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BP Petroleum Development Ltd., Norway

Well 6507/10-1
Petroleum Engineering
Completion Report

by

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&

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Approved by: P.L. Burke

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Summary

Well 6507/10-1 was spudded on 10th July 1982 by the semi-submersible drilling rig Sedco 707. The well was abandoned on 18th October 1982 at a depth of 3695 m BRT having reached Triassic rocks.

The well location was chosen as the first exploration well under licence 075 its main target being Mid Jurassic sands in the NE corner of block 6507/10 (the 'T' prospect).

The well penetrated the top of the Mid Jurassic sandstone at 2881 m BRT though the sands proved to be 100% water saturated. A secondary target of Lower Jurassic sand was also encountered but found to be water wet. A further target of Triassic grey beds was not reached.

A good set of logs and RFT data were obtained from the well. RFT data indicated a normally pressured reservoir at the datum level of 2900 m BRT, with all reservoir pressures lying on a common water gradient. A computerised log interpretation by Intercomp UK Ltd. showed no indications of hydrocarbons but estimated total net sand to be 542 m with zone average porosities ranging from 18 to 25%.

Core coverage was poor with a total of 15.2 m taken in two cores, one from the top of the Mid Jurassic and one from the top of the lower Jurassic sand. Permeability estimates were therefore difficult but it could be inferred that whilst the Mid Jurassic sand shows excellent poroperm characteristics, the Lower Jurassic is poorer.

After running logs the well was abandoned without any production/injection tests.

