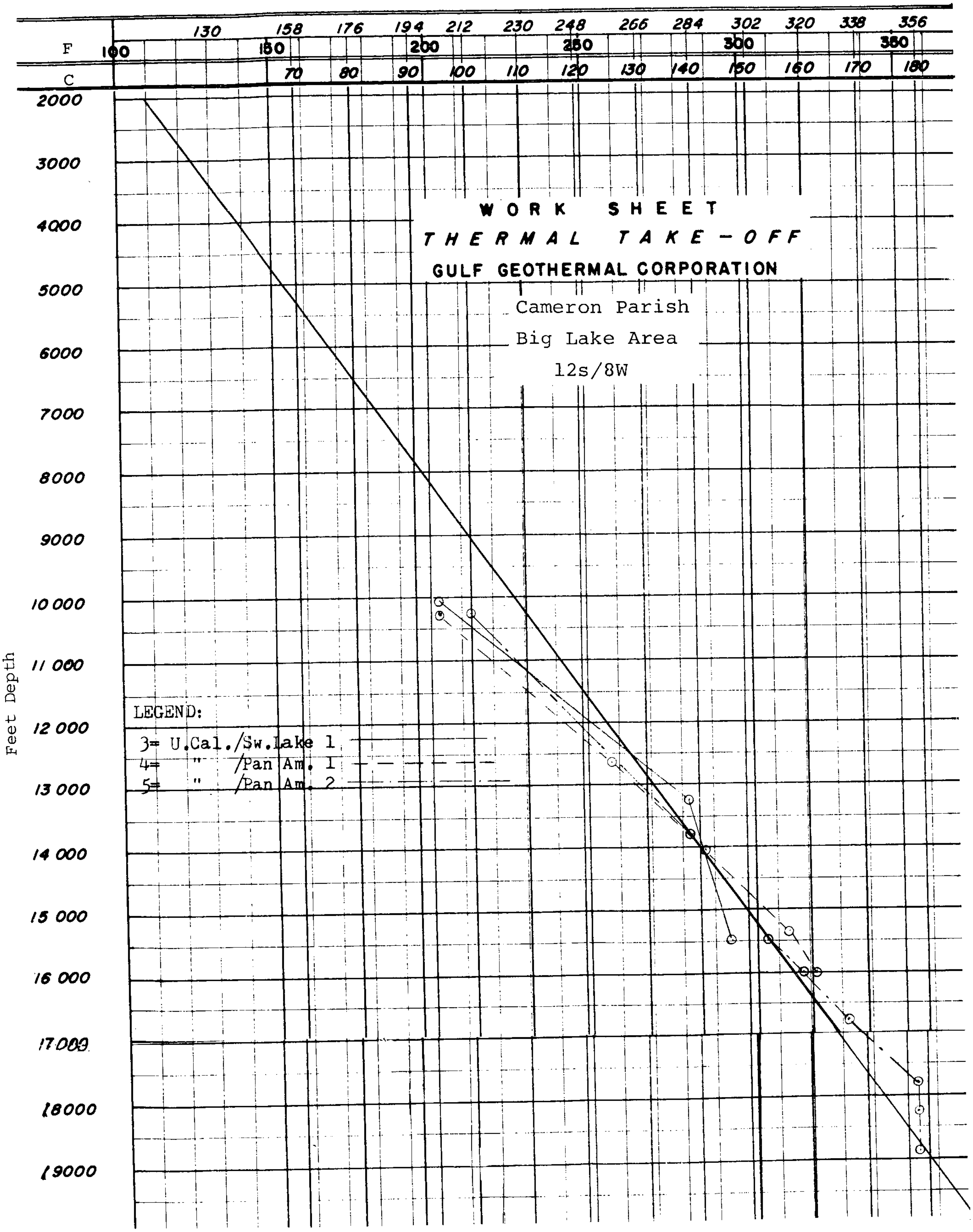


FIGURE 4: COMPOSITE OF GEOTHERMAL GRADIENTS, WELLS #3, #4, #5

of 278°F. This is remarkably close to the temperature that we had earlier estimated using the bottom hole temperatures from the conventional electric log with correction per AAPG temperature survey usage. The close correlation between this corrective method and the actual temperature log is strong support for the procedure that Magma Gulf has utilized in evaluating the geothermal pattern of the entire Gulf Coast.

It is obvious that the deeper portion of the graben where the sand is extrapolated to 18,000 feet in depth or more is most desirable for encountering temperatures in excess of 350°F. Temperatures slightly above 300°F. are expected at shallower depths of 15,000 feet. Since well data concerning sand distribution and thickness are available at the shallower depths, the proposed well site should be located near available well control even though the expected temperatures are lower. However, with the success of the initial well, a second well should be drilled in the deeper part of the basin.

D. DISTRIBUTION OF GEOPRESSURE

The subsurface in the Sweet Lake area is characterized by hydrostatic pressures to the base of the massive sand sequence at a depth varying from 8,740 to 9,400 feet. The underlying thick Anahuac shale formation is geopressured at a mud weight equivalent averaging between 15 and 16 pounds per gallon. Geopressures are reduced in the "Miogyp" sand to a minimum mud weight equivalent of 12 to 13 pounds per gallon. This is characteristic of many thick extensive sand bodies whose volumes accommodate the loss of pressurized fluid from the confining shales.

The pressure curves were computed from resistivity logs by Records and Associates for eight key wells and plotted to show variation with depth of pressure expressed in mud weight. (See Appendix B). Columns on Table 1 list the following information derived from these graphs:

a) Minimum mud weight in the sand

b) Pressure at top of sand based on this minimum mud weight

c) Pressure in excess of hydrostatic pressure

The minimum expected pressures at the top of the "Miogyp" sand vary from 8,700 to 10,800 psi. The three wells (#3, #4, #5) in the target reservoir vary from 8,950 to 9,850 psi with equivalent mud weights of 12.0 to 13.1 pounds per gallon.

More pertinent is the geopressure factor -- the excess pressure above hydrostatic pressure. This varies from 1,900 to 4,500 psi with the value from wells #3, #4 and #5 ranging from 2,350 to 3,050 psi. This is several times the anticipated pressure loss due to frictional flow in the production string, so we anticipate a well head pressure of 2,000 psi or more. Records and Associates are currently preparing an analysis of expected flow rates and pressures.

Velocity variation with depth is affected by the geopressure distribution. Exhibit B of the Parsons seismic report (Appendix A) depicts this graphically. Computations based on the sonic log of well #3 portray a progressive increase in velocity with depth to the top of the geopressured zone at 9,000 feet in depth. There an abrupt decrease in velocity occurs to 10,000 feet with gradual increase in velocity below that depth. However, in the interval from 14,000 to 14,500 feet in depth where the "Miogyp" sand is present, higher velocities are present, indicating lower geopressures.

E. <u>SAND CHARACTER</u>

Total thickness of the "Miogyp" sand, net sand thickness, and sand percentage are also presented on Table 1. Net sand thickness is also plotted on Plate B. Sand pattern on electric logs of selected wells are presented in Appendix C.

Net sand exceeds 400 feet in the three key wells in the graben but is expectedly thinner on the adjacent higher fault blocks. Well #14 on the upthrown fault block to the southwest of the graben has virtually the same sand and net sand thickness as the wells in the graben farther east. Furthermore, because of similar north-westerly dip both in the graben and in the fault block containing this well to the south the sand is at approximately the same depth as in the eastern portion of the graben. Consequently, the sand is prospective in this area also. Presence of the sand in this thickness south of the basin supports a conclusion that it is present throughout the basin and probably in much greater thickness than in the structurally higher wells surrounding the basin.

No core analysis is available for the sand but interpretation based on logs can be made. Porosity computations have been made from a sonic log in well #3 and a bulk density log in well #4. Porosity of 22% was obtained in each case which adds corroboration of this excellent porosity value. Permeability in such a sand is also expected to be high, but no value is available.

F. SALINITY OF FLUID

Electric log computations have provided salinity data in the "Miogyp" sand of key wells. Salinities are presented on Table 1 and range from 46,000 ppm to 100,000 ppm. The highest salinities appear to be at greatest depths. Wells #3 and #5 in the graben have the highest salinity values.

G. PETROLEUM PRODUCTION

Of the 17 wells listed on Table 1, five have been produced. Perforation depths are listed on the table. Well #4 was plugged and abandoned in 1976 after producing gas from a thin sand 195 feet below the base of the "Miogyp" sand. Well #7 produced oil from the Camerina 2 zone. The three wells in Big Lake Field (#15, #16, #17) produced from shallower sands in the upper Anahuac formation.

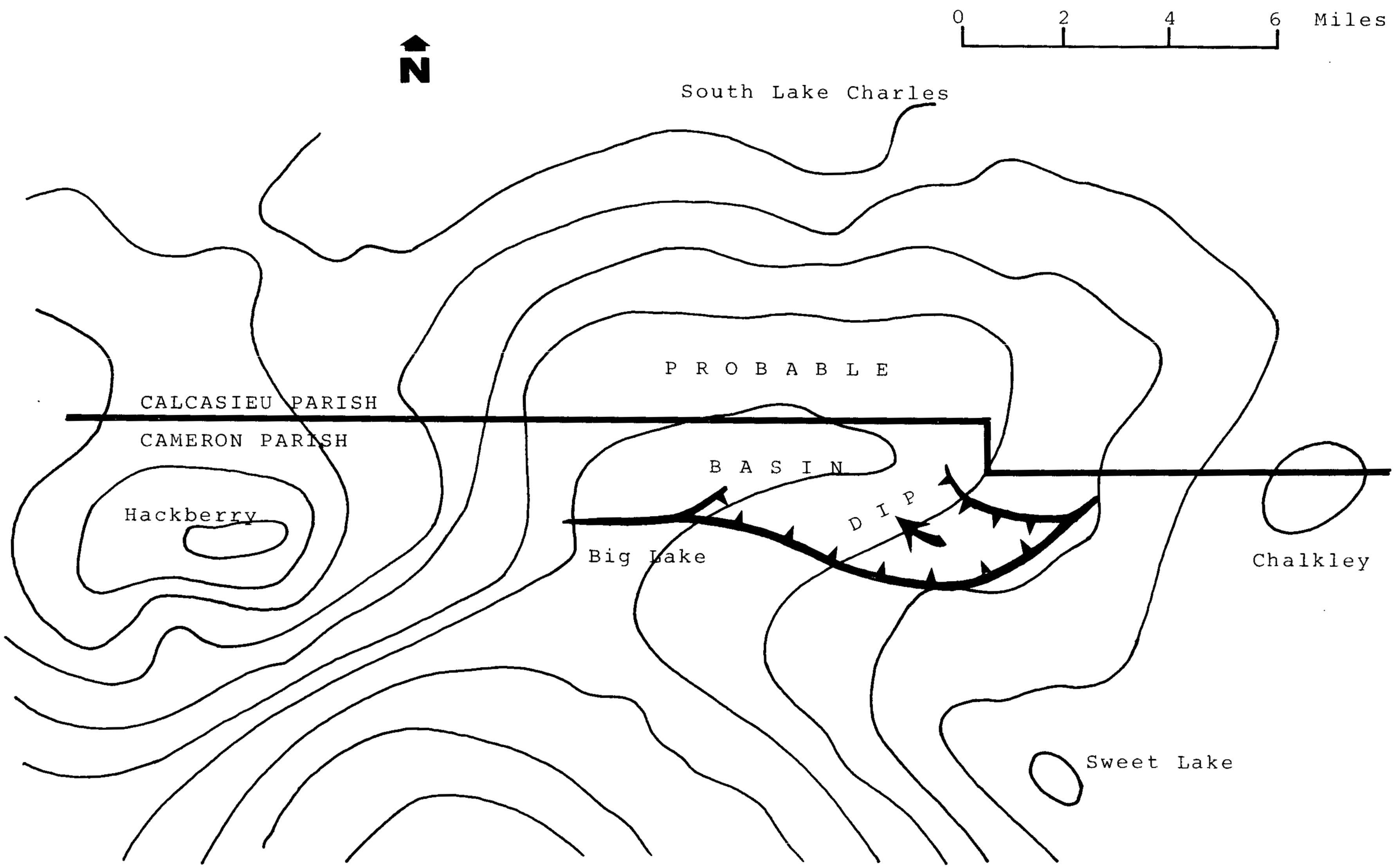
No production from the "Miogyp" sand has occurred in the vicinity. Plate A shows well #3 as located near the top of a potential structure. An undrilled petroleum prospect is also located nearby on the downthrown northern side of the fault on the south side of the graben to the southeast of wells #4 and #5. Gas shows appear to be present in the "Miogyp" sand in well #9 which is located on a structural high north of a fault downthrown to the south.

