

PRODUCTION ENGINEERING
RESEARCH & DEVELOPMENT

ROXY ANDEX WHITEWATER

3-2-3-21W1 * 3235

13-2-3-21W1 * 3217

06 528

SPECIAL CORE ANALYSIS STUDY

prepared for
ROXY PETROLEUM LTD.

FILE 84-PE-4003



JUNE 1984

***tti GEOTECH* nical resources ltd.**

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INTRODUCTION

A comprehensive series of special core tests of Roxy Andex Whitewater 3-2-3-21W1 and 13-2-3-21W1 was conducted in order to provide reservoir engineering data for the design of a waterflood project. The experimental program consisted of the following tests:

1. Two samples were chosen to determine if fines migration was a problem in this reservoir.
2. Seven samples which represented a range of porosities were selected for determination of a correlation between Formation Resistivity Factor at Overburden Pressure and Porosity. The samples selected encompassed a porosity range of 4.9% to 15.6%.
3. Two of the samples selected for 1) were used for determination of a correlation between Formation Resistivity Index and Fractional Brine Saturation.
4. Five samples which represented a range of porosities and permeabilities were selected for determination of Mercury Injection Capillary Pressures. The tests included Drainage and Imbibition studies. The results of these tests were used to determine pore size distributions, recovery efficiencies and irreducible wetting phase saturations. The samples selected encompassed a porosity range of 4.3% to 14.4% and a permeability range of 0.02 mD to 255.26 mD.
5. Four samples were selected for determination of Oil/Brine Relative Permeabilities.

Interpretation of the results was supplemented by relating the properties of the core measured in the tests described above, to the porosities and permeabilities of the samples. In this way, correlations were determined between the special core properties and routine core properties. This allowed generation of SATLOGS (logs which graphically present the saturation of hydrocarbons, irreducible water and mobile water) which indicate the tendency of a particular interval of the reservoir to produce water. A description of the techniques used to generate the SATLOG is contained in the Appendix. SATLOGS were generated for five wells (3-2-3-21W1, 13-2-3-21W1, 6-2-3-21W1, 10-2-3-21W1, and 14-2-3-21W1).

In the following report, the results of each type of test are individually described. Some of the results are then combined and used to generate SATLOGS. The SATLOGS are then used to identify potential reservoir problems.

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GEOLOGICAL DESCRIPTION

ROXY PETROLEUM LTD.

ROXY ANDEX WHITEWATER
3-2-3-21W1

| <u>Sample</u> | <u>Depth</u> | <u>Description</u> |
|---------------|--------------|---|
| 1 | 807.51 m | Limestone; light brown, hard, micro to very finely crystalline, sucrosic, recrystallized bioclastic (coarse lower size particles), dolomitic, occasional Brachiopod, anhydritic (pore filling cement), <u>fair pin-point and interparticle porosity.</u> |
| 2 | 807.55 m | Limestone; light brown, hard, micro to very finely crystalline, sucrosic, recrystallized bioclastic (coarse lower size particles), dolomitic, occasional Brachiopod, anhydritic (pore filling cement), <u>fair pin-point and interparticle porosity.</u> |
| 3 | 808.53 m | Limestone; light brown, hard, micro to very finely crystalline, sucrosic, recrystallized bioclastic (coarse lower size particles), dolomitic, occasional Brachiopod, anhydritic (pore filling cement), <u>fair pin-point and interparticle porosity.</u> |
| 4 | 808.50 m | Limestone; light brown, hard, micro to very finely crystalline, sucrosic, recrystallized bioclastic (coarse lower size particles), dolomitic, occasional Brachiopod, anhydritic (pore filling cement), <u>fair pin-point and interparticle porosity.</u> |
| 5 | 810.06 m | Limestone; buff brown, hard, bioclastic (coarse size particles), finely crystalline sparry-calcite matrix, slightly anhydritic (pore filling cement), <u>fair to possibly good interparticle porosity.</u> |

ROXY ANDEX WHITEWATER
3-2-3-21W1

Page 2

| <u>Sample</u> | <u>Depth</u> | <u>Description</u> |
|---------------|--------------|---|
| 6 | 810.02 m | Limestone; buff brown, hard, bioclastic (coarse size particles), finely crystalline sparry-calcite matrix, slightly anhydritic (pore filling cement), <u>fair to possibly good interparticle porosity.</u> |
| 7 | 809.96 m | Limestone; buff brown, hard, bioclastic (coarse size particles), finely crystalline sparry-calcite matrix, slightly anhydritic (pore filling cement), <u>fair to possibly good interparticle porosity.</u> |
| 8 | 809.98 m | Limestone; buff brown, hard, bioclastic (coarse size particles), finely crystalline sparry-calcite matrix, slightly anhydritic (pore filling cement), <u>fair to possibly good interparticle porosity.</u> |
| 9 | 812.25 m | Limestone; brown, hard, bioclastic (coarse size particles), very fine crystalline sucrosic sparry-calcite matrix, minor anhydrite pore filling cement, <u>good to excellent interparticle porosity.</u> |
| 10 | 812.28 m | Limestone; brown, hard, bioclastic (coarse size particles), very fine crystalline sucrosic sparry-calcite matrix, minor anhydrite pore filling cement, <u>good to excellent interparticle porosity.</u> |
| 11 | 812.24 m | Limestone; brown, hard, bioclastic (coarse size particles), very fine crystalline sucrosic sparry-calcite matrix, minor anhydrite pore filling cement, <u>good to excellent interparticle porosity.</u> |
| 12 | 812.21 m | Limestone; brown, hard, bioclastic (coarse size particles), very fine crystalline sucrosic sparry-calcite matrix, minor anhydrite pore filling cement, <u>good to excellent interparticle porosity.</u> |

GEOLOGICAL DESCRIPTION

ROXY PETROLEUM LTD.

ROXY ANDEX WHITEWATER
13-2-3-21W1

| <u>Sample</u> | <u>Depth</u> | <u>Description</u> |
|---------------|--------------|---|
| 13 | 795.24 m | Limestone; light brown, hard, recrystallized bioclastic (medium to coarse size particles), slightly dolomitic, microcrystalline calcite matrix, anhydritic (fossil replacement and pore filling cement), <u>fair interparticle porosity.</u> |
| 14 | 795.22 m | Limestone; light brown, hard, recrystallized bioclastic (medium to coarse size particles), slightly dolomitic, microcrystalline calcite matrix, anhydritic (fossil replacement and pore filling cement), <u>fair interparticle porosity.</u> |

ROXY ANDEX WHITEWATER
3-2-3-21W1

| <u>Sample</u> | <u>Depth</u> | <u>Description</u> |
|---------------|--------------|--|
| 15 | 813.40 m | Limestone; very light brown, hard, microcrystalline, sucrosic, recrystallized bioclastic, highly anhydritic, very light hematite stain, abundant small vugs (filled with anhydrite in part), <u>poor to possibly fair vugular porosity.</u> |
| 16 | 813.43 m | Limestone; very light brown, hard to very hard, microcrystalline, sucrosic, recrystallized bioclastic, highly anhydritic, very light hematite stain, very rare small vugs (filled with anhydrite), <u>poor vugular porosity.</u> |

FINES MOBILIZATION STUDY

To estimate the extent of permeability impairment due to the migration of fines, liquid permeabilities were measured at increasing values of flow velocity. The tests were performed at an overburden pressure of 11.0 MPa, a pore pressure of 6.9 MPa and a temperature of 32°C. Simulated flood water was used for these tests. Two core plugs were tested (Samples #8B and #12A) over the velocity ranges 0.00066 to 0.01193 cm/s and 0.0003 to 0.0223 cm/s respectively. After completing tests over the full velocity range, the flow was reduced to the initial value in order to allow a direct comparison between permeabilities at similar flow conditions. The flow was then reversed to determine directional affects.

The results of the tests are shown in the following tables and figures. Neither plug demonstrates any significant dependence of permeability on flow velocity for either direction of flow. This implies that fines will not be mobilized during a field waterflood.

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ROXY ANDEX WHITEWATER
3-2-3-21W1

1984 May 02

SAMPLE #8B

| | | | |
|------------|------------------|-------------------------|------|
| Formation: | Upper Whitewater | Porosity percent: | 13.7 |
| Depth: | 809.98 m | Permeability mD: | 4.36 |
| | | Critical Velocity (Uc): | N/A |

**FINES MOBILIZATION
PERMEABILITY VERSUS VELOCITY DATA**

| Run Number | Flow Velocity (cm/s) | Pressure Drop Across Sample (kPa) | Permeability (mD) |
|------------------------|-------------------------|---|----------------------|
| Forward Flow | | | |
| 1 | 0.00066 | 137.14 | 1.67 |
| 2 | 0.00124 | 240.14 | 1.79 |
| 3 | 0.00233 | 495.60 | 1.65 |
| 4 | 0.00475 | 979.95 | 1.68 |
| 5 | 0.00595 | 1270.22 | 1.65 |
| 6 | 0.00956 | 1995.62 | 1.67 |
| 7 | 0.01179 | 2503.49 | 1.64 |
| Forward Flow, Endpoint | | | |
| 8 | 0.00042 | 107.56 | 1.36 |
| Reverse Flow | | | |
| 9 | 0.00038 | 95.01 | 1.40 |
| 10 | 0.00064 | 145.82 | 1.53 |
| 11 | 0.00112 | 224.36 | 1.74 |
| 12 | 0.00232 | 468.50 | 1.73 |
| 13 | 0.00473 | 998.36 | 1.65 |
| 14 | 0.00710 | 1521.19 | 1.63 |
| 15 | 0.00950 | 2024.72 | 1.64 |
| 16 | 0.01193 | 2562.23 | 1.62 |

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ROXY ANDEX WHITEWATER

3-2-3-21W1

FINES MOBILIZATION

(STANDARD PLOT)

Sample #88

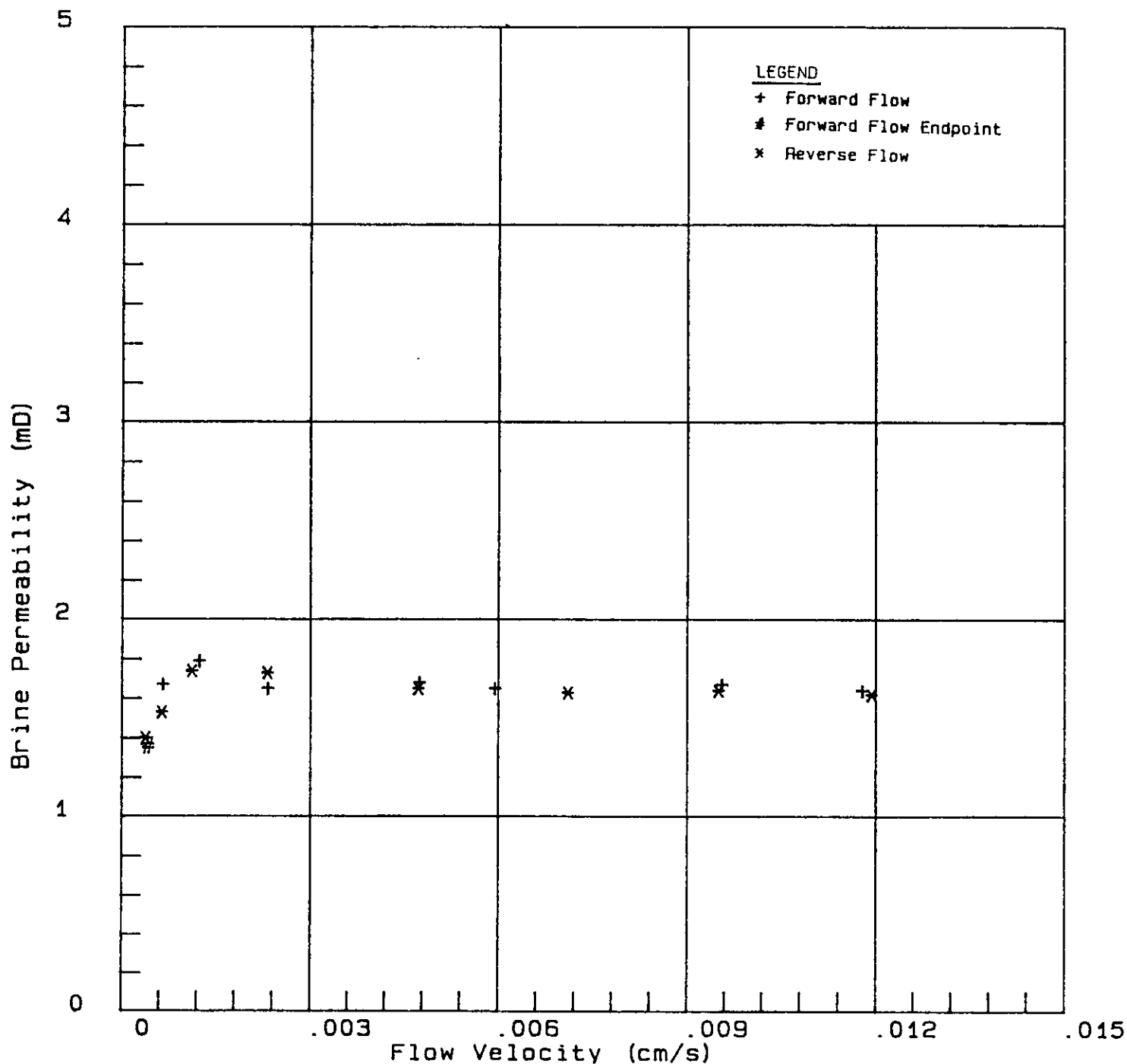
Depth : 809.98 m

Formation : Upper Whitewater

Porosity (ϕ) : 13.7%

Permeability (K) : 4.36mD

Critical Velocity (u_c) : N/A



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ROXY ANDEX WHITEWATER
3-2-3-21W1

1984 May 10

SAMPLE #12A

Formation: Upper Whitewater
Depth: 812.21 m

Porosity percent: 14.3
Permeability mD: 54.73
Critical Velocity (Uc): N/A

**FINES MOBILIZATION
PERMEABILITY VERSUS VELOCITY DATA**

| Run Number | Flow Velocity (cm/s) | Pressure Drop Across Sample (kPa) | Permeability (mD) |
|------------------------|-------------------------|---|----------------------|
| Forward Flow | | | |
| 1 | 0.0003 | 11.86 | 13.22 |
| 2 | 0.0011 | 37.92 | 12.89 |
| 3 | 0.0014 | 47.71 | 13.14 |
| 4 | 0.0018 | 62.67 | 13.39 |
| 5 | 0.0024 | 83.15 | 13.20 |
| 6 | 0.0028 | 96.25 | 13.42 |
| 7 | 0.0038 | 129.14 | 13.36 |
| 8 | 0.0047 | 162.72 | 13.32 |
| 9 | 0.0061 | 213.81 | 13.16 |
| 10 | 0.0090 | 315.64 | 13.18 |
| 11 | 0.0120 | 390.24 | 14.09 |
| 12 | 0.0147 | 495.11 | 13.62 |
| 13 | 0.0194 | 621.56 | 14.36 |
| 14 | 0.0175 | 623.56 | 12.88 |
| 15 | 0.0223 | 734.22 | 13.96 |
| Forward Flow, Endpoint | | | |
| 16 | 0.0004 | 14.20 | 13.00 |
| Reverse Flow | | | |
| 17 | 0.0004 | 14.75 | 11.87 |
| 18 | 0.0008 | 27.23 | 12.87 |
| 19 | 0.0011 | 39.71 | 12.54 |
| 20 | 0.0018 | 65.71 | 12.35 |
| 21 | 0.0024 | 82.81 | 13.48 |
| 22 | 0.0031 | 105.15 | 13.51 |
| 23 | 0.0037 | 125.97 | 13.55 |
| 24 | 0.0047 | 160.30 | 13.64 |
| 25 | 0.0061 | 201.40 | 13.83 |
| 26 | 0.0073 | 241.66 | 13.89 |
| 27 | 0.0097 | 310.82 | 14.30 |
| 28 | 0.0124 | 407.62 | 14.03 |
| 29 | 0.0204 | 693.47 | 13.55 |

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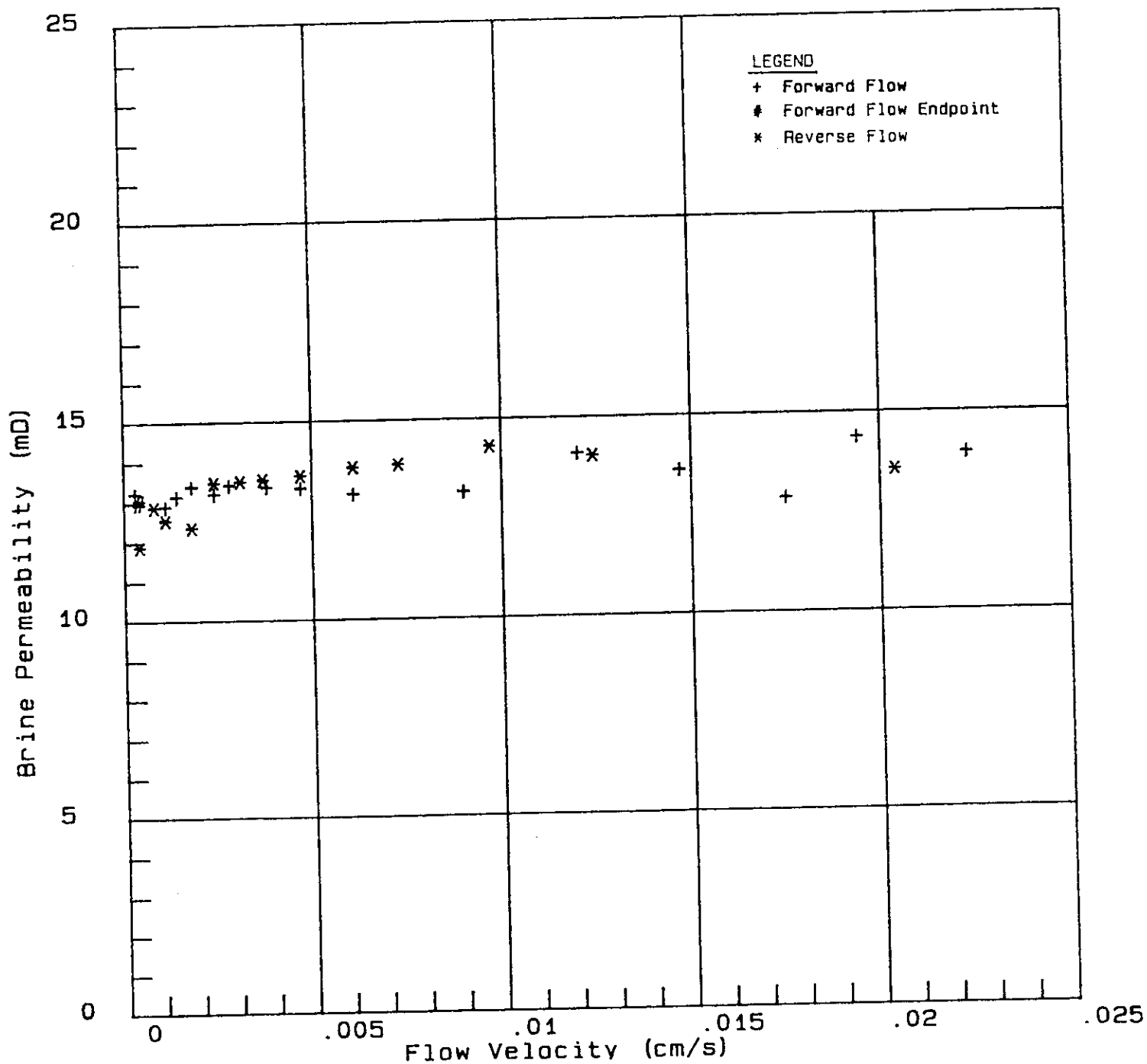
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FINES MOBILIZATION
(STANDARD PLOT)

Sample #12A
Depth : 812.21 m
Formation : Upper Whitewater

Porosity (ϕ) : 14.3%
Permeability (K) : 54.73mD
Critical Velocity (u_c) : N/A



FORMATION RESISTIVITY FACTORS

A general description of Formation Resistivity testing is provided in the Appendix. The measured Formation Resistivity Factors are presented in the following table and figure. Although seven samples were tested, only four were used to determine the correlation equation (one sample broke during testing and two were rejected because of their lithology). The results for these four samples are very well correlated by the equation

$$F_R = \frac{0.85}{\phi_f^{2.12}} .$$

The coefficients $m = 2.12$ and $a = 0.85$ are typical for the type of rock tested.

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ROXY ANDEX WHITEWATER
3-2-3-21W1

1984 May 02

Formation: Upper Whitewater

FORMATION FACTOR DATA

EFFECTIVE OVERBURDEN PRESSURE 11.0 MPa

| Fractional Porosity | Formation Resistivity Factor |
|------------------------|---------------------------------|
| 0.049 | N/A ² |
| 0.064 | 1002.92 ¹ |
| 0.073 | 216.04 |
| 0.077 | 355.02 ¹ |
| 0.145 | 52.02 |
| 0.152 | 44.79 |
| 0.156 | 43.97 |

$$F_R = \frac{0.85}{\phi_f^{2.12}}$$

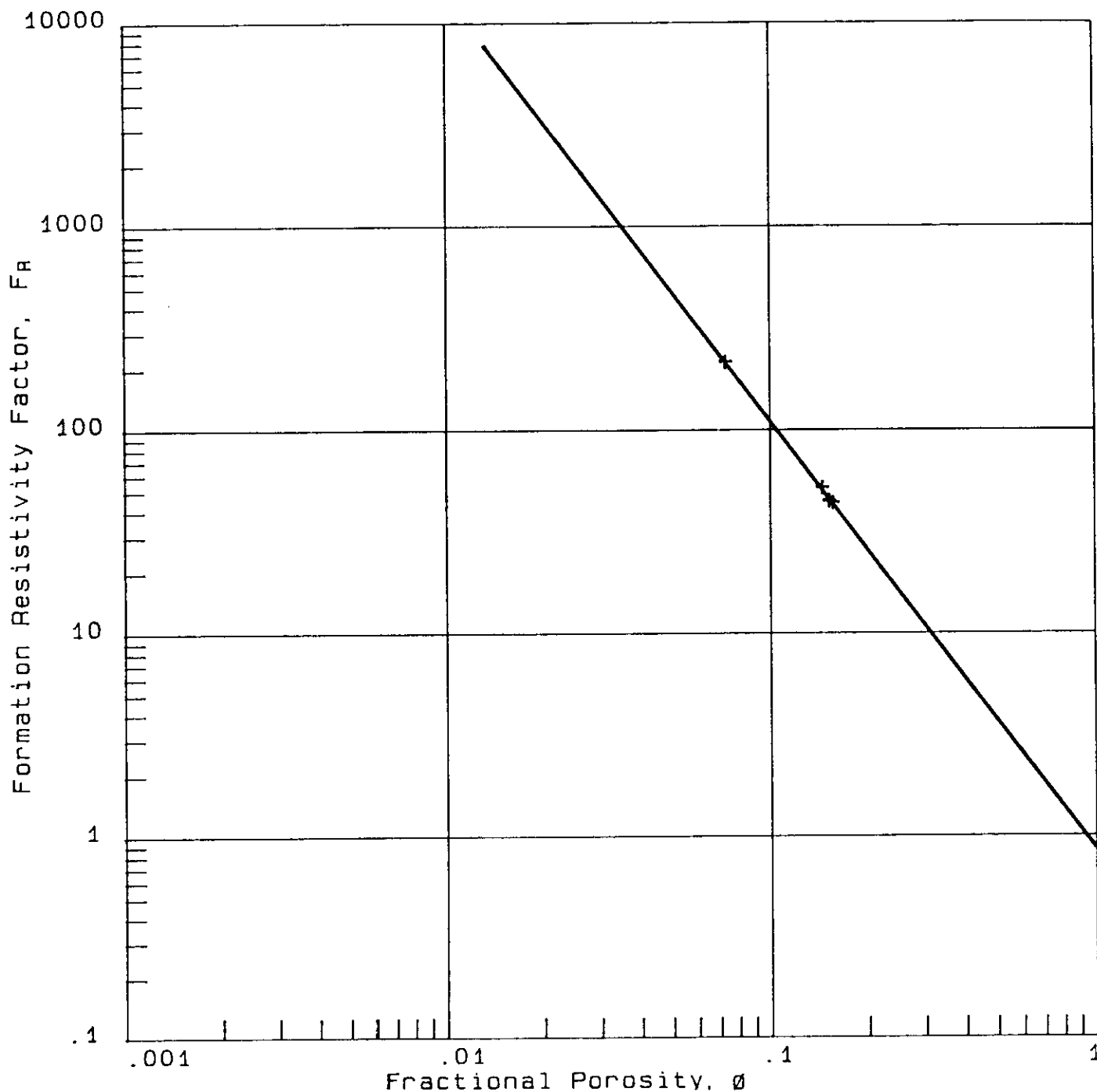
-
1. Rejected due to lithology, see attached geological description.
 2. Sample broke during F_R determination.

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14 JUN 1984

FORMATION RESISTIVITY FACTOR
($F_R = a/\phi^m$)

| | | | | |
|-------------------|---|------------------|--------------------|--------|
| FORMATION | : | Upper Whitewater | | |
| Cem. Factor (m) | : | 2.12 | Porosity Cons. (a) | : 0.85 |
| Overburden Press. | : | 11.0 MPa | Corr. Coeff. | : 1.00 |



FORMATION RESISTIVITY INDICES

A general description of Formation Resistivity Index testing is provided in the Appendix. The measured Formation Resistivity Indices are presented in the following tables and figures. The last figure contains a composite plot which consolidates the data of the previous figures.

The composite data is very well correlated by the equation

$$I_R = \frac{1}{S_w^{1.42}} .$$

No unusual problems were encountered during these tests.

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ROXY ANDEX WHITEWATER
3-2-3-21W1

1984 May 03

SAMPLE #6A

Formation: Upper Whitewater
Depth: 810.02 m

Porosity percent: 14.5
Permeability mD: 15.88
Grain Density kg/m³: 2708

RESISTIVITY INDEX DATA

Fractional Brine
Saturation

Formation Resistivity
Index

| | |
|-------|------|
| 1.000 | 1.00 |
| 0.915 | 1.09 |
| 0.902 | 1.04 |
| 0.892 | 1.04 |
| 0.878 | 1.07 |
| 0.856 | 1.11 |
| 0.772 | 1.23 |
| 0.762 | 1.37 |
| 0.718 | 1.54 |
| 0.662 | 1.71 |
| 0.643 | 1.68 |
| 0.611 | 1.79 |
| 0.574 | 2.03 |
| 0.532 | 2.34 |
| 0.513 | 2.45 |
| 0.476 | 2.70 |
| 0.425 | 3.03 |
| 0.379 | 3.54 |
| 0.350 | 4.00 |

$$I_R = \frac{1}{S_w^{1.29}}$$

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FORMATION RESISTIVITY INDEX

$$(I_R = 1/S_w^n)$$

Sample #6A

Depth : 810.02 m

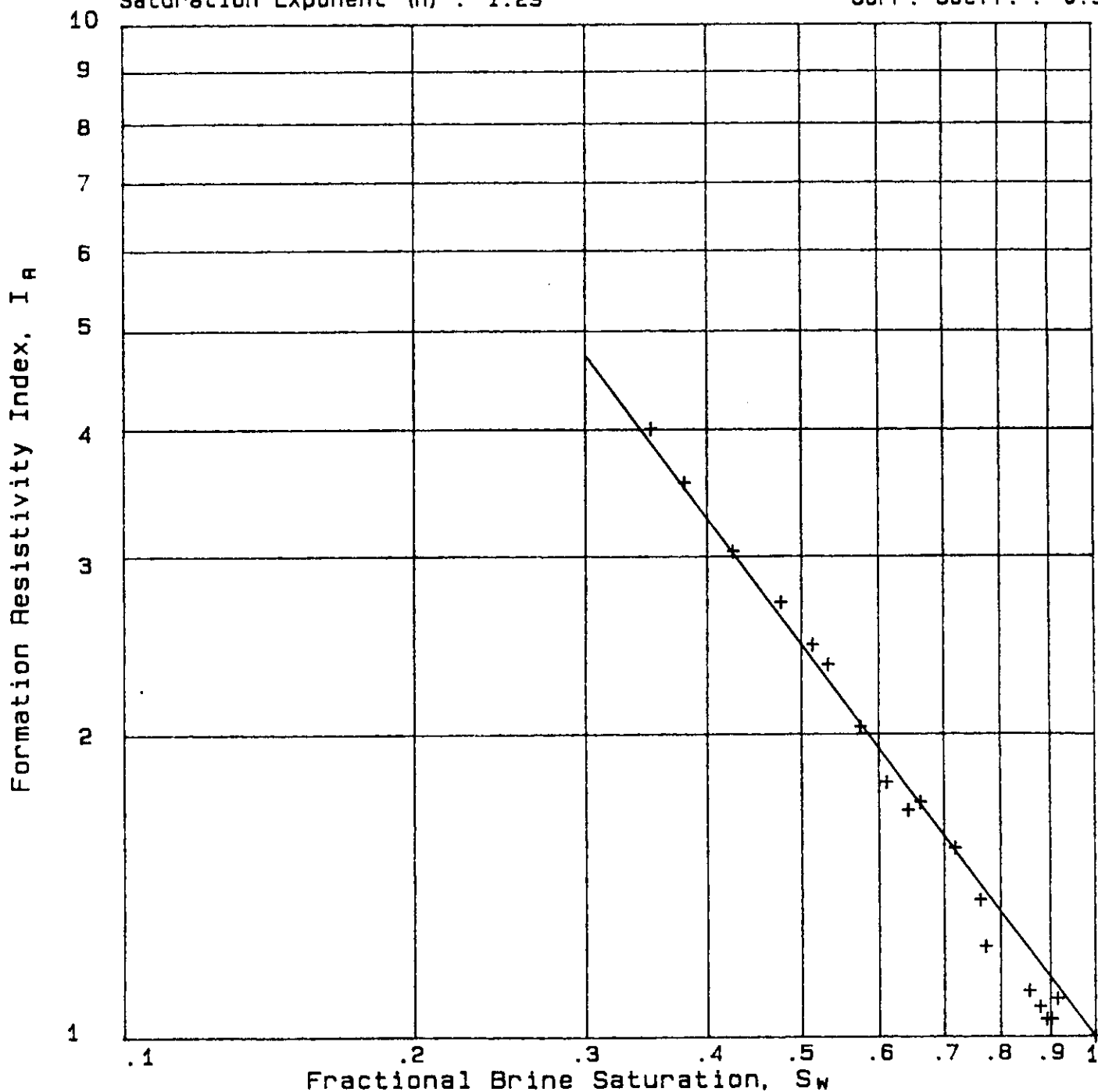
Formation : Upper Whitewater

Saturation Exponent (n) : 1.29

Porosity : 14.5%

Permeability : 15.88mD

Corr. Coeff. : 0.98



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ROXY ANDEX WHITEWATER
3-2-3-21W1

1984 May 03

SAMPLE #10A

Formation: Upper Whitewater
Depth: 812.28 m

Porosity percent: 15.6
Permeability mD: 421.03
Grain Density kg/m³: 2728

RESISTIVITY INDEX DATA

Fractional Brine
Saturation

Formation Resistivity
Index

| | |
|-------|------|
| 1.000 | 1.00 |
| 0.853 | 1.18 |
| 0.815 | 1.18 |
| 0.806 | 1.20 |
| 0.723 | 1.42 |
| 0.709 | 1.39 |
| 0.667 | 1.50 |
| 0.655 | 1.81 |
| 0.610 | 1.87 |
| 0.518 | 2.53 |
| 0.501 | 2.53 |
| 0.430 | 3.37 |
| 0.362 | 4.62 |
| 0.319 | 5.87 |
| 0.301 | 6.28 |
| 0.281 | 7.48 |
| 0.264 | 8.39 |

$$I_R = \frac{1}{S_w^{1.49}}$$

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FORMATION RESISTIVITY INDEX

$$(I_R = 1/S_w^n)$$

Sample #10A

Depth : 812.28 m

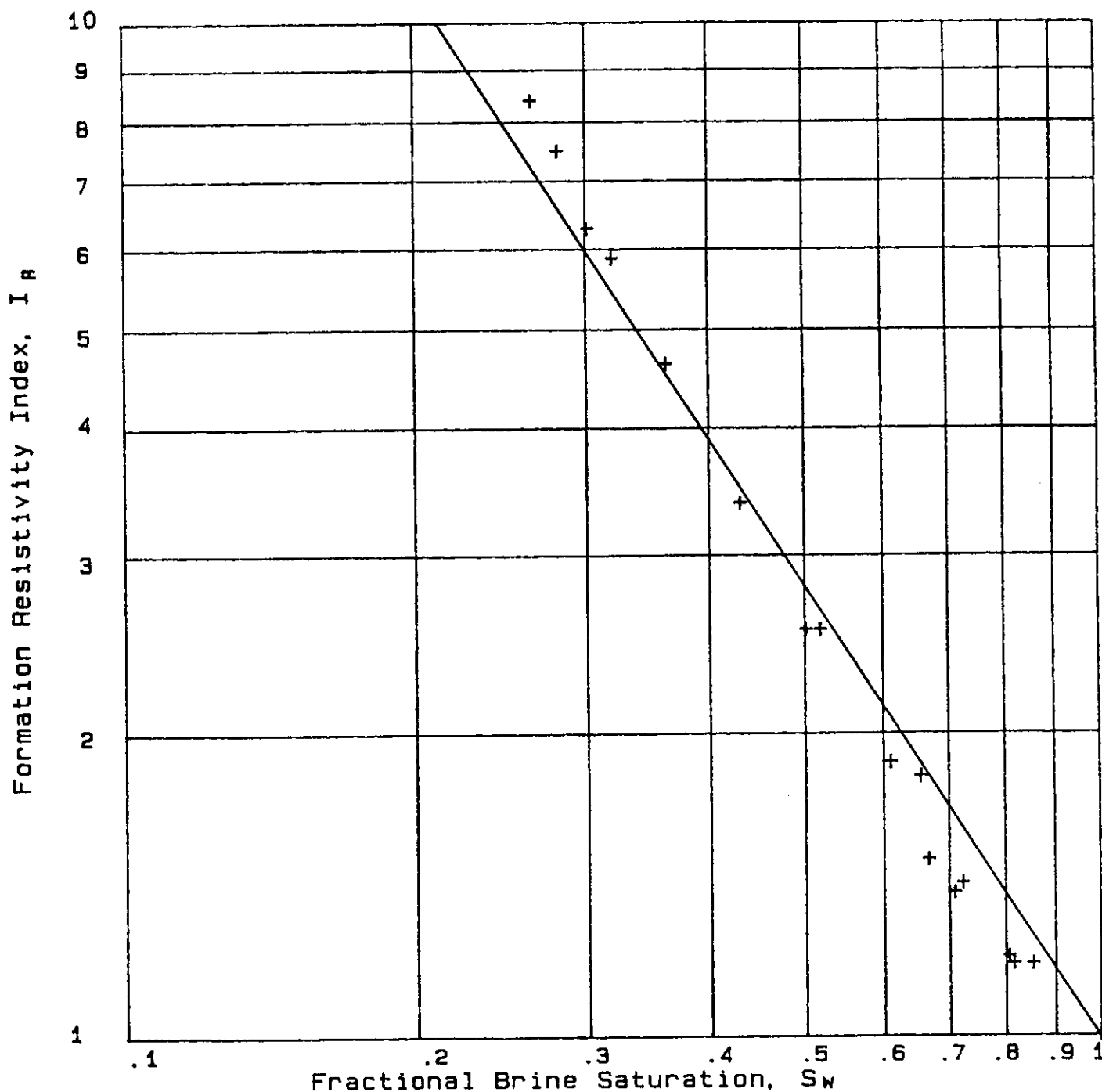
Formation : Upper Whitewater

Saturation Exponent (n) : 1.49

Porosity : 15.6%

Permeability : 421.03mD

Corr. Coeff. : 0.97



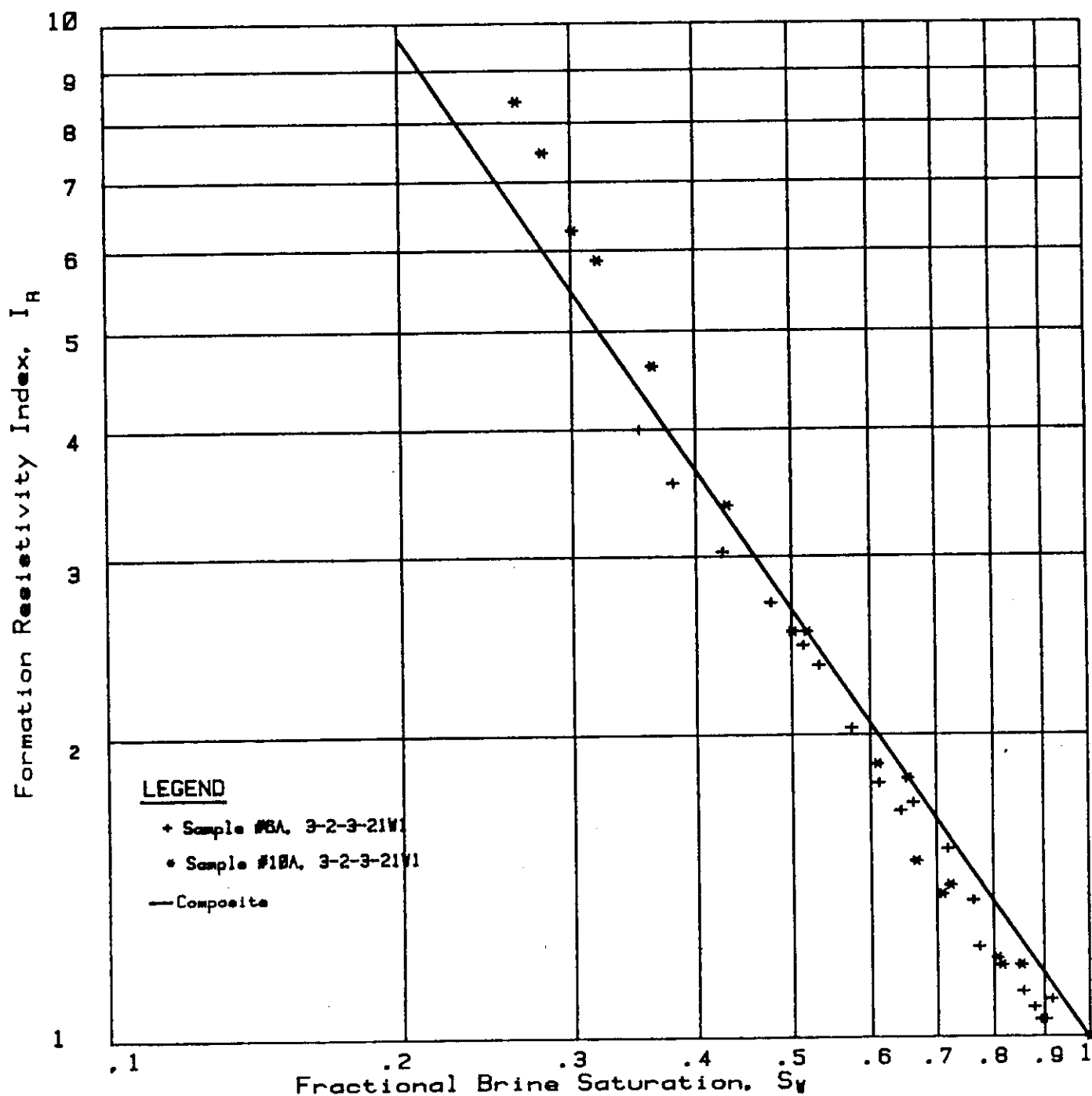
COMPOSITE FORMATION RESISTIVITY INDEX

$$(I_R = 1/S_V^n)$$

Formation : Upper Whitewater

Corr. Coeff. : 0.96

Saturation Exponent (n) : 1.42



MERCURY INJECTION CAPILLARY PRESSURE

A general description of Mercury Injection Capillary Pressure is provided in the Appendix. The measured Mercury Injection Capillary Pressure data are presented in the following figures and tables. Following the data for each sample are the results of the Pore Size Distribution calculations.