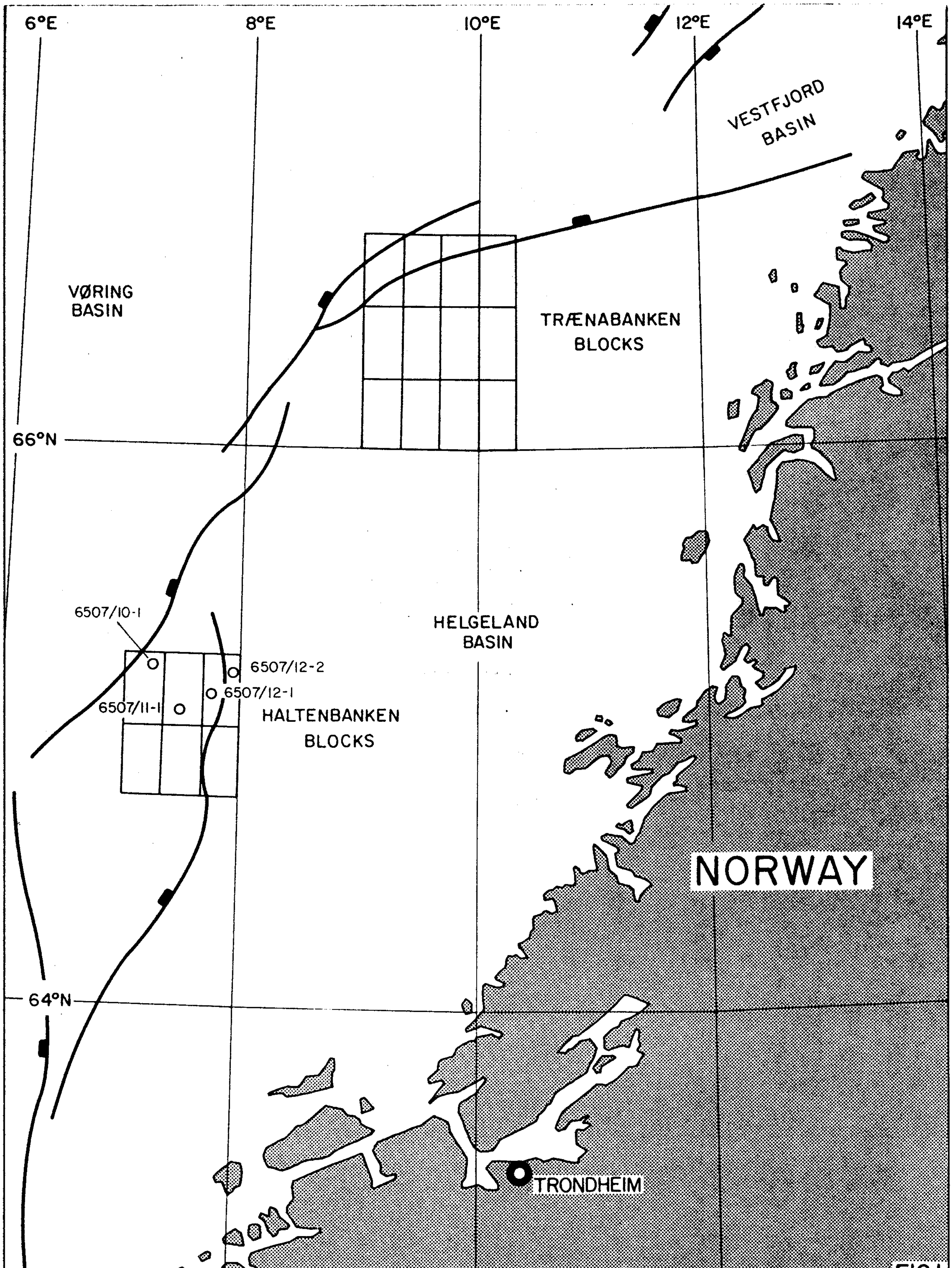

FIG.1.

BP PETROLEUM DEVELOPMENT LTD. NORWAY	
Ref: GP/NO/230	
Author: I. PRICE	
Date: MAY 1982	Drg No: 6383

LOCATION MAP

NOTE

In this report the following unit names have been used for lithologies considered separate which are identified in the log analysis.

Age	Unit	Interval mBRT
	Heather	2835 - 2881
Mid-Jurassic	Brent	2881 - 2994
	Drake	2994 - 3080,5
Lower Jurassic	Cook	3080.5 - 3299
	Coal Unit	3299 - 3650
Triassic	Triassic	3650 - 3695 (TD)

NB. The well reached TD whilst still in the Coal unit which extends into the Triassic.
For the purposes of log analysis however, since a change in reservoir properties can be seen, the unit is called Triassic below 3650 mBRT in this report.

6507/10-1 GENERAL WELL DATA

Licence Number	: 075
Licencees	: BP - 30% (Operator)
	: Statoil - 50%
	: Arco - 10%
	: Union Oil - 10%
Well Type	: Exploration
Spud Date	: 10/7/82
Well Completed	: 1/11/82
Status	: Abandoned without testing
Rig	: Sedco 707
RTE	: 25 m (AMSL)
Water depth	: 297 m
TD	: 3695 mBRT
Hole size at TD	: 8.5 in.

1. Hydrocarbon Indications

An 11% C_1 gas peak was recorded from a Miocene sandstone at 590 m BRT but no fluorescence was noted.

Sandstone in the interval 1790-1805 m BRT produced a slow crush cut fluorescence as did the Upper Jurassic mudstone between 2779 m BRT and 2828 m BRT.

No other indications of hydrocarbons were recorded.

2. Core Analysis

Two conventional cores were cut in the Jurassic sandstone interval. Core 1 recovered 6.85 m from 2883-2892 m BRT in Brent sandstone. Core 2 recovered 8.3 m in Lower Jurassic sandstone from 3077.5-3087.1 m BRT (logged depths). Table 1 gives the cored intervals and recoveries.

Conventional core analyis was performed on plugs cut at approximately 30 cm intervals. The following parameters were determined:-

a) Helium and saturation porosities
b) Horizontal and vertical air permeabilities
c) Residual fluid saturations
d) Grain density

The helium porosity, grain density and horizontal and vertical permeability are given in Tables 2 and 3 for both cases.

Core 1, taken in the Middle Jurassic, has an average helium porosity of 20% and an average grain density of 2.67 gm/cc. The arithmetic average of the core air permeabilities is 2420 mD.

Core 2, taken in the Lower Jurassic or Cook Formation has an average helium porosity of 19% and an average grain density of 2.75 gm/cc. The high value of average grain density is attributed to the presence of siderite in the core causing individual core grain densities of as much as 3.0 gm/cc. This can be correlated with the expected response on the litho-density log proving that the high grain densities are not representative of the sandstone matrix grain density. The arithmetic average of the core air permeabilities is 550 mD.

Figure 1 shows the relationship between the core helium porosities and the core air permeabilities.

3. Log Interpretation

3.1.1 Introduction

A summary of the wireline logs run in 6507/10-1 is shown in Table 4.

A computer processed interpretation of the 8½" open hole logs was performed by Intercomp (UK) Ltd. using their INTERLOG program.