H. SIZE OF BASIN

The seismic lines and most of the wells are located in the vicinity of the eastern termination of the basin. This is because the geological interpretation of prior data was uncertain, and the present study was designed to determine the fault pattern in that area. Furthermore, few wells have been drilled in the deeper part of the basin, the exception being the early well #13 which was drilled in 1956.

The present interpretation depicts the northern fault turning northward in Sec. 11, T.12S., R.8W. It is likely that the basin extends a considerable distance north of the present study with the referenced fault forming its eastern extent. A review of proprietary gravity supports this conclusion that the present study includes only the southeastern portion of a larger basin. Gravity "form" lines (all that we are permitted to present) present this conclusion on Fig. 5. The basin appears to be a collapse feature associated with salt withdrawal to supply the Hackberry-Big Lake-Sweet Lake salt ridge to the south.

Although the present study maps only a portion of the total basin, the area depicted on Plate A embraces 12 square miles. Net sand in the basin exceeds 400 feet in thickness with a consequent estimate of 1 cubic mile of sand volume in the area mapped. Extension of the basin northward as discussed above should double or triple the sand volume estimate.



NOTE: Faults bounding graben shown as heavy lines with dip northwest toward main basin indicated by "positive" form lines.

FIGURE 5: PROPRIETARY GRAVITY INTERPRETATION SHOWN BY "FORM" LINES

V CONCLUSIONS AND WELL SITE LOCATION

This investigation has demonstrated a basin bounded on the northeast and south by two faults forming a graben and joining eastward. The "Miogyp" sand has a net sand thickness averaging over 400 feet in the graben where it dips northwestward from a depth of 14,000 feet to depths below 18,000 feet 3 to 6 miles westward. The basin has a mapped extent of 12 square miles thus containing a cubic mile of sand. Probable extension of the basin northward may provide several times this volume.

Temperatures range from below 300°F. to above 350°F. dependent on depth. The sand has a geopressured differential 1,900 psi to more than 3,000 psi above hydrostatic pressure. Saturated methane content (in fresh water) under such pressure-temperature condition should range from 35 cu.ft./barrel at well #3 and 40 cu. ft./barrel at well #4 to 55 cu. ft./barrel in the deepest parts of the basin. Salinities which range up to 100,000 ppm will likely substantially reduce these amounts, however.

The original proposal specified a well to twin well #3 in SW¼ sec 7, T.12S., R.7W. However, the results of this study indicate that the sand is deeper in NW¼ sec 7 and hence this site is preferable to obtain higher temperatures and pressures. An alternate site in S½ sec 13, T.12S., R.8W. near wells #4 and #5 is also desirable and would place the well nearer the middle of the graben away from the bounding faults. Currently, Magma Gulf holds geothermal leases on sec 7 and 18, T.12S., R.7W. so the drillsite in NW¼ sec 7 is now available. Negotiations to obtain leases in S½ sec 13 and N½ sec 24, T.12S., R.8W. are continuing. Consequently, the alternate site may also become available before the well is spudded.

APPENDIX A

GEOPHYSICAL EVALUATION

By

Brian E. Parsons

Note: Exhibit A of this report has been incorporated into an expanded structural map (Plate A)

GEOPHYSICAL EVALUATION
MAGMA GULF GEOTHERMAL PROSPECT
NORTH SWEET LAKE AREA
CAMERON PARISH, LA.

Seven seismic lines totaling approximately 27 miles were used to evaluate a proposed drill-site for the Magma Gulf geothermal prospect, sec. 7, 12S, 7W, North Sweet Lake area, Cameron Parish, La. The lines were purchased from Union Oil Company of California in August, 1978. They were shot around 1969 by United Geophysical using dynamite. They are six fold data and are rated good to poor. No reprocessing has been done at this point.

The seismic lines, combined with well control, were used to construct a structure map on top of the Miogypsina sand, Camerina zone, Frio formation. This thick sand is the objective geothermal reservoir in the area.

Procedure

The following steps were used to prepare the Miogypsina structure map.

1. Coordination with Dr. C. O. Durham on formation tops and fault cuts in wells in the area of interest.

2. Computation of a velocity function using the sonic (velocity) log from the Union of California Sweet Lake Land and Oil 1, sec. 7, 12S, 7W, Cameron Parish.

3. Correlation of the seismic data with the subsurface (well log) data based on the velocity function for time-depth relationship.

4. Interpretation of faulting based on seismic and subsurface data.

5. Hand migration of some of the seismic data for proper position in space.

6. Conversion of Miogypsina seismic times to depth based on the velocity function and contouring map.

Geology

Previous interpretation of this area by other workers indicated a complicated fault system. Our combined geophysical-geological work shows that much of the stratigraphic thinning previously interpreted as faulting is actually due to thinning across a paleo-structural high. Recognition of this simplifies the structural picture tremendously.

Velocity Function

The velocity values used for time-depth correlations are listed in Table 1. The velocity function for these values is plotted on Exhibit B as interval velocity vs depth. The sharp decrease in interval velocity with depth at 8840 feet marks the top of the geopressured interval. Geologically, this is associated with the base of the massive Miocene sands and the top of the massive Anahuac shale. Below the log depth of 15,500 (Table 1) time-depth relationships were extrapolated using a .44 ft./sec./ft. increase in velocity with depth shown on Exhibit B.

Migration

Only one of the seven lines was migrated. Fortunately, this was the north-south line CJ near the proposed location. For the most part, dips were not great enough to seriously distort the map. However, it was necessary to migrate the down-to-the-north fault on line CA, section 7, 12S, 7W, some 1400 feet N 45° W because of dips. This migration is shown on the Miogypsina structure map, Exhibit A. The velocity function used for this migration is the average line in Exhibit B.

Geological - Geophysical Interpretation

The Miogypsina structure map shown on Exhibit A represents our geological-geophysical interpretation of structure at the level of the objective geothermal reservoir. The proposed geothermal well location shown on this map is in a graben between a large down-to-the-south fault on the north and a down-to-the-north fault on the south. For the most part the Miogypsina sand in this graben dip north to northwest around 17° from about 14000 to 18000 feet. The exception is southeast dips of 10° to 20° encountered in the Union of Cal. Sweet Lake Land and Oil 1 just above the Miogypsina sand.* The small "splinter" fault in section 7, 12S, 7W, off the larger down-to-the-north fault could account for these southeast dips by rotation between the two faults.

Brian E. Parsons
Consulting Geologist-Geophysicist
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Houston, Texas 77090

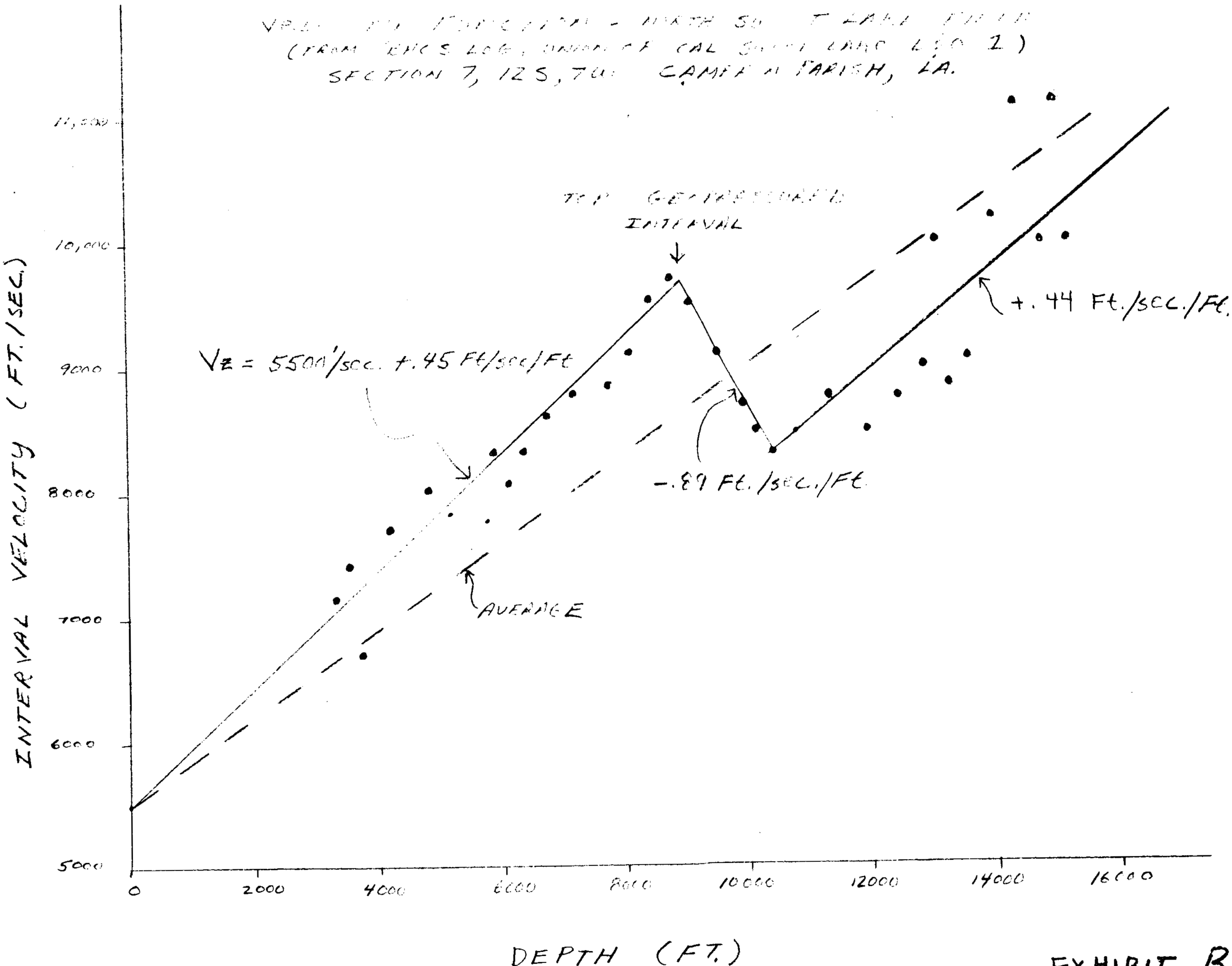
*The dipmeter log in this well was not run over the Miogypsina interval because of borehole condition.