Except for Sample #11A, the irreducible (residual) wetting phase saturations trend with permeability, being generally lower for higher permeabilities. Sample #11A has the second lowest residual of the samples tested, while it has the highest permeability. Again with the exception of Sample #11A, the recovery efficiencies also trend with permeability. The capillary pressure curves themselves behave as expected; the "rough" appearance of the curve for Sample #15A was caused by experimental difficulties inherent in testing tight samples such as this. The starting saturations (the first point on the drainage curve) correlated well with visible surface porosity.

An examination of the pore size distributions in the 0-50 micron range indicates that, for all of the samples, a significant number of large surface pores (either pores that were cut during plugging or pores which communicated with the surface through throats with radii greater than 50 microns) were present. Furthermore, the vast majority of pore throats have radii of less than 5 microns. These two facts imply a pore structure which consists of large pores which communicate through small throats. Sample #15A in particular had several large pores visible on the surface, yet has over 50% of its pore size distribution below a pore entry radius of 1 micron. Some of the Pore Size Distribution tables show small negative values; these are due to small inaccuracies inherent in the pressure measurements and to round off errors. They are very small and do not influence the plotted data.



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ROXY ANDEX WHITEWATER
3-2-3-21W1

DATE : 04 JUN 1984
SAMPLE # 1A

MERCURY POROSIMETRY DATA

DEPTH : 807.51 m
Formation : UPPER WHITEWATER
Residual Wet. Phase Sat. : 17%

Permeability : 0.34 mD
Porosity : 8.8%
Recovery efficiency : 26%

| | | Wetting Phase Saturation Percent Pore Space | |
|------------------|-----------------|--|------------|
| Pressure PSIA | Pressure KPA | Drainage | Imbibition |
| 0.00 | 0.00 | 100.00 | |
| 1.10 | 7.56 | 87.94 | 33.97 |
| 1.30 | 8.93 | 87.57 | 33.97 |
| 1.80 | 12.38 | 87.19 | 33.72 |
| 2.30 | 15.83 | 86.94 | 33.59 |
| 2.80 | 19.28 | 86.62 | 33.34 |
| 3.30 | 22.72 | 86.43 | 33.34 |
| 4.30 | 29.62 | 86.31 | 32.84 |
| 5.30 | 36.51 | 85.67 | 32.71 |
| 6.30 | 43.41 | 85.67 | 32.33 |
| 7.30 | 50.30 | 85.55 | 32.08 |
| 8.30 | 57.20 | 85.42 | 31.83 |
| 9.30 | 64.09 | 85.30 | 31.32 |
| 10.30 | 70.99 | 85.04 | 30.82 |
| 11.30 | 77.88 | 84.79 | 30.32 |
| 12.30 | 84.78 | 84.79 | 29.81 |
| 13.30 | 91.67 | 84.79 | 29.43 |
| 14.30 | 98.57 | 84.54 | 28.93 |
| 16.10 | 110.98 | 84.41 | 27.67 |
| 21.10 | 145.45 | 83.40 | 26.15 |
| 31.10 | 214.40 | 80.13 | 22.75 |
| 41.10 | 283.35 | 67.77 | 21.24 |
| 51.10 | 352.29 | 60.83 | 20.35 |
| 61.10 | 421.24 | 55.41 | 19.97 |
| 71.10 | 490.19 | 51.88 | 19.72 |
| 81.10 | 559.14 | 47.84 | 19.09 |
| 91.10 | 628.09 | 45.07 | 18.84 |
| 100.00 | 689.48 | 42.17 | 18.84 |
| 110.00 | 758.43 | 39.90 | 18.59 |
| 120.00 | 827.38 | 38.13 | 18.46 |
| 130.00 | 896.32 | 36.37 | 18.27 |
| 140.00 | 965.27 | 34.98 | 18.34 |
| 150.00 | 1034.22 | 33.97 | 18.21 |
| 160.00 | 1103.17 | 32.59 | 18.21 |
| 180.00 | 1241.06 | 30.95 | 18.21 |
| 200.00 | 1378.96 | 29.81 | 18.15 |
| 250.00 | 1723.70 | 27.54 | 18.08 |
| 300.00 | 2068.44 | 25.15 | 17.55 |
| 350.00 | 2413.18 | 24.26 | 17.01 |
| 400.00 | 2757.92 | 23.00 | 16.48 |
| 450.00 | 3102.66 | 21.99 | 15.94 |
| 500.00 | 3447.40 | 21.74 | 15.88 |
| 550.00 | 3792.14 | 21.24 | 15.85 |
| 600.00 | 4136.88 | 20.23 | 15.81 |
| 650.00 | 4481.62 | 19.72 | 15.81 |
| 700.00 | 4826.36 | 19.60 | 15.81 |
| 750.00 | 5171.10 | 19.22 | 15.81 |
| 800.00 | 5515.84 | 18.71 | 15.81 |
| 900.00 | 6205.32 | 18.46 | 15.69 |
| 1000.00 | 6894.80 | 17.83 | 15.69 |
| 1100.00 | 7584.28 | 17.45 | 15.69 |
| 1200.00 | 8273.76 | 17.33 | 15.69 |
| 1300.00 | 8963.24 | 17.07 | 15.69 |
| 1400.00 | 9652.72 | 16.82 | 15.69 |
| 1500.00 | 10342.20 | 16.19 | 15.69 |
| 1600.00 | 11031.68 | 16.07 | 15.62 |
| 1700.00 | 11721.16 | 15.56 | 15.56 |
| 1800.00 | 12410.64 | 14.93 | 14.93 |

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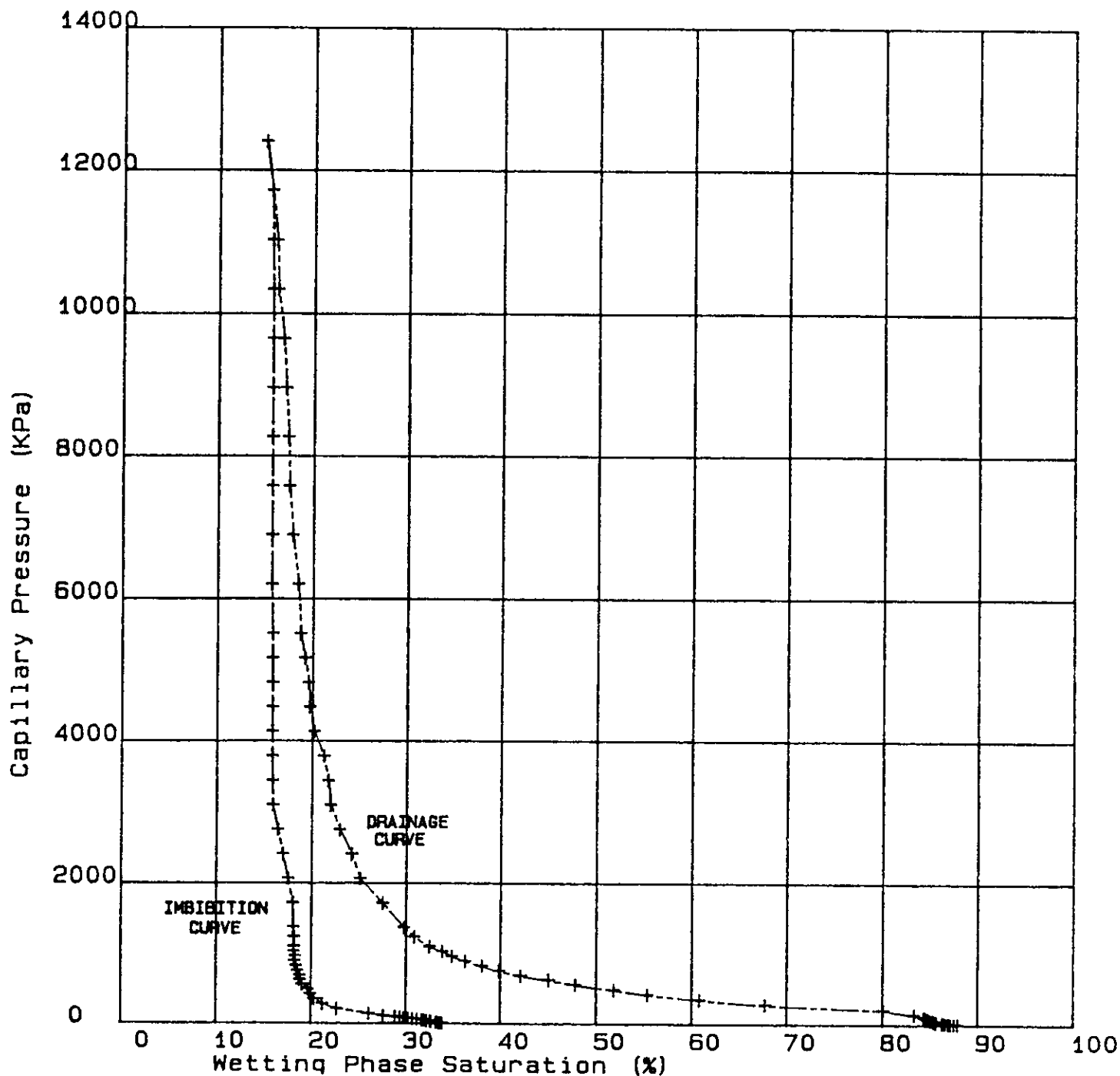
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18 MAY 1984

MERCURY INJECTION CAPILLARY PRESSURE

| | | | |
|---------------------------|--------------------|---------------------|----------|
| FORMATION | : Upper Whitewater | | |
| Sample #1A | | Permeability | : 0.34mD |
| Depth | : 807.51m | Porosity | : 8.8% |
| Residual Wet. Phase Sat.: | 17% | Recovery Efficiency | : 26% |



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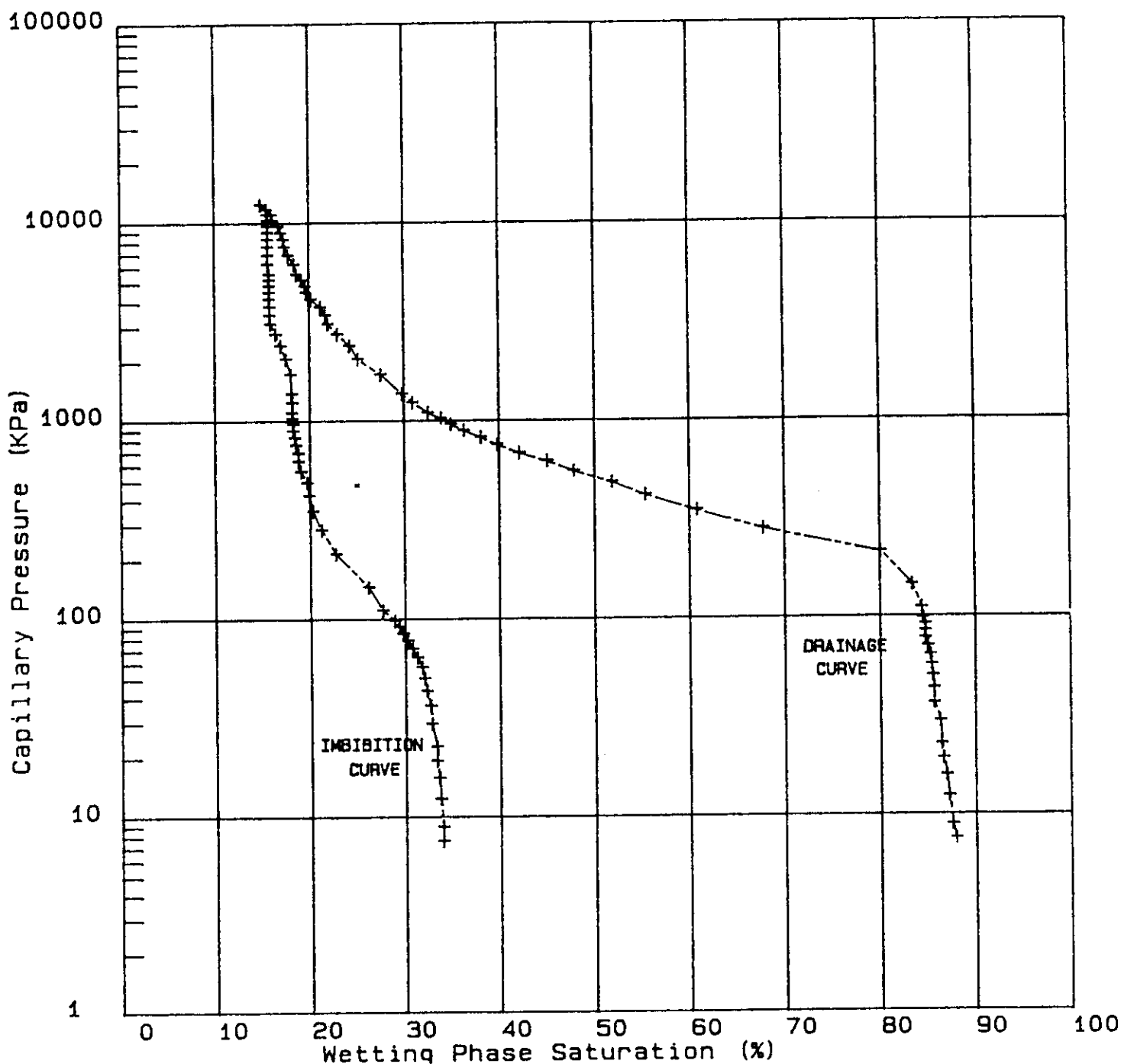
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3-2-3-21W1

18 MAY 1984

MERCURY INJECTION CAPILLARY PRESSURE

| | | | |
|---------------------------|--------------------|---------------------|----------|
| FORMATION | : Upper Whitewater | | |
| Sample #1A | | Permeability | : 0.34mD |
| Depth | : 807.51m | Porosity | : 8.8% |
| Residual Wet. Phase Sat.: | 17% | Recovery Efficiency | : 26% |



ROXY PETROLEUMS LTD
ROXY ANDEX WHITEWATER
3-2-3-21W1

DATE : 31 MAY 1984
SAMPLE # 1A

PORE SIZE DISTRIBUTION DATA

Depth : 807.51 m
Formation : UPPER WHITEWATER

Permeability : 0.34 mD
Porosity : 8.8 %

| Pore Entry Radius (Microns) | Percent of Pore Space | | Pore Entry Radius (Microns) | Percent of Pore Space | |
|--------------------------------|--------------------------|------------|--------------------------------|--------------------------|------------|
| Initial | 100.0 | | 25.00 | 85.7 | -0.1 |
| 50.00 | 86.5 | 13.5 | 24.00 | 85.6 | 0.1 |
| 49.00 | 86.4 | 0.1 | 23.00 | 85.6 | 0.0 |
| 48.00 | 86.4 | 0.0 | 22.00 | 85.6 | 0.0 |
| 47.00 | 86.4 | 0.0 | 21.00 | 85.6 | 0.0 |
| 46.00 | 86.4 | 0.0 | 20.00 | 85.7 | -0.1 |
| 45.00 | 86.4 | 0.0 | 19.00 | 85.6 | 0.1 |
| 44.00 | 86.4 | 0.0 | 18.00 | 85.6 | 0.0 |
| 43.00 | 86.4 | 0.0 | 17.00 | 85.5 | 0.1 |
| 42.00 | 86.3 | 0.1 | 16.00 | 85.4 | 0.1 |
| 41.00 | 86.3 | 0.0 | 15.00 | 85.3 | 0.1 |
| 40.00 | 86.3 | 0.0 | 14.00 | 85.4 | -0.1 |
| 39.00 | 86.3 | 0.0 | 13.00 | 85.3 | 0.1 |
| 38.00 | 86.3 | 0.0 | 12.00 | 85.1 | 0.2 |
| 37.00 | 86.3 | 0.0 | 11.00 | 84.9 | 0.2 |
| 36.00 | 86.2 | 0.1 | 10.00 | 84.8 | 0.1 |
| 35.00 | 86.2 | 0.0 | 9.00 | 84.8 | 0.0 |
| 34.00 | 86.2 | 0.0 | 8.00 | 84.5 | 0.3 |
| 33.00 | 86.3 | -0.1 | 7.00 | 84.4 | 0.1 |
| 32.00 | 86.2 | 0.1 | 6.00 | 83.9 | 0.5 |
| 31.00 | 86.1 | 0.1 | 5.00 | 83.0 | 0.9 |
| 30.00 | 86.0 | 0.1 | 4.00 | 81.1 | 1.9 |
| 29.00 | 85.9 | 0.1 | 3.00 | 73.2 | 7.9 |
| 28.00 | 85.8 | 0.1 | 2.00 | 59.0 | 14.2 |
| 27.00 | 85.7 | 0.1 | 1.00 | 40.7 | 18.3 |
| 26.00 | 85.6 | 0.1 | 0.06 | 15.1 | 25.6 |
| | | | 0.00 | 0.0 | 15.1 |
| | | | | | ----- |
| | | | | | 100.0 |

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ROXY PETROLEUMS LTD
ROXY ANDEX WHITEWATER
3-2-3-21W1

05 JUN 1984

PORE SIZE DISTRIBUTION

Formation : Upper Whitewater

Sample #1A

Porosity

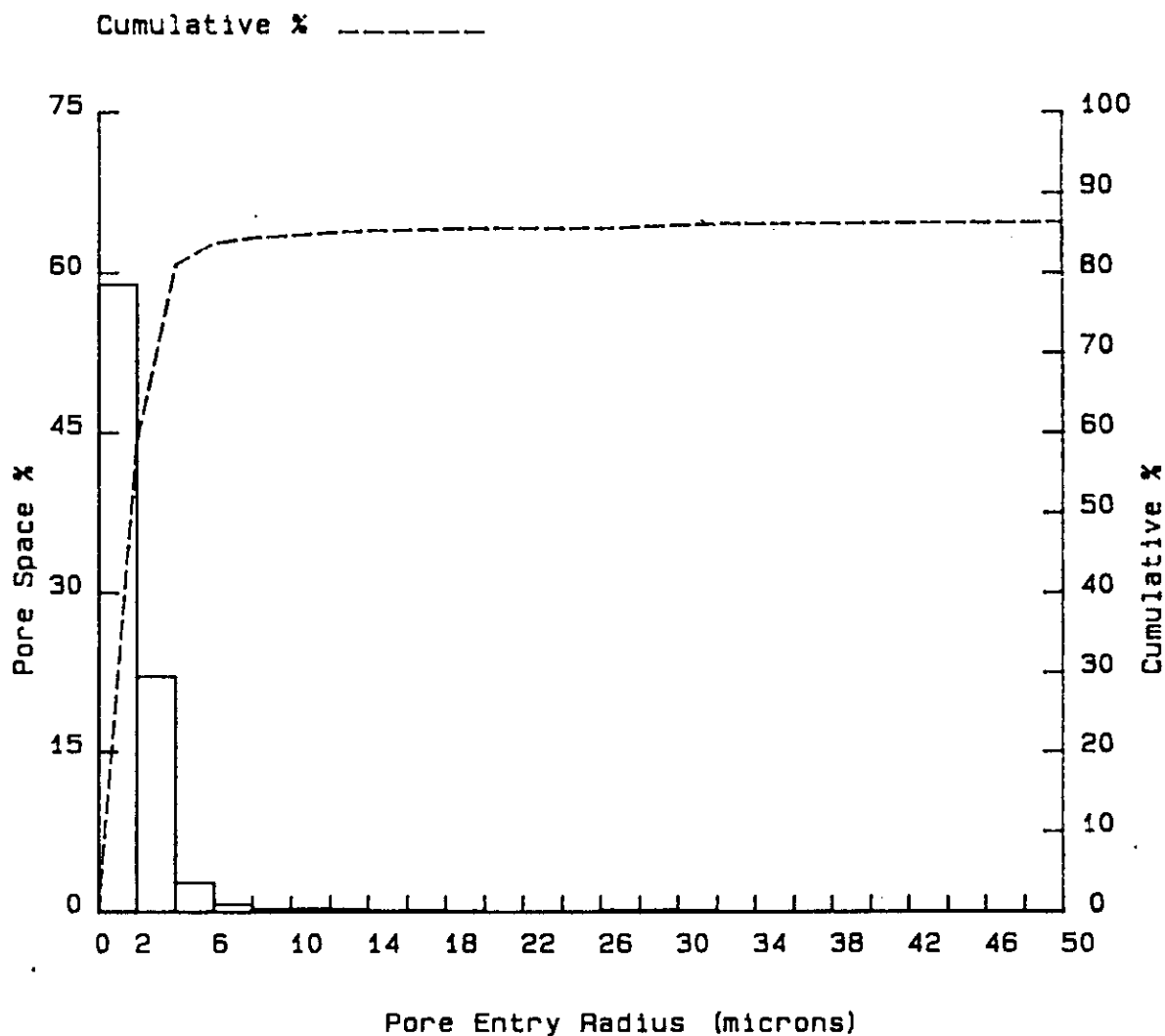
: 8.8%

Depth

: 807.51m

Permeability

: 0.34mD



ROXY PETROLEUMS LTD
 ROXY ANDEX WHITEWATER
 3-2-3-21W1

DATE : 05 JUN 1984
 SAMPLE # 1A

PORE SIZE DISTRIBUTION DATA

Depth : 807.51 m
 Formation : UPPER WHITEWATER

Permeability : 0.34 mD
 Porosity : 8.8 %

| Pore Entry Radius (Microns) | Percent of Pore Space | | Pore Entry Radius (Microns) | Percent of Pore Space | |
|--------------------------------|--------------------------|------|--------------------------------|--------------------------|-------|
| Initial | 100.0 | | 2.00 | 59.0 | 14.2 |
| 5.00 | 83.0 | 17.0 | 1.00 | 40.7 | 18.3 |
| 4.00 | 81.1 | 1.9 | 0.06 | 15.1 | 25.6 |
| 3.00 | 73.2 | 7.9 | 0.00 | 0.0 | 15.1 |
| | | | | | ----- |
| | | | | | 100.0 |

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ROXY PETROLEUMS LTD
ROXY ANDEX WHITEWATER
3-2-3-21W1

05 JUN 1984

PORE SIZE DISTRIBUTION

Formation : Upper Whitewater

Sample #1A

Depth

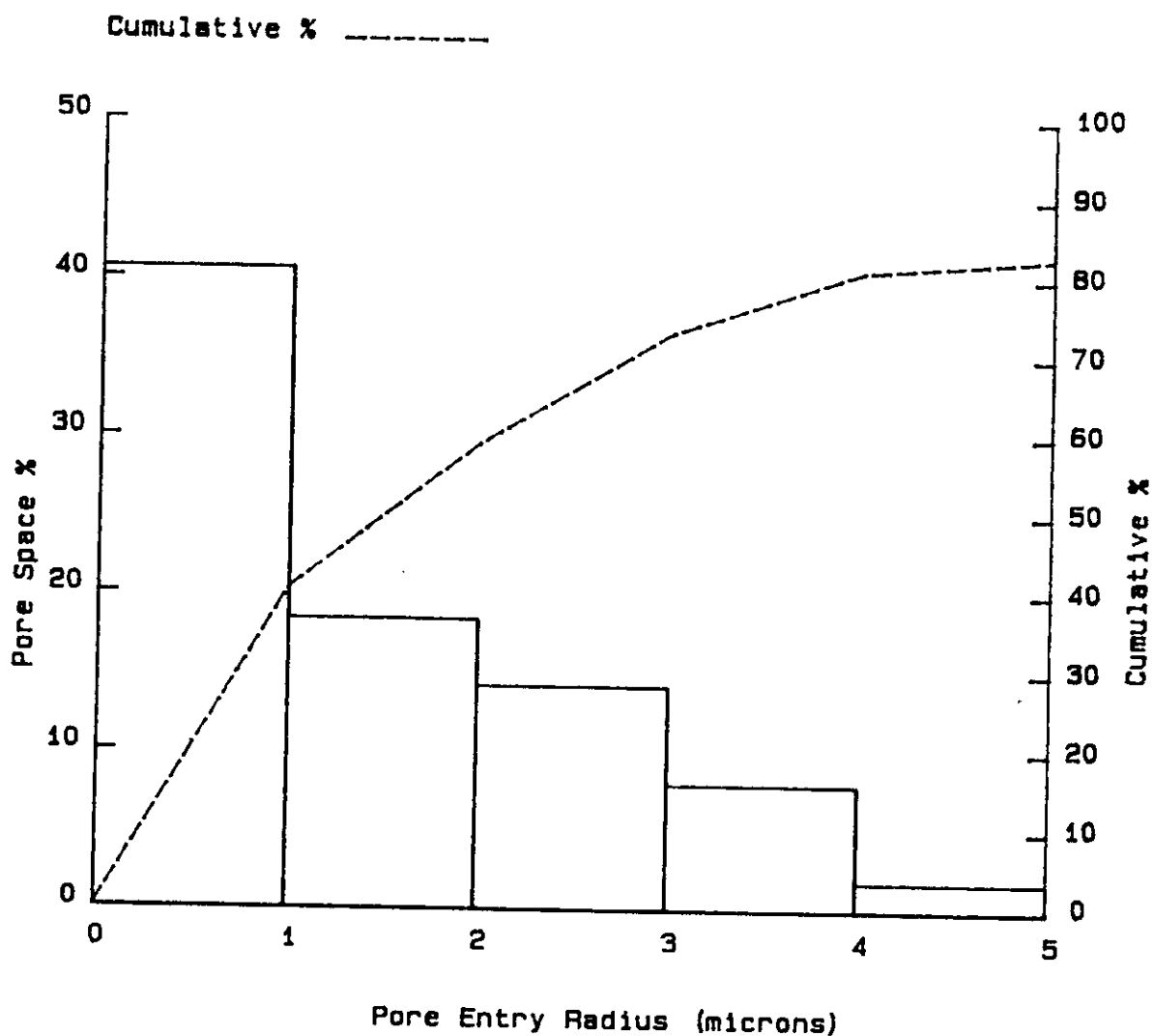
: 807.51m

Porosity

: 8.8%

Permeability

: 0.34mD



ROXY PETROLEUMS LTD
 ROXY ANDEX WHITEWATER
 3-2-3-21W1

DATE : 04 JUN 1984
 SAMPLE # 3A

MERCURY POROSIMETRY DATA

DEPTH : 808.53 m
 Formation : UPPER WHITEWATER
 Residual Wet. Phase Sat. : 12%

Permeability : 0.85 mD
 Porosity : 14.4%
 Recovery efficiency : 31%

| | | Wetting Phase Saturation Percent Pore Space | |
|------------------|-----------------|--|------------|
| Pressure PSIA | Pressure KPA | Drainage | Imbibition |
| 0.00 | 0.00 | 100.00 | |
| 1.06 | 7.31 | 89.85 | 35.60 |
| 1.26 | 8.69 | 89.76 | 35.60 |
| 1.76 | 12.13 | 89.50 | 35.60 |
| 2.26 | 15.58 | 89.45 | 35.42 |
| 2.76 | 19.03 | 89.45 | 35.34 |
| 3.26 | 22.47 | 89.41 | 35.34 |
| 4.26 | 29.37 | 89.41 | 35.16 |
| 5.26 | 36.26 | 89.32 | 35.16 |
| 6.26 | 43.16 | 89.32 | 35.16 |
| 7.26 | 50.05 | 89.23 | 35.16 |
| 8.26 | 56.95 | 89.23 | 35.16 |
| 9.26 | 63.84 | 89.23 | 35.16 |
| 10.26 | 70.74 | 89.23 | 35.07 |
| 11.26 | 77.63 | 89.23 | 34.98 |
| 12.26 | 84.53 | 89.14 | 34.72 |
| 13.26 | 91.42 | 89.05 | 34.81 |
| 14.26 | 98.32 | 89.05 | 34.63 |
| 16.06 | 110.73 | 89.05 | 34.54 |
| 21.06 | 145.20 | 88.96 | 33.74 |
| 31.06 | 214.15 | 88.88 | 31.71 |
| 41.06 | 283.10 | 88.88 | 26.93 |
| 61.06 | 420.99 | 88.43 | 21.35 |
| 71.06 | 489.94 | 88.35 | 20.12 |
| 81.06 | 558.89 | 87.55 | 18.43 |
| 91.06 | 627.84 | 85.87 | 17.64 |
| 100.00 | 689.48 | 82.77 | 16.93 |
| 110.00 | 758.43 | 75.96 | 16.13 |
| 120.00 | 827.38 | 70.91 | 15.51 |
| 130.00 | 896.32 | 65.60 | 15.51 |
| 140.00 | 965.27 | 60.29 | 14.89 |
| 150.00 | 1034.22 | 55.51 | 14.89 |
| 160.00 | 1103.17 | 51.80 | 14.54 |
| 175.00 | 1206.59 | 48.52 | 14.27 |
| 180.00 | 1241.06 | 47.37 | 14.27 |
| 190.00 | 1310.01 | 45.16 | 13.92 |
| 200.00 | 1378.96 | 42.86 | 13.92 |
| 250.00 | 1723.70 | 31.18 | 13.21 |
| 300.00 | 2068.44 | 25.07 | 12.77 |
| 350.00 | 2413.18 | 22.15 | 12.24 |
| 400.00 | 2757.92 | 19.67 | 12.24 |
| 450.00 | 3102.66 | 17.73 | 12.24 |
| 500.00 | 3447.40 | 16.84 | 12.06 |
| 550.00 | 3792.14 | 16.13 | 11.71 |
| 600.00 | 4136.88 | 15.25 | 11.44 |
| 650.00 | 4481.62 | 14.54 | 11.44 |
| 700.00 | 4826.36 | 14.36 | 11.44 |
| 750.00 | 5171.10 | 14.01 | 11.44 |
| 800.00 | 5515.84 | 13.30 | 11.35 |
| 900.00 | 6205.32 | 13.04 | 11.27 |
| 1000.00 | 6894.80 | 12.59 | 11.27 |
| 1100.00 | 7584.28 | 11.97 | 11.09 |
| 1200.00 | 8273.76 | 11.62 | 10.91 |
| 1300.00 | 8963.24 | 11.44 | 10.87 |
| 1400.00 | 9652.72 | 11.18 | 10.82 |
| 1500.00 | 10342.20 | 10.91 | 10.82 |
| 1600.00 | 11031.68 | 10.91 | 10.82 |
| 1700.00 | 11721.16 | 10.82 | 10.78 |
| 1800.00 | 12410.64 | 10.73 | 10.73 |

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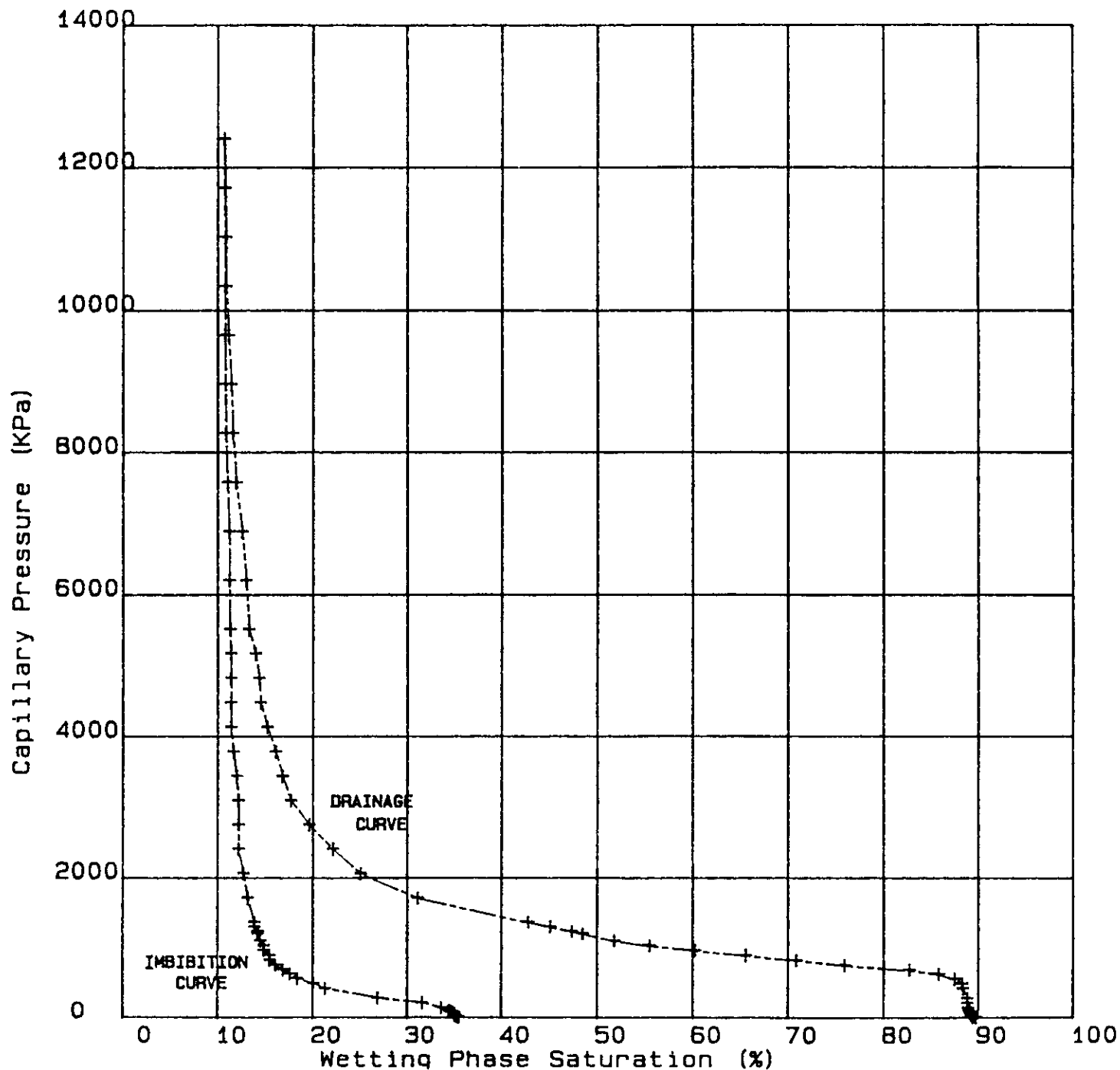
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ROXY PETROLEUMS LTD.
ROXY ANDEX WHITEWATER
3-2-3-21W1

18 MAY 1984

MERCURY INJECTION CAPILLARY PRESSURE

| | | | |
|---------------------------|--------------------|---------------------|----------|
| FORMATION | : Upper Whitewater | | |
| Sample #3A | | Permeability | : 0.85mD |
| Depth | : 808.53m | Porosity | : 14.4% |
| Residual Wet. Phase Sat.: | 12% | Recovery Efficiency | : 31% |