3.2 Method

An examination of the logs indicated the possible presence of heavy radioactive minerals particularly in the Brent and Cook sequences. To determine the extent of this mineral presence a preliminary run was made using the Intercomp 'ROCKS' program. This program take the responses from several logs and fits a lithological matrix 'solution' based on sand, clay and other minerals. The results indicated that whilst minerals such as mica, pyrite, siderite and glauconite were present, the quantities of each was very small.

This being the case, it was felt that a conventional neutron-density crossplot analysis using a shaly/sand model would provide an adequate solution. For the analysis the gross interval was zoned accordingly to geological event and the parameters used in each zone are listed in Table 7. The main zonal difference is the formation water resistivity Rw which has been obtained from a crossplot of porosity vs $1/\sqrt{Rt}$.

Porosity was measured from the neutron/density crossplot after correcting for shale. Vshale was taken as the minimum value from the normal shale indicators.

Water saturations were calculated using the Indonesia equation.

3.3 Results

The analysis showed all the permeable intervals to be 100% water saturated thus confirming the RFT gradient measured. A summary of the net/gross percentages and average porosities for each interval is shown in Table 8. In the absence of extensive core data, net sand was defined by a straight 10% porosity cut off. This produced results similar to the method of assuming net pay where mud cake is present.

On a zone by zone basis the results are:

3.3.1 Heather (2835-2881 m BRT)

This is an interval of siltstone/mudstone showing some porosity -

Gross interval	46 m
Net Pay	6.4 m
Net/Gross	13,9%
Average Ø	14.2%

3.3.2 Brent (2881-2994 m BRT)

This is predominantly a good clean sand section apart from two small coarsening up sequences at 2908 and 2917 m BRT. Average porosity is 24.4% over the 110 m of net sand and there is a good agreement between log and core porosities. The small amount of core data makes any porosity/permeability relationship difficult to correlate over a range of porosities but in general permeabilities are high, approximately 1000 mD for 20% porosity. Calculated water saturations from the Indonesia equation using an Rw value of 0.36 Ω m are all close to 100% adding confidence to the porosity prediction.

Gross interval	113 m
Net Pay	109.9 m
Net/Gross	97.2%
Average Ø	24.4%

3.3.3 Drake (2994-3080.5 m BRT)

This section is predominantly shale with possibly some poor porosity development around 3025 m BRT.

Gross interval	86.5 m
Net Pay	2.6 m
Net/Gross	3%
Average Ø	14.4%

3.3.4 Cook (3080.5-3299 m BRT)

This Lower Jurassic sandstone unit has, in general, lower porosities than the Mid Jurassic averaging 18.5% over 187 m of net sand due to the higher volumes of dispersed shale in the sand.
Core no. 2 included 5 m of the top of the Cook sand providing some porosity/permeability data. These showed a good match with log porosity and indicated that the poroperm characteristics were not as good as the Brent sand. Once again this is probably due to the dispersed nature of the shale.

Water saturations of 100% were calculated using an Rw value of 0.27 Ω m.

Gross interval	218.5 m
Net Pay	187.3 m
Net/Gross	85.7%
Average Ø	18.5%

3.3.5 Coal Unit (3299-3650 m BRT)

This section is composed of interbedded sand, shale and coal sequence, the sand intervals being less continuous in the lower part of the unit. Average porosity is similar to the Cook at 19.7% over the 222 m of net sand although the net to gross ratio is reduced. It should be noted that once again net sand was derived from a straight 10% porosity cut off and does include very thin sections which are likely not contribute to production in a development situation. Ignoring these a more representative figure for net sand would be about 200 m representing a net/gross ratio of 57%.

Water saturations were again 100% using an Rw value of .25 Ω m.

Gross interval	351 m
Net Pay	222.4 m
Net/Gross	63.3%
Average Ø	19.7%

3.3.6 <u>Triassic (3650 m BRT - TD)</u>

The top of the Triassic includes two fairly clean sand intervals which together net 14 m having average porosities of 19.1%. Rw from crossplots in the Triassic indicate a higher formation water salinity (Rw=.016 Ω m). The change in salinity appears to be around 3600 m BRT from the SP deflection. This suggests the Triassic top could be around 3600 instead of 3650 m BRT.

Gross interval*	45 m
Net Pay	13.7 m
Net/Gross	30%
Average porosity	19.1%

* Note that the well reached TD in this interval thus Gross interval does not represent a unit thickness.