Table 1

Velocity Function-North Sweet Lake
(From BHCS Log, Union of Cal.
Sweet Lake Land and Oil 1)

Depth	Two-Way Time	Average Velocity	Interval Depth	Interval Time/Thickness	Interval Velocity
3300	1.000	6600	1650	.5/3300	6600
3550	1.070	6635	3425	.035/250	7140
3720	1.116	6666	3635	.023/170	7410
3850	1.154	6672	3785	.019/130	6667
4680	1.370	6832	4265	.108/830	7690
5100	1.474	6919	4890	.052/420	8000
5400	1.550	6967	5250	.038/300	7810
5740	1.634	7025	5570	.042/340	8060
5900	1.674	7048	5820	.020/160	7750
6010	1.700	7070	5955	.013/110	8330
6240	1.756	7107	6125	.028/230	8060
6670	1.858	7179	6455	.051/430	8330
6880	1.906	7219	6775	.024/210	8620
7600	2.070	7342	7240	.082/720	8770
7970	2.152	7407	7785	.041/370	8850
8350	2.234	7475	8160	.041/380	9090
8700	2.306	7545	8525	.036/350	9520
8980	2.364	7597	8840	.029/280	9710
9350	2.440	7664	9165	.038/370	9520
9880	2.556	7730	9615	.058/530	9090
10100	2.606	7751	9990	.025/220	8700
10350	2.664	7770	10225	.029/250	8470
10700	2.748	7787	10525	.042/350	8330
11000	2.818	7806	10850	.035/300	8470
11880	3.018	7872	11440	.100/880	8770
12200	3.092	7891	12040	.037/320	8470
12750	3.216	7929	12475	.062/550	8770
13050	3.282	7952	12900	.033/300	9010
13190	3.310	7969	13120	.014/140	10000
13350	3.346	7979	13270	.018/160	8850
13790	3.442	8012	13570	.048/440	9090
14150	3.512	8058	13970	.035/360	10200
14700	3.610	8144	14425	.049/550	11110
14890	3.648	8163	14795	.019/190	10000
15040	3.674	8187	14965	.013/150	11110
15430	3.752	8224	15235	.039/390	10000
16000	3.855	8300	15715	.051/570	11067
16500	3.944	8367	16250	.044/500	11235
17000	4.031	8434	16750	.043/500	11479
17500	4.116	8503	17250	.042/500	11699
18000	4.20	8571	17750	.041/500	11919

A-4



INTERVAL VELOCITY (FT./SEC.)
11,000
10,000
9000
8000
7000
6000
5000
0
2000
4000
6000
8000
10000
12000
14000
16000
DEPTH (FT.)
Vz = 5500'/sec. +.45 Ft/sec/Ft
-.89 Ft./sec./Ft
+.44 Ft./sec./Ft.
AVERAGE

EXHIBIT B

APPENDIX B

PRESSURE - DEPTH PROFILES FOR SELECTED WELLS

By

Louis Records and Associates

Note: Sand position in pressure in psi at top of sand is based on lightest mud weight minus hydrostatic pressure at top of sand, thus equalling minimum pressure in excess of hydrostatic pressure.

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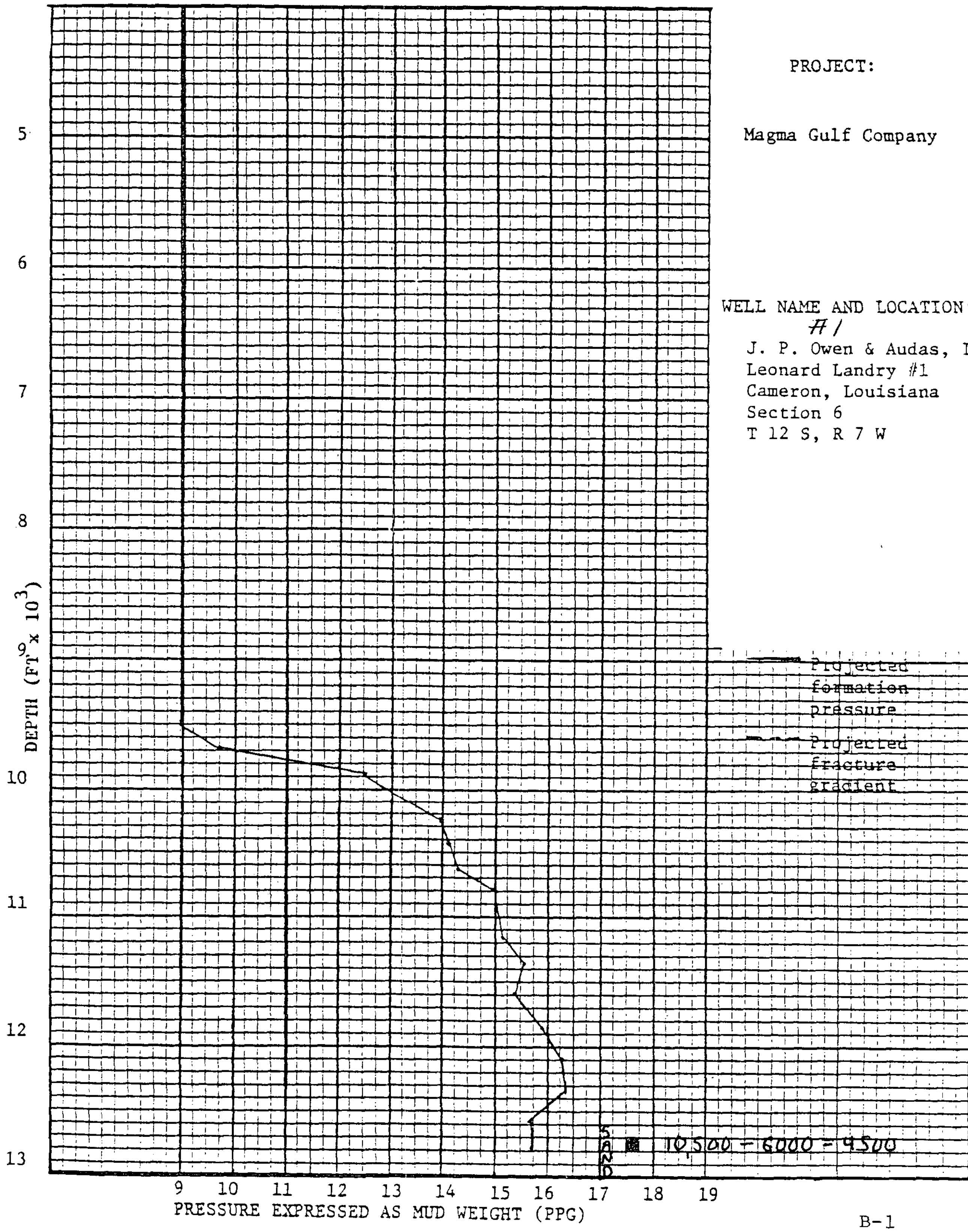
LAFAYETTE, LOUISIANA 70501



PROJECT:

Magma Gulf Company

WELL NAME AND LOCATION:
#1
J. P. Owen & Audas, Inc.
Leonard Landry #1
Cameron, Louisiana
Section 6
T 12 S, R 7 W

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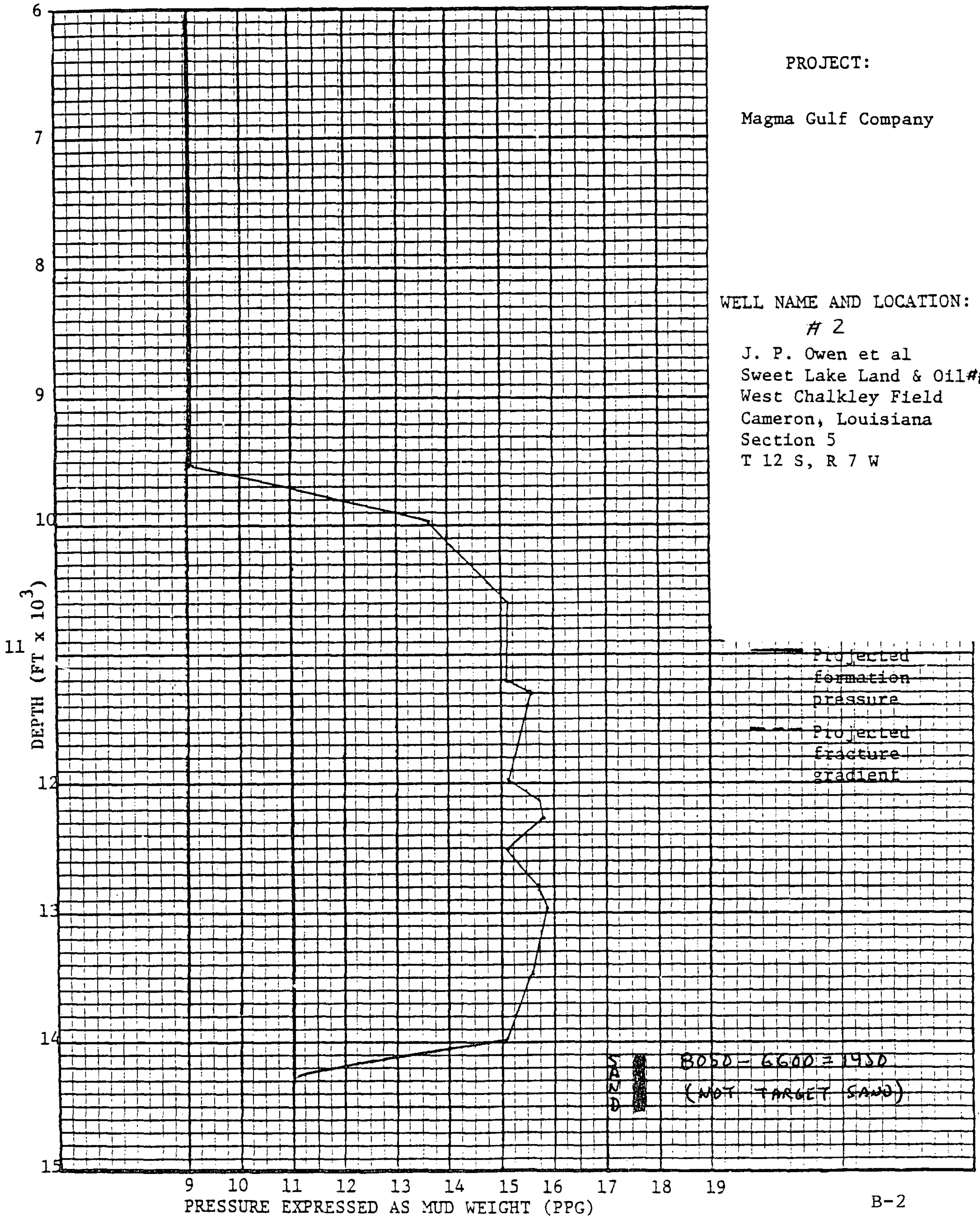
LAFAYETTE, LOUISIANA 70501