GEOTECH PRODUCTION ENGINEERING RESEARCH & DEVELOPMENT

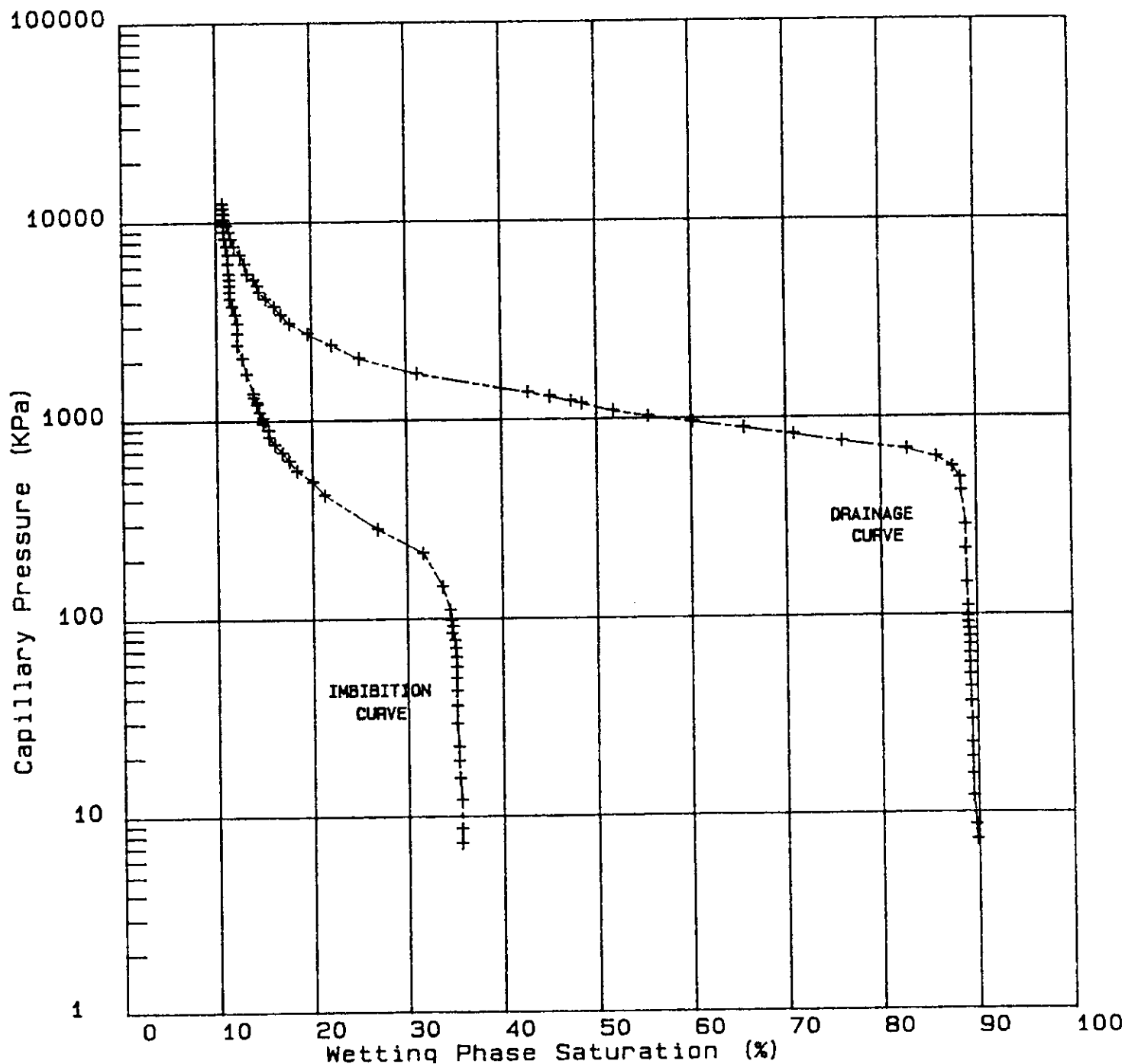
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ROXY PETROLEUMS LTD.
ROXY ANDEX WHITEWATER
3-2-3-21W1

18 MAY 1984

MERCURY INJECTION CAPILLARY PRESSURE

| | | | |
|---------------------------|--------------------|---------------------|----------|
| FORMATION | : Upper Whitewater | | |
| Sample #3A | | Permeability | : 0.85mD |
| Depth | : 808.53m | Porosity | : 14.4% |
| Residual Wet. Phase Sat.: | 12% | Recovery Efficiency | : 31% |



ROXY PETROLEUMS LTD
ROXY ANDEX WHITEWATER
3-2-3-21W1

DATE : 31 MAY 1984
SAMPLE # 3A

PORE SIZE DISTRIBUTION DATA

Depth : 808.53 m
Formation : UPPER WHITEWATER

Permeability : 0.85 mD
Porosity : 14.4 %

| Pore Entry Radius (Microns) | Percent of Pore Space | | Pore Entry Radius (Microns) | Percent of Pore Space | |
|--------------------------------|--------------------------|------|--------------------------------|--------------------------|-------|
| Initial | 100.0 | | 25.00 | 89.3 | 0.0 |
| 50.00 | 89.4 | 10.6 | 24.00 | 89.3 | 0.0 |
| 49.00 | 89.4 | 0.0 | 23.00 | 89.3 | 0.0 |
| 48.00 | 89.4 | 0.0 | 22.00 | 89.3 | 0.0 |
| 47.00 | 89.4 | 0.0 | 21.00 | 89.3 | 0.0 |
| 46.00 | 89.4 | 0.0 | 20.00 | 89.3 | 0.0 |
| 45.00 | 89.4 | 0.0 | 19.00 | 89.3 | 0.0 |
| 44.00 | 89.4 | 0.0 | 18.00 | 89.3 | 0.0 |
| 43.00 | 89.4 | 0.0 | 17.00 | 89.2 | 0.1 |
| 42.00 | 89.4 | 0.0 | 16.00 | 89.2 | 0.0 |
| 41.00 | 89.4 | 0.0 | 15.00 | 89.2 | 0.0 |
| 40.00 | 89.4 | 0.0 | 14.00 | 89.2 | 0.0 |
| 39.00 | 89.4 | 0.0 | 13.00 | 89.2 | 0.0 |
| 38.00 | 89.4 | 0.0 | 12.00 | 89.2 | 0.0 |
| 37.00 | 89.4 | 0.0 | 11.00 | 89.2 | 0.0 |
| 36.00 | 89.4 | 0.0 | 10.00 | 89.2 | 0.0 |
| 35.00 | 89.4 | 0.0 | 9.00 | 89.1 | 0.1 |
| 34.00 | 89.4 | 0.0 | 8.00 | 89.1 | 0.0 |
| 33.00 | 89.4 | 0.0 | 7.00 | 89.0 | 0.1 |
| 32.00 | 89.4 | 0.0 | 6.00 | 89.0 | 0.0 |
| 31.00 | 89.4 | 0.0 | 5.00 | 89.0 | 0.0 |
| 30.00 | 89.4 | 0.0 | 4.00 | 88.9 | 0.1 |
| 29.00 | 89.4 | 0.0 | 3.00 | 88.9 | 0.0 |
| 28.00 | 89.4 | 0.0 | 2.00 | 88.6 | 0.3 |
| 27.00 | 89.3 | 0.1 | 1.00 | 78.2 | 10.4 |
| 26.00 | 89.3 | 0.0 | 0.06 | 10.8 | 67.4 |
| | | | 0.00 | 0.0 | 10.8 |
| | | | | | 100.0 |

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ROXY PETROLEUMS LTD
ROXY ANDEX WHITEWATER
3-2-3-21W1

05 JUN 1984

PORE SIZE DISTRIBUTION

Formation : Upper Whitewater

Sample #3A

Porosity

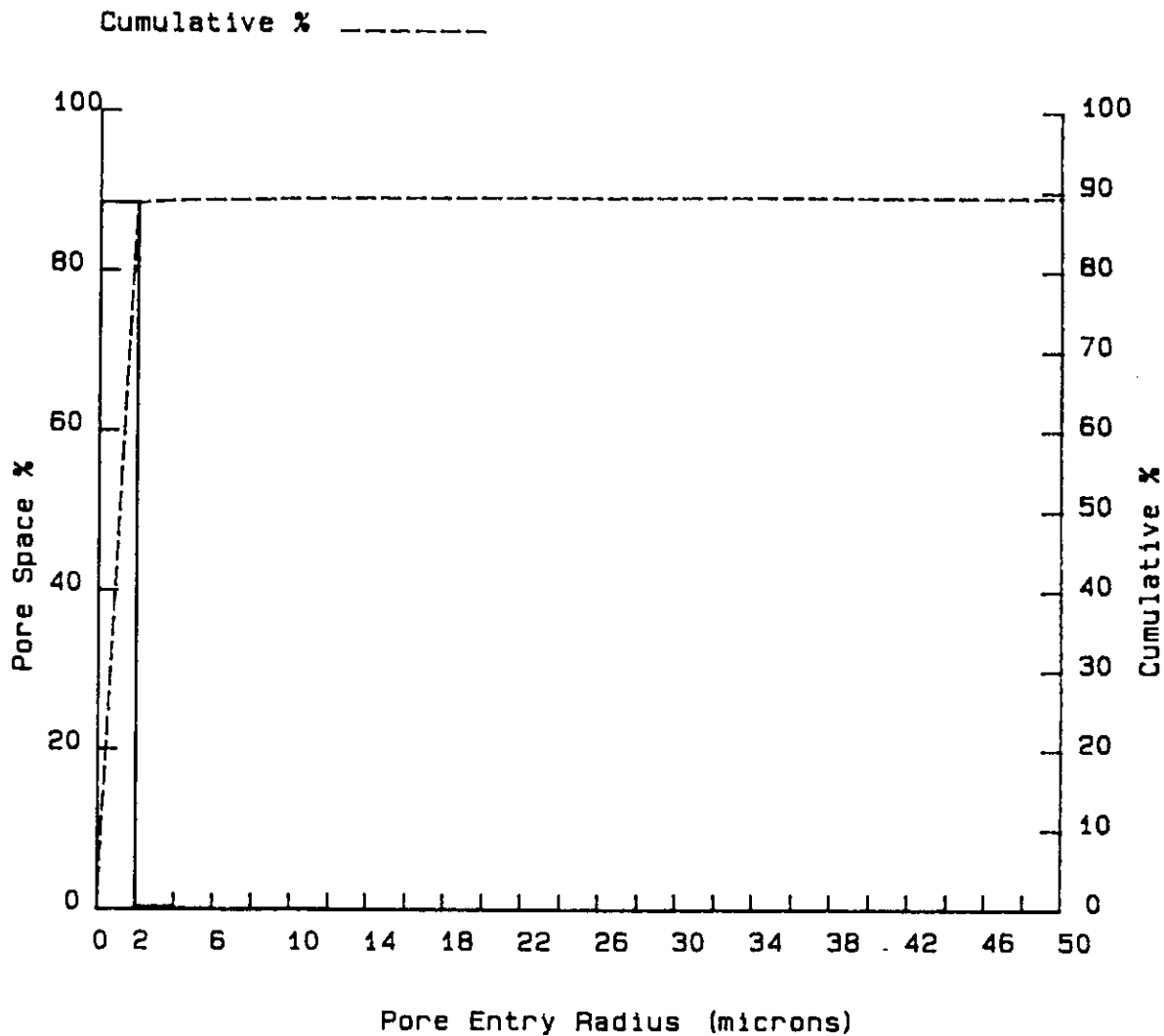
: 14.4%

Depth

: 808.53m

Permeability

: 0.85mD



ROXY PETROLEUMS LTD
 ROXY ANDEX WHITEWATER
 3-2-3-21W1

DATE : 05 JUN 1984
 SAMPLE # 3A

PORE SIZE DISTRIBUTION DATA

Depth : 808.53 m
 Formation : UPPER WHITEWATER

Permeability : 0.85 mD
 Porosity : 14.4 %

| Pore Entry Radius (Microns) | Percent of Pore Space | | Pore Entry Radius (Microns) | Percent of Pore Space | |
|--------------------------------|--------------------------|------|--------------------------------|--------------------------|-------|
| Initial | 100.0 | | 2.00 | 88.6 | 0.3 |
| 5.00 | 89.0 | 11.0 | 1.00 | 78.2 | 10.4 |
| 4.00 | 88.9 | 0.1 | 0.06 | 10.8 | 67.4 |
| 3.00 | 88.9 | 0.0 | 0.00 | 0.0 | 10.8 |
| | | | | ----- | |
| | | | | | 100.0 |

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ROXY PETROLEUMS LTD
ROXY ANDEX WHITEWATER
3-2-3-21W1

05 JUN 1984

PORE SIZE DISTRIBUTION

Formation : Upper Whitewater

Sample #3A

Porosity

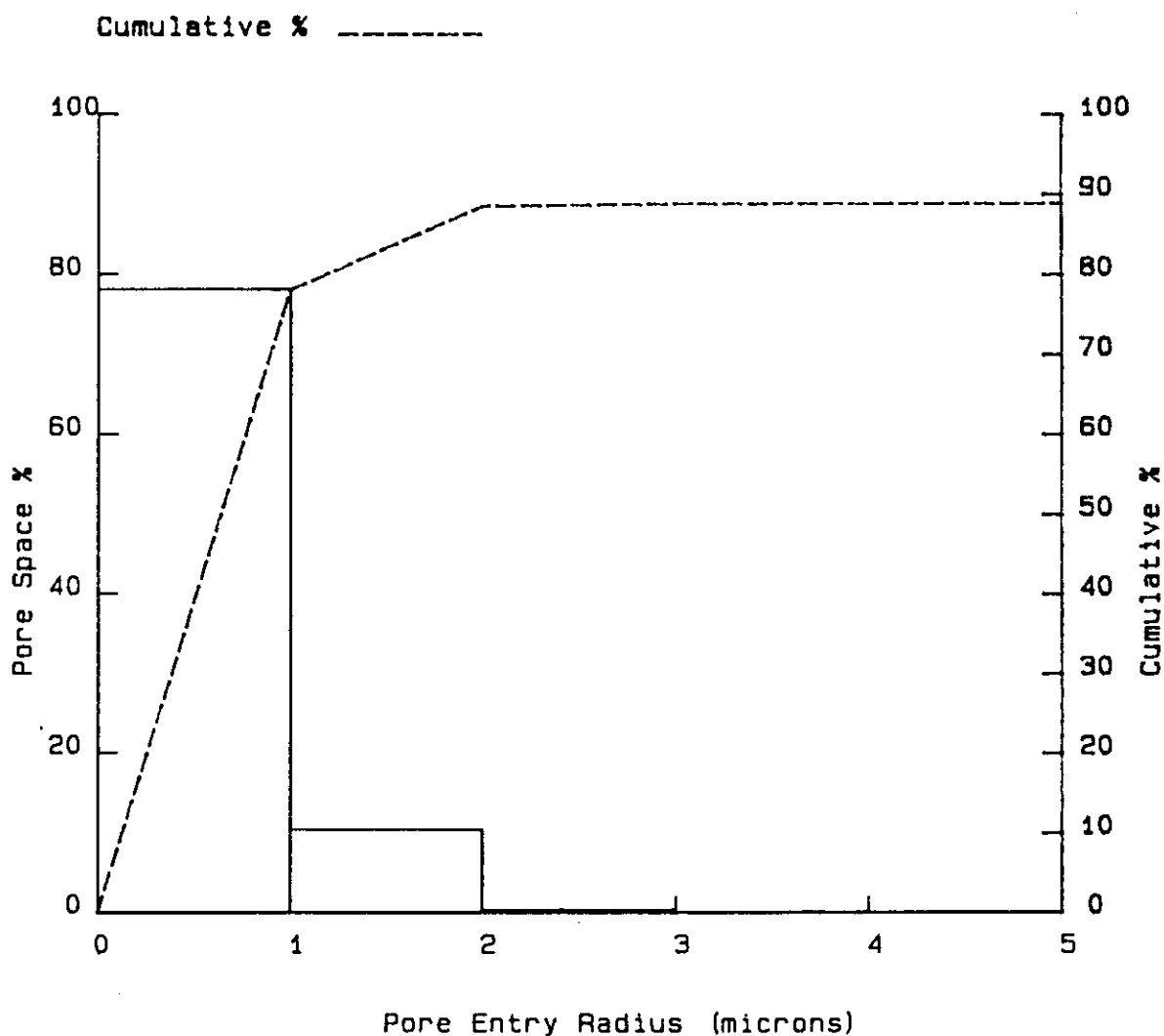
: 14.4%

Depth

: 808.53m

Permeability

: 0.85mD





ROXY PETROLEUMS LTD
ROXY ANDEX WHITEWATER
3-2-3-21W1

DATE : 04 JUN 1984
SAMPLE # 7A

MERCURY POROSIMETRY DATA

DEPTH : 809.96 m
Formation : UPPER WHITEWATER
Residual Wet. Phase Sat. : 4%

Permeability : 2.88 mD
Porosity : 13.9%
Recovery efficiency : 47%

| | | Wetting Phase Saturation Percent Pore Space | |
|------------------|-----------------|--|------------|
| Pressure PSIA | Pressure KPA | Drainage | Imbibition |
| 0.00 | 0.00 | 100.00 | |
| 1.09 | 7.51 | 93.83 | 46.05 |
| 1.29 | 8.88 | 93.70 | 46.05 |
| 1.79 | 12.33 | 93.58 | 46.05 |
| 2.29 | 15.78 | 93.33 | 46.05 |
| 3.29 | 22.67 | 93.33 | 46.05 |
| 4.29 | 29.57 | 93.25 | 45.97 |
| 5.29 | 36.46 | 93.00 | 45.88 |
| 6.29 | 43.36 | 93.00 | 45.88 |
| 7.29 | 50.25 | 92.91 | 45.63 |
| 8.29 | 57.15 | 92.74 | 45.63 |
| 9.29 | 64.04 | 92.49 | 45.30 |
| 10.29 | 70.94 | 92.49 | 44.88 |
| 11.29 | 77.83 | 92.41 | 44.54 |
| 12.29 | 84.72 | 92.33 | 44.29 |
| 13.29 | 91.62 | 92.16 | 43.79 |
| 14.29 | 98.51 | 92.16 | 43.29 |
| 16.09 | 110.93 | 91.57 | 42.87 |
| 21.09 | 145.40 | 90.40 | 41.28 |
| 31.09 | 214.35 | 85.30 | 37.18 |
| 41.09 | 283.30 | 80.86 | 34.67 |
| 51.09 | 352.24 | 74.75 | 32.16 |
| 61.09 | 421.19 | 70.49 | 29.90 |
| 71.09 | 490.14 | 66.22 | 28.23 |
| 81.09 | 559.09 | 62.87 | 26.05 |
| 91.09 | 628.04 | 59.94 | 24.46 |
| 100.00 | 689.48 | 57.60 | 23.29 |
| 110.00 | 758.43 | 55.09 | 21.53 |
| 120.00 | 827.38 | 52.83 | 20.19 |
| 130.00 | 896.32 | 50.49 | 18.94 |
| 140.00 | 965.27 | 48.98 | 17.93 |
| 150.00 | 1034.22 | 47.22 | 16.76 |
| 160.00 | 1103.17 | 45.80 | 16.01 |
| 170.00 | 1172.12 | 44.54 | 15.17 |
| 180.00 | 1241.06 | 43.46 | 14.33 |
| 200.00 | 1378.96 | 41.03 | 13.58 |
| 250.00 | 1723.70 | 36.59 | 10.99 |
| 300.00 | 2068.44 | 31.99 | 9.56 |
| 350.00 | 2413.18 | 28.56 | 8.39 |
| 400.00 | 2757.92 | 25.80 | 7.64 |
| 450.00 | 3102.66 | 23.62 | 7.05 |
| 500.00 | 3447.40 | 21.28 | 6.80 |
| 550.00 | 3792.14 | 19.77 | 6.47 |
| 600.00 | 4136.88 | 17.77 | 5.88 |
| 650.00 | 4481.62 | 16.43 | 5.72 |
| 700.00 | 4826.36 | 15.00 | 5.72 |
| 750.00 | 5171.10 | 14.17 | 5.55 |
| 800.00 | 5515.84 | 13.00 | 5.34 |
| 900.00 | 6205.32 | 11.49 | 5.13 |
| 1000.00 | 6894.80 | 10.15 | 4.88 |
| 1100.00 | 7584.28 | 8.98 | 4.54 |
| 1200.00 | 8273.76 | 7.72 | 4.46 |
| 1300.00 | 8963.24 | 6.47 | 4.29 |
| 1400.00 | 9652.72 | 6.05 | 4.29 |
| 1500.00 | 10342.20 | 5.88 | 4.29 |
| 1600.00 | 11031.68 | 5.21 | 4.21 |
| 1700.00 | 11721.16 | 4.13 | 4.21 |
| 1800.00 | 12410.64 | 3.96 | 3.96 |

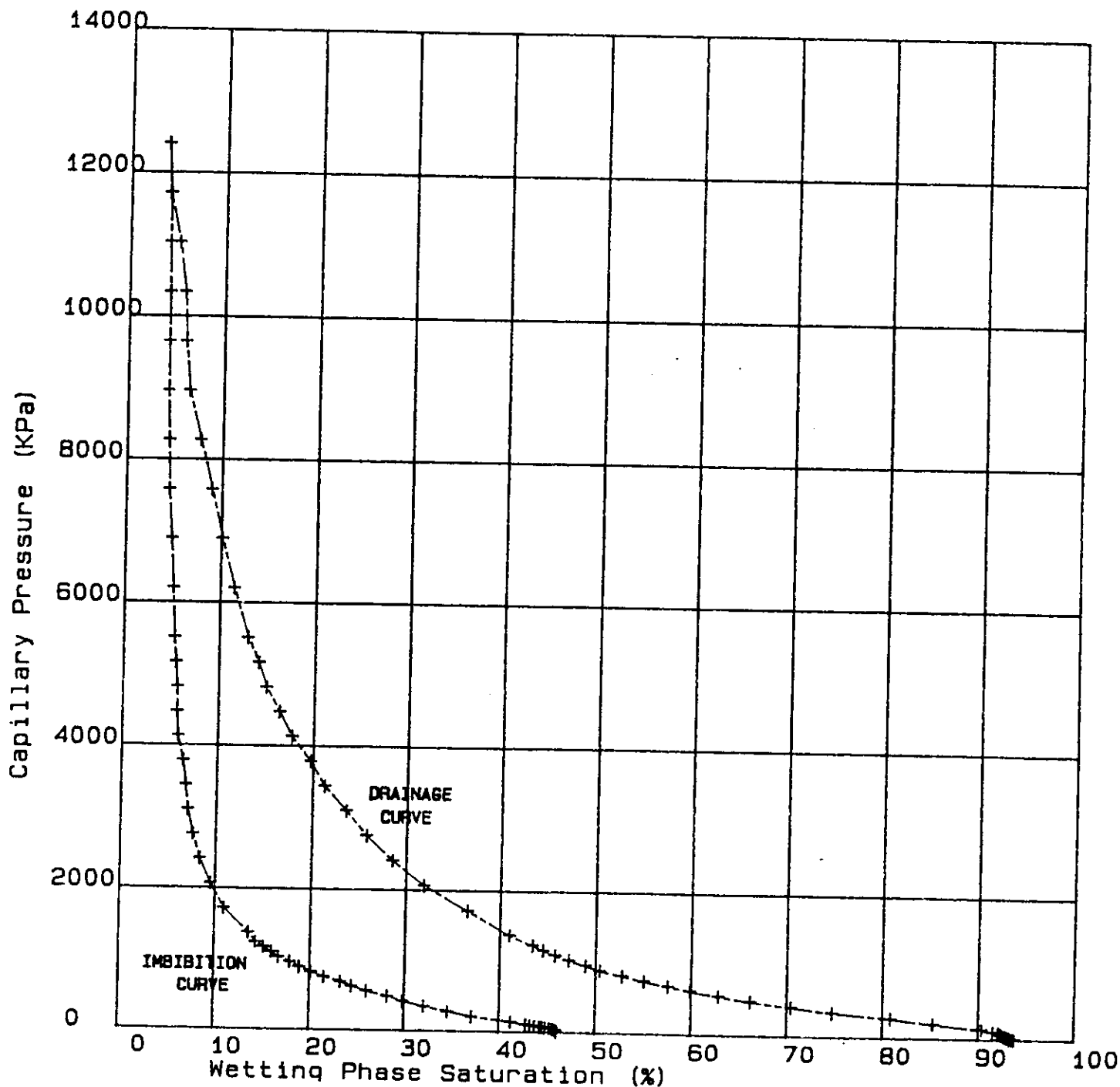
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ROXY PETROLEUMS LTD.
ROXY ANDEX WHITEWATER
3-2-3-21W1

18 MAY 1984

MERCURY INJECTION CAPILLARY PRESSURE

| | | | |
|---------------------------|--------------------|---------------------|----------|
| FORMATION | : Upper Whitewater | | |
| Sample #7A | | Permeability | : 2.88mD |
| Depth | : 809.96m | Porosity | : 13.9% |
| Residual Wet. Phase Sat.: | 4% | Recovery Efficiency | : 47% |



GEOTECH PRODUCTION ENGINEERING RESEARCH & DEVELOPMENT

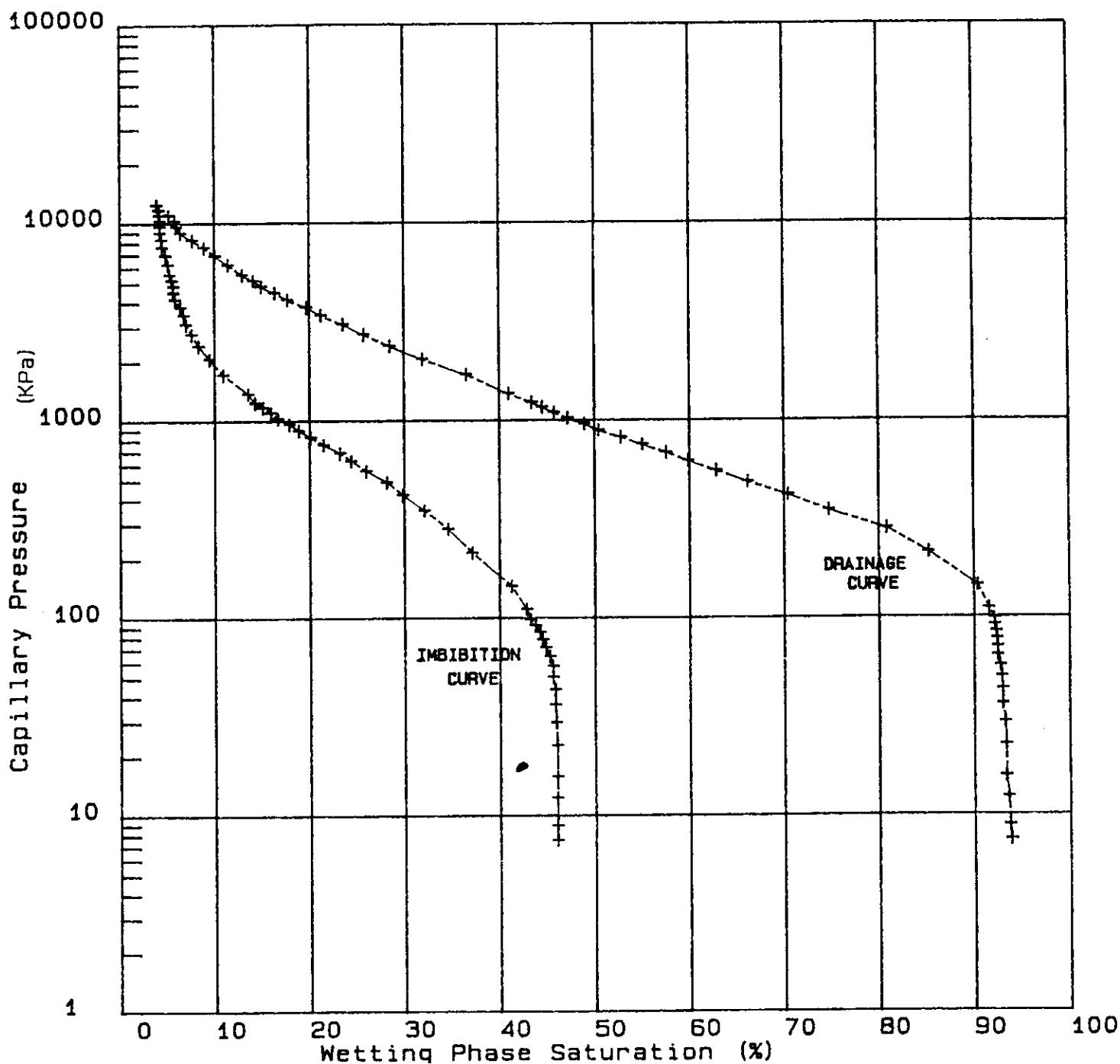
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ROXY PETROLEUMS LTD.
ROXY ANDEX WHITEWATER
3-2-3-21W1

18 MAY 1984

MERCURY INJECTION CAPILLARY PRESSURE

| | | | |
|--------------------------|--------------------|---------------------|----------|
| FORMATION | : Upper Whitewater | Permeability | : 2.88mD |
| Sample #7A | | Porosity | : 13.9% |
| Depth | : 809.96m | Recovery Efficiency | : 47% |
| Residual Wet. Phase Sat. | : 4% | | |



ROXY PETROLEUMS LTD
ROXY ANDEX WHITEWATER
3-2-3-21W1

DATE : 31 MAY 1984
SAMPLE # 7A

PORE SIZE DISTRIBUTION DATA

Depth : 809.96 m
Formation : UPPER WHITEWATER

Permeability : 2.88 mD
Porosity : 13.9 %

| Pore Entry Radius (Microns) | Percent of Pore Space | | Pore Entry Radius (Microns) | Percent of Pore Space | |
|--------------------------------|--------------------------|------------|--------------------------------|--------------------------|------------|
| Initial | 100.0 | | 25.00 | 93.0 | -0.1 |
| 50.00 | 93.3 | 6.7 | 24.00 | 93.0 | 0.0 |
| 49.00 | 93.2 | 0.1 | 23.00 | 93.0 | 0.0 |
| 48.00 | 93.3 | -0.1 | 22.00 | 92.9 | 0.1 |
| 47.00 | 93.3 | 0.0 | 21.00 | 92.9 | 0.0 |
| 46.00 | 93.3 | 0.0 | 20.00 | 93.0 | -0.1 |
| 45.00 | 93.3 | 0.0 | 19.00 | 93.0 | 0.0 |
| 44.00 | 93.3 | 0.0 | 18.00 | 92.9 | 0.1 |
| 43.00 | 93.3 | 0.0 | 17.00 | 92.9 | 0.0 |
| 42.00 | 93.3 | 0.0 | 16.00 | 92.8 | 0.1 |
| 41.00 | 93.3 | 0.0 | 15.00 | 92.7 | 0.1 |
| 40.00 | 93.3 | 0.0 | 14.00 | 92.6 | 0.1 |
| 39.00 | 93.2 | 0.1 | 13.00 | 92.5 | 0.1 |
| 38.00 | 93.2 | 0.0 | 12.00 | 92.5 | 0.0 |
| 37.00 | 93.2 | 0.0 | 11.00 | 92.5 | 0.0 |
| 36.00 | 93.2 | 0.0 | 10.00 | 92.4 | 0.1 |
| 35.00 | 93.2 | 0.0 | 9.00 | 92.2 | 0.2 |
| 34.00 | 93.2 | 0.0 | 8.00 | 92.1 | 0.1 |
| 33.00 | 93.2 | 0.0 | 7.00 | 91.5 | 0.6 |
| 32.00 | 93.2 | 0.0 | 6.00 | 90.9 | 0.6 |
| 31.00 | 93.2 | 0.0 | 5.00 | 89.7 | 1.2 |
| 30.00 | 93.1 | 0.1 | 4.00 | 86.9 | 2.8 |
| 29.00 | 93.1 | 0.0 | 3.00 | 82.8 | 4.1 |
| 28.00 | 93.0 | 0.1 | 2.00 | 73.3 | 9.5 |
| 27.00 | 93.0 | 0.0 | 1.00 | 55.9 | 17.4 |
| 26.00 | 92.9 | 0.1 | 0.06 | 4.0 | 51.9 |
| | | | 0.00 | 0.0 | 4.0 |
| | | | | | ----- |
| | | | | | 100.0 |

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ROXY PETROLEUMS LTD
ROXY ANDEX WHITEWATER
3-2-3-21W1

05 JUN 1984

PORE SIZE DISTRIBUTION

Formation : Upper Whitewater

Sample #7A

Depth

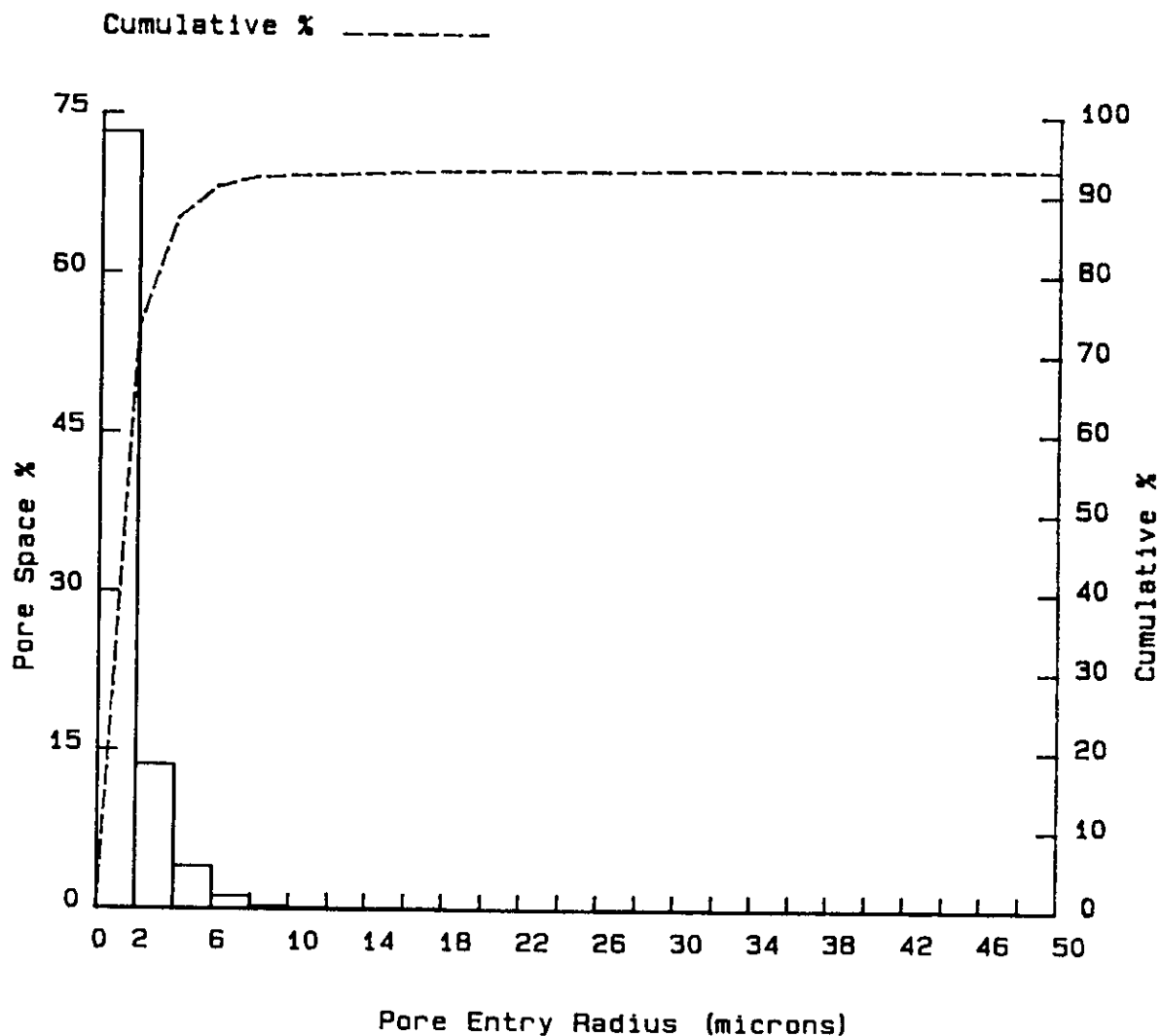
: 809.96m

Porosity

: 13.9%

Permeability

: 2.88mD



ROXY PETROLEUMS LTD
 ROXY ANDEX WHITEWATER
 3-2-3-21W1

DATE : 05 JUN 1984
 SAMPLE # 7A

PORE SIZE DISTRIBUTION DATA

Depth : 809.96 m
 Formation : UPPER WHITEWATER

Permeability : 2.88 mD
 Porosity : 13.9 %

| Pore Entry Radius (Microns) | Percent of Pore Space | | Pore Entry Radius (Microns) | Percent of Pore Space | |
|--------------------------------|--------------------------|------|--------------------------------|--------------------------|-------|
| Initial | 100.0 | | 2.00 | 73.3 | 9.5 |
| 5.00 | 89.7 | 10.3 | 1.00 | 55.9 | 17.4 |
| 4.00 | 86.9 | 2.8 | 0.06 | 4.0 | 51.9 |
| 3.00 | 82.8 | 4.1 | 0.00 | 0.0 | 4.0 |
| | | | | | 100.0 |