3.4 <u>Discussion of Results</u>

With the relatively small amounts of core data available, the means of cross checking log results was limited. However, a good porosity match was achieved over the sections that were cored.

As was mentioned earlier, there was concern over the presence of heavy minerals in some sections. These had been confirmed but quantities were estimated at being less than 10%. The log analysis used assumed a shaly sand model therefore the presence of any minerals, no matter how small the quantity, introduced some error to the solution. This error could not be measured since the minerals could not be accurately quantified. The only comment that can be made is that the minerals being heavier than the sandstone matrix would have the effect of underestimating porosities thus the solution could be on the pessimistic side.

4. Formation Testing

4.1 Wireline Formation Tests

The Schlumberger Repeat Formation Tester (RFT) was run as part of the final logging suite. The temperature corrected pressure measurements are shown listed in Table 5 and plotted in Figure 1.

Twenty pressure measurements were attempted in the Middle and Lower Jurassic sandstones and the Coal unit. Eighteen reliable pressure measurements were obtained giving a formation pressure gradient of 0.46 psi/ft (1.05 psi/m) confirming the sandstones to be water bearing.

No sampling was attempted with the RFT tool.

4.2 Drill Stem Tests

No drill stem tests were performed.

5. Reservoir Pressure and Temperature

5.1 Reservoir Pressure

The Schlumberger RFT tool was run as part of the final logging suite. The temperature corrected RFT pressure measurements are listed in Table 5 and plotted in Figure 1.

Successful pressure measurements were made in the Lower and Middle Jurassic sandstones and the sandstone intervals in the Coal unit. Figure 1 shows all the main sandstone intervals to be in pressure communication. Using the least squares method the formation pressure gradient is calculated at 0.458 psi/ft (1.50 psi/m) confirming the sandstones as water bearing.

Reservoir pressure at a datum depth of 2900 m BRT. (2776 mss) is established to be 4320 psi $\pm$ 26 psi.

5.2 Reservoir Temperature

The only downhole temperature data available is from the logging runs. 3 maximum reading thermometers were attached to each tool run in the hole. The highest of the three readings together with the time since circulation had ceased is recorded in Table 6. The results are plotted versus depth in Figure 2 along with and extrapolated TD temperature using a Horner type plot.

From Figure 2, the temperature at the reservoir datum of 2900 m BRT is 208^{o}F.

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Table 1 - Well 6507/10-1 Cored Intervals and Recovery

Core No	Interval		Recovery (m)	Recovery Percentage (%)
	Drilled Depth (mBRT)	Logged Depth (mBRT)		
1	2780.5 - 2889.5	2883 - 2892	6.85	76
2	3073.6 - 3083.2	3077.5 - 3087.5	8.30	86.5

Table 2 Well 6507/10-1 Results of Conventional Core Analysis

Core 1 2780.5 - 2889.5 mBRT (cored depth)
2883 - 2892 mBRT (logged depth)

Plug No.	Cored Depth (mBRT)	Horizon Perm. (MD)	Vert. Perm (MD)	Heluim Porosity (%)	Grain Density (g/cc)
1	2881.04	1594	293	19.4	2.68
2	2881.30	1121	832	20.6	2.67
3	2881.60	728	350	19.4	2.66
4	2881.93	724	590	20.1	2.77
5	2882.27	517	466	21.5	2.65
6	2882.60	621	321	21.1	2.68
7	2883.00	2556	324	18.3	2.67
8	2883.30	833	278	20.3	2.65
9	2883.60	681	589	18.9	2.67
10	2883.90	1430	248	18.8	2.65
11	2884.50	3651	446	21.7	2.66
12	2885.00	2120	632	19.7	2.67
13	2885.30	928	284	20.4	2.66
14	2885.60	4299	2638	23.4	2.65
15	2886.04	3279	1839	14.4	2.66
16	2886.60	6831	6016	22.5	2.66
17	2886.93	6790	3323	22.1	2.66
18	2887.25	4840	1250	22.5	2.70
Arithmetic Mean		2420	1150		
Geometric Mean		1700	680		
Harmonic Mean		1250	500		

Average Core Porosity = 20%

Average Core Grain Density = 2.67 g/cc

Table 3 - Well 6507/10-1 Results of Conventional Core Analysis

Core 2 3073.6 - 3083.2 mBRT (cored depth)
3077.5 - 3087.1 mBRT (logged depth)