PROJECT:

Magma Gulf Company

WELL NAME AND LOCATION:
#2
J. P. Owen et al
Sweet Lake Land & Oil #1
West Chalkley Field
Cameron, Louisiana
Section 5
T 12 S, R 7 W



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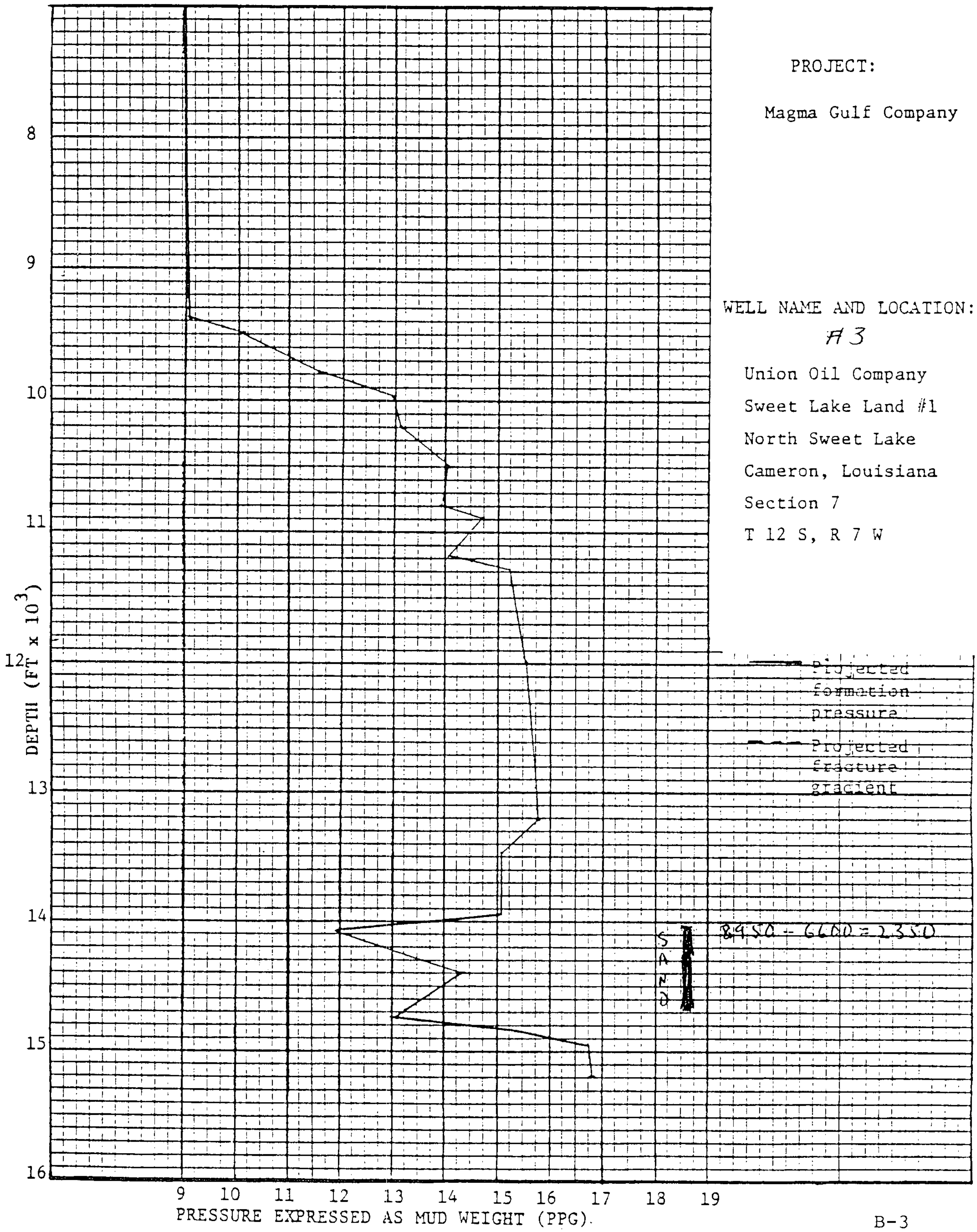

PROJECT:

Magma Gulf Company

WELL NAME AND LOCATION:

A3

Union Oil Company
Sweet Lake Land #1
North Sweet Lake
Cameron, Louisiana
Section 7
T 12 S, R 7 W

LOUIS RECORDS & ASSOCIATES, INC.

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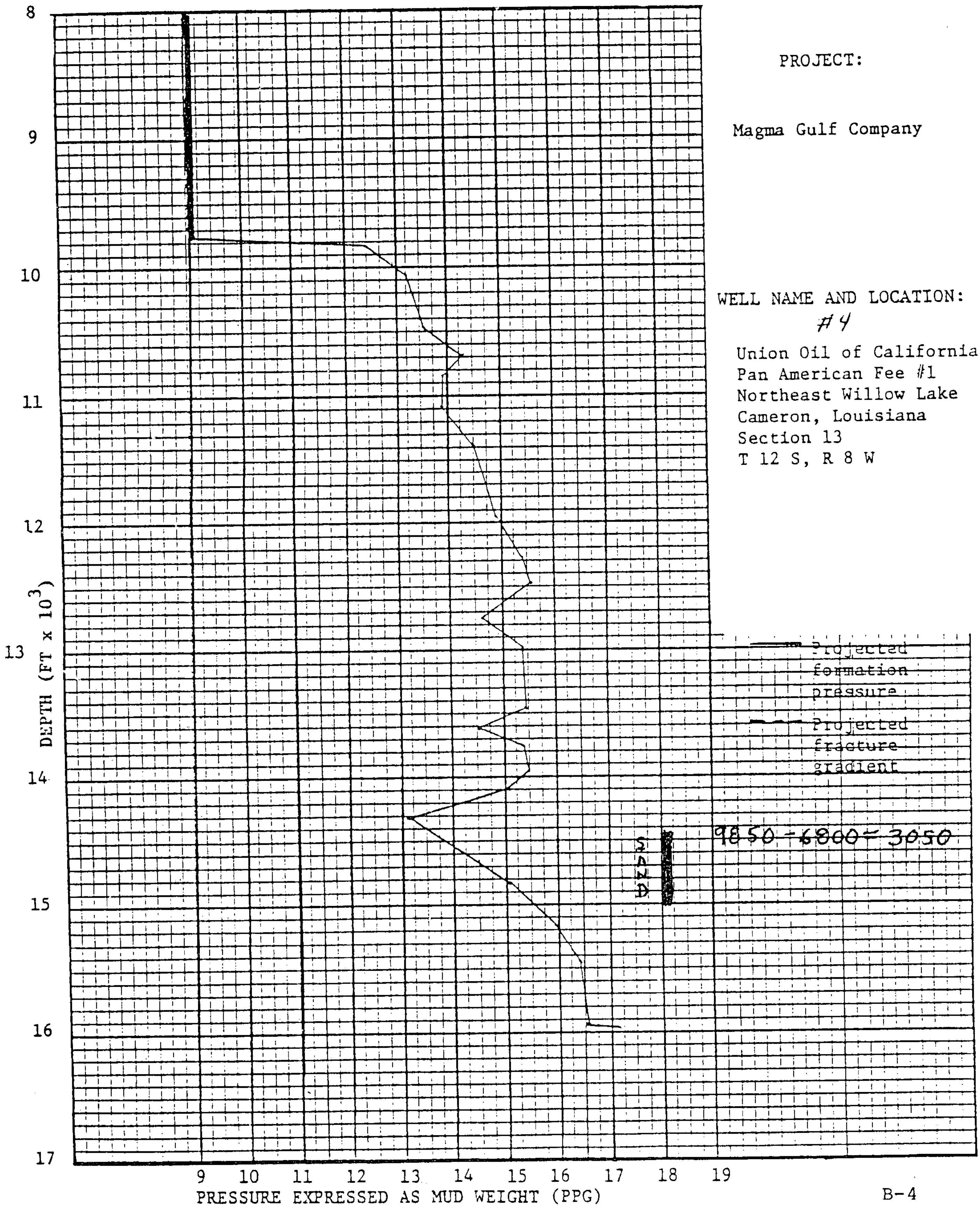
LAFAYETTE, LOUISIANA 70501

PROJECT:

Magma Gulf Company

WELL NAME AND LOCATION:
#4
Union Oil of California
Pan American Fee #1
Northeast Willow Lake
Cameron, Louisiana
Section 13
T 12 S, R 8 W