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ROXY PETROLEUMS LTD
ROXY ANDEX WHITEWATER
3-2-3-21W1

05 JUN 1984

PORE SIZE DISTRIBUTION

Formation : Upper Whitewater

Sample #7A

Depth

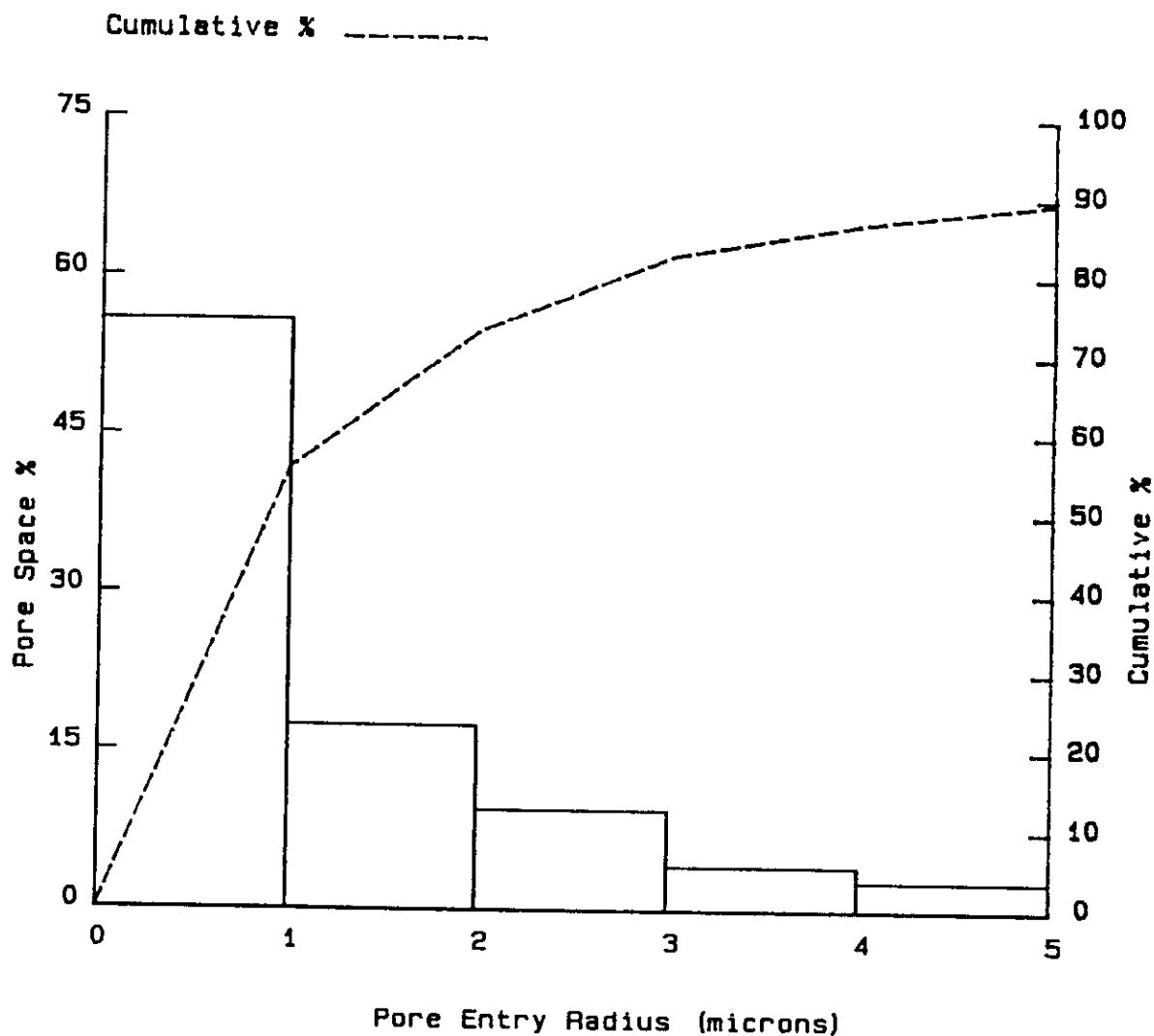
: 809.96m

Porosity

: 13.9%

Permeability

: 2.88mD



MERCURY POROSIMETRY DATA

DEPTH : 812.24 m
 Formation : UPPER WHITEWATER
 Residual Wet. Phase Sat. : 9%

Permeability : 255.26 mD
 Porosity : 14.0%
 Recovery efficiency : 45%

| | | Wetting Phase Saturation Percent Pore Space | |
|------------------|-----------------|--|------------|
| Pressure PSIA | Pressure KPA | Drainage | Imbibition |
| 0.00 | 0.00 | 100.00 | |
| 1.09 | 7.54 | 95.75 | 47.60 |
| 1.29 | 8.91 | 95.76 | 47.60 |
| 1.79 | 12.36 | 95.59 | 46.23 |
| 2.29 | 15.80 | 94.38 | 44.86 |
| 2.79 | 19.25 | 93.18 | 40.44 |
| 3.29 | 22.70 | 91.33 | 37.79 |
| 3.79 | 26.15 | 87.07 | 34.09 |
| 4.29 | 29.59 | 82.81 | 32.73 |
| 4.79 | 33.04 | 74.85 | 30.55 |
| 5.29 | 36.49 | 70.02 | 29.51 |
| 5.79 | 39.94 | 62.95 | 28.14 |
| 6.29 | 43.38 | 59.01 | 26.94 |
| 6.79 | 46.83 | 55.72 | 26.05 |
| 7.29 | 50.28 | 53.46 | 25.57 |
| 7.79 | 53.73 | 51.54 | 24.77 |
| 8.29 | 57.17 | 49.69 | 24.20 |
| 9.29 | 64.07 | 47.03 | 22.76 |
| 10.29 | 70.96 | 44.70 | 21.71 |
| 11.29 | 77.86 | 42.77 | 21.07 |
| 12.29 | 84.75 | 41.41 | 20.27 |
| 13.29 | 91.65 | 40.20 | 19.94 |
| 14.29 | 98.54 | 39.24 | 19.62 |
| 16.09 | 110.95 | 37.63 | 18.66 |
| 21.09 | 145.43 | 34.09 | 17.13 |
| 26.09 | 179.90 | 32.00 | 16.33 |
| 31.09 | 214.37 | 30.39 | 15.68 |
| 36.09 | 248.85 | 29.03 | 14.80 |
| 41.09 | 283.32 | 28.22 | 14.72 |
| 51.09 | 352.27 | 26.62 | 13.91 |
| 61.09 | 421.22 | 25.49 | 13.51 |
| 71.09 | 490.17 | 24.69 | 13.03 |
| 81.09 | 559.11 | 23.96 | 12.87 |
| 91.09 | 628.06 | 23.40 | 12.39 |
| 100.00 | 689.48 | 23.00 | 12.39 |
| 110.00 | 758.43 | 22.44 | 12.39 |
| 120.00 | 827.38 | 21.87 | 11.66 |
| 135.00 | 930.80 | 21.31 | 11.50 |
| 140.00 | 965.27 | 21.31 | 11.10 |
| 160.00 | 1103.17 | 20.51 | 10.78 |
| 180.00 | 1241.06 | 20.02 | 10.46 |
| 200.00 | 1378.96 | 19.30 | 10.14 |
| 250.00 | 1723.70 | 18.58 | 9.82 |
| 300.00 | 2068.44 | 17.37 | 9.82 |
| 350.00 | 2413.18 | 16.49 | 9.73 |
| 400.00 | 2757.92 | 16.00 | 9.73 |
| 450.00 | 3102.66 | 15.20 | 9.73 |
| 500.00 | 3447.40 | 14.72 | 9.73 |
| 550.00 | 3792.14 | 14.32 | 9.49 |
| 600.00 | 4136.88 | 13.83 | 9.25 |
| 650.00 | 4481.62 | 13.43 | 9.01 |
| 700.00 | 4826.36 | 12.71 | 9.01 |
| 750.00 | 5171.10 | 12.31 | 8.93 |
| 800.00 | 5515.84 | 11.99 | 8.93 |
| 900.00 | 6205.32 | 11.91 | 8.77 |
| 1000.00 | 6894.80 | 11.34 | 8.53 |
| 1100.00 | 7584.28 | 10.62 | 8.53 |
| 1200.00 | 8273.76 | 9.90 | 8.53 |
| 1300.00 | 8963.24 | 9.49 | 8.50 |
| 1400.00 | 9652.72 | 9.25 | 8.48 |
| 1500.00 | 10342.20 | 9.01 | 8.45 |
| 1600.00 | 11031.68 | 8.85 | 8.45 |
| 1700.00 | 11721.16 | 8.53 | 8.37 |
| 1800.00 | 12410.64 | 8.29 | 8.29 |

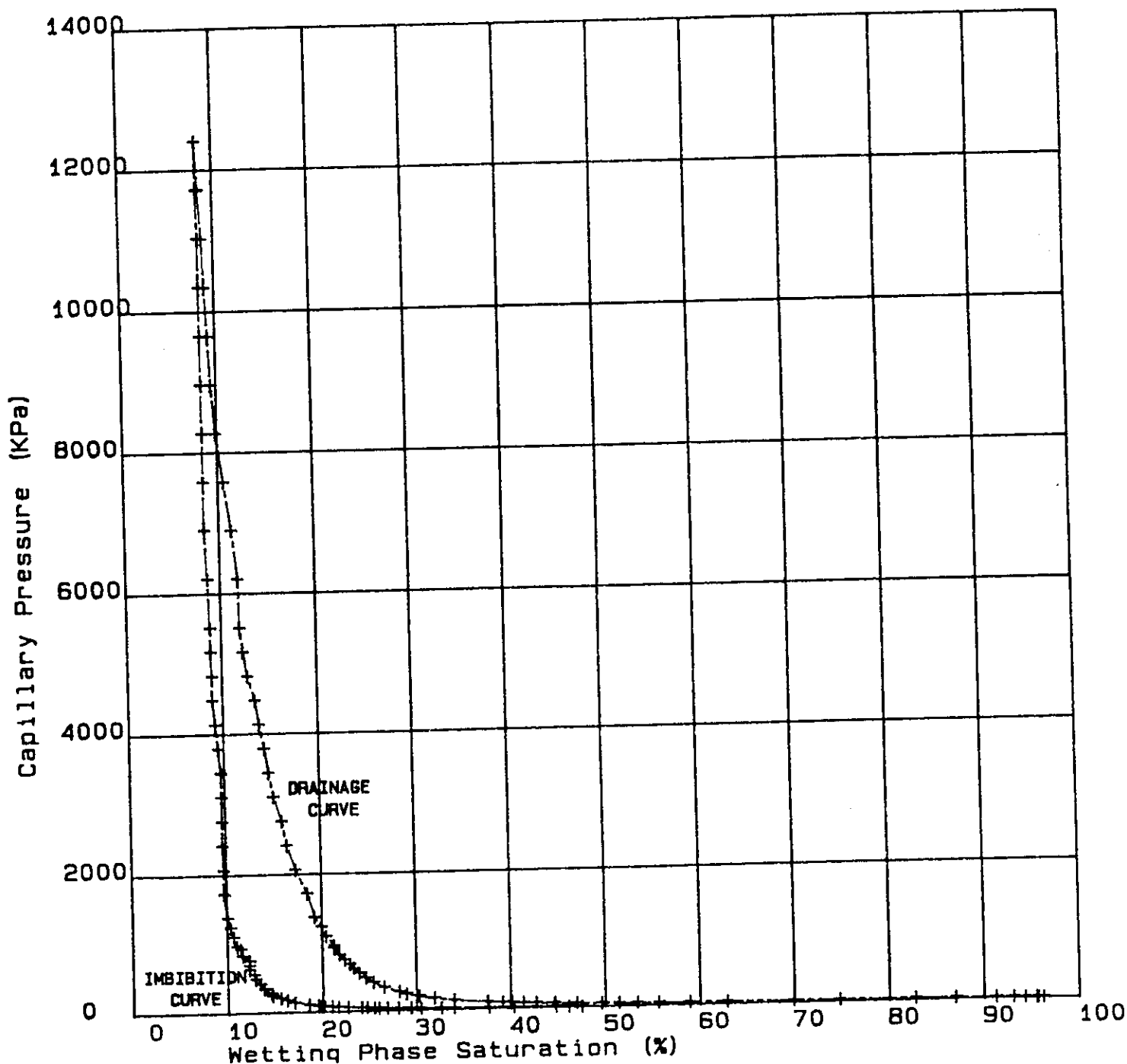
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ROXY PETROLEUMS LTD.
ROXY ANDEX WHITEWATER
3-2-3-21W1

18 MAY 1984

MERCURY INJECTION CAPILLARY PRESSURE

| | | | |
|---------------------------|--------------------|---------------------|------------|
| FORMATION | : Upper Whitewater | | |
| Sample #11A | | Permeability | : 255.26mD |
| Depth | : 812.24m | Porosity | : 14.0% |
| Residual Wet. Phase Sat.: | 9% | Recovery Efficiency | : 45% |



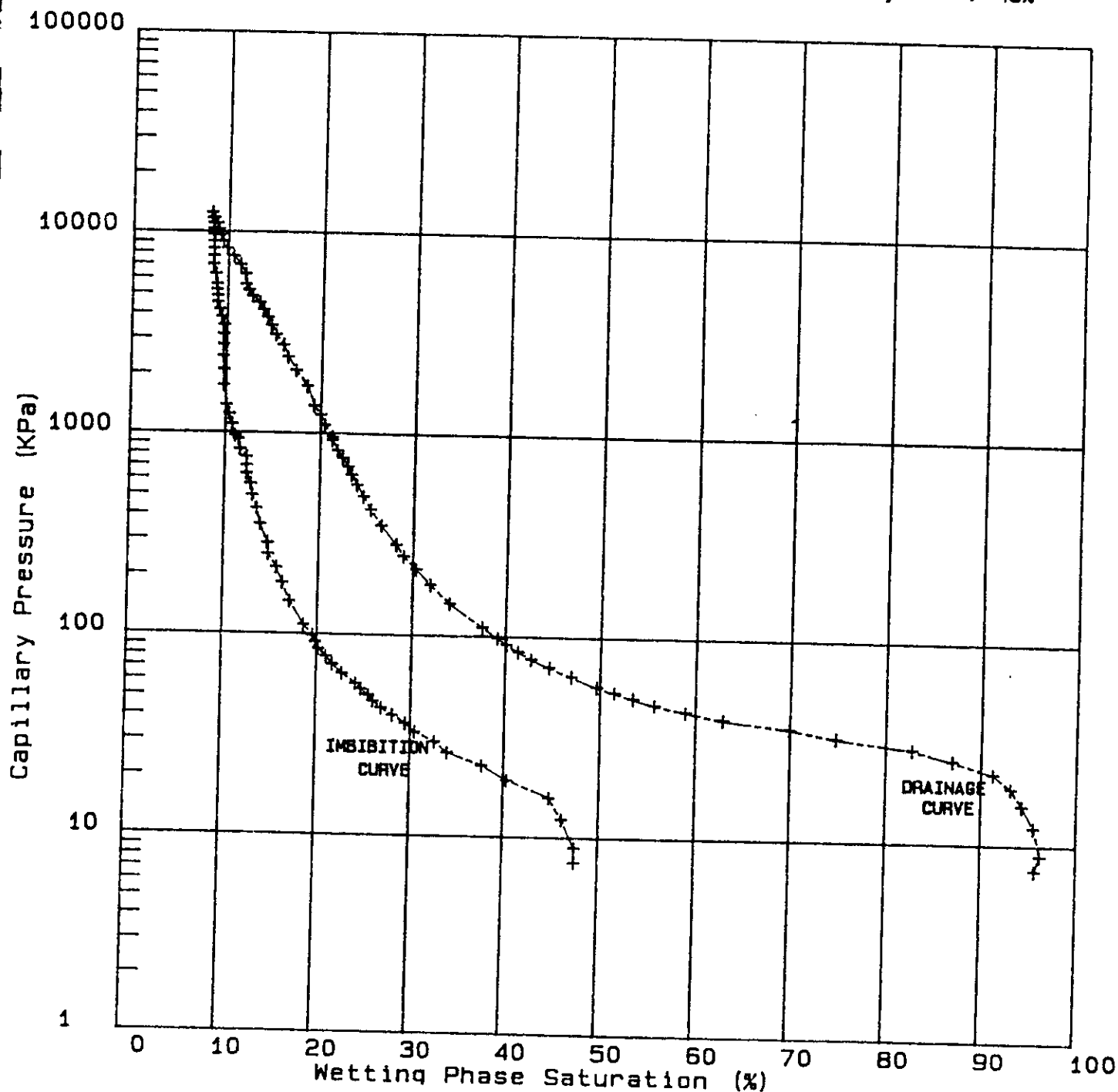
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ROXY PETROLEUMS LTD.
ROXY ANDEX WHITEWATER
3-2-3-21W1

18 MAY 1984

MERCURY INJECTION CAPILLARY PRESSURE

| | | | |
|---------------------------|--------------------|---------------------|------------|
| FORMATION | : Upper Whitewater | | |
| Sample #11A | | Permeability | : 255.26mD |
| Depth | : 812.24m | Porosity | : 14.0% |
| Residual Wet. Phase Sat.: | 9% | Recovery Efficiency | : 45% |



ROXY PETROLEUMS LTD
ROXY ANDEX WHITEWATER
3-2-3-21W1

DATE : 31 MAY 1984
SAMPLE # 11A

PORE SIZE DISTRIBUTION DATA

Depth : 812.24 m
Formation : UPPER WHITEWATER

Permeability : 255.26 mD
Porosity : 14.0 %

| Pore Entry Radius (Microns) | Percent of Pore Space | | Pore Entry Radius (Microns) | Percent of Pore Space | |
|--------------------------------|--------------------------|-----|--------------------------------|--------------------------|-------|
| Initial | 100.0 | | 25.00 | 69.1 | 1.9 |
| 50.00 | 91.6 | 8.4 | 24.00 | 66.6 | 2.5 |
| 49.00 | 91.4 | 0.2 | 23.00 | 63.8 | 2.8 |
| 48.00 | 91.1 | 0.3 | 22.00 | 61.8 | 2.0 |
| 47.00 | 90.7 | 0.4 | 21.00 | 60.0 | 1.8 |
| 46.00 | 90.3 | 0.4 | 20.00 | 58.1 | 1.9 |
| 45.00 | 89.9 | 0.4 | 19.00 | 56.3 | 1.8 |
| 44.00 | 89.4 | 0.5 | 18.00 | 54.7 | 1.6 |
| 43.00 | 88.9 | 0.5 | 17.00 | 53.2 | 1.5 |
| 42.00 | 88.4 | 0.5 | 16.00 | 51.7 | 1.5 |
| 41.00 | 87.9 | 0.5 | 15.00 | 50.0 | 1.7 |
| 40.00 | 87.4 | 0.5 | 14.00 | 48.6 | 1.4 |
| 39.00 | 86.8 | 0.6 | 13.00 | 47.0 | 1.6 |
| 38.00 | 86.2 | 0.6 | 12.00 | 45.4 | 1.6 |
| 37.00 | 85.5 | 0.7 | 11.00 | 43.7 | 1.7 |
| 36.00 | 84.8 | 0.7 | 10.00 | 42.1 | 1.6 |
| 35.00 | 84.1 | 0.7 | 9.00 | 40.6 | 1.5 |
| 34.00 | 83.3 | 0.8 | 8.00 | 39.1 | 1.5 |
| 33.00 | 82.3 | 1.0 | 7.00 | 37.5 | 1.6 |
| 32.00 | 80.7 | 1.6 | 6.00 | 35.7 | 1.8 |
| 31.00 | 79.0 | 1.7 | 5.00 | 33.5 | 2.2 |
| 30.00 | 77.2 | 1.8 | 4.00 | 31.5 | 2.0 |
| 29.00 | 75.2 | 2.0 | 3.00 | 28.9 | 2.6 |
| 28.00 | 73.8 | 1.4 | 2.00 | 26.2 | 2.7 |
| 27.00 | 72.4 | 1.4 | 1.00 | 22.6 | 3.6 |
| 26.00 | 71.0 | 1.4 | 0.06 | 8.3 | 14.3 |
| | | | 0.00 | 0.0 | 8.3 |
| | | | | | ----- |
| | | | | | 100.0 |

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ROXY ANDEX WHITEWATER
3-2-3-21W1

05 JUN 1984

PORE SIZE DISTRIBUTION

Formation : Upper Whitewater

Sample #11A

Porosity

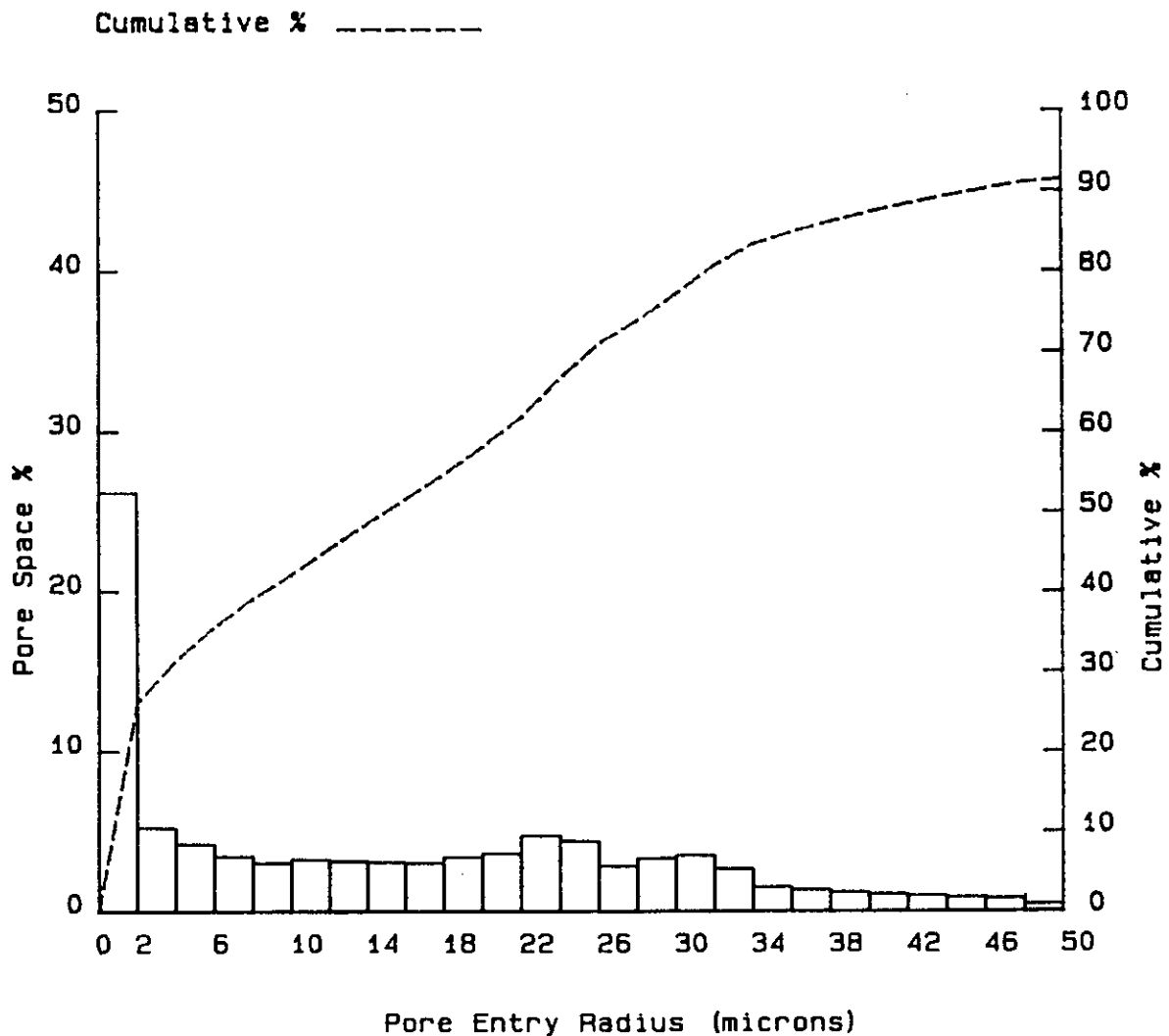
: 14.0%

Depth

: 812.24m

Permeability

: 255.26mD



ROXY PETROLEUMS LTD
 ROXY ANDEX WHITEWATER
 3-2-3-21W1

DATE : 05 JUN 1984
 SAMPLE # 11A

PORE SIZE DISTRIBUTION DATA

Depth : 812.24 m
 Formation : UPPER WHITEWATER

Permeability : 255.26 mD
 Porosity : 14.0 %

| Pore Entry Radius (Microns) | Percent of Pore Space | | Pore Entry Radius (Microns) | Percent of Pore Space | |
|--------------------------------|--------------------------|------|--------------------------------|--------------------------|-------|
| Initial | 100.0 | | 2.00 | 26.2 | 2.7 |
| 5.00 | 33.5 | 66.5 | 1.00 | 22.6 | 3.6 |
| 4.00 | 31.5 | 2.0 | 0.06 | 8.3 | 14.3 |
| 3.00 | 28.9 | 2.6 | 0.00 | 0.0 | 8.3 |
| | | | | ----- | |
| | | | | | 100.0 |

ROXY PETROLEUMS LTD
ROXY ANDEX WHITEWATER
3-2-3-21W1

14 JUN 1984

PORE SIZE DISTRIBUTION

Formation : Upper Whitewater

Sample #11A

Depth

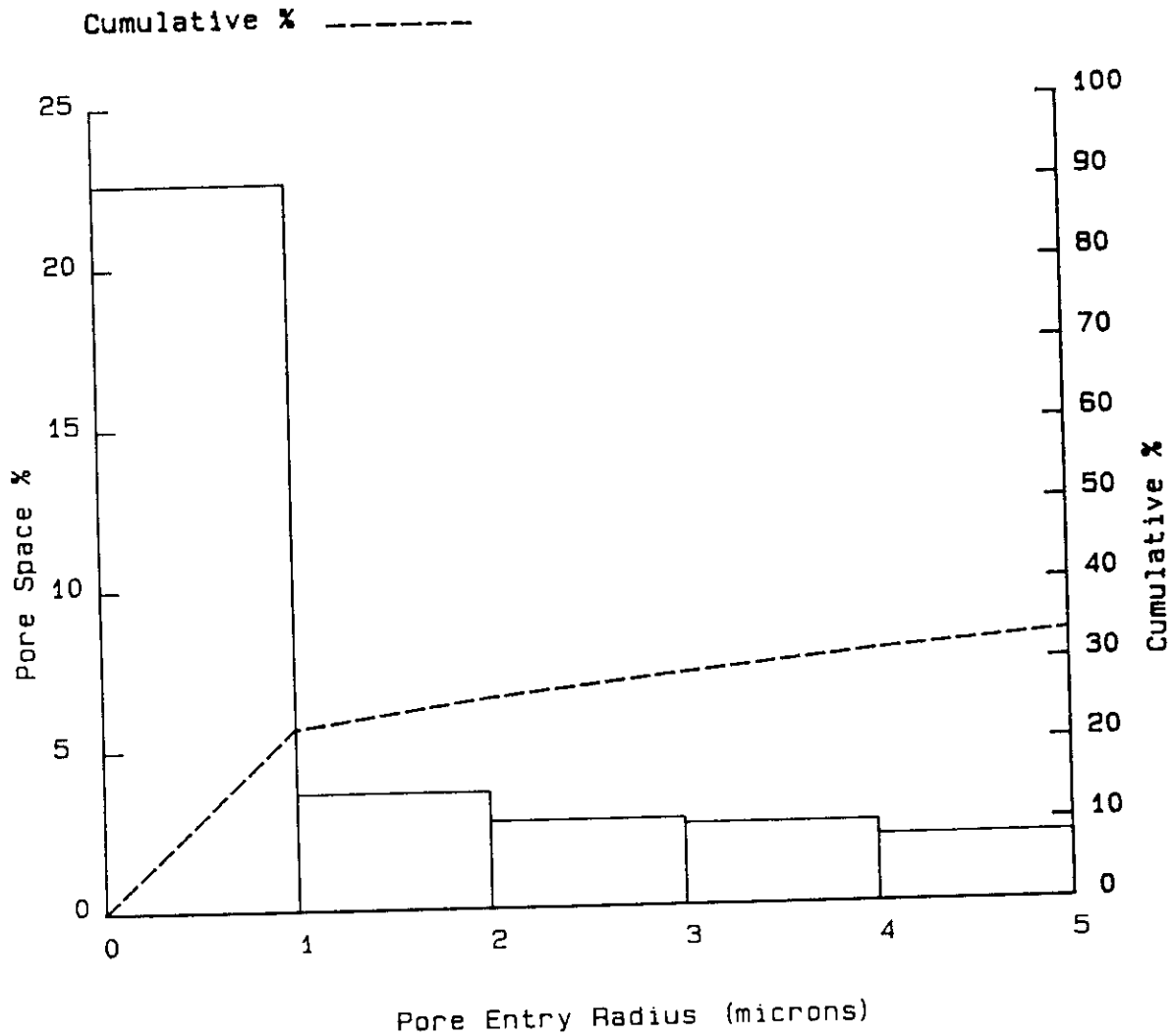
: 812.24m

Porosity

Permeability

: 14.0%

: 255.26mD



ROXY PETROLEUMS LTD
ROXY ANDEX WHITEWATER
3-2-3-21W1

DATE : 04 JUN 1984
SAMPLE # 15A

MERCURY POROSIMETRY DATA

DEPTH : 813.40 m
Formation : UPPER WHITEWATER
Residual Wet. Phase Sat. : 23%

Permeability : 0.02 mD
Porosity : 4.3%
Recovery efficiency : 26%

| | | Wetting Phase Saturation Percent Pore Space | |
|------------------|-----------------|--|------------|
| Pressure PSIA | Pressure KPA | Drainage | Imbibition |
| 0.00 | 0.00 | 100.00 | |
| 1.03 | 7.09 | 85.60 | 36.26 |
| 1.23 | 8.46 | 85.60 | 34.44 |
| 2.23 | 15.35 | 79.97 | 32.62 |
| 2.73 | 18.80 | 79.64 | 31.62 |
| 3.23 | 22.25 | 79.30 | 30.96 |
| 4.23 | 29.14 | 78.64 | 29.97 |
| 5.23 | 36.04 | 77.98 | 29.64 |
| 6.23 | 42.93 | 77.65 | 28.97 |
| 7.23 | 49.83 | 77.65 | 28.64 |
| 8.23 | 56.72 | 77.65 | 28.64 |
| 9.23 | 63.62 | 77.98 | 28.31 |
| 10.23 | 70.51 | 77.65 | 28.31 |
| 11.23 | 77.41 | 76.99 | 28.31 |
| 12.23 | 84.30 | 76.99 | 28.31 |
| 13.23 | 91.20 | 76.99 | 27.98 |
| 14.23 | 98.09 | 77.62 | 27.65 |
| 16.03 | 110.50 | 76.32 | 26.99 |
| 21.03 | 144.98 | 75.66 | 25.66 |
| 31.03 | 213.92 | 74.01 | 23.34 |
| 41.03 | 282.87 | 69.04 | 23.01 |
| 51.03 | 351.82 | 65.73 | 22.68 |
| 61.03 | 420.77 | 62.42 | 22.68 |
| 71.03 | 489.72 | 60.10 | 22.68 |
| 81.03 | 558.66 | 57.12 | 22.68 |
| 100.00 | 689.48 | 54.80 | 21.69 |
| 120.00 | 827.38 | 51.82 | 21.69 |
| 140.00 | 965.27 | 49.17 | 21.52 |
| 160.00 | 1103.17 | 46.85 | 21.36 |
| 180.00 | 1241.06 | 43.87 | 21.19 |
| 200.00 | 1378.96 | 40.23 | 21.03 |
| 250.00 | 1723.70 | 38.91 | 19.70 |
| 300.00 | 2068.44 | 35.60 | 19.70 |
| 350.00 | 2413.18 | 34.27 | 19.70 |
| 400.00 | 2757.92 | 32.62 | 19.70 |
| 450.00 | 3102.66 | 31.62 | 19.04 |
| 500.00 | 3447.40 | 30.63 | 19.70 |
| 550.00 | 3792.14 | 29.64 | 19.37 |
| 600.00 | 4136.88 | 28.64 | 19.37 |
| 650.00 | 4481.62 | 28.31 | 19.04 |
| 700.00 | 4826.36 | 27.98 | 19.37 |
| 750.00 | 5171.10 | 26.99 | 19.04 |
| 800.00 | 5515.84 | 26.32 | 19.37 |
| 900.00 | 6205.32 | 25.66 | 19.70 |
| 1000.00 | 6894.80 | 23.68 | 19.04 |
| 1100.00 | 7584.28 | 23.34 | 19.70 |
| 1200.00 | 8273.76 | 22.68 | 19.37 |
| 1300.00 | 8963.24 | 22.35 | 19.37 |
| 1400.00 | 9652.72 | 21.95 | 19.70 |
| 1500.00 | 10342.20 | 21.52 | 19.37 |
| 1600.00 | 11031.68 | 21.03 | 19.70 |
| 1700.00 | 11721.16 | 20.70 | 19.37 |
| 1800.00 | 12410.64 | 19.37 | 19.37 |

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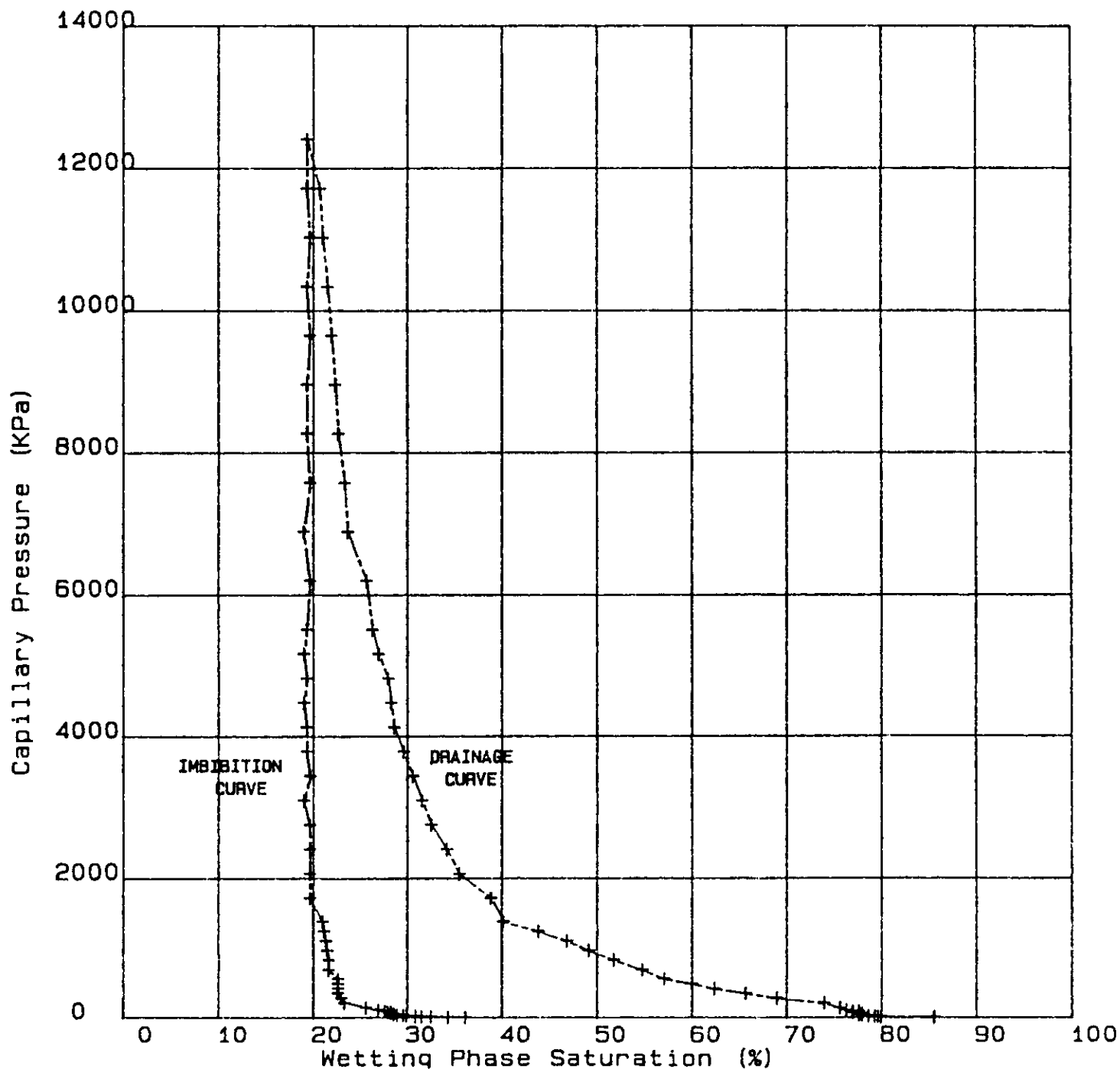
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ROXY PETROLEUMS LTD
ROXY ANDEX WHITEWATER
3-2-3-21W1

24 MAY 1984

MERCURY INJECTION CAPILLARY PRESSURE

| | | | |
|-------------------------|--------------------|---------------------|----------|
| FORMATION | : Upper Whitewater | | |
| Sample #15A | | Permeability | : 0.02mD |
| Depth | : 813.40m | Porosity | : 4.3% |
| Residual Wet Phase Sat. | : 23% | Recovery Efficiency | : 26% |