Plug No.	Depth (mBRT)	Cored Perm. (MD)	Horizon Perm. (MD)	Vert. Porosity (%)	Helium Grain Density (g/cc)
1	3076.95	0.67	-	6.7	2.69
2	3077.35	0.22	0.04	11.2	2.67
3	3077.70	118	95	27	2.66
4	3078.00	5.6	0.63	20.3	2.66
5	3078.35	2.0	0.38	16.8	2.65
6	3078.74	1.2	0.55	16.5	2.90
7	3079.00	10	0.91	18.8	2.83
8	3079.32	0.17	0.03	10.4	3.00
9	3080.00	1595	-	26.8	2.73
10	3080.40	1168	421	24.9	2.66
11	3081.03	3356	7812	28.8	2.65
12	3081.70	363	13	18.3	2.95

Arithmetic Mean	550
Geometric Mean	18
Harmonic Mean	1

Average Core Porosity = 19%
Average Grain Density
= 2.75 g/cc

Table 4: Wireline Logs Run on Well 6507/10-1

Run No:	Log	Interval (mBRT)	Maximum Temperature (^{o}F)
1A	ISF/BHCS/GR/SP	436 - 897	86
2B	ISF/BFCS/MSFL/CAL/GR/SP	903 - 1969	110
3A	CBL/VDL/GR	1700 - 1951	-
4C	ISF/BHCS/MSFL/CAL/GR/SP*	1818 - 2779	170
5D	ISF/BHCS/MSFL/CAL/GR/SP	2770 - 3697	210
5A	LDL//CNL/CAL/GR	2770 - 3697	228
5A	HDT**	2770 - 3415	228
5A	RFT/GR	2884 - 3658	226
5A	CST/GR***	2775 - 3667	212
5B	CBL/VDL/GR	1480 - 2769	177
5A	VSP	475 - 3685	-

* Logged running in only since weak point pulled after sticking at bottom.
No log recorded 1985 - 2183 mBRT due to tool calibration.

** Tool hanging up on running in - TD not reached.

*** 50 sidewall cores recovered from 60 attempted.

Table 5: Well 6507/10-1 RFT Pressure Data

Pt	Depth (mBRT)	Hydrostatic Pressure (psi)	Formation Pressure (psi)	Comments
1	2884	5103	4298	
2	2884	5105	4298	
3	2894	5125	4314	
4	2918.5	5174	4355	
5	2934	5193	4368	
6	2985	5285	4444	
7	3113.5	5511	4634	
8	3148.5	5577	-	Dry Test
9	3228.5	5725	4809	
10	3242	5751	4827	
11	3351.5	5967	4990	
12	3414.5	6073	5083	
13	3483	6194	5190	
14	3626.5	6450	5405	
15	3658	6512	5467	
16	3658	6513	5469	
17	3149	5575	-	Dry Test
18	2918.5	5160	4391	
19	2894	5115	4305	
20	2884	5098	4291	

NB: All pressures are temperature corrected.

Table 6: - Well 6507/10-1 Log Temperature Data

Run No	Log	Circulation Time hrs	Time Since Circulation Stop hrs	Max Temparature (^{o}F)	Depth (mBRT)
1A	ISF/BHCS	1.75	8.25	86	882
2B	ISF/BHCS	3.0	6.0	110	1944
4C	ISF/BHCS	3.5	9.0	170	2753
5D	ISF/BHCS	1.5	10.0	210	3670
5A	LDL/CNL	1.5	16.0	228	3685
5A	HDT	1.5	24.0	228	3500
5A	RFT	3.5	12.0	226	3665
5B	CBL/VDL	1.5	27.0	177	2762

Table 7: 6507/10-1 Zonal parameters used in the log interpretation

	Δt_{Fluid}	Δt_{Matrix}	Δt_{Clay}	R_{Clay}	R_w	Matrix	Clay	ϕ_N Matrix	ϕ_N Clay	GR_{Max}	GR_{Min}	SP_{Max}	SP_{Min}
	µs/ft	µs/ft	µs/ft	ΩM	ΩM	g/cc	g/cc	LPU	LPU	GAPI		mV	
HEATHER	189	48	97	2.6	.255	2.65	2.51	-4	29	134	90	57	5
MID-JURASSIC	189	55.5	91	4.94	.036	2.65	2.54	-4	24.5	105	30	55	7
DRAKE	189	55.5	94	2.75	.052	2.65	2.48	-4	29	135	87	58	7
COOK	189	55.5	86	10.7	.027	2.65	2.56	-4	28	120	45	45	-2
COAL	189	55.5	75	10.75	.025	2.65	2.68	-4	29	150	30	58	-5
TRIASSIC	189	55.5	74	6.67	.016	2.65	2.60	-4	36	140	26	74	0