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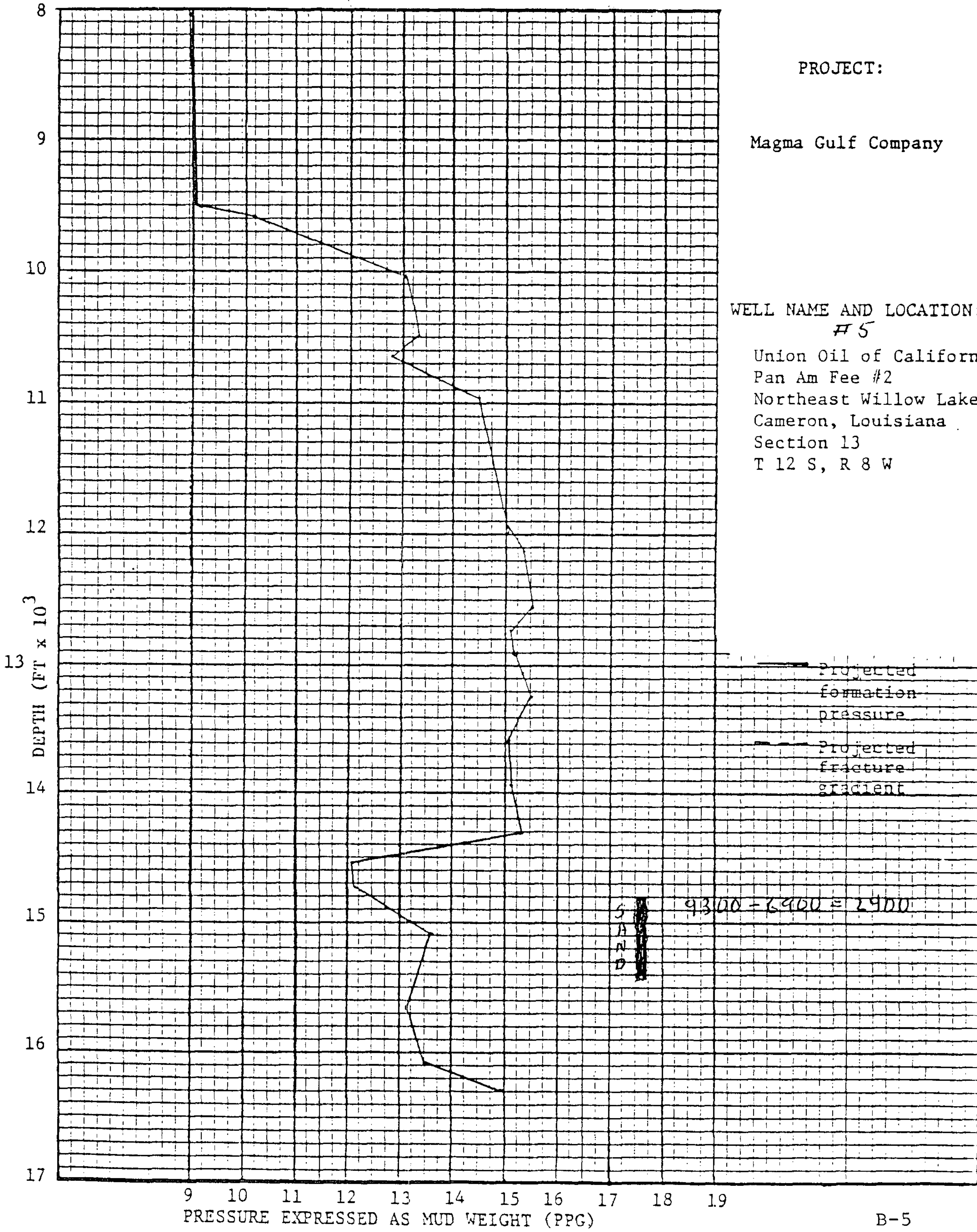
PROJECT:

Magma Gulf Company

WELL NAME AND LOCATION:
#5
Union Oil of Californi
Pan Am Fee #2
Northeast Willow Lake
Cameron, Louisiana
Section 13
T 12 S, R 8 W



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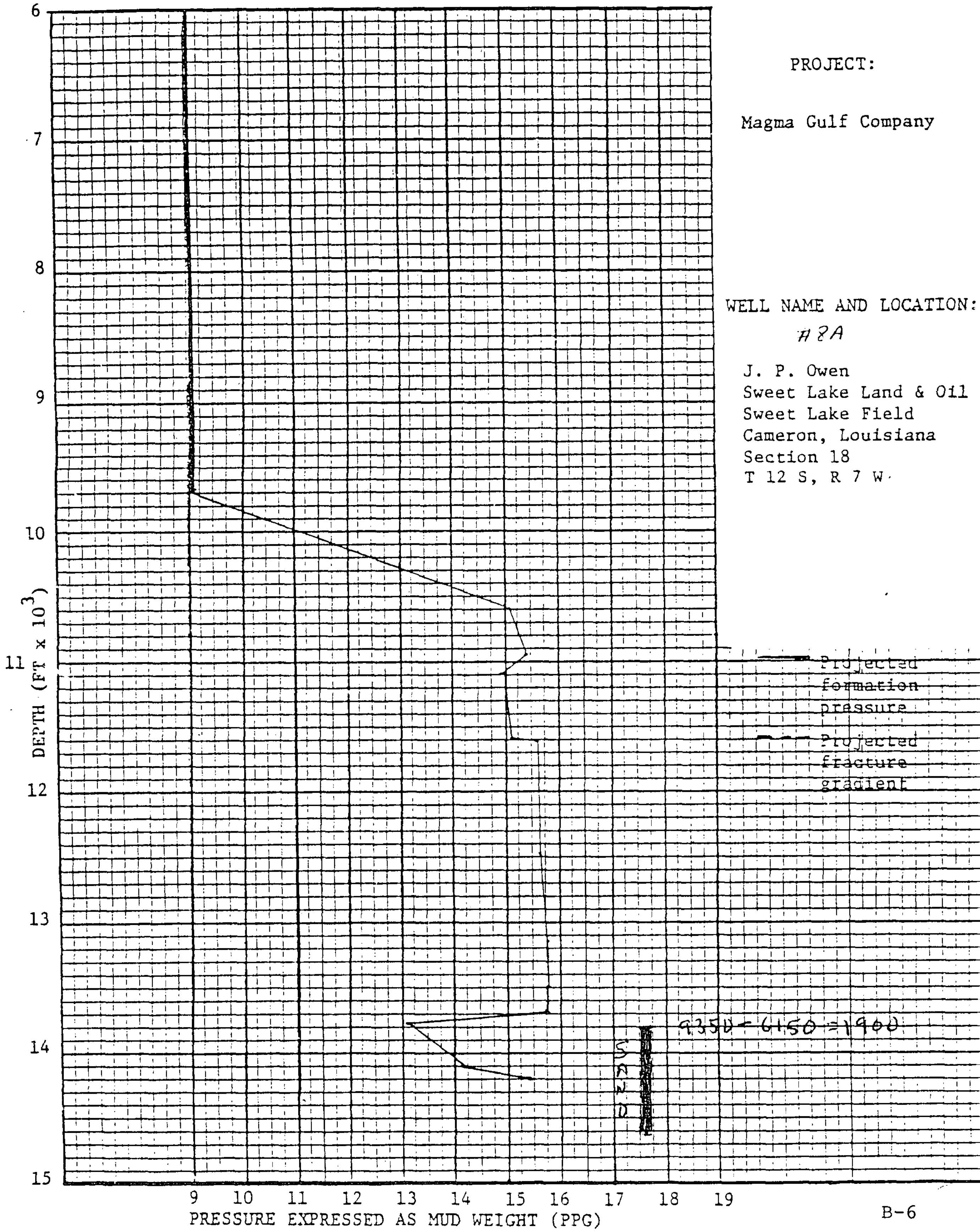

PROJECT:

Magma Gulf Company

WELL NAME AND LOCATION:

#8A

J. P. Owen
Sweet Lake Land & Oil #
Sweet Lake Field
Cameron, Louisiana
Section 18
T 12 S, R 7 W

LOUIS RECORDS & ASSOCIATES, INC.

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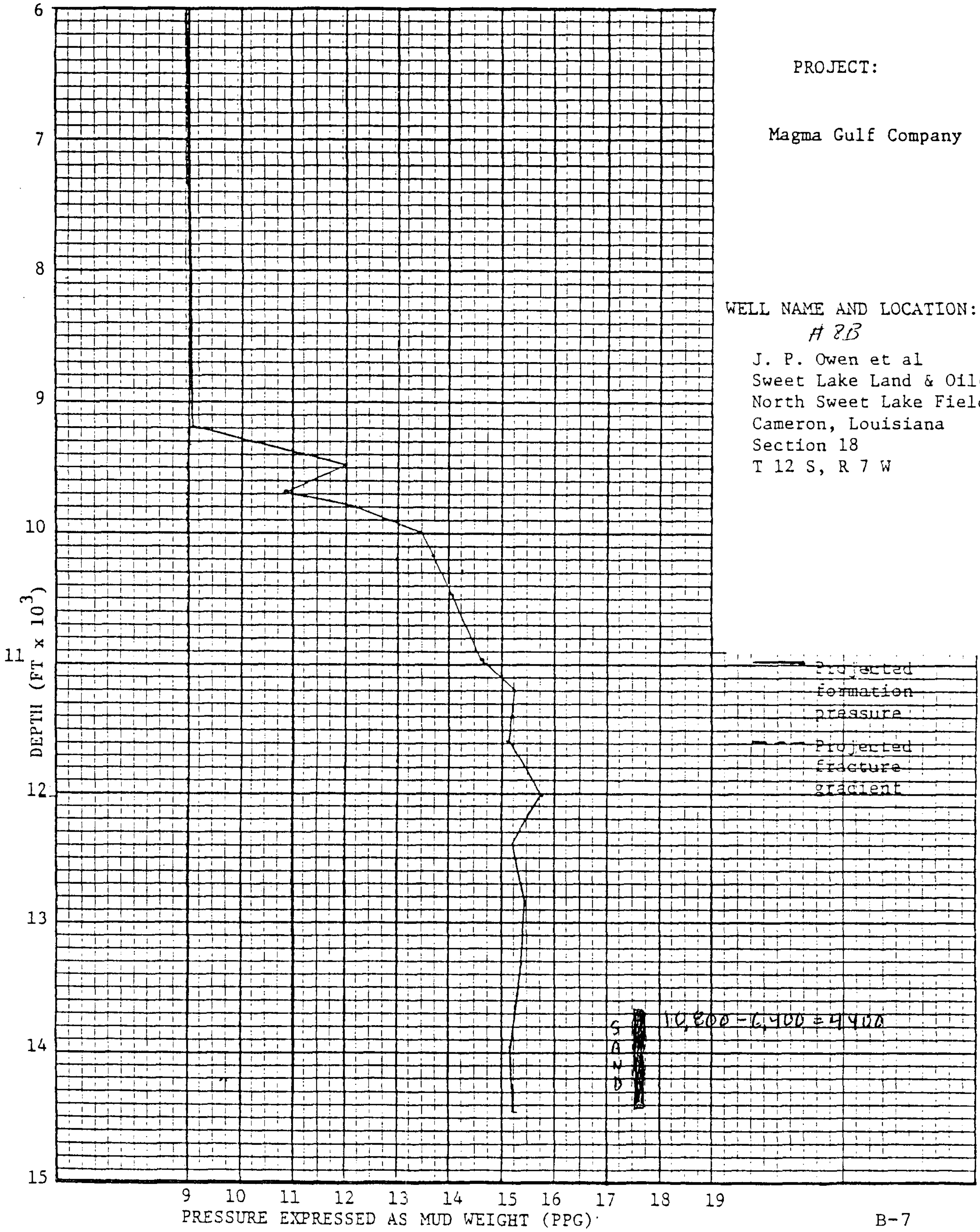

PROJECT:

Magma Gulf Company

WELL NAME AND LOCATION:
8B
J. P. Owen et al
Sweet Lake Land & Oil #2
North Sweet Lake Field
Cameron, Louisiana
Section 18
T 12 S, R 7 W

B-7

LOUIS RECORDS & ASSOCIATES, INC.