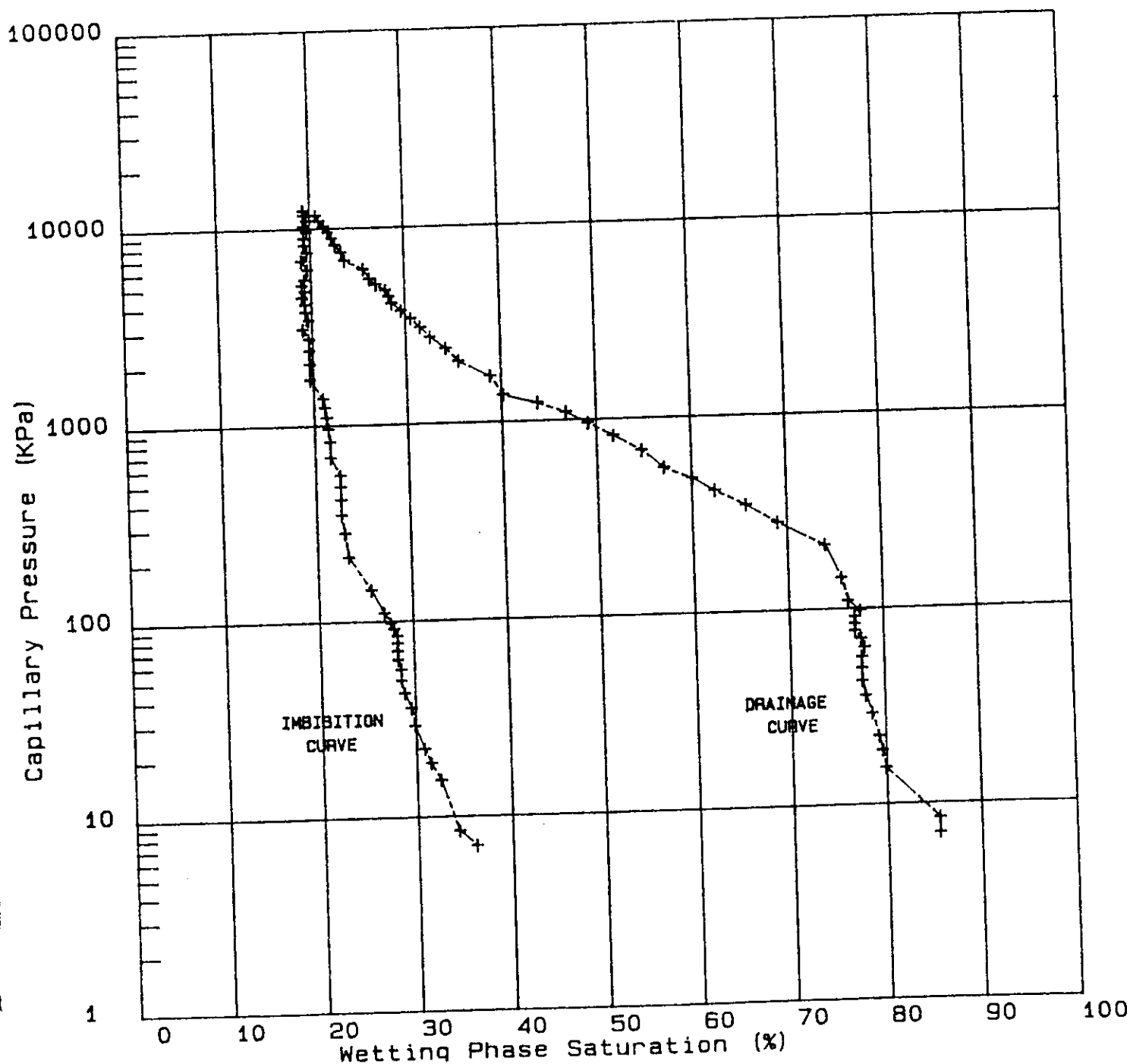
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ROXY PETROLEUMS LTD.
ROXY ANDEX WHITEWATER
3-2-3-21W1

24 MAY 1984

MERCURY INJECTION CAPILLARY PRESSURE

| | | | |
|--------------------------|--------------------|---------------------|----------|
| FORMATION | : Upper Whitewater | Permeability | : 0.02mD |
| Sample #15A | | Porosity | : 4.3% |
| Depth | : 813.40m | Recovery Efficiency | : 26% |
| Residual Wet. Phase Sat. | : 23% | | |



ROXY PETROLEUMS LTD
 ROXY ANDEX WHITEWATER
 3-2-3-21W1

DATE : 31 MAY 1984
 SAMPLE # 15A

PORE SIZE DISTRIBUTION DATA

Depth : 813.40 m
 Formation : UPPER WHITEWATER

Permeability : 0.02 mD
 Porosity : 4.3 %

| Pore Entry Radius (Microns) | Percent of Pore Space | | Pore Entry Radius (Microns) | Percent of Pore Space | |
|--------------------------------|--------------------------|------|--------------------------------|--------------------------|-------|
| Initial | 100.0 | | 25.00 | 78.0 | 0.0 |
| 50.00 | 79.3 | 20.7 | 24.00 | 77.9 | 0.1 |
| 49.00 | 79.3 | 0.0 | 23.00 | 77.8 | 0.1 |
| 48.00 | 79.3 | 0.0 | 22.00 | 77.8 | 0.0 |
| 47.00 | 79.3 | 0.0 | 21.00 | 77.7 | 0.1 |
| 46.00 | 79.2 | 0.1 | 20.00 | 77.6 | 0.1 |
| 45.00 | 79.2 | 0.0 | 19.00 | 77.6 | 0.0 |
| 44.00 | 79.2 | 0.0 | 18.00 | 77.6 | 0.0 |
| 43.00 | 79.1 | 0.1 | 17.00 | 77.6 | 0.0 |
| 42.00 | 79.1 | 0.0 | 16.00 | 77.6 | 0.0 |
| 41.00 | 79.0 | 0.1 | 15.00 | 77.6 | 0.0 |
| 40.00 | 79.0 | 0.0 | 14.00 | 77.8 | -0.2 |
| 39.00 | 79.0 | 0.0 | 13.00 | 78.0 | -0.2 |
| 38.00 | 78.9 | 0.1 | 12.00 | 77.8 | 0.2 |
| 37.00 | 78.9 | 0.0 | 11.00 | 77.3 | 0.5 |
| 36.00 | 78.8 | 0.1 | 10.00 | 77.0 | 0.3 |
| 35.00 | 78.7 | 0.1 | 9.00 | 77.0 | 0.0 |
| 34.00 | 78.7 | 0.0 | 8.00 | 77.5 | -0.5 |
| 33.00 | 78.6 | 0.1 | 7.00 | 76.3 | 1.2 |
| 32.00 | 78.6 | 0.0 | 6.00 | 76.0 | 0.3 |
| 31.00 | 78.5 | 0.1 | 5.00 | 75.4 | 0.6 |
| 30.00 | 78.4 | 0.1 | 4.00 | 74.6 | 0.8 |
| 29.00 | 78.3 | 0.1 | 3.00 | 71.2 | 3.4 |
| 28.00 | 78.2 | 0.1 | 2.00 | 64.6 | 6.6 |
| 27.00 | 78.1 | 0.1 | 1.00 | 53.8 | 10.8 |
| 26.00 | 78.0 | 0.1 | 0.06 | 19.7 | 34.1 |
| | | | 0.00 | 0.0 | 19.7 |
| | | | | | ----- |
| | | | | | 100.0 |

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ROXY ANDEX WHITEWATER
3-2-3-21W1

05 JUN 1984

PORE SIZE DISTRIBUTION

Formation : Upper Whitewater

Sample #15A

Porosity

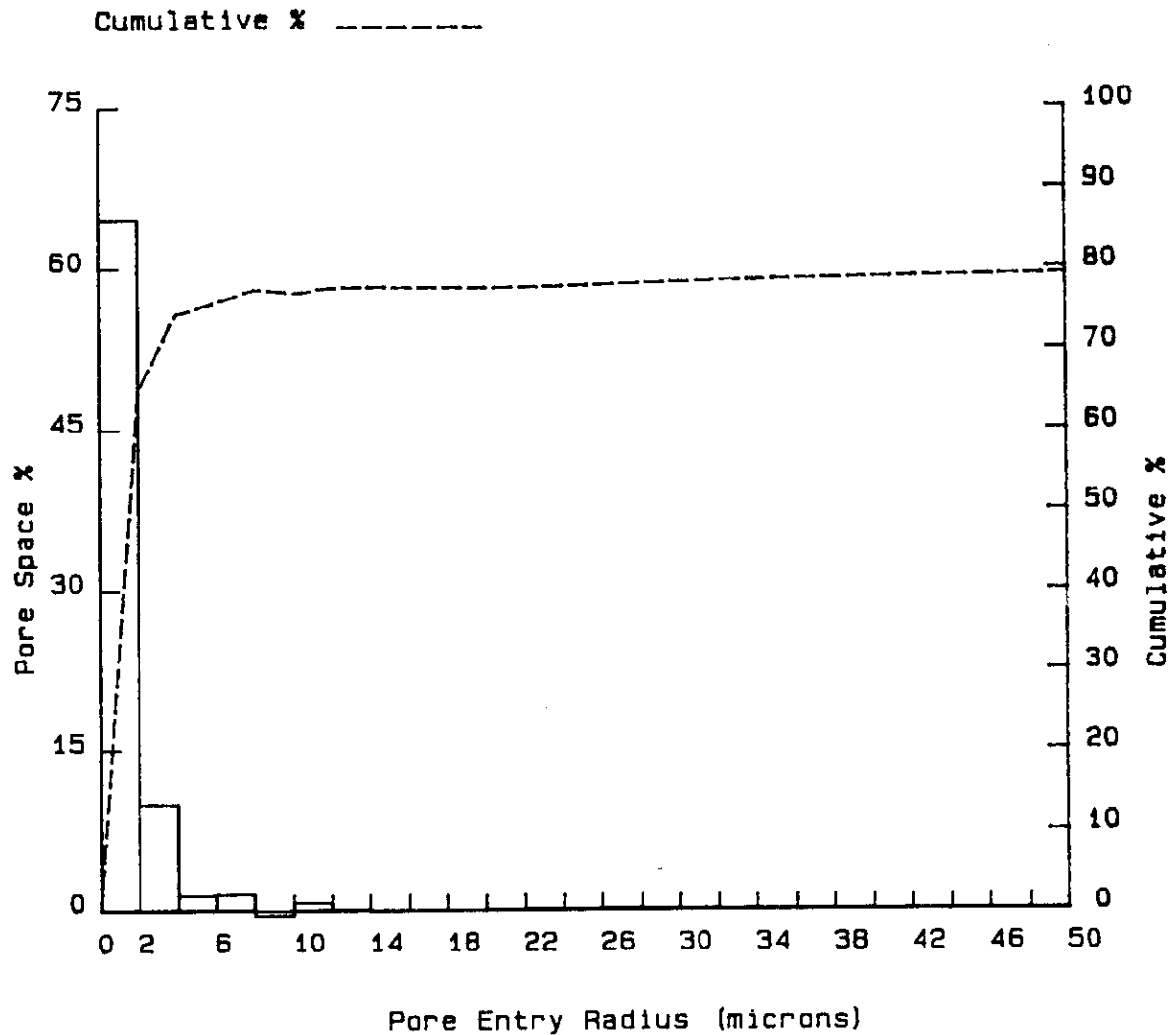
: 4.3%

Depth

: 813.40m

Permeability

: 0.02mD



ROXY PETROLEUMS LTD
 ROXY ANDEX WHITEWATER
 3-2-3-21W1

DATE : 05 JUN 1984
 SAMPLE # 15A

PORE SIZE DISTRIBUTION DATA

Depth : 813.40 m
 Formation : UPPER WHITEWATER

Permeability : 0.02 mD
 Porosity : 4.3 %

| Pore Entry Radius (Microns) | Percent of Pore Space | | Pore Entry Radius (Microns) | Percent of Pore Space | |
|--------------------------------|--------------------------|------|--------------------------------|--------------------------|-------|
| Initial | 100.0 | | 2.00 | 64.6 | 6.6 |
| 5.00 | 75.4 | 24.6 | 1.00 | 53.8 | 10.8 |
| 4.00 | 74.6 | 0.8 | 0.06 | 19.7 | 34.1 |
| 3.00 | 71.2 | 3.4 | 0.00 | 0.0 | 19.7 |
| | | | | | 100.0 |

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ROXY ANDEX WHITEWATER
3-2-3-21W1

05 JUN 1984

PORE SIZE DISTRIBUTION

Formation : Upper Whitewater

Sample #15A

Depth

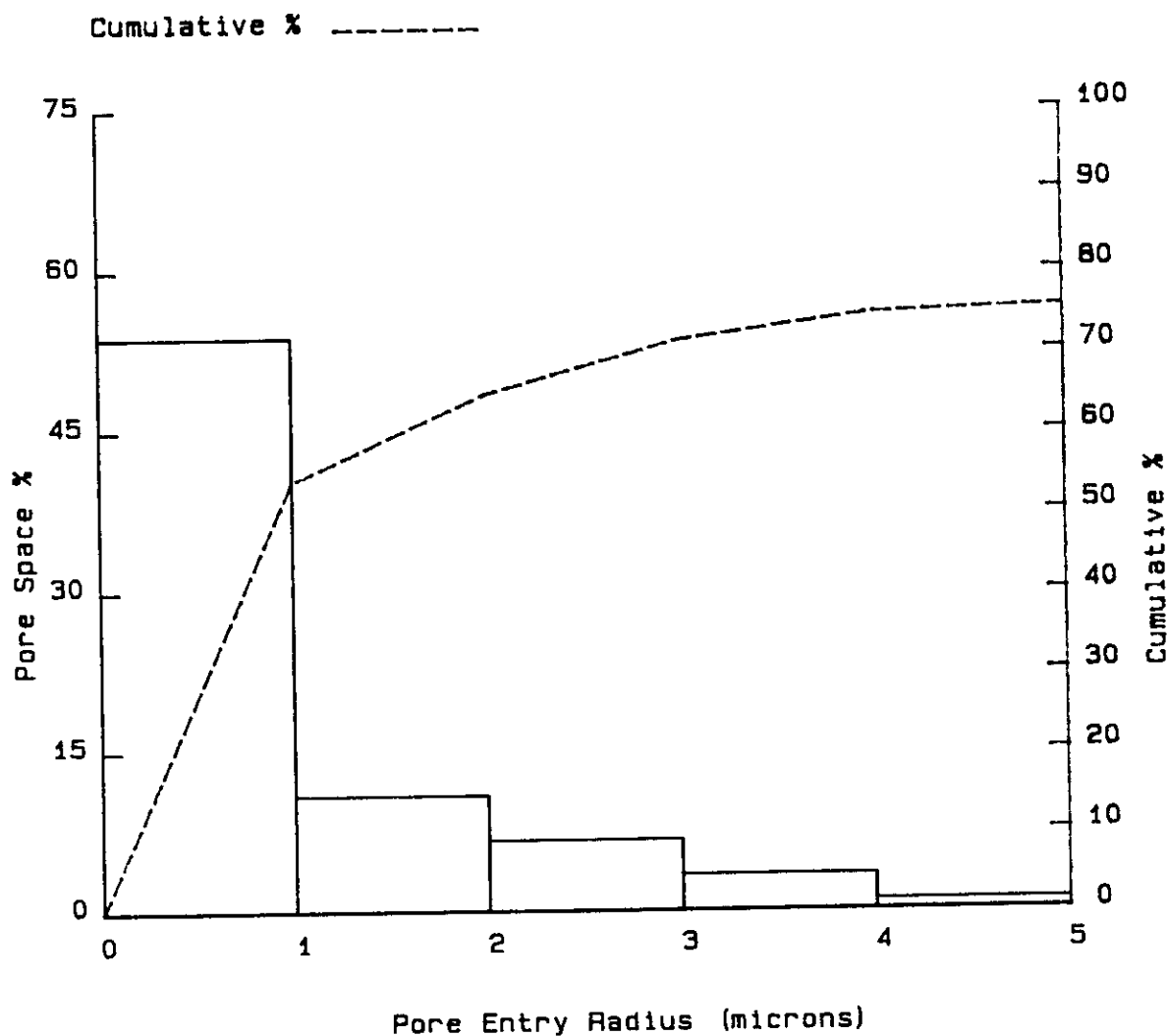
: 813.40m

Porosity

Permeability

: 4.3%

: 0.02mD



RELATIVE PERMEABILITY

A general description of Relative Permeability testing is provided in the Appendix. The experimental data and results are presented in the following tables and figures. The table containing the experimental data also includes the predictions of the "best-fit" history match.

When the oil production data was calculated, it was found that a good mass balance between injected fluids and produced fluids did not obtain. This problem was traced to a loss of oil during the separation of produced fluids; as much as 30% of the oil evaporated during this process alone, even though the separation was performed at ambient conditions. The oil production data was therefore corrected based on total injected fluids and produced water data. This correction was satisfactory for all samples except Sample #5A for which the correction was at best approximate. Because of the uncertainty in the data, this test was repeated. The results for Sample #5A are included in the present report; the results for the repeat test (Sample #5B) will follow at a later date.

The first table in the following collection of data contains a summary of the final results. The irreducible water saturations are based on the oil/brine capillary pressure tests performed in conjunction with the relative permeability tests. The residual oil saturations and end-point relative permeabilities were measured during the relative permeability tests and the relative permeability exponents were determined by history matching the experiment. Because of the very small amount of oil produced from Sample #14B and the very high pressure drop across the sample (at times the pressure drop was outside the range of the pressure transducer) no attempt was made to produce the relative permeability exponents. Sample #14B proved to have a considerably lower liquid permeability than originally suspected.

In all cases, including Sample #5A, a good match was obtained between the experimental and simulated data. The disagreements at early times for the pressure histories are due to uncertainties in the boundary condition at time zero; the time zero point is not used in determining the quality of the history match.

The relative permeability results are representative of a strongly water wet rock, with the end-point oil value being three-to-five times large than the end-point water value. All samples had medium to high end-point oil relative permeabilities (0.285 to 0.802) and low end-point water relative permeabilities (0.069 to 0.134). The water

relative permeabilities however are still sufficient to allow a waterflood to be performed. Comparing the data for samples from the two wells tested, there appears to be no systematic differences.

The water exponent for Sample 13B is not consistent with those for the remaining samples, being less than 1.0. This causes a convex upward relative permeability curve. On examination of this sample, it was found that a small fracture, that extended three quarters of the length, was present on one side of the plug. This fracture could lead to early breakthrough of water, a phenomenon which occurred in the experiment, which would cause the relative permeability exponent to decrease significantly. Excluding this one exponent, all other exponents, both for water and oil, show a remarkable consistency, being within 20% of 2.0.

Following the relative permeability data are tables and figures containing the oil/brine capillary pressure results used in the history matching simulations. These curves were determined by means of centrifugal techniques. Again these curves suggest a strongly water wet reservoir.

ROXY PETROLEUM LTD.

ROXY ANDEX WHITEWATER

3-2-3-21W1

13-2-3-21W1

SUMMARY OF RELATIVE PERMEABILITY DATA

| Sample # | Irreducible Water Saturation (S_w) | Residual Oil Saturation (S_o) | End-Point Water Rel. Perm. (K_{we}) | End-Point Oil Rel. Perm. (K_{oe}) | Rel. Water Perm. Exponent (n_w) | Rel. Oil Perm. Exponent (n_o) |
|----------|--|-----------------------------------|---|---------------------------------------|-------------------------------------|-----------------------------------|
| 57.02 5A | 0.204 | 0.112 | 0.0940 | 0.2849 | 2.1000 | 1.7160 |
| 58.9A | 0.256 | 0.254 | 0.1340 | 0.7192 | 2.0680 | 2.3240 |
| 44.4 13B | 0.294 | 0.256 | 0.0709 | 0.5711 | 0.4800 | 2.3448 |
| 14B | 0.578 | 0.404 | 0.0685 | 0.3892 | N/A | N/A |

ROXY PETROLEUM LTD.

ROXY ANDEX WHITEWATER
3-2-3-21W1

SAMPLE #5A

Depth: 810.06 m
Formation: Upper Whitewater

RELATIVE PERMEABILITY DATA

Core Parameters

| | |
|----------------------|----------------------|
| Length | 7.57 cm |
| Diameter | 2.52 cm ² |
| Cross-Sectional Area | 4.99 cm ² |
| Porosity | 0.170 |
| Pore Volume | 6.42 cm ³ |
| Liquid Permeability | 87.08 mD |

Fluid Properties

| | Water | Oil |
|----------------------|-----------------------------|---------------------------|
| Density | 1.079 gm/cm ³ | 0.8576 gm/cm ³ |
| Viscosity | 1.100 cp | 7.100 cp |
| Residual Saturation | 0.2040 | 0.1120 |
| End-Point Rel. Perm. | 0.0940 | 0.2849 |
| Rel. Perm. Exponent | 2.1000 | 1.7160 |
| Water Injection Rate | 0.200 cm ³ /min. | |

EXPERIMENTAL DATA

PREDICTION

| Time (min) | Water Production (cm ³) | Oil Production (cm ³) | Diff. Pressure (kPa) | Water Production (cm ³) | Oil Production (cm ³) | Diff. Pressure (kPa) |
|---------------|---|---|----------------------------|---|---|----------------------------|
| 1.0 | 0.00 | 0.19 | 169 | 0.00 | 0.19 | 123 |
| 11.0 | 0.00 | 2.19 | 120 | 0.00 | 2.19 | 135 |
| 21.0 | 1.40 | 2.79 | 109 | 0.94 | 3.25 | 112 |
| 51.0 | 6.73 | 3.47 | 92 | 6.35 | 3.84 | 84 |
| 61.0 | 8.44 | 3.75 | 81 | 8.26 | 3.92 | 81 |
| 71.0 | 10.11 | 4.09 | 75 | 10.20 | 3.98 | 79 |
| 81.0 | 11.80 | 4.39 | 75 | 12.15 | 4.02 | 77 |

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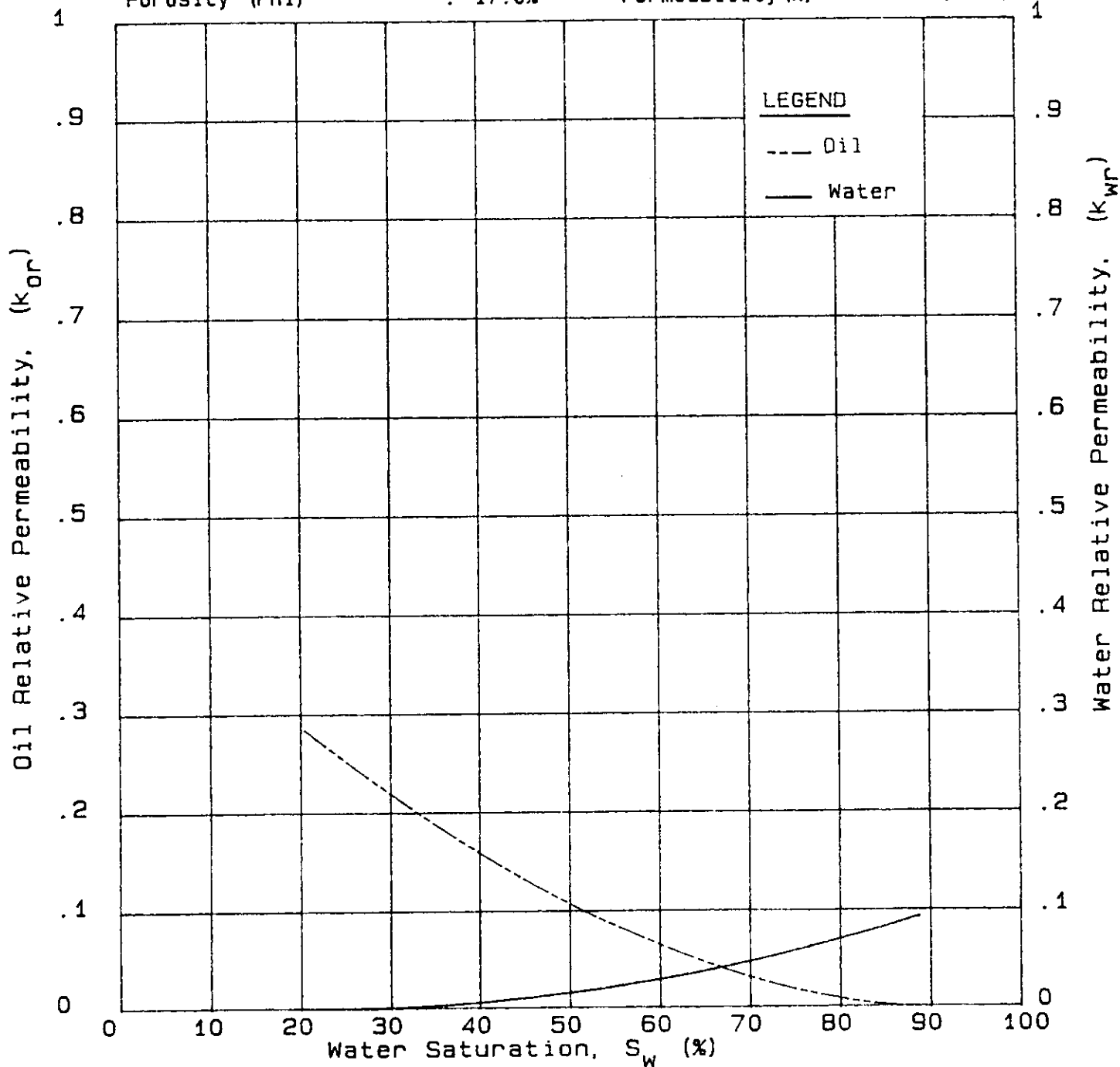
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ROXY ANDEX WHITEWATER
3-2-3-21W1

20 JUN 1984

RELATIVE PERMEABILITY (Standard Plot)

| | | | |
|-----------------------------|--------------------|----------------------------|-----------|
| DEPTH | : 810.06 m | SAMPLE # | 5A |
| FORMATION | : UPPER WHITEWATER | | |
| Irr. Wat. Sat. (S_{wr}) | : 0.204 | Res. Oil Sat. (S_{or}) | : 0.112 |
| End Wat. Perm. (k_{we}) | : 0.094 | End Oil Perm. (k_{pe}) | : 0.285 |
| Wat Exponent (n_w) | : 2.100 | Oil Exponent (n_o) | : 1.716 |
| Porosity (Φ) | : 17.0% | Permeability (k) | : 87.08mD |



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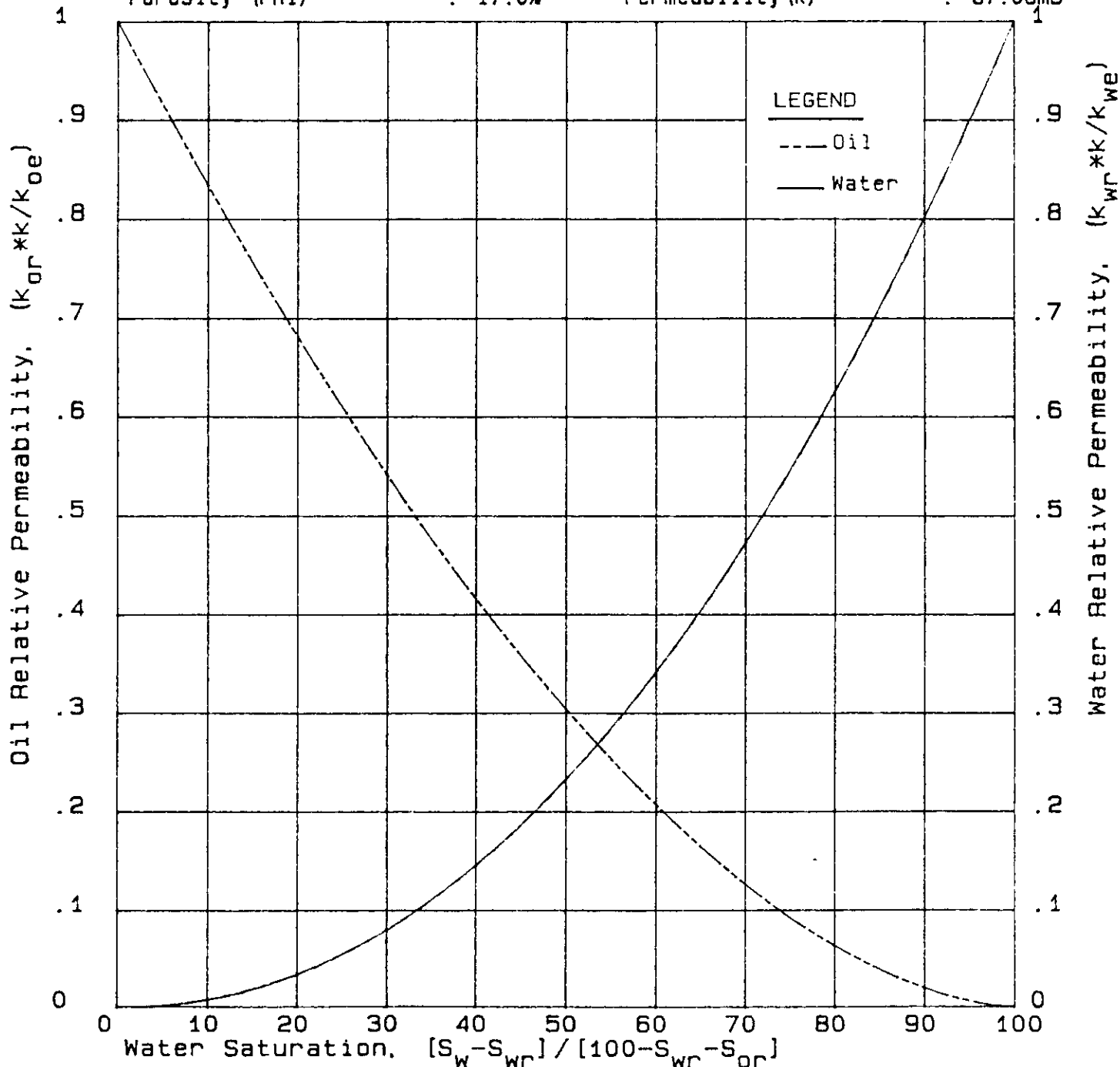
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ROXY ANDEX WHITEWATER
3-2-3-21W1

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RELATIVE PERMEABILITY (Normalized Plot)

| | | | |
|-----------------------------|--------------------|----------------------------|-----------|
| DEPTH | : 810.06 m | SAMPLE # | 5A |
| FORMATION | : UPPER WHITEWATER | | |
| Irr. Wat. Sat. (S_{wr}) | : 0.204 | Res. Oil Sat. (S_{or}) | : 0.112 |
| End Wat. Perm. (k_{we}) | : 0.094 | End Oil Perm. (k_{pe}) | : 0.285 |
| Wat Exponent (n_w) | : 2.100 | Oil Exponent (n_p) | : 1.716 |
| Porosity (Φ) | : 17.0% | Permeability (k) | : 87.08mD |



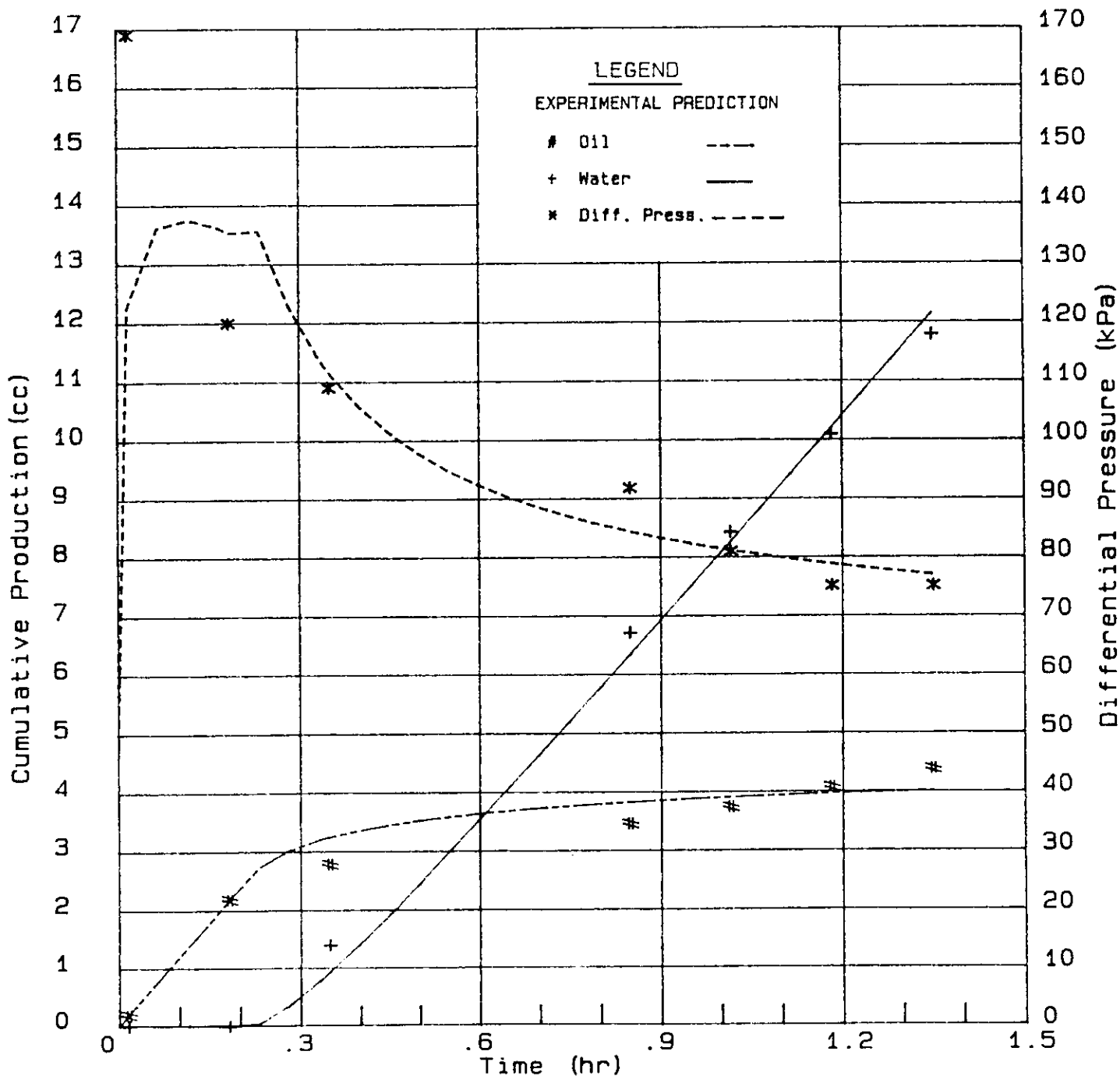
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3-2-3-21W1

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HISTORY MATCH

DEPTH : 810.06 m SAMPLE # 5A
FORMATION : UPPER WHITEWATER
Porosity (Phi) : 17.0% Permeability (k) : 87.08mD



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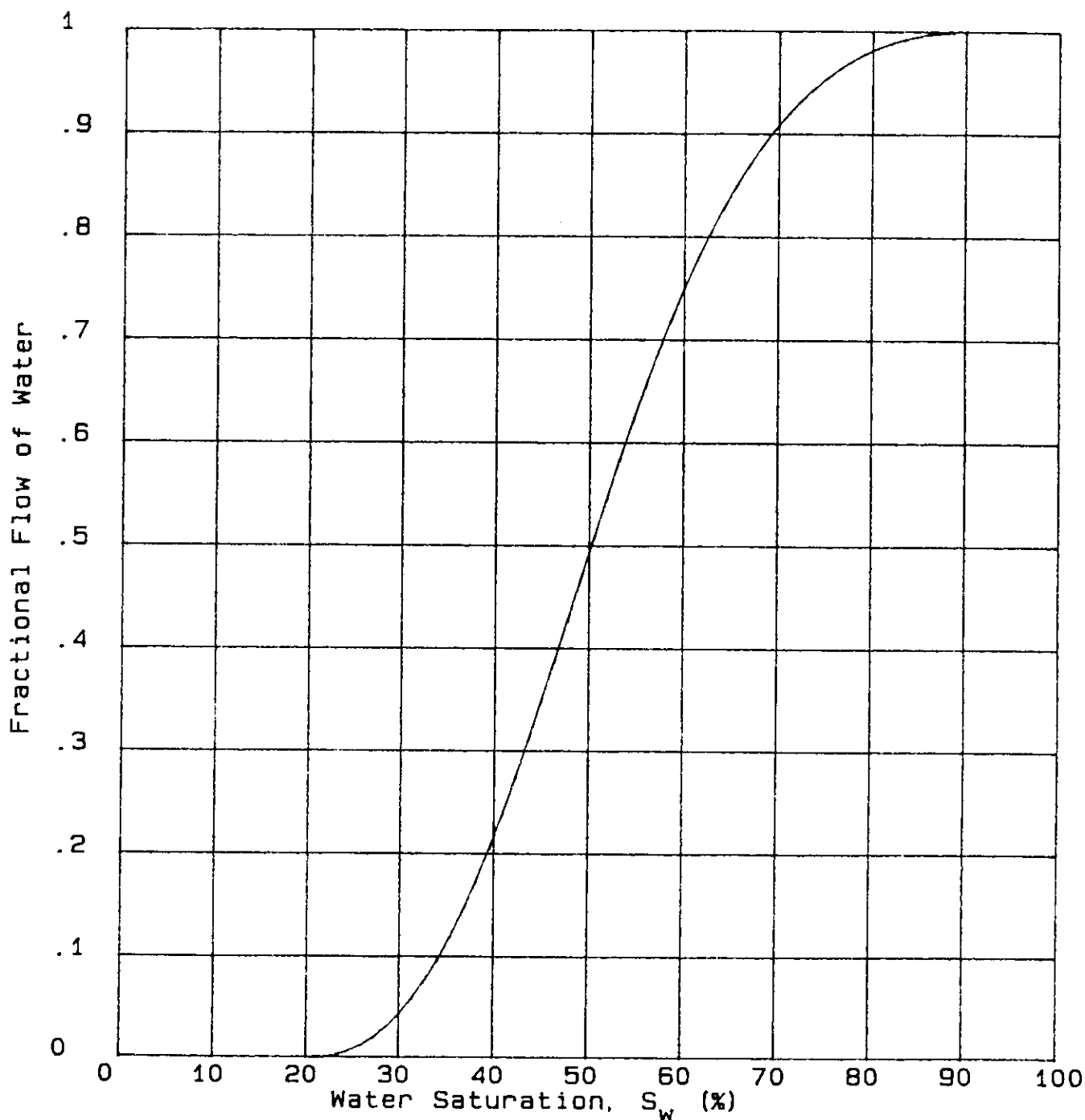
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ROXY ANDEX WHITEWATER
3-2-3-21W1

20 JUN 1984

FRACTIONAL FLOW

| | | | |
|-----------------------------|--------------------|----------------------------|-----------|
| DEPTH | : 810.06 m | SAMPLE # | 5A |
| FORMATION | : UPPER WHITEWATER | | |
| Irr. Wat. Sat. (S_{wr}) | : 0.204 | Res. Oil Sat. (S_{or}) | : 0.112 |
| Porosity (Φ) | : 17.0% | Permeability (k) | : 87.08mD |



ROXY PETROLEUM LTD.