6507/10-1 : LOG ANALYSIS

SAND	INTERVAL MBRT	GROSS METRES	NET METRES	NET/GROSS	AV.Ø
HEATHER	2835-2881	46	6.4	13.9%	14.2%
BRENT	2881-2994	113	109.9	97.2%	24.4%
DRAKE	2994-3080.5	86.5	2.6	3%	14.4%
COOK	3080.5-3299	218.5	187.3	85.7%	18.5%
COAL UNIT	3299-3650	351	222.4	63.3%	19.7%
TRIASSIC	3650-3695	45	13.7	30%	19.1%

NET SAND BASED ON 10% POROSITY CUT OFF

table 8

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2 Reservoir temperature versus depth

3 Core porosity versus core permeability

FIG.1 WELL 6507/10-1 RESERVOIR PRESSURE Vs. DEPTH

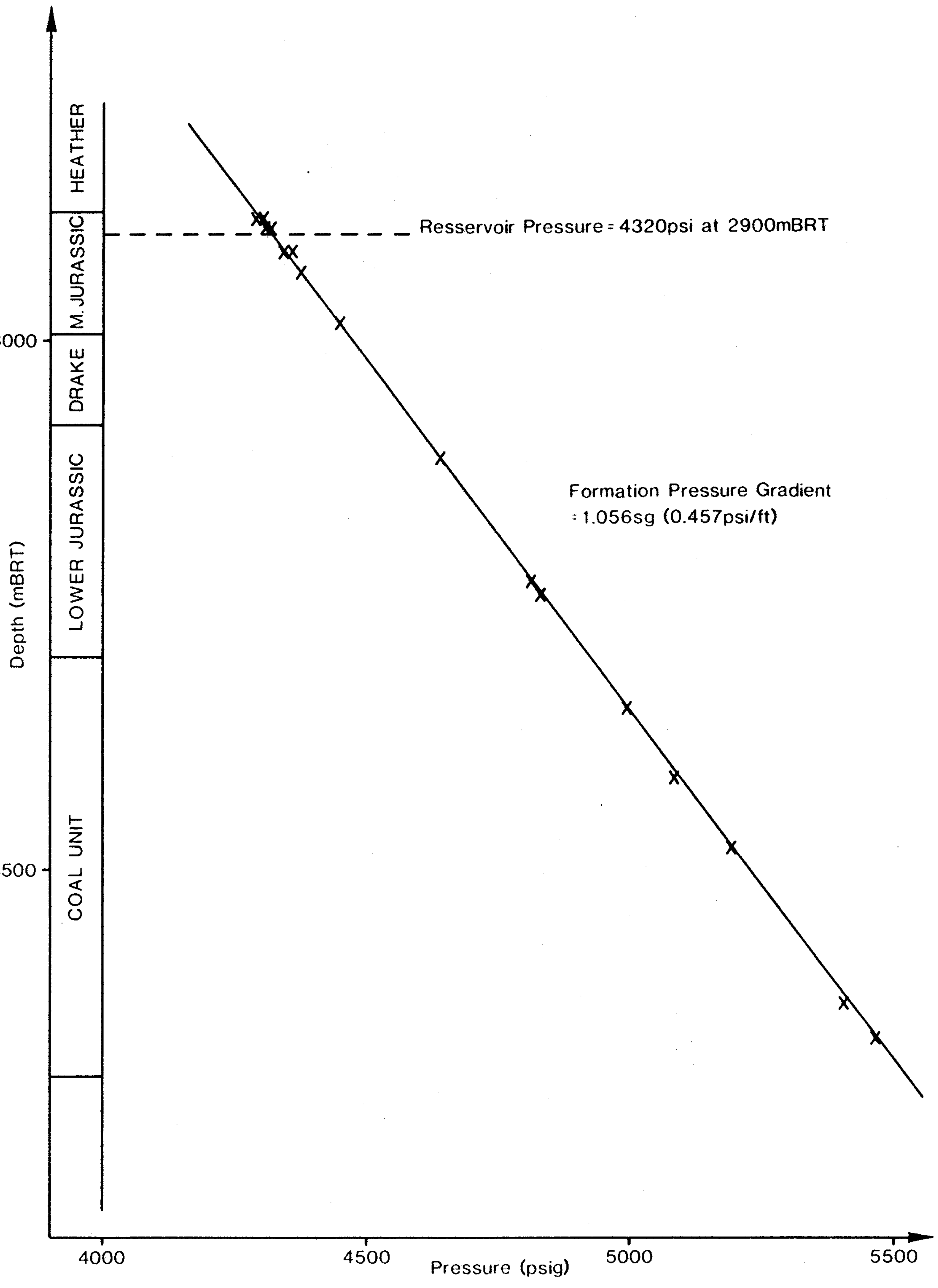

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FIG.2 WELL 6507/10-1 RESERVOIR TEMPERATURE Vs. DEPTH