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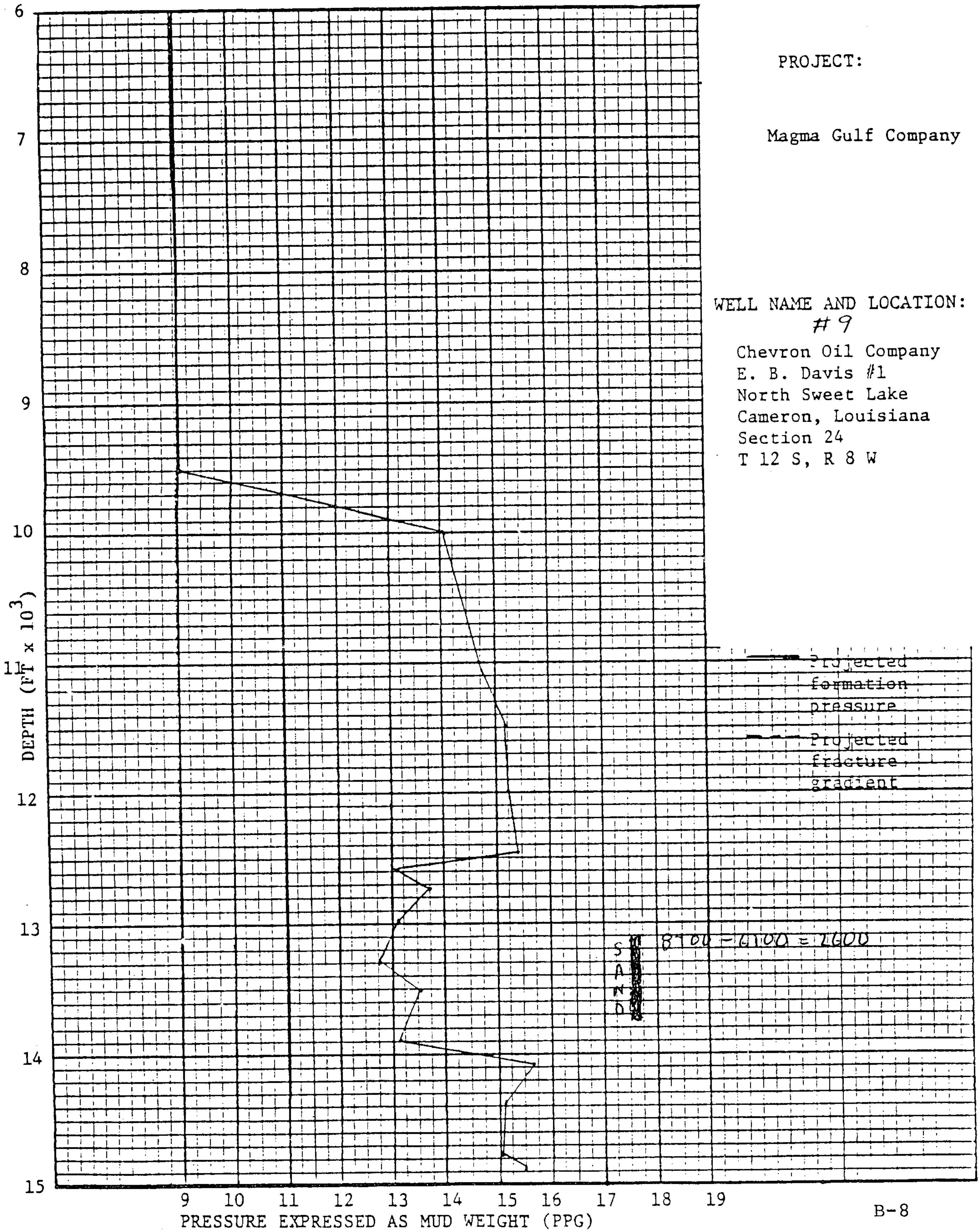
LAFAYETTE, LOUISIANA 70501

PROJECT:

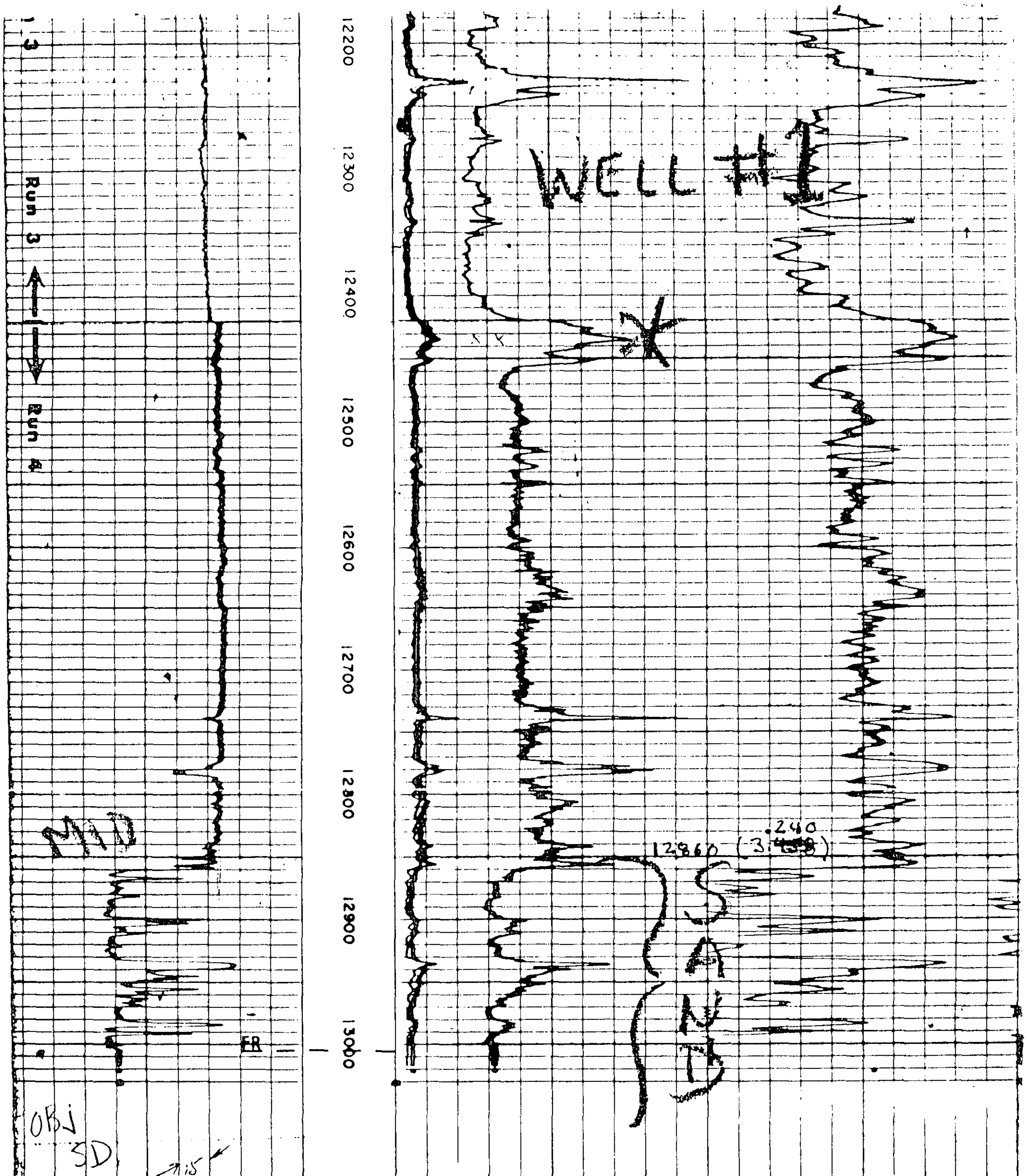
Magma Gulf Company

WELL NAME AND LOCATION:
#9
Chevron Oil Company
E. B. Davis #1
North Sweet Lake
Cameron, Louisiana
Section 24
T 12 S, R 8 W