ROXY ANDEX WHITEWATER

3-2-3-21W1

SAMPLE #5A

Depth: 810.06 m

Formation: Upper Whitewater

RELATIVE PERMEABILITY DATA
(Rock Properties)

| Water Saturation S_w | Water Relative Permeability K_{wr} | Oil Relative Permeability K_{or} |
|---------------------------|---|---------------------------------------|
| 0.204 | 0.0000 | 0.2849 |
| 0.238 | 0.0002 | 0.2609 |
| 0.272 | 0.0007 | 0.2378 |
| 0.307 | 0.0017 | 0.2156 |
| 0.341 | 0.0032 | 0.1943 |
| 0.375 | 0.0051 | 0.1739 |
| 0.409 | 0.0075 | 0.1545 |
| 0.443 | 0.0104 | 0.1360 |
| 0.478 | 0.0137 | 0.1186 |
| 0.512 | 0.0176 | 0.1021 |
| 0.546 | 0.0219 | 0.0867 |
| 0.580 | 0.0268 | 0.0724 |
| 0.614 | 0.0322 | 0.0591 |
| 0.649 | 0.0380 | 0.0470 |
| 0.683 | 0.0444 | 0.0361 |
| 0.717 | 0.0514 | 0.0264 |
| 0.751 | 0.0588 | 0.0180 |
| 0.785 | 0.0668 | 0.0110 |
| 0.820 | 0.0753 | 0.0055 |
| 0.854 | 0.0844 | 0.0017 |
| 0.888 | 0.0940 | 0.0000 |

ROXY PETROLEUM LTD.

ROXY ANDEX WHITEWATER
3-2-3-21W1

SAMPLE #9A

Depth: 812.25 m
Formation: Upper Whitewater

RELATIVE PERMEABILITY DATA

Core Parameters

| | |
|----------------------|----------------------|
| Length | 7.43 cm |
| Diameter | 2.51 cm ² |
| Cross-Sectional Area | 4.95 cm ² |
| Porosity | 0.102 |
| Pore Volume | 3.73 cm ³ |
| Liquid Permeability | 58.28 mD |

Fluid Properties

| | Water | Oil |
|----------------------|-----------------------------|---------------------------|
| Density | 1.079 gm/cm ³ | 0.8576 gm/cm ³ |
| Viscosity | 1.100 cp | 7.100 cp |
| Residual Saturation | 0.2560 | 0.2540 |
| End-Point Rel. Perm. | 0.1340 | 0.7192 |
| Rel. Perm. Exponent | 2.0680 | 2.3240 |
| Water Injection Rate | 0.200 cm ³ /min. | |

EXPERIMENTAL DATA

PREDICTION

| Time (min) | Water Production (cm ³) | Oil Production (cm ³) | Diff. Pressure (kPa) | Water Production (cm ³) | Oil Production (cm ³) | Diff. Pressure (kPa) |
|---------------|---|---|----------------------------|---|---|----------------------------|
| 2.4 | 0.00 | 0.48 | 101 | 0.00 | 0.48 | 100 |
| 12.4 | 1.24 | 1.24 | 110 | 1.04 | 1.44 | 106 |
| 22.4 | 3.05 | 1.42 | 98 | 2.92 | 1.55 | 93 |
| 30.7 | 4.91 | 1.57 | 93 | 4.54 | 1.60 | 88 |
| 40.7 | 6.85 | 1.63 | 81 | 6.50 | 1.63 | 84 |
| 50.7 | 8.73 | 1.75 | 72 | 8.48 | 1.66 | 82 |
| 60.7 | 10.67 | 1.81 | 74 | 10.46 | 1.68 | 80 |
| 70.7 | 12.65 | 1.83 | 78 | 12.44 | 1.69 | 79 |

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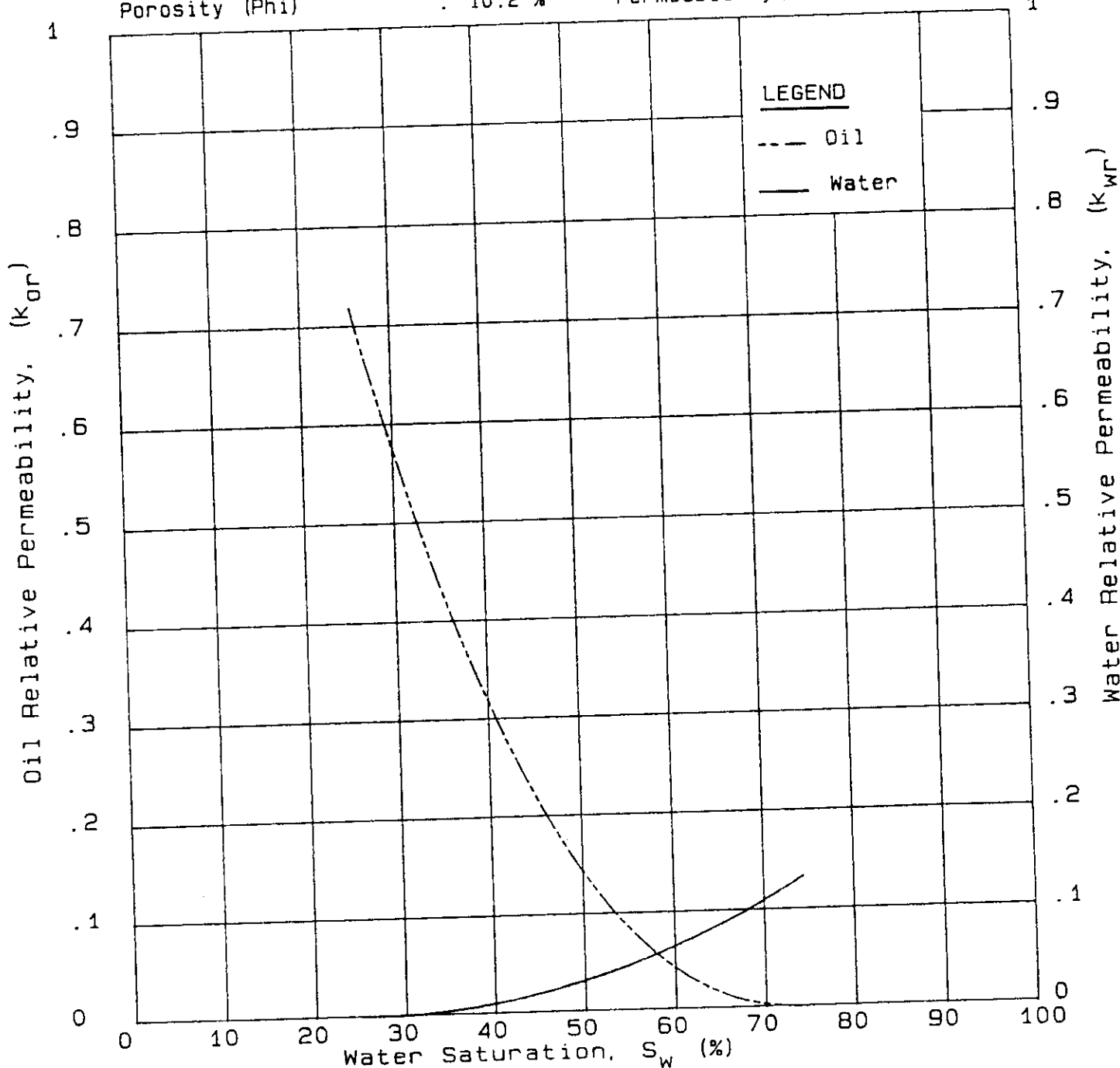
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ROXY ANDEX WHITEWATER
3-2-3-21W1

19 JUN 1984

RELATIVE PERMEABILITY (Standard Plot)

DEPTH : 812.25 m
FORMATION : UPPER WHITEWATER
Irr. Wat. Sat. (S_{wr}) : 0.256 Res. Oil Sat. (S_{or}) : 0.254
End Wat. Perm. (k_{we}) : 0.134 End Oil Perm. (k_{oe}) : 0.719
Wat Exponent (n_w) : 2.068 Oil Exponent (n_o) : 2.324
Porosity (Φ) : 10.2 % Permeability (k) : 58.28 mD

SAMPLE # 9A



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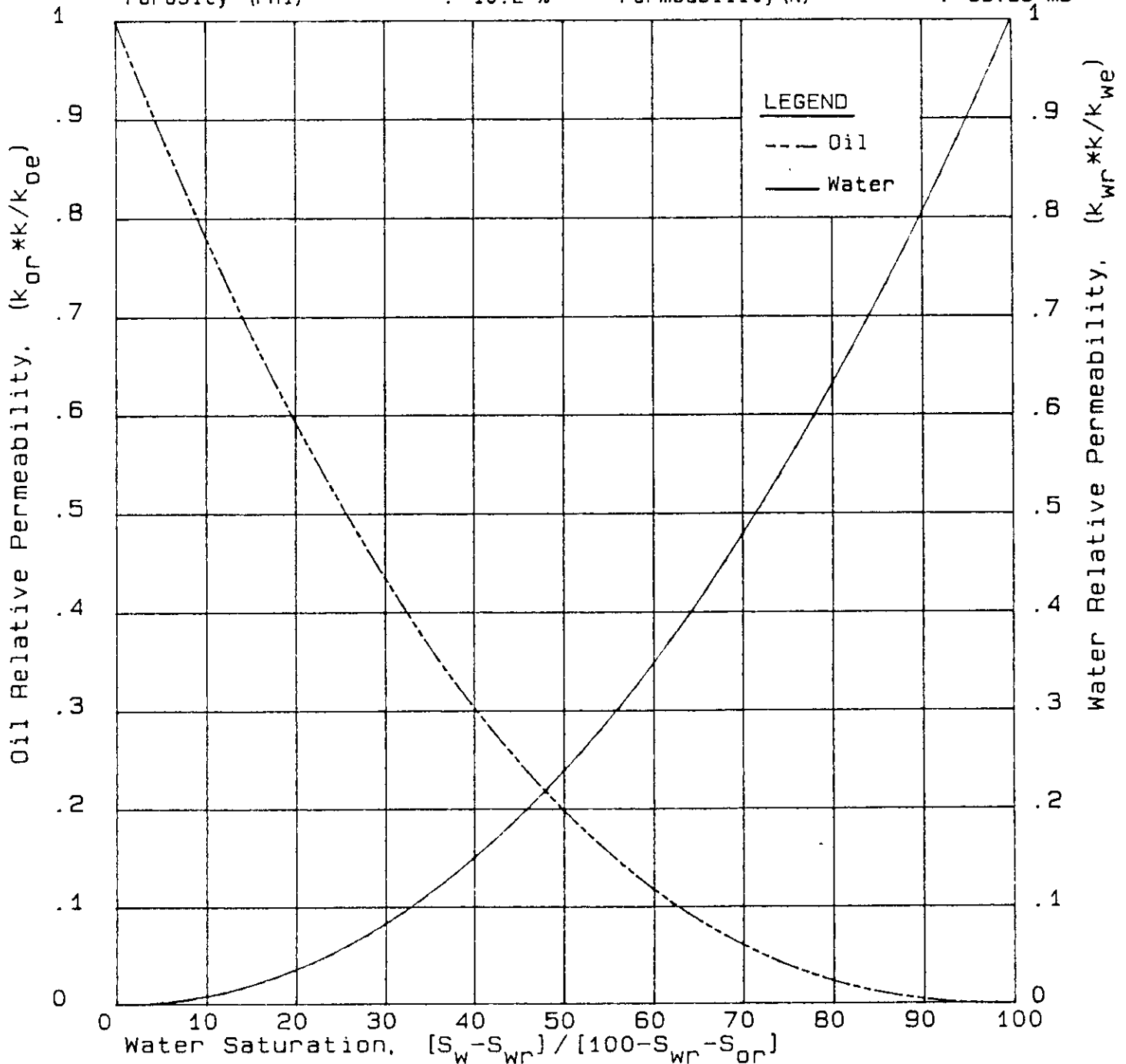
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ROXY ANDEX WHITEWATER
3-2-3-21W1

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RELATIVE PERMEABILITY (Normalized Plot)

| | | | |
|-----------------------------|--------------------|----------------------------|------------|
| DEPTH | : 812.25 m | SAMPLE # | 9A |
| FORMATION | : UPPER WHITEWATER | | |
| Irr. Wat. Sat. (S_{wr}) | : 0.256 | Res. Oil Sat. (S_{or}) | : 0.254 |
| End Wat. Perm. (k_{we}) | : 0.134 | End Oil Perm. (k_{oe}) | : 0.719 |
| Wat Exponent (n_w) | : 2.068 | Oil Exponent (n_o) | : 2.324 |
| Porosity (Φ) | : 10.2 % | Permeability (k) | : 58.28 mD |



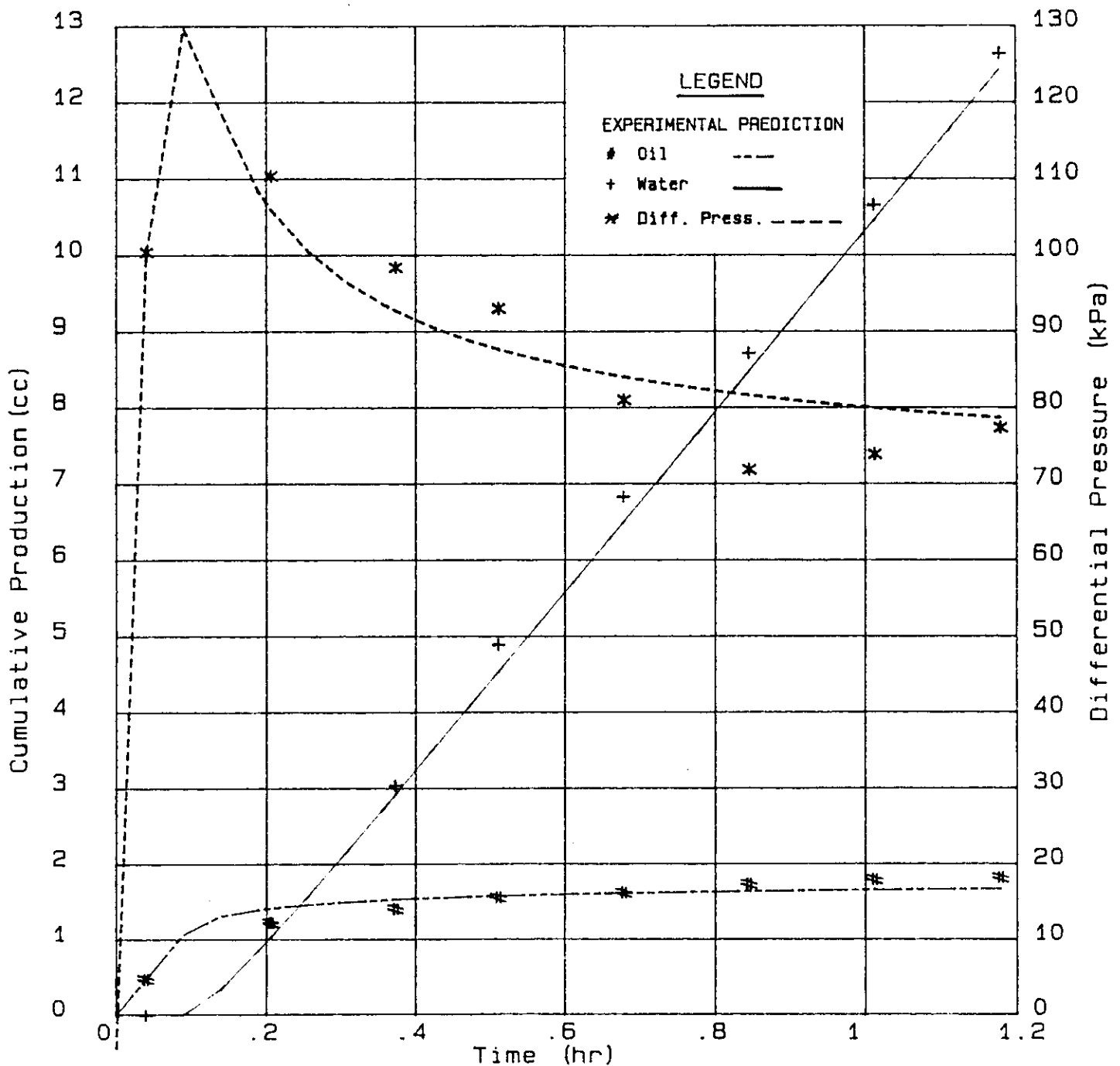
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HISTORY MATCH

DEPTH : 812.25 m SAMPLE # 9A
FORMATION : UPPER WHITEWATER
Porosity (Phi) : 10.2 % Permeability (k) : 58.28 mD



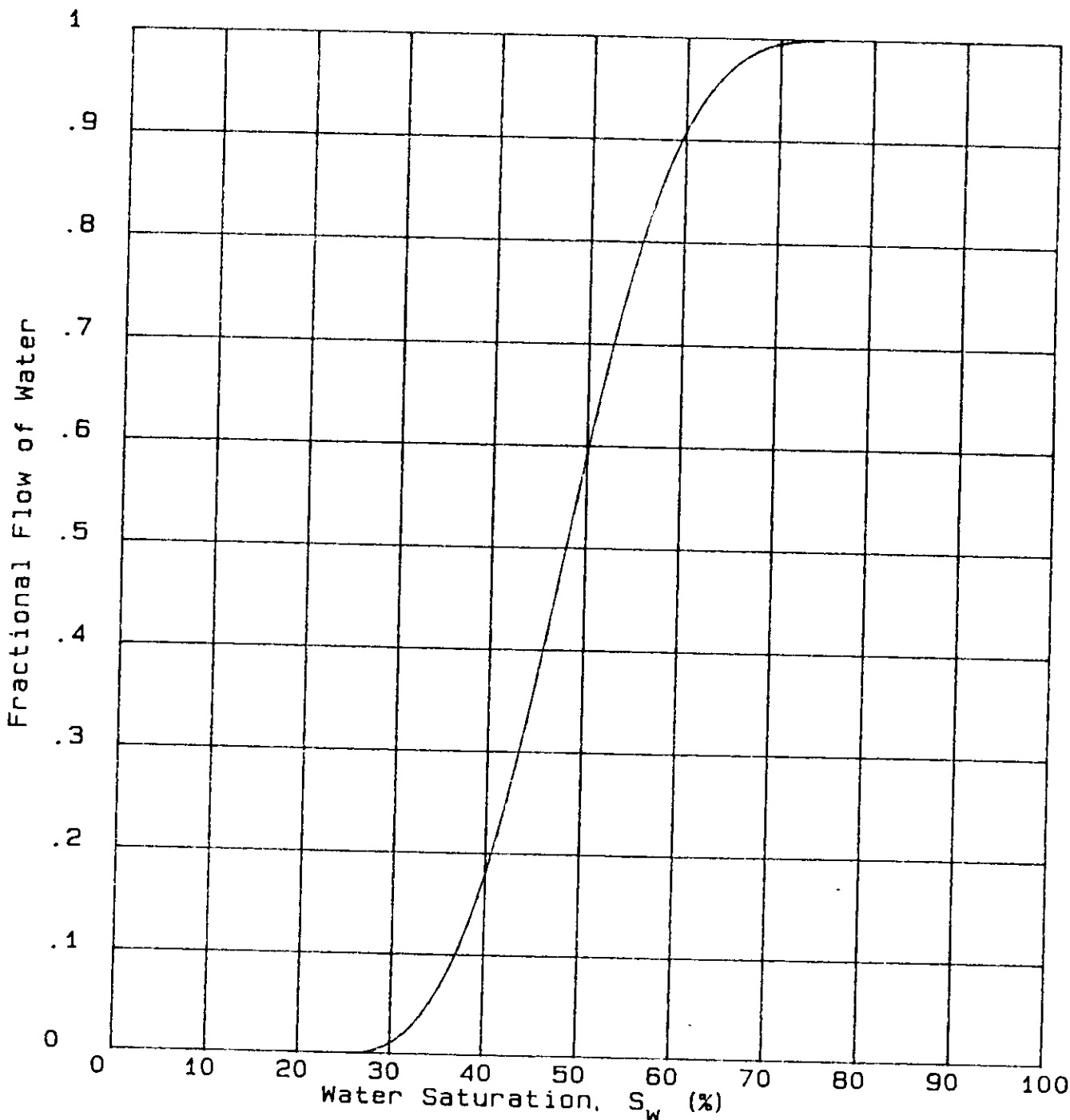
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ROXY ANDEX WHITEWATER
3-2-3-21W1

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FRACTIONAL FLOW

| | | | |
|-----------------------------|--------------------|----------------------------|------------|
| DEPTH | : 812.25 m | SAMPLE # | 9A |
| FORMATION | : UPPER WHITEWATER | | |
| Irr. Wat. Sat. (S_{wr}) | : 0.256 | Res. Oil Sat. (S_{or}) | : 0.254 |
| Porosity (Φ) | : 10.2 % | Permeability (k) | : 58.28 mD |



ROXY PETROLEUM LTD.

ROXY ANDEX WHITEWATER
3-2-3-21W1

SAMPLE #9A

Depth: 812.25 m
Formation: Upper Whitewater

RELATIVE PERMEABILITY DATA
(Rock Properties)

| Water Saturation S_w | Water Relative Permeability K_{wr} | Oil Relative Permeability K_{or} |
|---------------------------|---|---------------------------------------|
| 0.256 | 0.0000 | 0.7192 |
| 0.281 | 0.0003 | 0.6384 |
| 0.305 | 0.0011 | 0.5630 |
| 0.330 | 0.0027 | 0.4930 |
| 0.354 | 0.0048 | 0.4282 |
| 0.379 | 0.0076 | 0.3685 |
| 0.403 | 0.0111 | 0.3139 |
| 0.428 | 0.0153 | 0.2643 |
| 0.452 | 0.0201 | 0.2194 |
| 0.477 | 0.0257 | 0.1792 |
| 0.501 | 0.0320 | 0.1436 |
| 0.526 | 0.0389 | 0.1124 |
| 0.550 | 0.0466 | 0.0855 |
| 0.575 | 0.0550 | 0.0627 |
| 0.599 | 0.0641 | 0.0438 |
| 0.624 | 0.0739 | 0.0287 |
| 0.648 | 0.0845 | 0.0171 |
| 0.673 | 0.0958 | 0.0088 |
| 0.679 | 0.1078 | 0.0034 |
| 0.722 | 0.1205 | 0.0007 |
| 0.746 | 0.1340 | 0.0000 |

ROXY PETROLEUM LTD.

ROXY ANDEX WHITEWATER
13-2-3-21W1

SAMPLE #13B

Depth: 795.26 m
Formation: Lodgepole

RELATIVE PERMEABILITY DATA

Core Parameters

| | |
|----------------------|----------------------|
| Length | 7.62 cm |
| Diameter | 2.54 cm |
| Cross-Sectional Area | 5.07 cm ² |
| Porosity | 0.183 |
| Pore Volume | 7.08 cm ³ |
| Liquid Permeability | 44.40 mD |

Fluid Properties

| | Water | Oil |
|----------------------|-----------------------------|---------------------------|
| Density | 1.079 gm/cm ³ | 0.8576 gm/cm ³ |
| Viscosity | 1.100 cp | 7.100 cp |
| Residual Saturation | 0.2940 | 0.2560 |
| End-Point Rel. Perm. | 0.0709 | 0.5711 |
| Rel. Perm. Exponent | 0.4800 | 2.3448 |
| Water Injection Rate | 0.200 cm ³ /min. | |

EXPERIMENTAL DATA

PREDICTION

| Time (min) | Water Production (cm ³) | Oil Production (cm ³) | Diff. Pressure (kPa) | Water Production (cm ³) | Oil Production (cm ³) | Diff. Pressure (kPa) |
|---------------|---|---|----------------------------|---|---|----------------------------|
| 10.8 | 0.58 | 1.58 | 177 | 0.40 | 1.76 | 171 |
| 22.8 | 2.44 | 2.12 | 182 | 2.15 | 2.41 | 179 |
| 34.8 | 4.41 | 2.55 | 178 | 4.33 | 2.63 | 178 |
| 46.8 | 6.49 | 2.87 | 172 | 6.61 | 2.74 | 176 |
| 58.8 | 8.58 | 3.18 | 168 | 8.94 | 2.81 | 175 |

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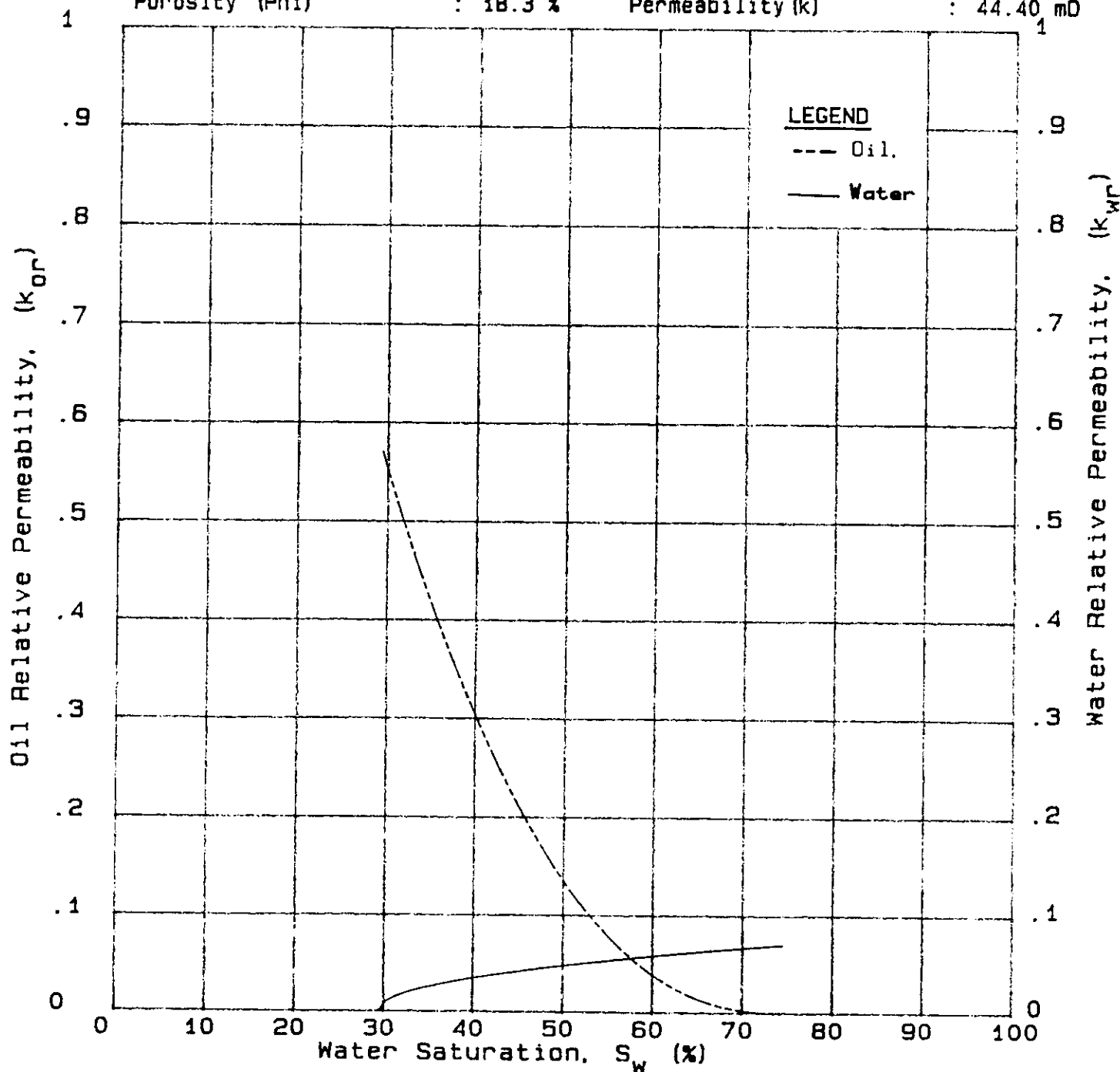
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ROXY ANDEX WHITEWATER
13-2-3-21W1

22 JUN 1984

RELATIVE PERMEABILITY

(Standard Plot)

| | | | |
|-----------------------------|-------------|----------------------------|------------|
| DEPTH | : 795.26 m | SAMPLE # | 138 |
| FORMATION | : Lodgepole | | |
| Irr. Wat. Sat. (S_{wr}) | : 0.294 | Res. Oil Sat. (S_{or}) | : 0.256 |
| End Wat. Perm. (k_{we}) | : 0.071 | End Oil Perm. (k_{oe}) | : 0.571 |
| Wat Exponent (n_w) | : 0.480 | Oil Exponent (n_o) | : 2.345 |
| Porosity (Φ) | : 18.3 % | Permeability (k) | : 44.40 mD |



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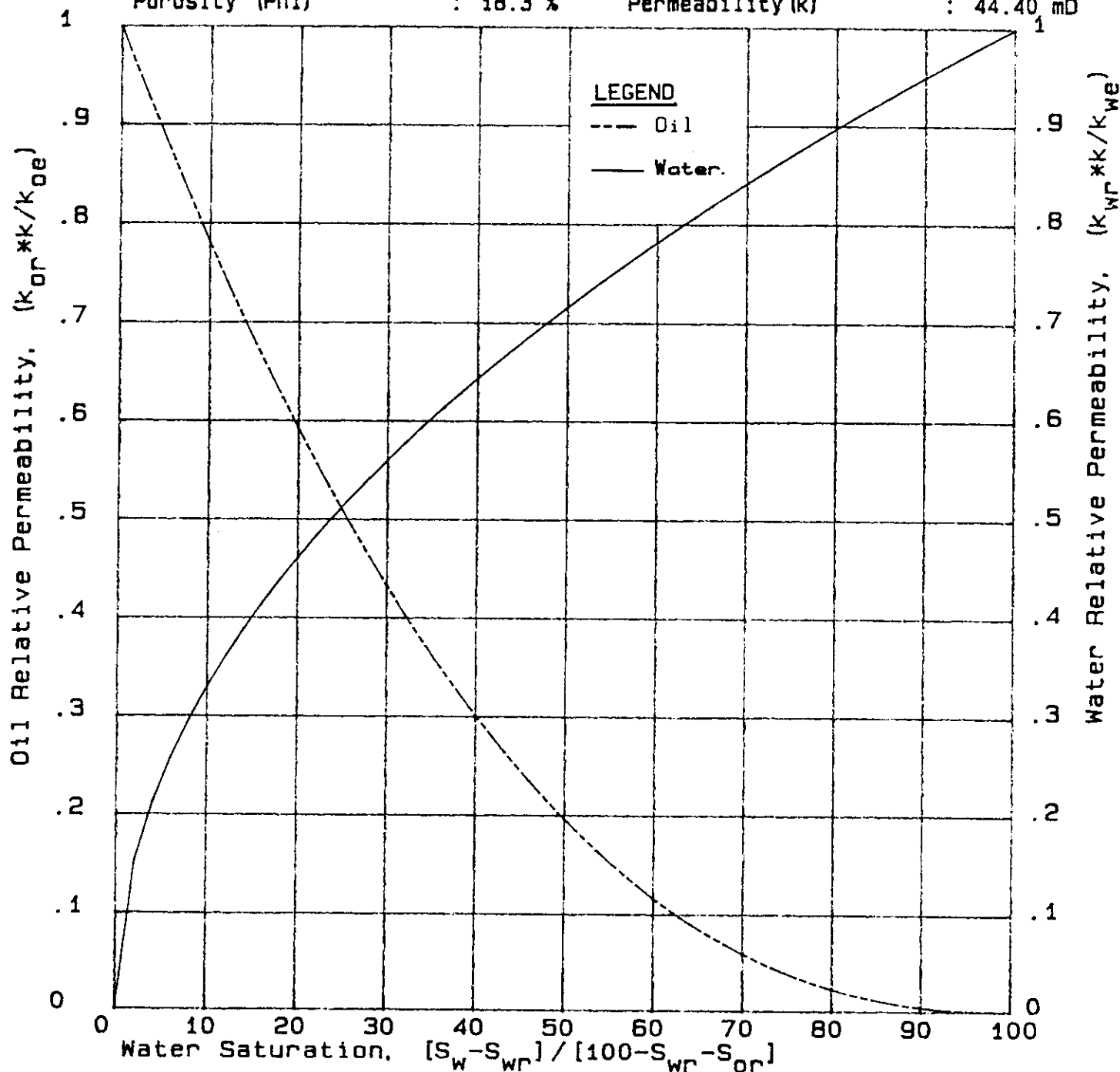
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ROXY ANDEX WHITEWATER
13-2-3-21W1

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RELATIVE PERMEABILITY

(Normalized Plot)

| | | | |
|-----------------------------|-------------|----------------------------|------------|
| DEPTH | : 795.26 m | SAMPLE # | 138 |
| FORMATION | : Lodgepole | | |
| Irr. Wat. Sat. (S_{wr}) | : 0.294 | Res. Oil Sat. (S_{or}) | : 0.256 |
| End Wat. Perm. (k_{we}) | : 0.071 | End Oil Perm. (k_{pe}) | : 0.571 |
| Wat Exponent (n_w) | : 0.480 | Oil Exponent (n_p) | : 2.345 |
| Porosity (Φ) | : 18.3 % | Permeability (k) | : 44.40 mD |



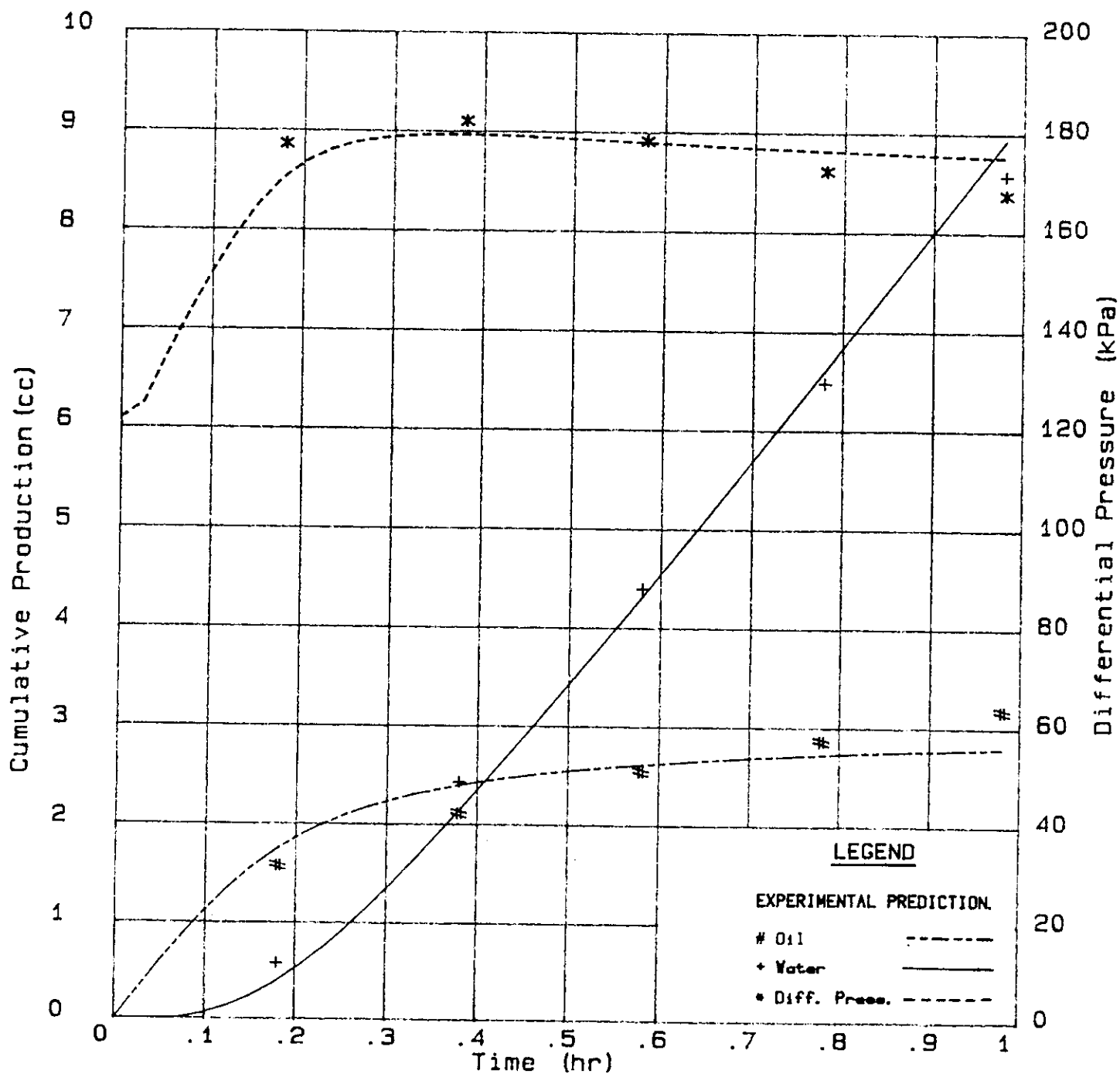
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HISTORY MATCH

DEPTH : 795.26 m SAMPLE # 13B
FORMATION : Lodgepole
Porosity (Phi) : 18.3 % Permeability (k) : 44.40 mD



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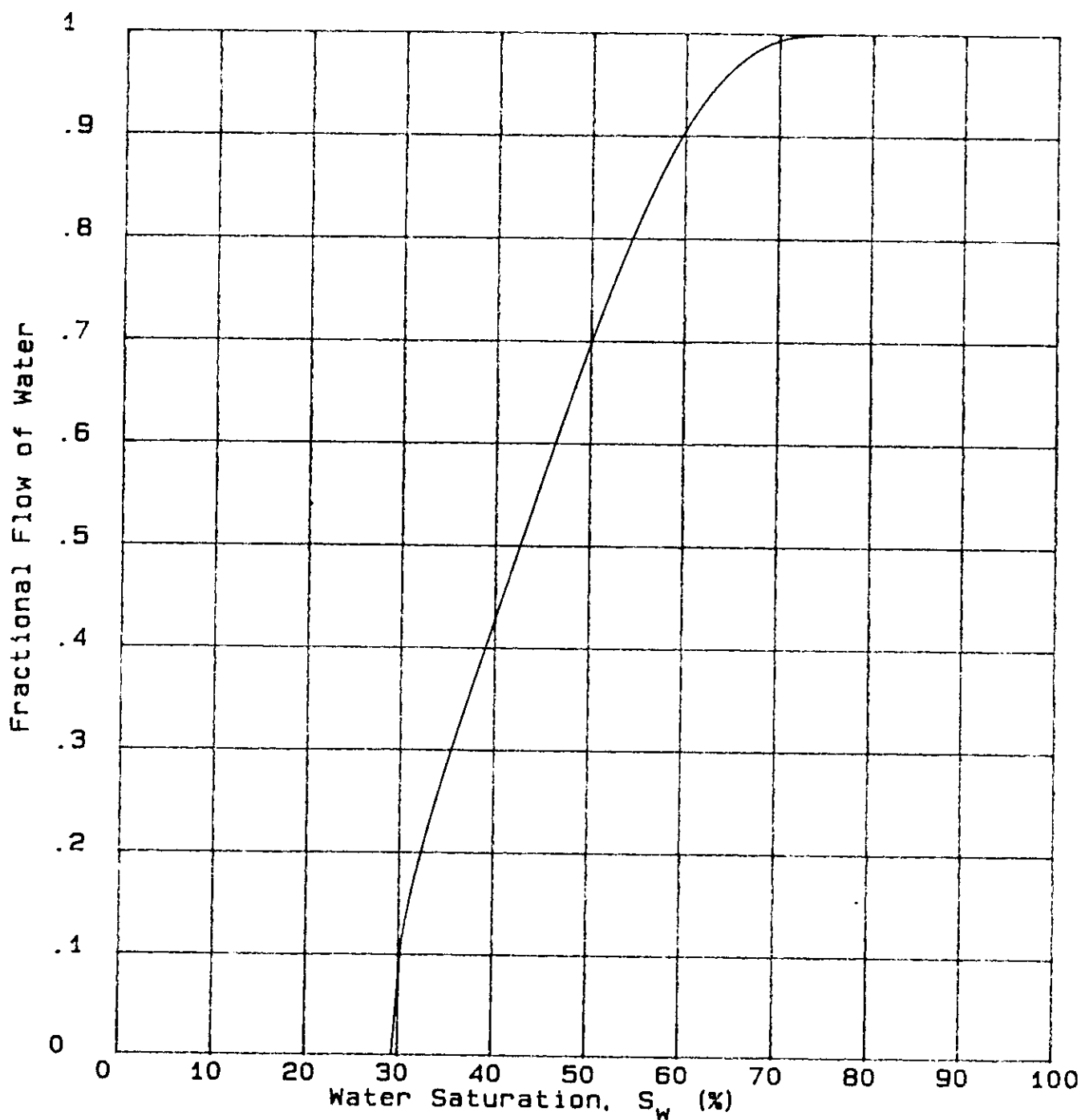
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ROXY ANDEX WHITEWATER
13-2-3-21W1

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FRACTIONAL FLOW

| | | | |
|-----------------------------|-------------|----------------------------|------------|
| DEPTH | : 795.26 m | SAMPLE # | 138 |
| FORMATION | : Lodgepole | | |
| Irr. Wat. Sat. (S_{wr}) | : 0.294 | Res. Oil Sat. (S_{or}) | : 0.256 |
| Porosity (Φ) | : 18.3 % | Permeability (k) | : 44.40 mD |



ROXY PETROLEUM LTD.