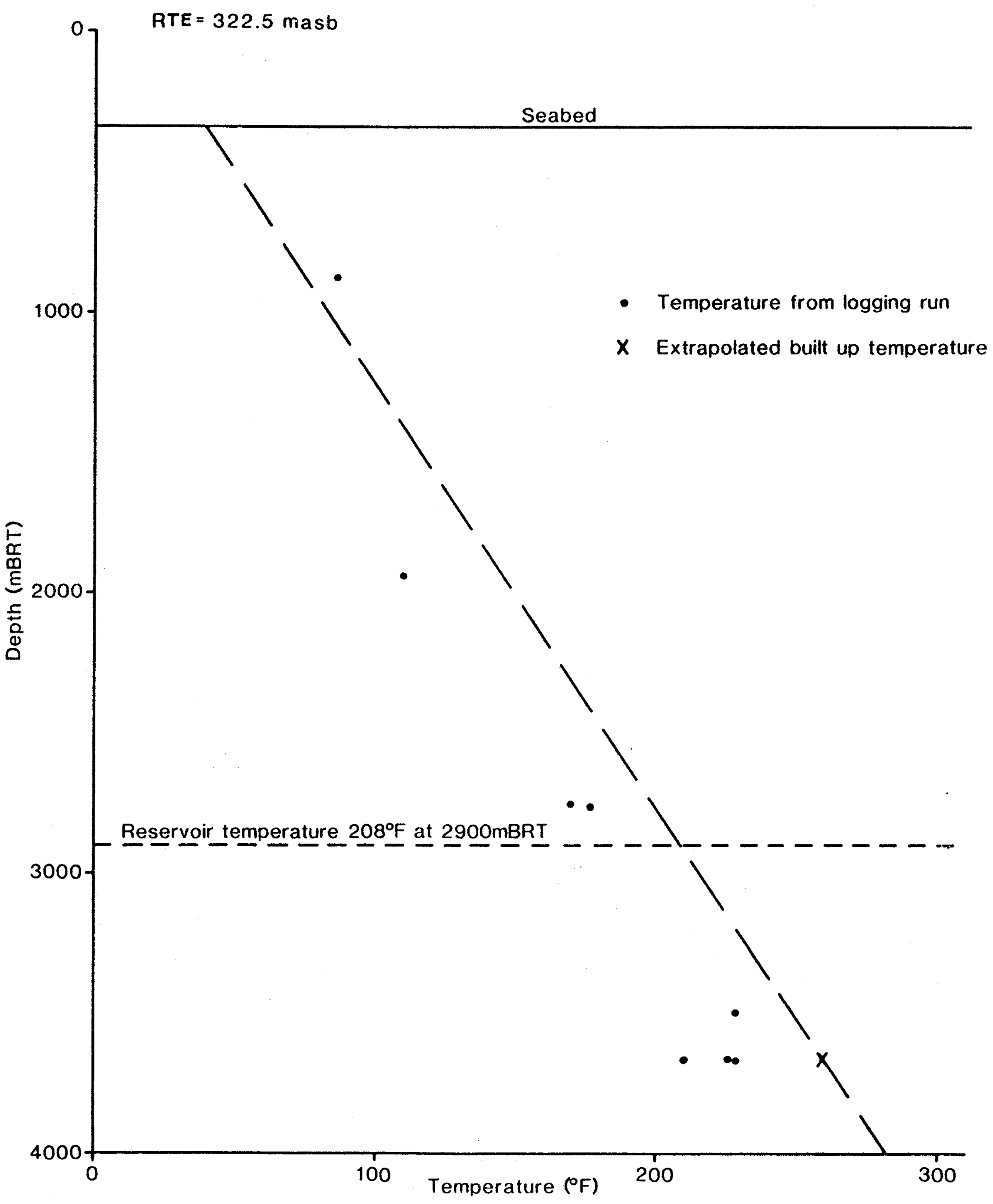

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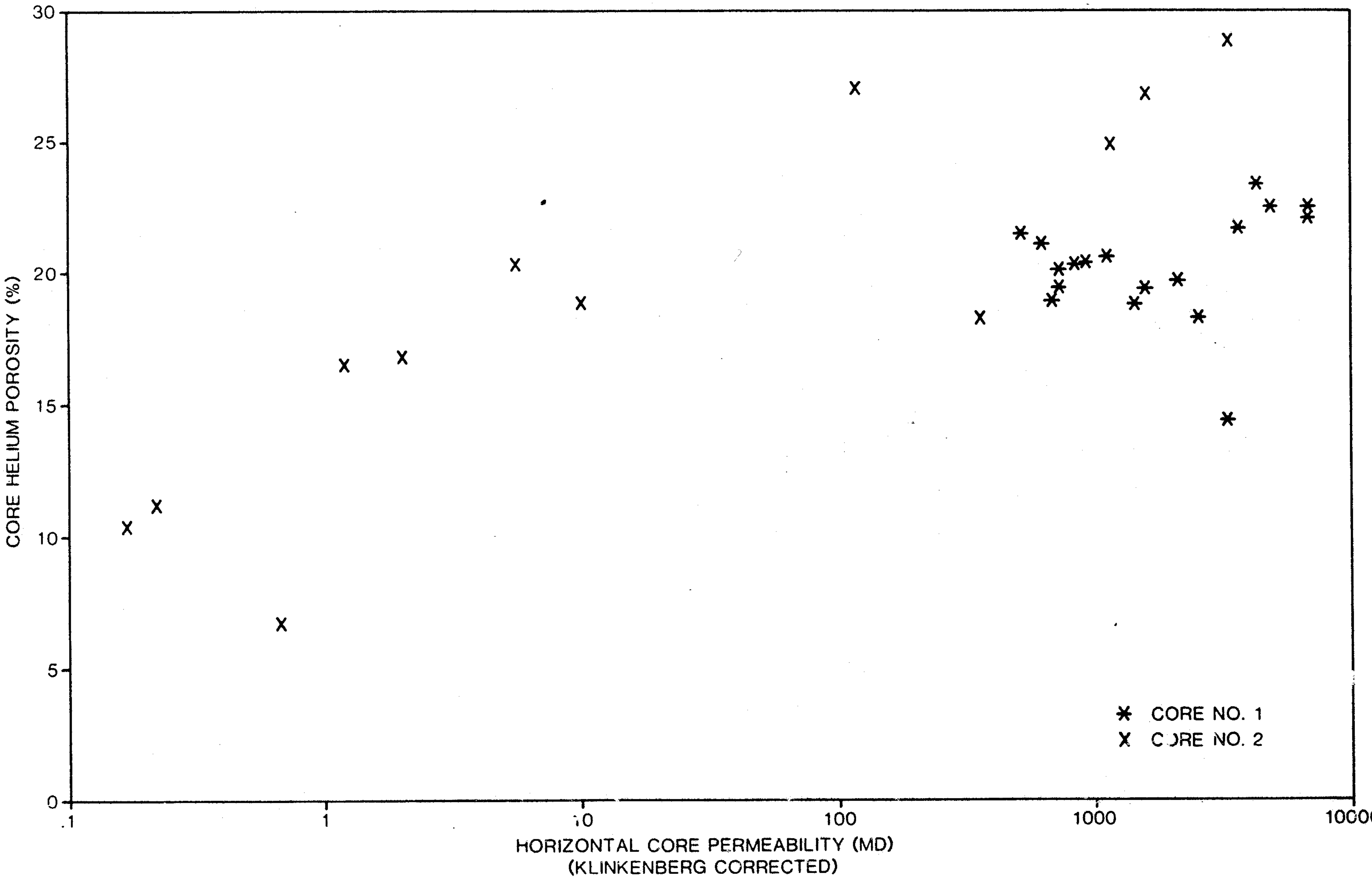
FIG.3 WELL 6507/10-1 CORE POROSITY Vs. CORE PERMEABILITY



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