APPENDIX C

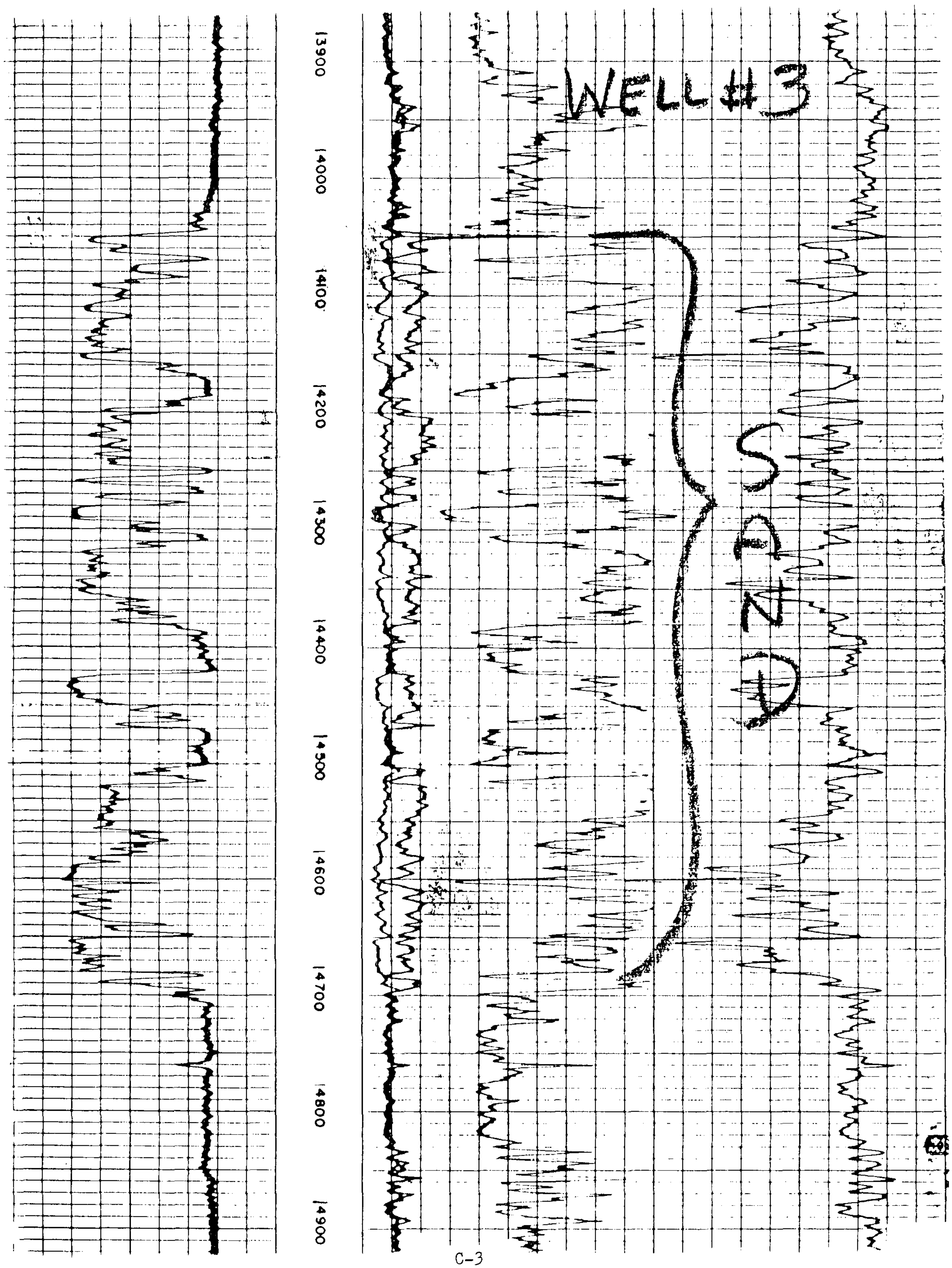
"MIOGYP" SAND ON SELECTED WELL LOGS

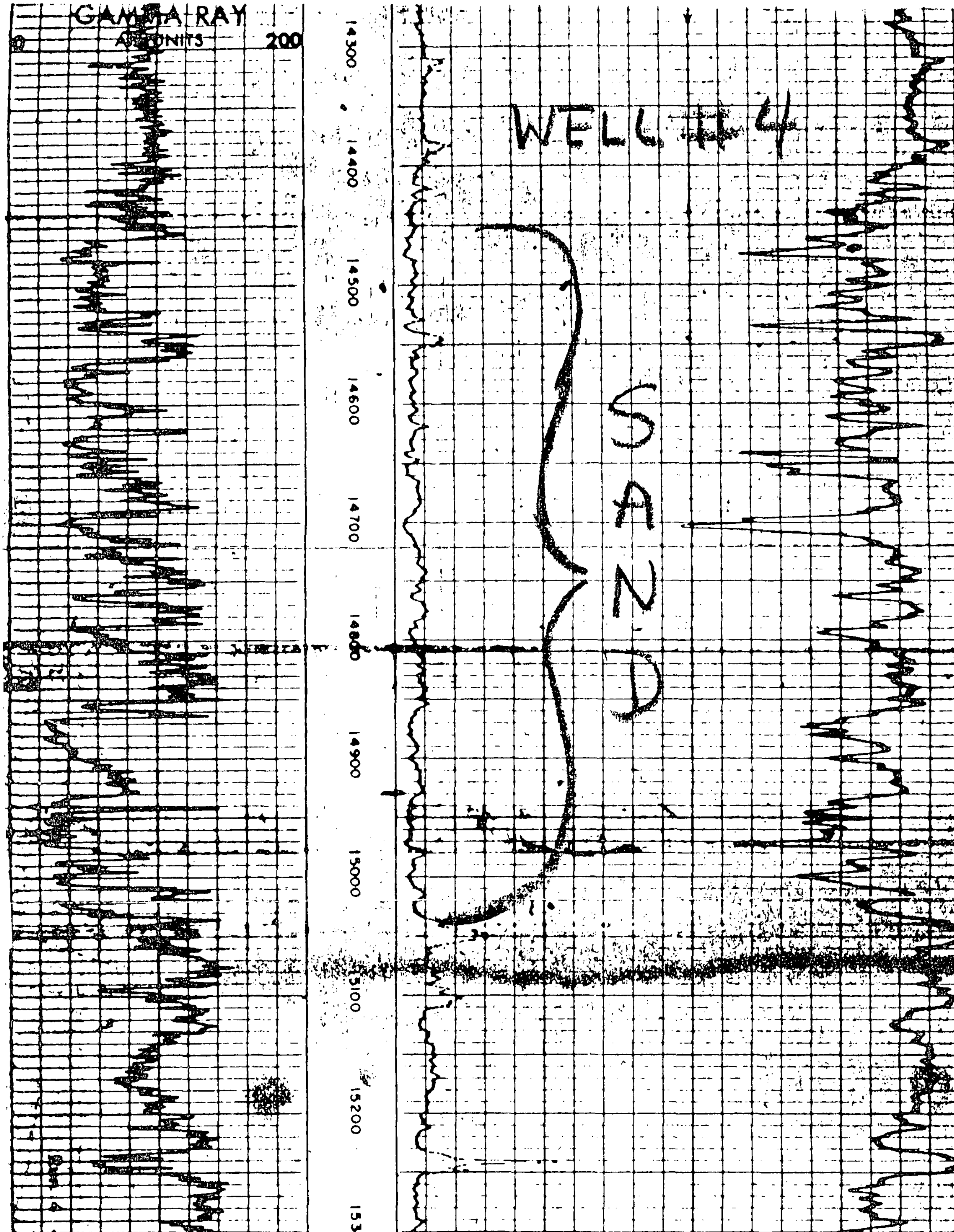


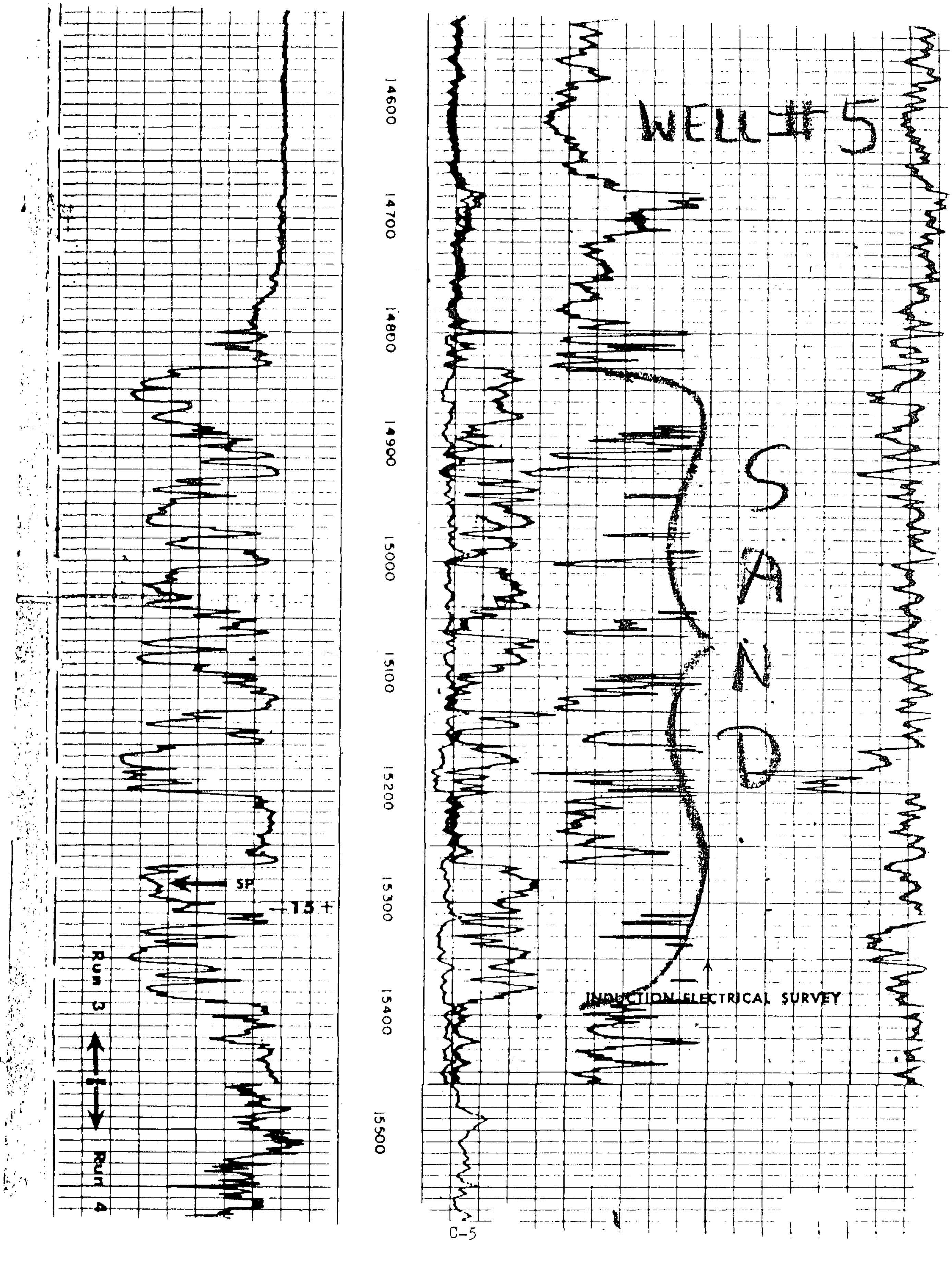
A - 16" - M
SHORT NORMAL

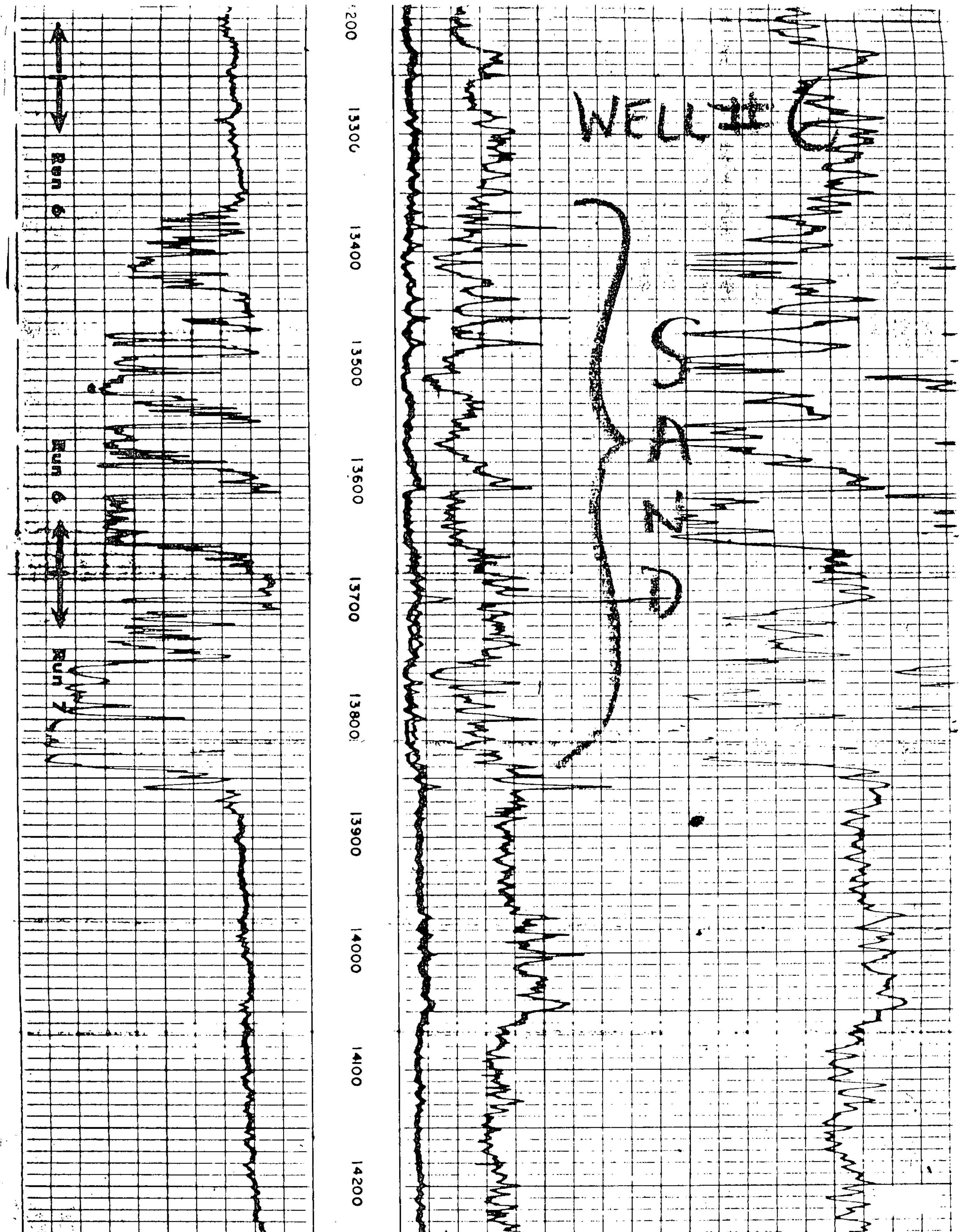
0 HIGH SCALE 100

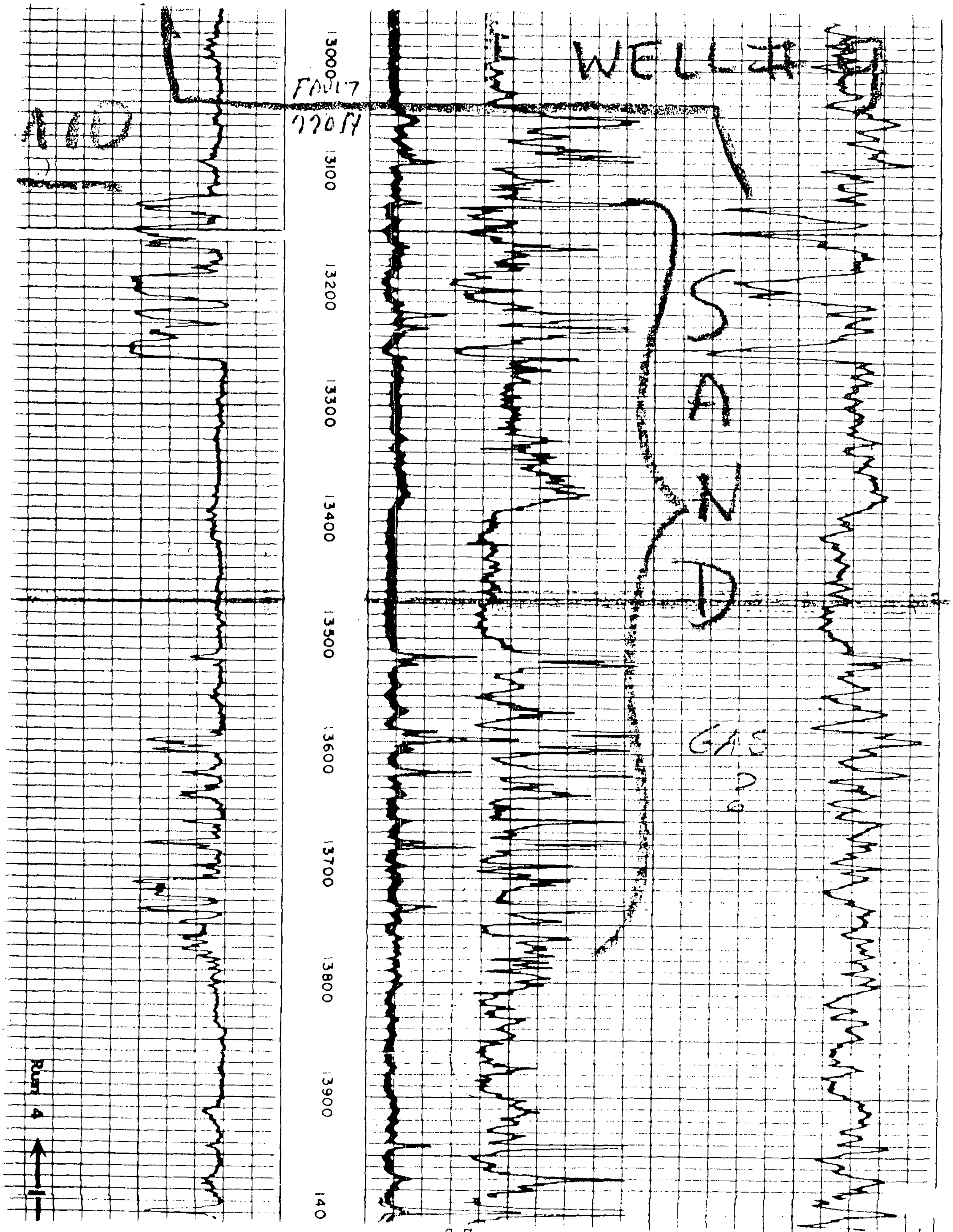
40" INDUCTION

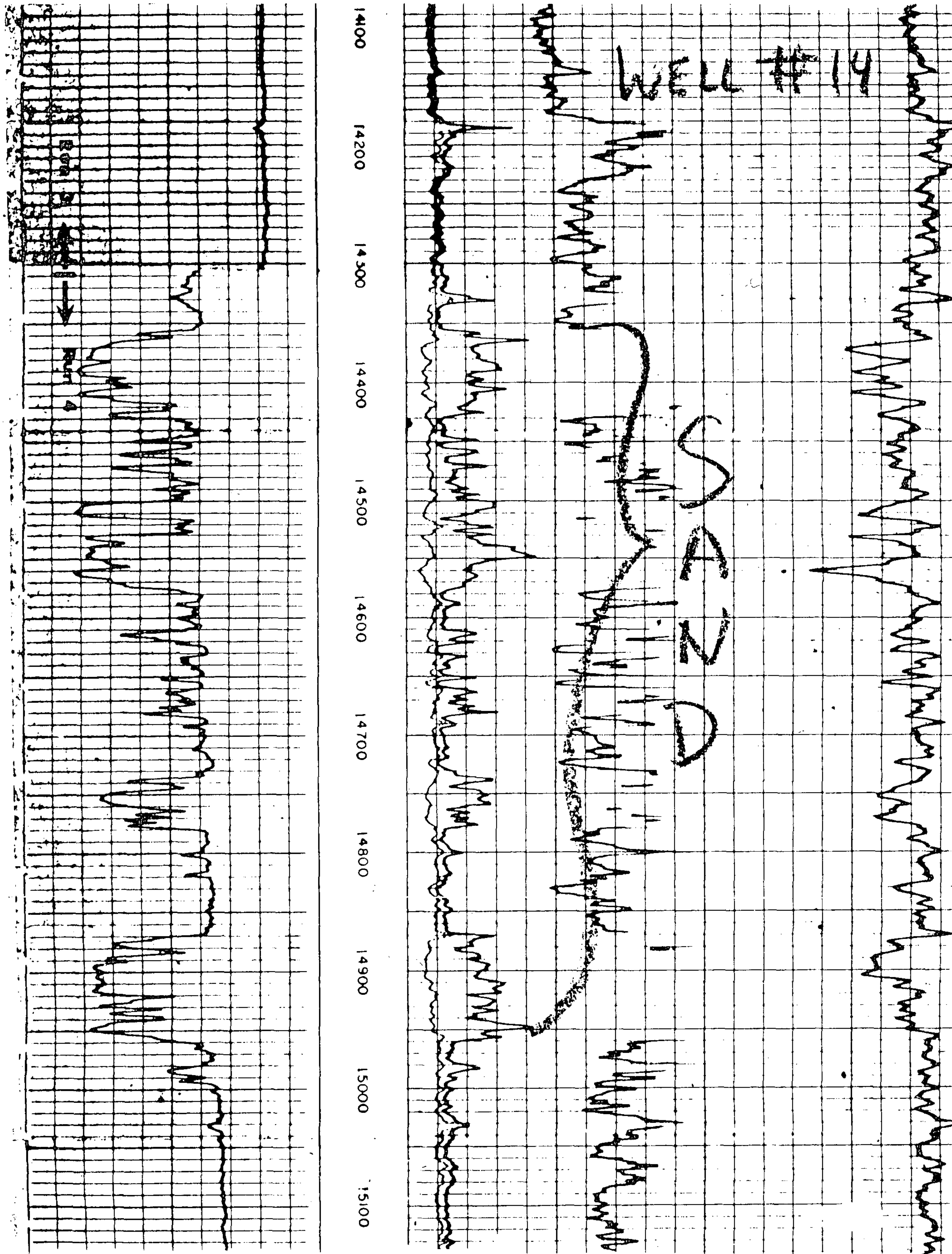

13900
14000
14100
14200
14300
14400
14500
14600
14700
14800
14900
WELL #3
SAND


GAMMA RAY
API UNITS
0
200
14300
14400
14500
14600
14700
14800
14900
15000
15100
15200
15300
WELL #4
SAND


WELL #5
SAND
INDUCTION-ELECTRICAL SURVEY
14600
14700
14800
14900
15000
15100
15200
15300
15400
15500
SP
15 +
Run 3
Run 4


13200
13300
13400
13500
13600
13700
13800
13900
14000
14100
14200
Run 6
Run 6
Run 7
WELL #6
SAND


13000
13100
13200
13300
13400
13500
13600
13700
13800
13900
140
Run 4
FAULT
WELL
SAND
GAS



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