ROXY ANDEX WHITEWATER
13-2-3-21W1

SAMPLE #13B

Depth: 795.26 m
Formation: Lodgepole

RELATIVE PERMEABILITY DATA
(Rock Properties)

| Water Saturation S_w | Water Relative Permeability K_{wr} | Oil Relative Permeability K_{or} |
|---------------------------|---|---------------------------------------|
| 0.294 | 0.0001 | 0.5711 |
| 0.317 | 0.0168 | 0.5064 |
| 0.339 | 0.0235 | 0.4461 |
| 0.362 | 0.0285 | 0.3901 |
| 0.384 | 0.0327 | 0.3384 |
| 0.407 | 0.0364 | 0.2909 |
| 0.429 | 0.0398 | 0.2475 |
| 0.452 | 0.0428 | 0.2080 |
| 0.474 | 0.0457 | 0.1724 |
| 0.497 | 0.0483 | 0.1406 |
| 0.519 | 0.0508 | 0.1124 |
| 0.542 | 0.0532 | 0.0878 |
| 0.564 | 0.0555 | 0.0666 |
| 0.587 | 0.0577 | 0.0487 |
| 0.609 | 0.0597 | 0.0339 |
| 0.632 | 0.0618 | 0.0221 |
| 0.654 | 0.0637 | 0.0131 |
| 0.677 | 0.0656 | 0.0067 |
| 0.699 | 0.0674 | 0.0026 |
| 0.722 | 0.0692 | 0.0005 |
| 0.744 | 0.0709 | 0.0000 |

OIL/BRINE CAPILLARY PRESSURE

ROXY PETROLEUM LTD.

ROXY ANDEX WHITEWATER
3-2-3-21W1

SAMPLE #5A

Formation: Upper Whitewater
Depth: 810.06 m

Porosity percent: 17.0
Permeability mD: 87.08
Grain Density kg/m³: 2693

OIL/BRINE CAPILLARY PRESSURE DATA

Capillary Pressure
(PSIG) (kPa)

Brine Saturation
(%)

| | | |
|-------|-------|-------|
| 0.00 | 0.00 | 97.29 |
| 0.25 | 1.72 | 84.15 |
| 0.50 | 3.45 | 65.51 |
| 1.00 | 6.89 | 54.00 |
| 2.00 | 13.79 | 43.75 |
| 3.00 | 20.68 | 36.90 |
| 5.00 | 34.47 | 31.50 |
| 9.00 | 62.05 | 23.80 |
| 12.50 | 86.18 | 20.39 |

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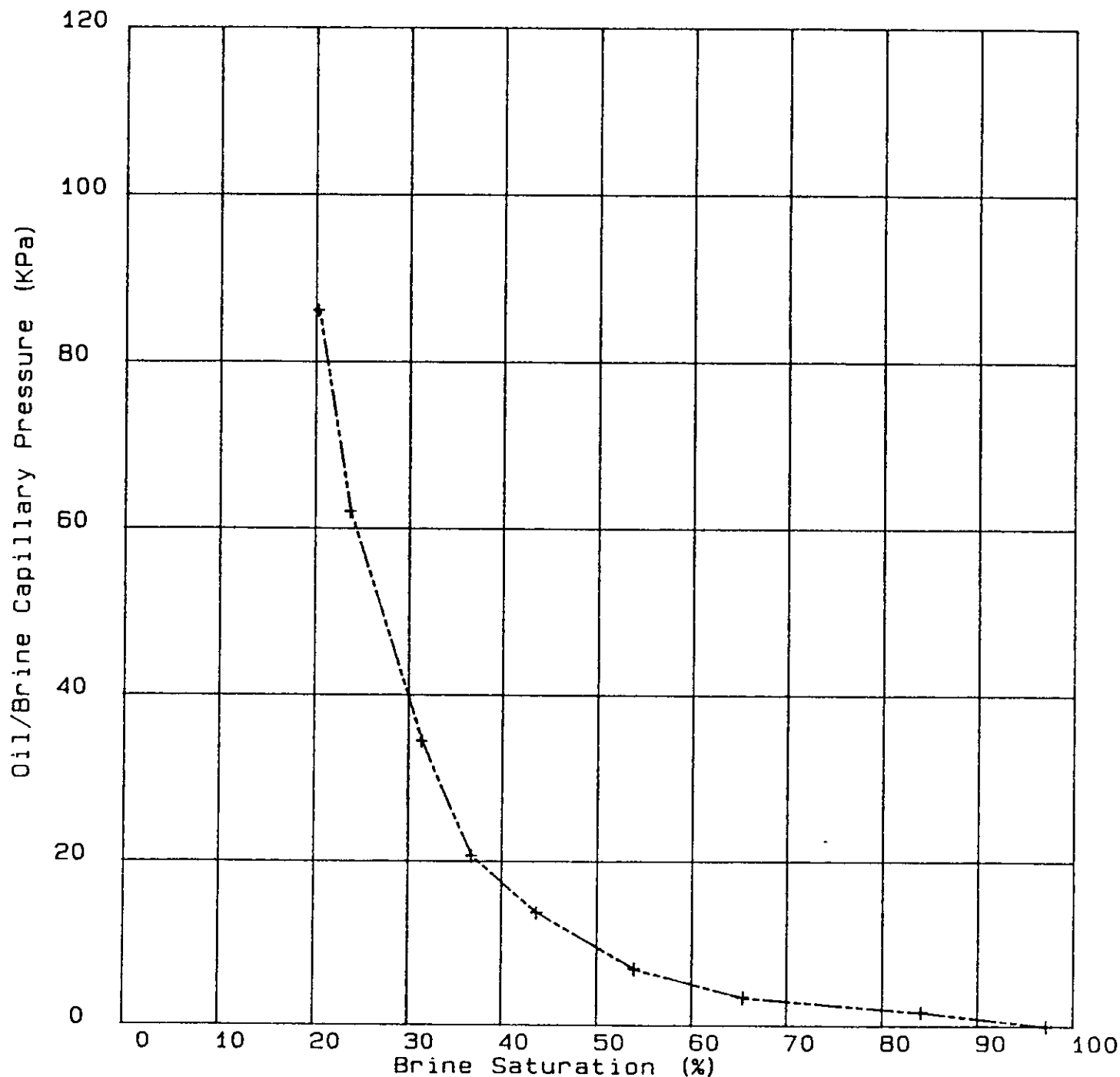
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ROXY ANDEX WHITEWATER
3-2-3-21W1

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RESTORED STATE CAPILLARY PRESSURE (OIL/BRINE)

| | | | |
|---------------------|--------------------|------------------------|-----------|
| FORMATION | : Upper Whitewater | | |
| Sample #5A | | Liquid Permeability | : 87.08mD |
| Depth | : 810.06m | Porosity | : 17.0% |
| Interfacial Tension | : 17.1mN/m | Irreducible Brine Sat. | : 20% |



ROXY PETROLEUM LTD.

ROXY ANDEX WHITEWATER
3-2-3-21W1

SAMPLE #9A

Formation: Upper Whitewater
Depth: 812.25 m

Porosity percent: 10.2
Permeability mD: 58.27
Grain Density kg/m³: 2740

OIL/BRINE CAPILLARY PRESSURE DATA

Capillary Pressure
(PSIG) (kPa)

Brine Saturation
(%)

| | |
|-------|-------|
| 0.00 | 0.00 |
| 0.25 | 1.72 |
| 0.50 | 3.45 |
| 1.00 | 6.90 |
| 2.00 | 13.79 |
| 3.00 | 20.68 |
| 5.00 | 34.47 |
| 9.00 | 62.05 |
| 12.50 | 86.18 |

| |
|-------|
| 97.25 |
| 86.75 |
| 62.75 |
| 54.27 |
| 45.00 |
| 40.25 |
| 35.20 |
| 28.65 |
| 25.60 |

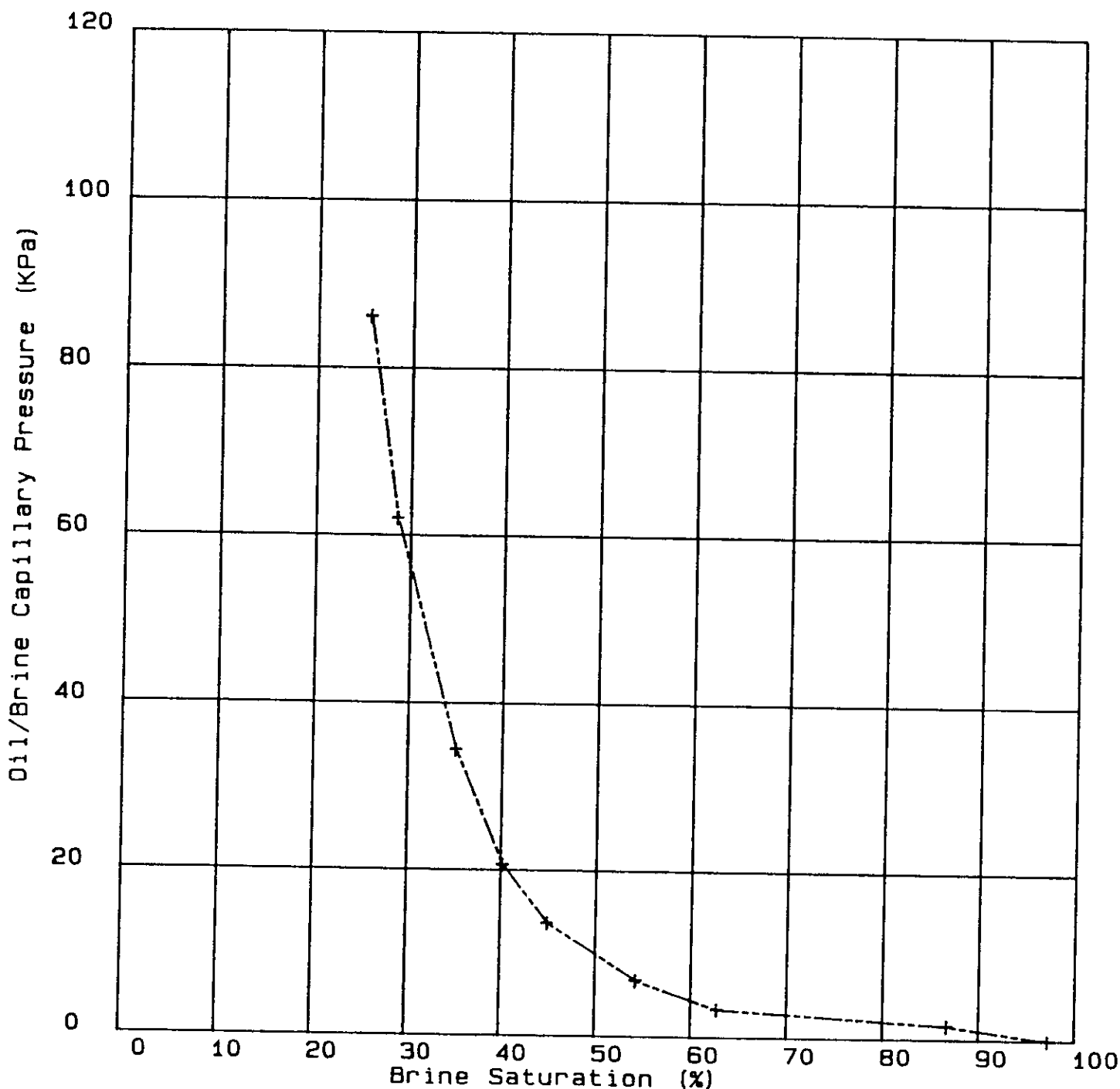
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ROXY ANDEX WHITEWATER
3-2-3-21W1

15 JUN 1984

*RESTORED STATE CAPILLARY PRESSURE
(OIL/BRINE)*

| | | | |
|---------------------|--------------------|------------------------|-----------|
| FORMATION | : Upper Whitewater | | |
| Sample #9A | | Liquid Permeability | : 58.27mD |
| Depth | : 812.25m | Porosity | : 10.2% |
| Interfacial Tension | : 17.1mN/m | Irreducible Brine Sat. | : 26% |



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ROXY ANDEX WHITEWATER
13-2-3-21W1

SAMPLE #13B

Formation: Lodgepole
Depth: 795.26 m

Porosity percent: 18.3
Permeability mD: 44.40
Grain Density kg/m³: 2711

OIL/BRINE CAPILLARY PRESSURE DATA

| Capillary Pressure (PSIG) (kPa) | | Brine Saturation (%) |
|---|-------|-------------------------|
| <hr/> | | <hr/> |
| 0.00 | 0.00 | 100.00 |
| 0.25 | 1.72 | 95.44 |
| 0.50 | 3.45 | 93.00 |
| 1.00 | 6.89 | 80.64 |
| 2.00 | 13.79 | 70.50 |
| 3.00 | 20.68 | 55.22 |
| 5.00 | 34.47 | 47.50 |
| 9.00 | 62.05 | 37.50 |
| 12.00 | 82.74 | 29.39 |

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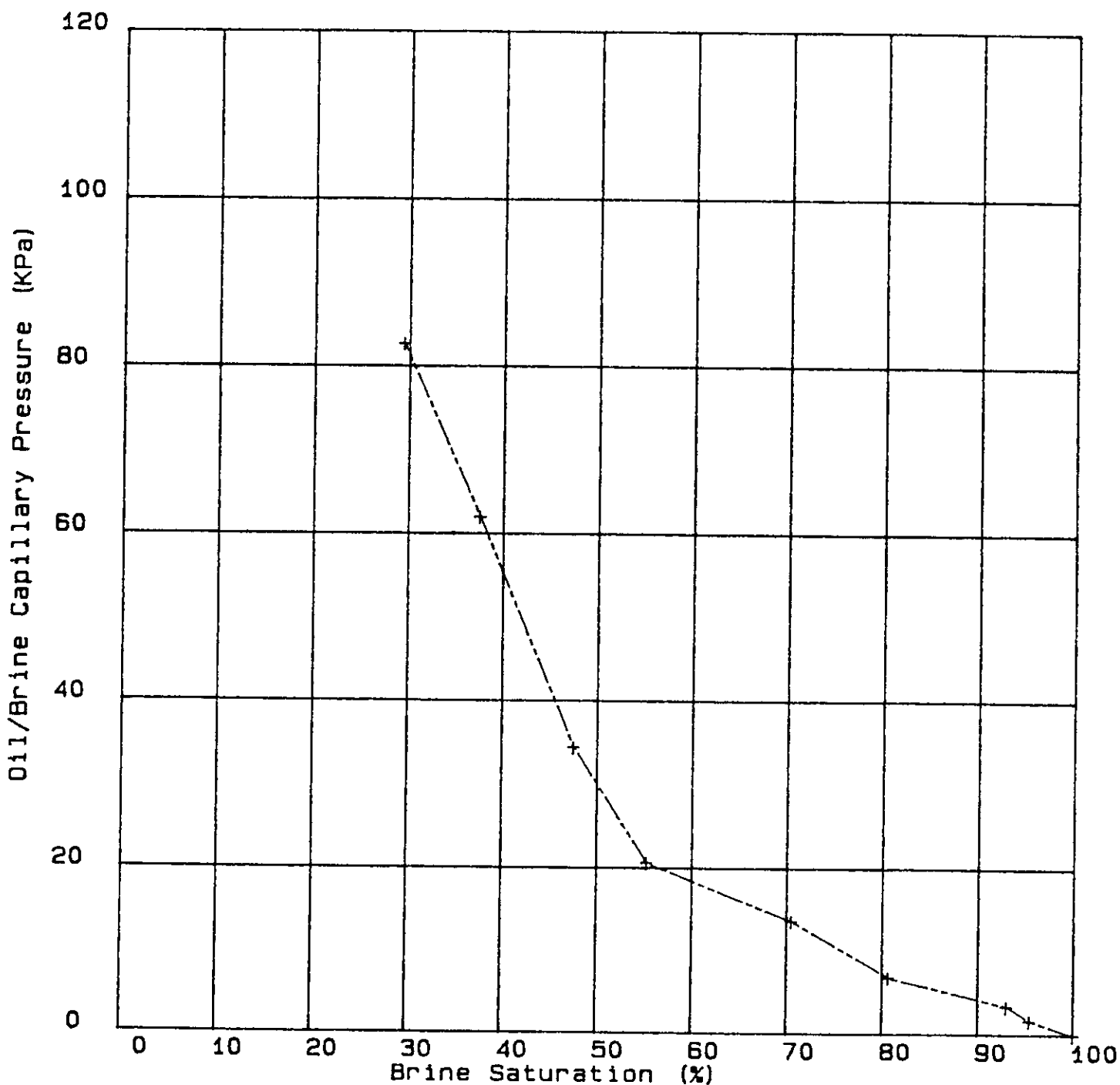
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13-2-3-21W1

21 JUN 1984

RESTORED STATE CAPILLARY PRESSURE (OIL/BRINE)

| | | | |
|---------------------|-------------|------------------------|-----------|
| FORMATION | : Lodgepole | | |
| Sample #13B | | Liquid Permeability | : 44.40mD |
| Depth | : 795.26m | Porosity | : 18.3% |
| Interfacial Tension | : 17.1mN/m | Irreducible Brine Sat. | : 29% |



ROXY PETROLEUM LTD.

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13-2-3-21W1

SAMPLE #14B

Formation: Lodgepole
Depth: 797.22 m

Porosity percent: 11.5
Permeability mD: 0.64
Grain Density kg/m³: 2717

OIL/BRINE CAPILLARY PRESSURE DATA

| Capillary Pressure (PSIG) (kPa) | | Brine Saturation (%) |
|---|-------|-------------------------|
| <hr/> | | <hr/> |
| 0.00 | 0.00 | |
| 0.25 | 1.72 | 95.32 |
| 0.50 | 3.45 | 89.33 |
| 1.00 | 6.89 | 87.20 |
| 2.00 | 13.79 | 86.41 |
| 4.00 | 27.58 | 83.40 |
| 6.00 | 41.37 | 78.50 |
| 9.00 | 62.05 | 73.40 |
| 12.50 | 86.19 | 64.00 |
| | | 57.67 |

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18 JUN 1984

RESTORED STATE CAPILLARY PRESSURE (OIL/BRINE)

FORMATION

: LODGEPOLE

Sample #14B

Liquid Permeability

: 0.64mD

Depth

: 797.22m

Porosity

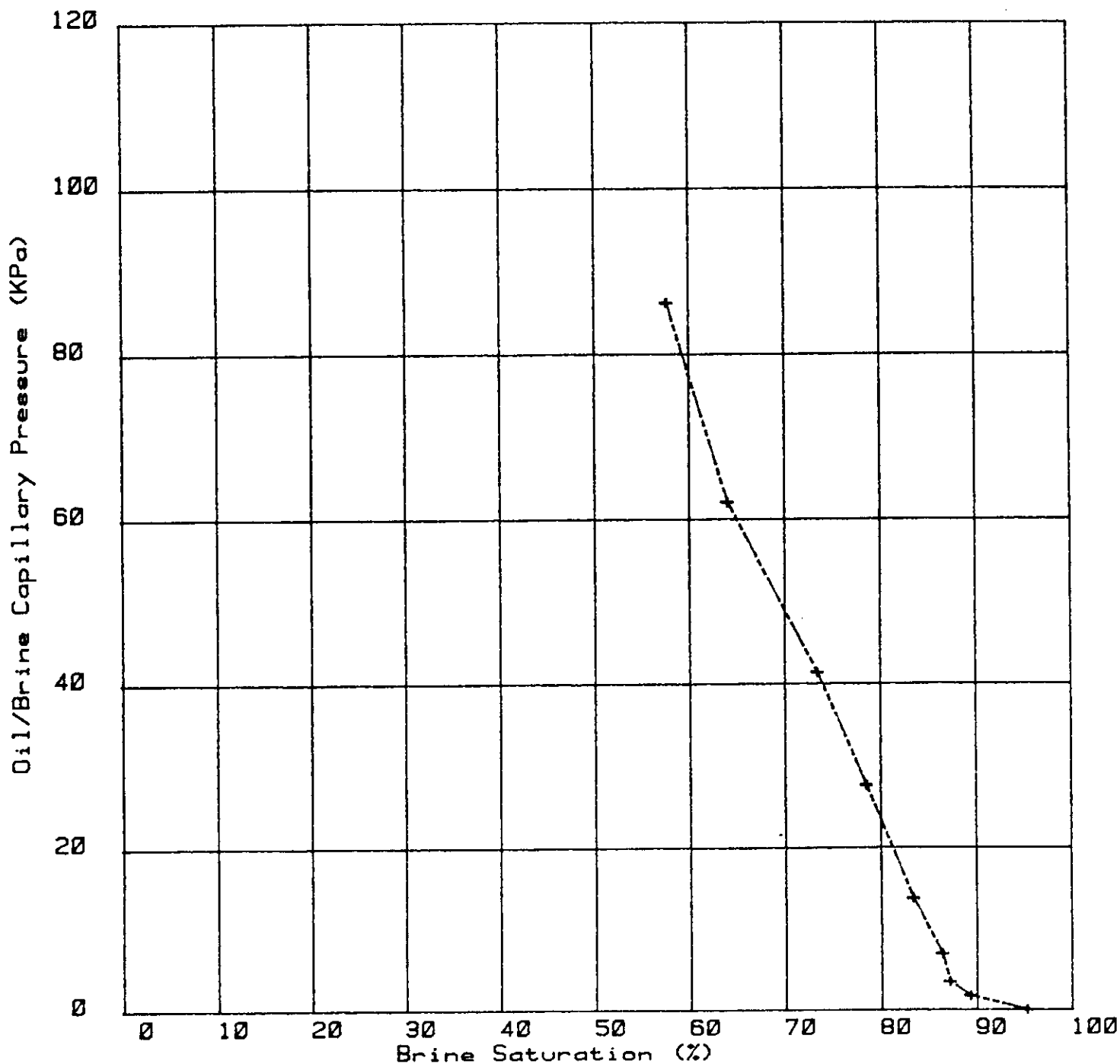
: 11.5%

Interfacial Tension

: 17.1mN/m

Irreducible Brine Sat.

: 58%



SATLOG

A description of the procedure used to generate the SATLOG is contained in the Appendix. The SATLOG data for the five wells are presented on the following figures; the last figure shows the equation used to correlate the surface area with the residual saturation. The features of the SATLOG plot are as follows:

1. The left track contains the Total Gamma Ray, to aid in depth correlation with downhole logs, and the permeability measured during Routine Core Analysis.
2. The middle track contains a plot of the porosity with shading to illustrate hydrocarbon, mobile water and irreducible water saturations.
3. The last track contains a plot of fluid saturations, with shading to illustrate hydrocarbon, mobile water and irreducible water.
4. In zones where mobile water saturations are low, water production should be low; in zones where mobile water saturations are high, water production should be high.
5. Zones which indicate good porosity but no oil are zones with low resistivities as measured by logging. These zones may contain small amounts of oil that are not detected because they are insufficient to cause an increase in the electrical resistivity of the formation.

Interpretations of the SATLOGS follow:

| <u>Depth</u> | <u>Interpretation</u> |
|-------------------------|--|
| Well 3-2-3-21W1 | |
| 807.6-811.1 m | Good oil zone that should produce with low to medium water cut. |
| 811.1-815.5 m | Fair oil zone that should produce with a medium to high water cut. |
| 815.5-822.0 m | No oil indicated. |
| 822.0-823.6 m | Fair oil zone that should produce with a medium to high water cut. |
| 823.6-825.1 m | Water zone. |
| Well 13-2-3-21W1 | |
| 794.0-803.1 m | Good oil zone that should produce with low to medium water cut. |
| 803.1-807.8 m | No oil indicated. |

| | |
|---------------|--|
| 807.8-808.8 m | Very little oil; highly mobile water zone. |
| 808.8-810.0 m | Good oil zone that should produce with a medium water cut. |

Well 6-2-3-21W1

| | |
|---------------|---|
| 804.8-813.3 m | Good oil zone that should produce with low to medium water cut. |
| 813.3-821.0 m | Little oil indicated; considerable highly mobile water. |

Well 10-2-3-21W1

| | |
|---------------|---|
| 800.6-805.3 m | Good oil zone that should produce with low to medium water cut. |
| 805.3-807.5 m | Fair oil that should produce with a medium to high water cut. |
| 807.5-813.3 m | No oil indicated; some highly mobile water. |
| 813.3-818.9 m | Poor to fair oil; some highly mobile water. |

Well 14-2-3-21W1

| | |
|---------------|---|
| 787.9-789.5 m | Highly mobile water zone. |
| 789.5-796.8 m | Good oil zone that should produce with low to medium water cut. |
| 796.8-805.3 m | Little oil; several zones of highly mobile water. |

The residual saturation correlation used to generate the SATLOG plot was based on the mercury injection results only. The two oil/brine residual oil saturations are shown on the figure for comparison purposes only. Although a fair amount of scatter is evident in the data, the correlation is sufficiently good for the purpose of producing the SATLOG. The oil/brine data points both lie above the mercury data but are reasonably close to those points. The oil/brine residual saturations are expected to be higher than the mercury derived values because of the more complicated phenomena experienced in complex oil/brine systems as compared with the idealized mercury/vacuum systems. As a result, the conclusions regarding the amount of mobile water in the reservoir are conservative in that slightly more mobile water is predicted by the SATLOG than is actually present.

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ROXY ANDEX WHITEWATER
3-2-3-21W1

1984 June 15

Formation: Upper Whitewater

IRREDUCIBLE WATER SATURATION
VERSUS
SPECIFIC SURFACE AREA
DATA

| Sample Number | Fractional Irreducible Water Saturation | Specific Surface Area |
|------------------|---|--------------------------|
|------------------|---|--------------------------|

Mercury Injection Capillary Pressure

| | | |
|-----|--------|--------|
| 1A | 0.1698 | 0.0193 |
| 3A | 0.1203 | 0.0255 |
| 7A | 0.0413 | 0.0131 |
| 11A | 0.0861 | 0.0014 |
| 15A | 0.2263 | 0.0247 |

Oil/Brine Capillary Pressure

| | | |
|----|--------|--------|
| 5A | 0.2039 | 0.0028 |
| 9A | 0.2560 | 0.0016 |

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3-2-3-21W1

19 JUN 1984

IRREDUCIBLE WATER SATURATION VS SPECIFIC SURFACE AREA

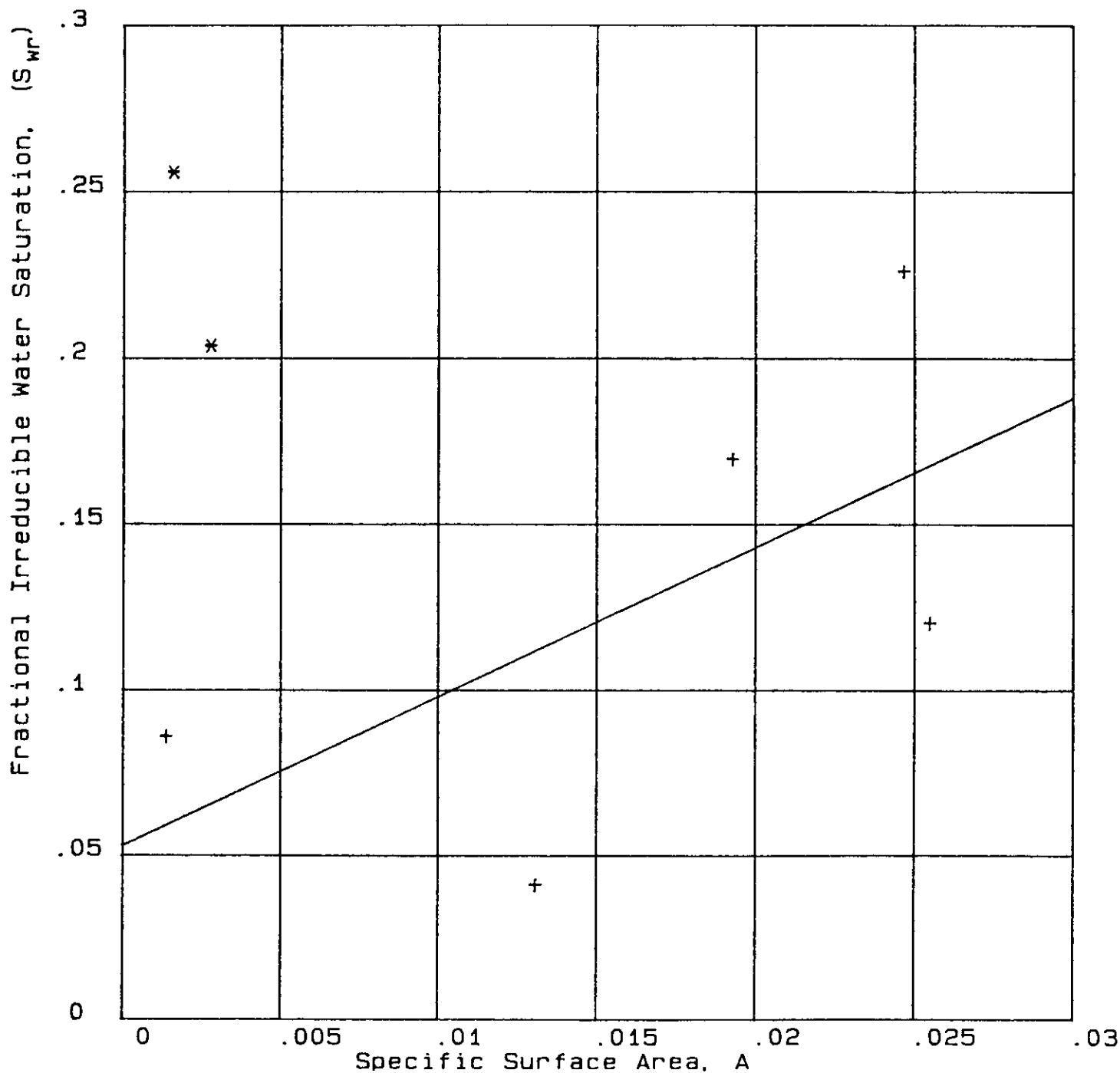
DEPTH : 807 (m) to 825 (m)
FORMATION : Upper Whitewater
Equation : $Y = .0531 + 4.5044 * X$

LEGEND

* Oil/Brine

+ Mercury/Vacuum

Corr Coeff = .3866



APPENDIX

ELECTRICAL MEASUREMENTS

Electrical properties of cores are dependent on pore geometry. This geometry and the saturating fluids define for a given formation the parameters used in electrical down-hole log calculations of in situ porosity and water saturations. These values directly affect calculated values of residual oil. Properties of many formations can be approximated by generalized constants. However, sufficient deviations occur and accurate values are sufficiently important to justify determinations of constants for specific reservoirs.

FORMATION RESISTIVITY FACTOR

The formation resistivity factor (F_R) is the ratio of the resistivity of a 100-percent brine-saturated sample to the resistivity of the saturating brine. Data obtained on a series of samples of varying porosity from one formation are plotted on log-log paper as Formation Resistivity Factor versus Fractional Porosity. The slope of the line that best represents the data points evaluates m ; the value of F_R at fractional porosity of 1.0 represents a in the equation:

$$F_R = R_O/R_w = \frac{a}{\phi^m}$$

where

- F_R = Formation resistivity factor
- R_O = Resistivity of 100-percent brine-saturated sample
- R_w = Resistivity of saturating brine
- ϕ = Fractional porosity
- m = Cementation (porosity) exponent (normal range: 1.8 to 2.5)
- a = F_R value at fractional porosity of 1.0 (normal range: 0.6 to 1.42)

Formation resistivity factors are normally determined at atmospheric pressure and ambient temperature. However, if porosities are less than 10 percent, or if the formations are deep and have great overburden pressures, tests under overburden conditions are recommended. Unusual pore geometry will also result in increased sensitivity of resistivity to overburden pressure. The cementation value m is normally higher under overburden conditions. Several tests are made to define F_R as a function of confining pressure.

HYDROCARBON RESISTIVITY INDEX

The hydrocarbon resistivity index (I_R) is the ratio of the resistivity of a partially saturated sample to the resistivity of the 100-percent brine-saturated sample. The brine-saturated samples are desaturated by displacement of the brine with air in a restored-state capillary pressure cell. The electrical resistivity is measured at each of several desaturation points. The data are plotted as a log-log function of Resistivity Index versus Water Saturation. The slope of the line that best fits the points and passes through a value of 1.0 at 100-percent brine saturation represents the n factor in the equation:

$$I_R = R_t/R_o = 1.00/S_w^n$$

where

- I_R = Resistivity index
- R_t = True resistivity at a given water saturation
- R_o = Resistivity of a 100-percent brine-saturated sample
- S_w = Water saturation (fraction of pore volume)
- n = Saturation exponent (normal range: 1.4 to 2.2)

This excerpt taken largely from "Determination of Residual Oil Saturation" by the Interstate Oil Compact Commission, June 1978.

MERCURY INJECTION CAPILLARY PRESSURE

Experimental Procedure

The bulk volume of a clean core sample is measured with calipers. Using a Boyle's law porosimeter, the pore volume and porosity are also determined. The sample is then placed in a pycnometer and evacuated. The pycnometer is filled with mercury and the bulk volume is redetermined. Additional mercury is injected into the core at a number of fixed pressures. The amount of mercury injected at each pressure and the injection pressures are recorded. From the total pore volume and the total volume of mercury injected, the saturation of the vacuum (which is the wetting "phase") is calculated. Hence, the capillary pressure/saturation relationship is determined. The resulting relationship applies for a drainage process since the wetting phase saturation is decreasing. The relationship for an imbibition process may be obtained by withdrawing the mercury at a number of fixed pressures. The relationship for a redrainage process may be obtained by reinjecting the mercury at a number of fixed pressures.

When the mercury is first introduced into the pycnometer, it sometimes invades surface pores of the sample, being driven in by its hydrostatic head. This is particularly true for vuggy samples with large surface pores. If surface pores are invaded, the bulk volume measured during the filling of the pycnometer will not agree with that originally measured with calipers. This can lead to different interpretations of pore size distributions as discussed below.

Interpretation of the Results

The capillary pressure curve is often plotted by assuming that the bulk volume determined during the filling of the cell is the correct bulk volume. This may lead to a loss of valuable information concerning the pore size distribution. The capillary curves plotted in this report are based on the bulk volumes and pore volumes originally measured before mercury injection.

In an actual reservoir, all communications with large pores, the type that are exposed at the surface of core plugs during the plugging process, are through small pore throats. The amount of mercury which invades the plug during the filling process is therefore not representative of true displacement processes. Therefore, in order to calculate residual saturations and recovery efficiencies, this initial invasion which occurs when the pycnometer is originally being filled, must be corrected for. The residual saturation of the wetting phase is therefore given by the expression

$$S_{wr} = S_{wmp}/S_i \times 100.0,$$

where S_i is the initial saturation and S_{wmp} is the saturation at maximum injection pressure. The saturation of the wetting phase at the end of the imbibition process must also be corrected using the expression

$$S_{wm} = S_{we}/S_i \times 100.0,$$

where S_{we} is the saturation at the end of the imbibition curve. The recovery efficiency is given by

$$R_e = (S_{nm} - S_{nr})/S_{nm} \times 100.0,$$

where S_{nm} is the maximum saturation of the non-wetting phase

$$S_{nm} = 100.0 - S_{wr}$$

and S_{nr} is the minimum saturation of the non-wetting phase

$$S_{nr} = 100.0 - S_{wm}.$$

From the original drainage capillary pressure plot, pore throat entry radii can be estimated by means of the equation

$$r = \frac{2 \delta \cos \theta}{P_c}$$

where δ is the interfacial tension (480 dynes/cm for mercury/vacuum) and θ is the contact angle (140° for mercury/vacuum). If r is in microns and P_c is in kPa, this equation reduces to

$$r = \frac{735.3642}{P_c}$$

Pore size distributions are calculated for two ranges, 0-50 microns and 0-5 microns, in intervals of 2 microns and 1 micron respectively. The calculations are performed by computing the pressures corresponding to integer radii and, by means of interpolation of the capillary pressure experimental data, calculating the corresponding saturations. The percentage saturation change for each radius (i.e. pressure) change is then determined by subtraction.

The capillary pressure curve used in the calculation of pore size distributions is that for original drainage and is based on the bulk volume measured with calipers. This method has the advantage that it accounts for the large pores which may be originally invaded during the

filling of the pycnometer. These pores exist throughout the porous medium. If the bulk volume determined during initial filling of the cell is used, the volume of these large pores is assigned to the size of the throat through which they communicate with the surface of the plug. All information on large pores is then lost. The caliper measured bulk volume method is particularly appropriate when the pore size distributions of vuggy, carbonate plugs are being studied. For sandstone plugs, the difference between the two bulk volumes is typically small; therefore, the actual bulk volume used is not important.

SAMPLE CALCULATIONS

| <u>Well</u> | <u>Sample</u> | <u>Recovery Efficiency</u> | <u>Residual Saturation</u> |
|-------------|---------------|----------------------------|----------------------------|
| 3-2-3-21W1 | #1A | 26% | 17% |

Residual Wetting Phase Saturation Calculation

$$S_{wr} = \frac{14.93}{87.94} \times 100$$

$$S_{wr} = 16.98\% \quad (17\%)$$

Recovery Efficiency Calculation

$$S_{wm} = \frac{33.97}{87.94} \times 100$$

$$S_{wm} = 38.63\% \quad (39\%)$$

$$R_e = \frac{(100 - 16.98) - (100 - 38.63)}{(100 - 16.98)} \times 100$$

$$R_e = 26.08\% \quad (26\%)$$

RELATIVE PERMEABILITY

EXPERIMENTAL PROCEDURE

The relative permeability is measured by means of an unsteady state experimental technique and a computer simulation interpretive method. The experimental procedure for restored core consists of the following basic steps:

1. A core plug is cut from a core sample, gently cleaned by recycling solvents through it, then dried in an oven. The porosity and gas permeability of the plugs are then measured using routine petrophysical techniques. In addition, routine densities and viscosities of all fluids are determined at the temperature and pore pressure used in the experiment.
2. The plug is mounted in a core holder and sleeved with either a flexible aluminum tube or plastic heat shrink tubing. The core holder is then placed in a pressure jacket and the jacket is placed in a temperature controlled chamber. The chamber is raised to the reservoir temperature and a pressure equal to the overburden pressure which is applied to the outside of the core sleeve by pressurizing the jacket.
3. The plug is evacuated, then saturated at the reservoir pore pressure with brine which simulates the connate reservoir brine. The amount of fluid required to saturate the core is measured and the porosity of the plug is calculated. The plug is then flooded with connate water and a permeability to water is calculated.
4. For a water/oil relative permeability, the plug is flooded with the specified flood water at field realistic flood rates and a study of permeability change with time is performed. If the permeability decreases with time, either a clay swelling problem or a fines mobilization problem is indicated and further testing is suspended until consultation can be held with the client. If no permeability degradation is noted, the core is then reflooded with connate brine until the initial conditions are restored. For a gas/oil or gas/water test, this step is not performed.
5. The plug is flooded with reservoir oil until a residual water saturation is obtained. The end point relative permeability to oil is measured at the end of this flooding procedure. By mass balance calculations, the residual water saturation, S_{wr} , and the initial oil in place, are obtained.

If desired, additional data can be collected during this step and oil-increasing, oil/brine relative permeability curves can be obtained.

6. The plug is flooded with the specified displacement fluid (water or gas) at field realistic flow rates. The produced fluids are collected and separated in order to determine cumulative production versus time data. In addition, the differential pressure across the cell is measured as a function of time. The flood proceeds until no more oil is being produced and at that time the end point permeability to water is measured. The residual oil saturation is determined by a mass balance calculation.
7. The plug is removed from its holder and recleaned. The mass of oil in the core is measured during this cleaning process in order to check the previously calculated residual oil value.
8. The capillary pressure characteristics of the plug are determined for the fluids used in the displacement.

INTERPRETING THE EXPERIMENTAL DATA

Direct computer simulation is used to interpret relative permeability data from the displacement experiments. The method is applied by assuming that relative permeability is related to saturation by means of expressions of the form (for a two phase system)

$$k_{or} = k_{oe} ((S_o - S_{or}) / (1 - S_{wr} - S_{or}))^{n_o}$$

and

$$k_{wr} = k_{we} ((S_w - S_{wr}) / (1 - S_{wr} - S_{or}))^{n_w},$$

where k_{or} and k_{wr} are the relative permeabilities, k_{oe} and k_{we} are the end point relative permeabilities (k_{or} at S_{wr} and k_{wr} at S_{or}), S_o and S_w are the saturations, S_{or} is the residual oil saturation, S_{wr} is the irreducible water saturation, and n_o and n_w are the saturation exponents. The "history" of the experiment

(i.e. the productions of the two phases and the pressure differential across the cell as functions of time) is matched by varying the n_o and n_w , and performing one-dimensional numerical simulations. The k_{oe} , k_{we} , S_{or} and S_{wr} are measured during the experiment. In order to properly account for capillary effects without going to the extreme step of increasing the pressure drop in order to make them negligible, capillary pressures are measured directly on reservoir plugs and input into the numerical simulator. In this way, all capillary pressure related phenomena, including core end effects, are properly accounted for.

USING THE RESULTS

The relative permeability results are presented in two forms: the standard plot, which shows the two relative permeability curves as functions of the brine saturation, and the normalized plot, which shows the two relative permeability curves as ratios of their respective end-point values plotted against a normalized brine saturation given by

$$S_w' = (S_w - S_{wr}) / (1 - S_{wr} - S_{or}).$$

In addition to the relative permeability curves, the "history" of the experiment is plotted along with the results of the "best fit" numerical simulation. The fractional flow of the brine as a function of brine saturation is also plotted.

The data may be input into reservoir simulators in two manners: if the simulator allows equation input, the k_{oe} , k_{we} , S_{or} , S_{wr} , n_o , and n_w can be input directly; since most simulators require tabular input, the relative permeability data is tabulated for your convenience.

TECHNICAL NOTE 84-001

SATLOG: Estimation of hydrocarbon, irreducible water, and producible water saturations using mercury injection capillary pressure, routine core analysis and wireline resistivity data.

Application:

- (i) Evaluation of in situ fluid saturations
- (ii) Estimation of hydrocarbon and water cuts
- (iii) Selection of completion intervals

INTRODUCTION

In clean relatively homogeneous petroleum reservoirs it is often possible to mathematically relate the capillary forces measured in a few select samples to the properties of a much broader interval using porosity and permeability values obtained by routine core analysis procedures. Mercury injection capillary pressure measurement provides insight into the surface forces, pore geometry, and distribution of pore throat radii that govern irreducible wetting phase saturation. This information is then extrapolated throughout the entire interval through application of the mathematical model. Assuming the system is water wet and that only brine and potential hydrocarbons saturate the reservoir rock, the distribution of mobile and immobile fluids can be calculated using the core data in conjunction with analysis of the deep induction or lateral resistivity log.

CORE ANALYSIS

Concurrently with the routine core analysis, several samples are selected for capillary pressure measurement by mercury injection porosimetry. As mercury is a non wetting fluid, the injection is equivalent to drainage of the wetting phase from the porous medium. At low pressure mercury begins filling the large pores, with increasing pressure smaller and smaller pore throat radii are penetrated. Ultimately a point is reached where no further injection occurs with increased pressure. The un-injected fraction of the pore volume is equivalent to the irreducible wetting phase saturation. If the system is water wet then this is the irreducible or immobile component of the brine saturation.

The irreducible or connate water saturation is a function of the total surface area of the pore system. In general, as the pore size distribution is skewed toward smaller pore throat radii, irreducible water saturations increase and permeability decreases. A mathematical tool which relates porosity and permeability to surface area is the Kozeny Equation:

Kozeny Equation

$$A = \phi \left(\frac{\phi}{K} \right)^{1/2} \left(\frac{1}{C} \right)^{1/2}$$

A = Specific Surface Area
 ϕ = Fractional Porosity
 K = Permeability
 C = The Kozeny Constant

Permeabilities and porosities of the mercury injected samples are entered into the Kozeny Equation and specific surface areas are calculated for each sample. Surface area is in turn related to irreducible water saturation through a linear equation. Non-linearity at this point reflects heterogeneity of the porous medium and indicates unsuitability for further analysis. The terms of the Kozeny Equation and the slope (m) and intercept (b) of the linear relation are collected in the form:

$$(S_w)_{irr} = m \phi \left(\frac{\phi}{K} \right)^{1/2} \left(\frac{1}{C} \right)^{1/2} + b$$

Using the above equation irreducible water saturations as a function of porosity and permeability are calculated for all samples in the interval.

RESISTIVITY LOG ANALYSIS

The open hole induction or lateral resistivity log is digitized. Using appropriate values for cementation exponent (m), saturation exponent (n), formation brine resistivity (R_w) and porosity values obtained through core analysis, total water saturations are calculated over the interval via Archie's Equation:

$$S_w = \left(\frac{a}{\phi^m} \frac{R_w}{R_t} \right)^{1/n}$$

Unity minus the total water saturation yields the potential hydrocarbon saturation. Total water minus irreducible water equals the producible component of the brine.

FLUID SATURATIONS CORRELATION (SATLOG)

The SATLOG (Figure 1) presents the results of analysis on the standard API 1:240 vertical scale. The Total Core Gamma Ray is presented for correlation between wireline logs and driller's depth. Potential hydrocarbon (darkly shaded), mobile water (clear), and irreducible water (horizontal stripes) saturations are displayed on both the 0 to 100 percent saturation scale and as a fraction of porosity. Permeability is presented in the total GR track for correlation with irreducible water saturation.

Inspection of Figure 1 reveals a zone between 1207 meters and 1214.5 meters with generally good porosity and permeability interbedded with three tight streaks. Most of the interval shows total water saturation near 20%. In the tight streaks water saturation increases to 60% due to capillary effects. Throughout the zone water saturation is almost entirely irreducible. **Substantial hydrocarbon production with minimal or no water cut is indicated.** Below 1215 meters mobile water saturation approaches 100%, indicating that **water production should be expected.**

Optionally, the same information can be presented in terms of the **Fluid Resistivity Log** (Figure 2). Three resistivity curves are displayed over a four decade 0.2 to 2000 ohm-meter scale. R_o , the resistivity at 100% brine saturation is calculated from Archie's equation and core porosity. R_t , true log resistivity is a playback of the wireline response, and $(R_w)_{irr}$ is calculated from irreducible water saturation as derived above and Archie's Equation.

As with the **SATLOG** presentation, a zone with potential for water free production is indicated above 1215 meters. With the log values (R_t) approaching calculated 100% S_w readings (R_o), a high probability for water production is indicated. A transition zone is evident from 1215-1221 meters with the oil-water contact indicated at 1221 meters.

CONCLUSION

The **SATLOG** technique may provide useful insight into the effects of surface forces in the reservoir as they relate to mobile versus immobile water saturations. Hydrocarbon production may be maximized through the recognition of true and false transition zones, and through optimal selection of completion intervals. However it should be stressed that the underlying assumptions of homogeneity and water wettedness place strict limitations upon the applicability of the technique.

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ABC OIL & GAS LTD
ABC ET AL BLUE HILLS
-1-1-1W5

SATLOG
Hydrocarbon

Mobile
Water

Irreducible
Water

01 JAN 199

GR

150

01 Kh mD 1000

30 Core Porosity

0100 Fluid Saturation

1200

1225

* Fluid Saturation derived
from Core Analysis and
Resistivity Log Data
 $a = 1$ $m = 2$ $n = 2$
 $R_w = 0.10 \text{ ohm} \cdot \text{m}$

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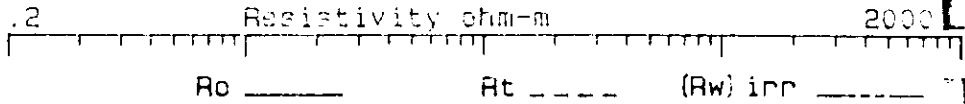
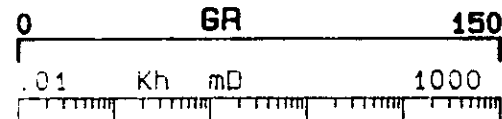
ABC OIL & GAS LTD
ABC ET AL BLUE HILLS
1-1-1-1W5

RESLOG

01 Jan 1999

$a = 1$ $m = 2$ $n = 2$

$R_w = 0.10$ ohm-m



1200

1225

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PROXY PETROLEUMS LTD
PROXY ANDEX WHITEWATER
9-2-3-21W1

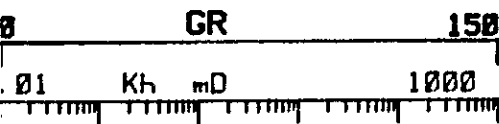
21 JUN 1984

SATLOG

$S_o + S_g$

$S_w - S_{wr}$

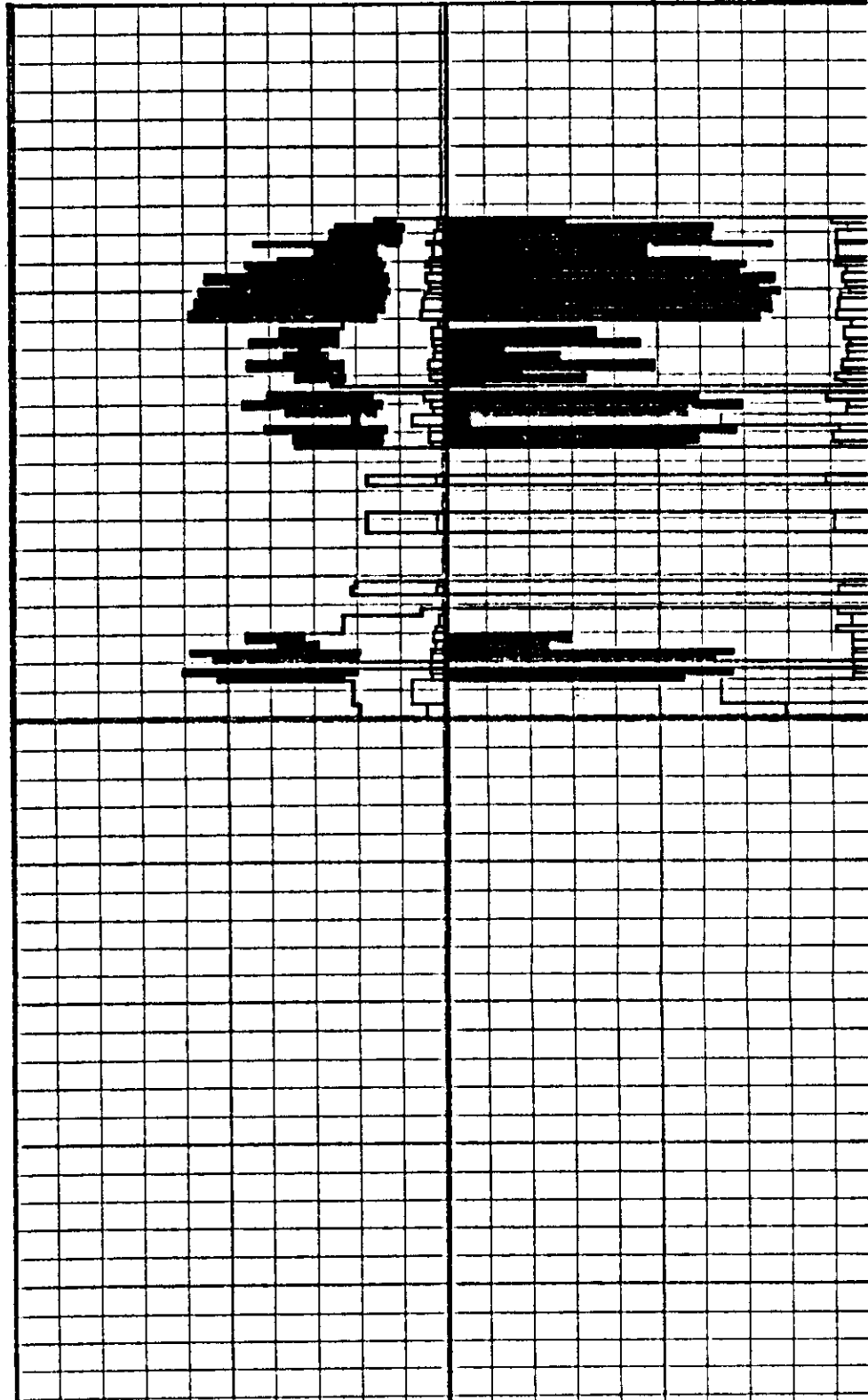
S_{wr}



90 Absolute Saturations 0 100 Fluid Saturation 0

800

825



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ROXY PETROLEUMS LTD
ROXY ANDEX WHITEWATER
13-2-3-21W1

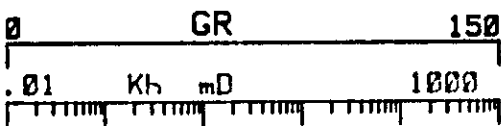
21 JUN 1984

SATLOG

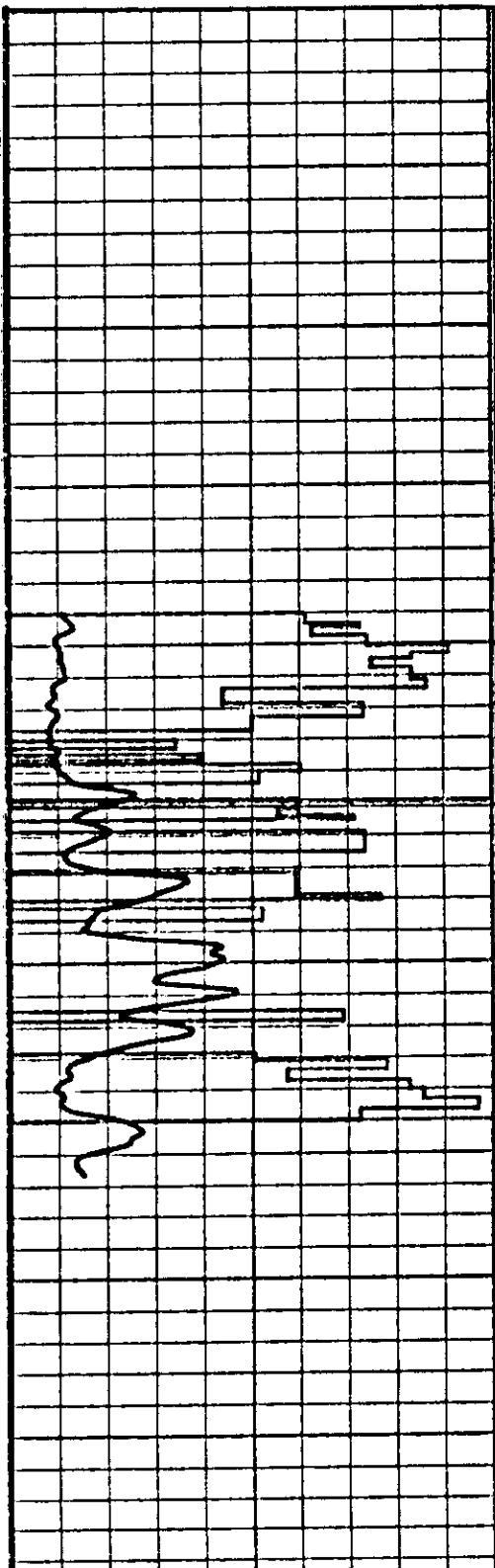
$S_o + S_g$

$S_w - S_{wr}$

S_{wr}

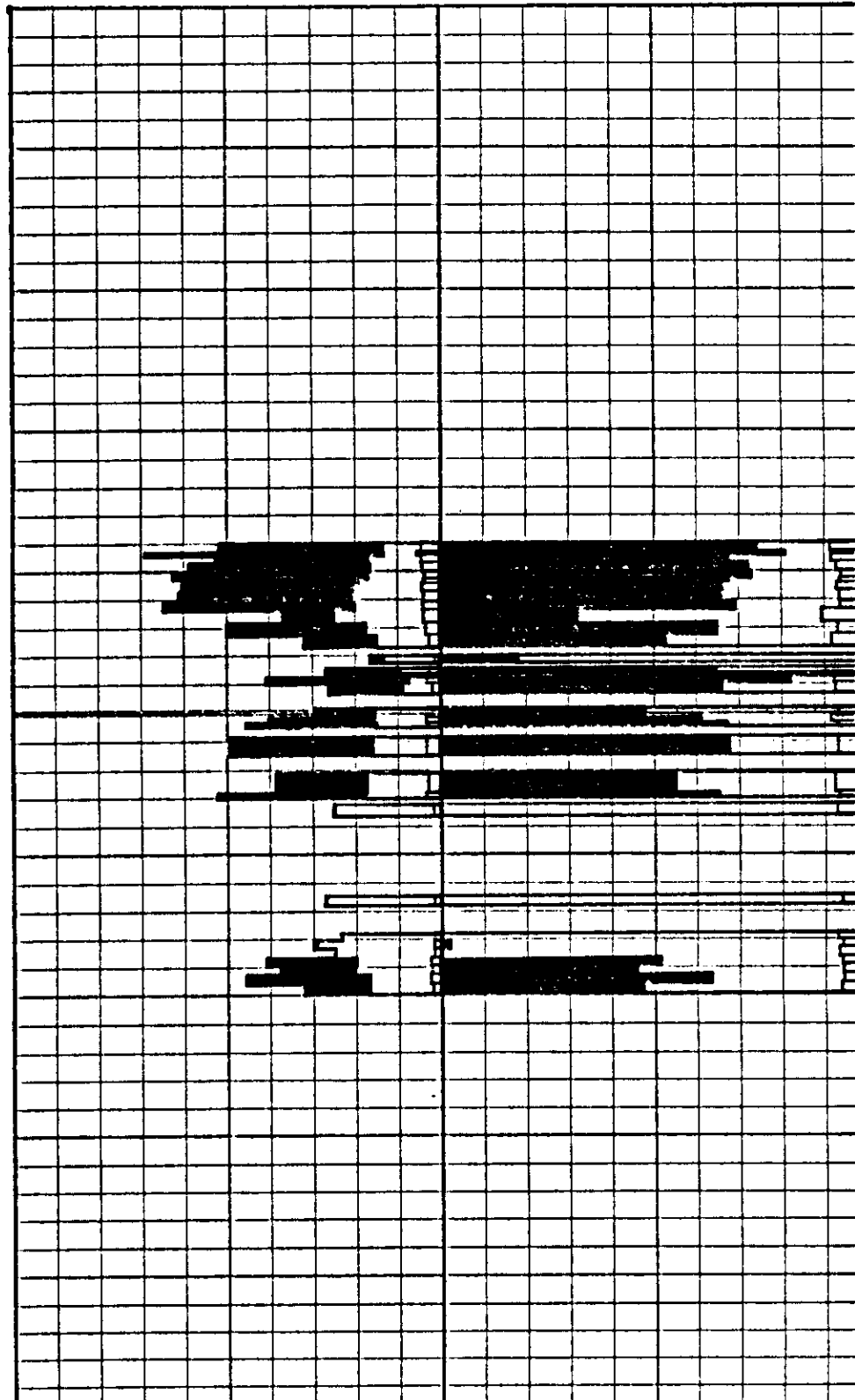


30 Absolute Saturation 0 100 Fluid Saturation 0



775

800



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8-2-3-21W1

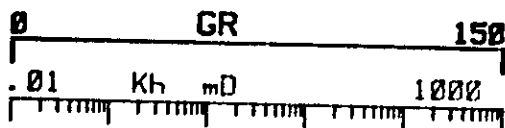
SATLOG

21 JUN 1

$S_o + S_g$

$S_w - S_{wr}$

S_{wr}

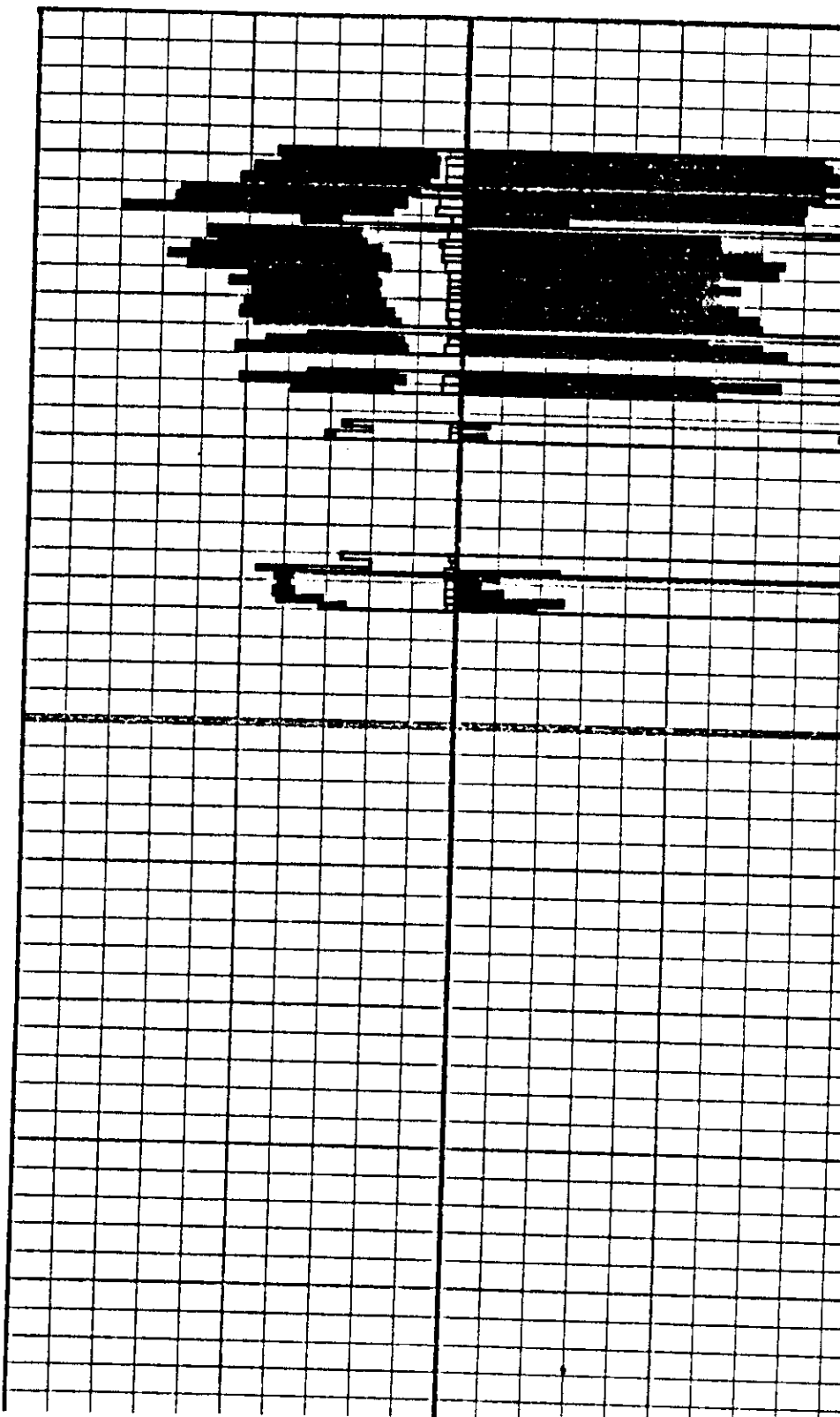


30 Absolute Saturations 0 100 Fluid Saturation

800

825

850



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ROXY ANDEX WHITEWATER
10-2-3-21W1

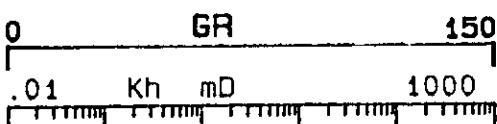
21 JUN 1984

SATLOG

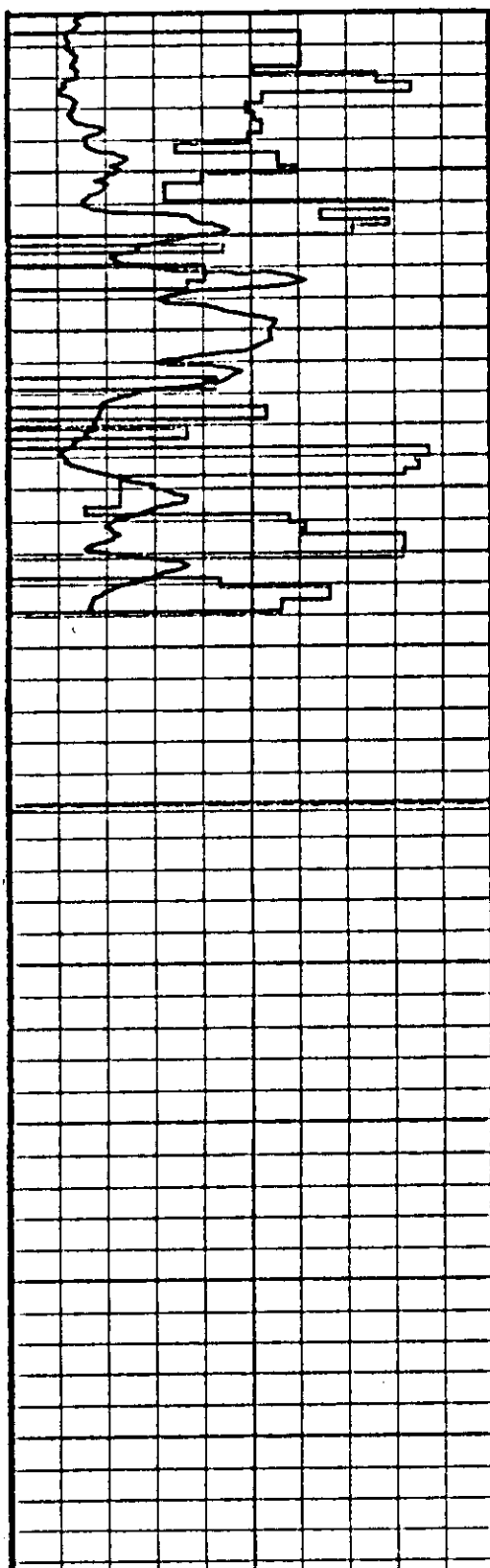
$S_o + S_g$

$S_w - S_{wr}$

S_{wr}

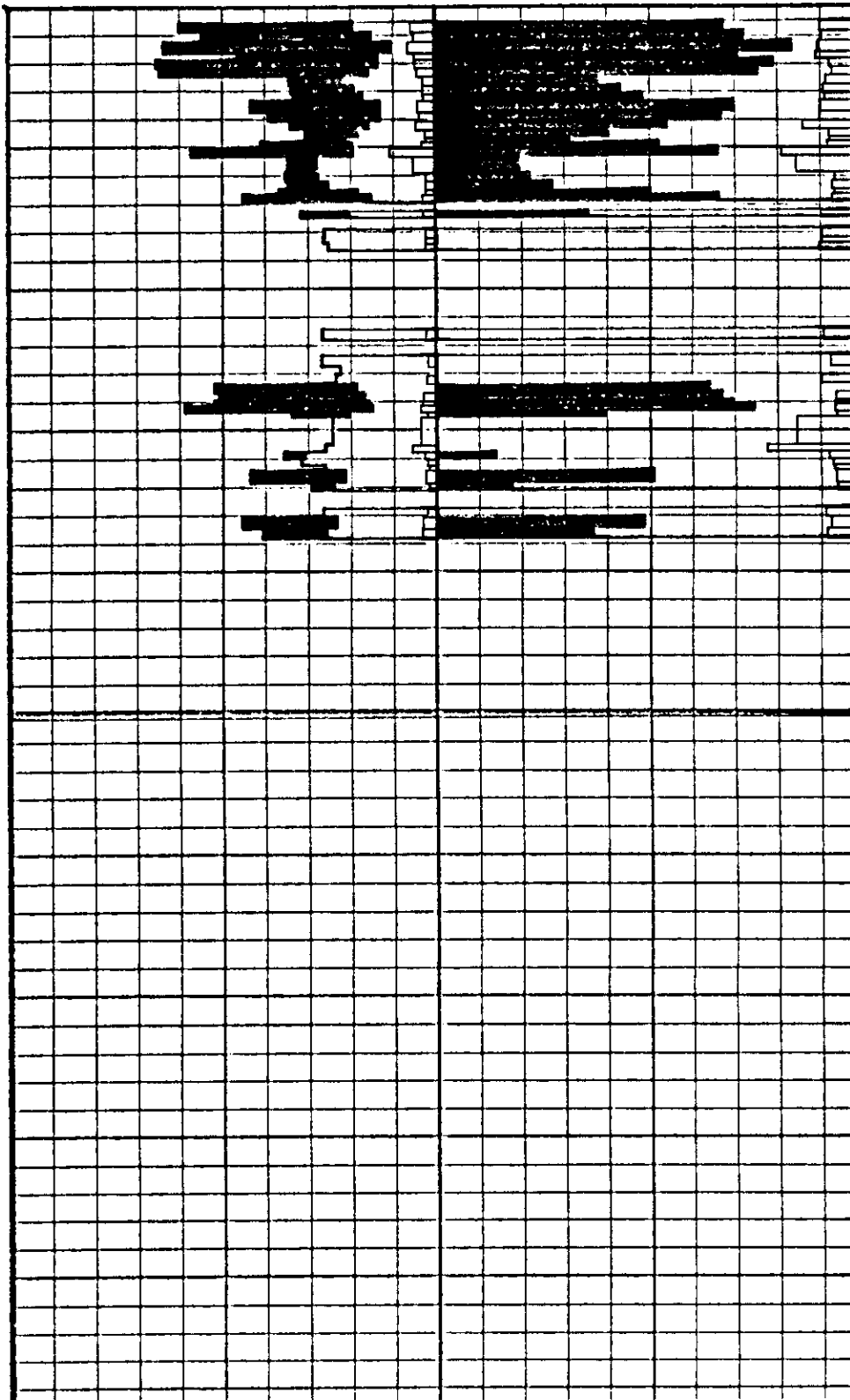


30 Absolute Saturations 0 100 Fluid Saturation 0



800

825



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ROXY ANDEX WHITEWATER
14-2-3-21W1

SATLOG

21 JUN 198

$S_o + S_g$

$S_w - S_{wr}$

S_{wr}

GR 150
0.01 Kh mD 1000

30 Absolute Saturations 0 100 Fluid Saturation 0

775

800

PRODUCTION ENGINEERING
RESEARCH & DEVELOPMENT

ROXY ANDEX WHITEWATER

3-2-3-21W1

RELATIVE PERMEABILITY ANALYSIS
(supplement)

prepared for
ROXY PETROLEUM LTD.

FILE 84-PE-4003



JUNE 1984

tti GEOTECH*nical resources ltd.*
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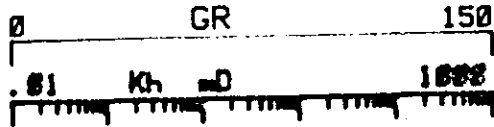
17 JUL 1984

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ROXY ANDEX WHITEWATER
13-2-3-21W1

RESLOG

$S_o + S_g$

S_w



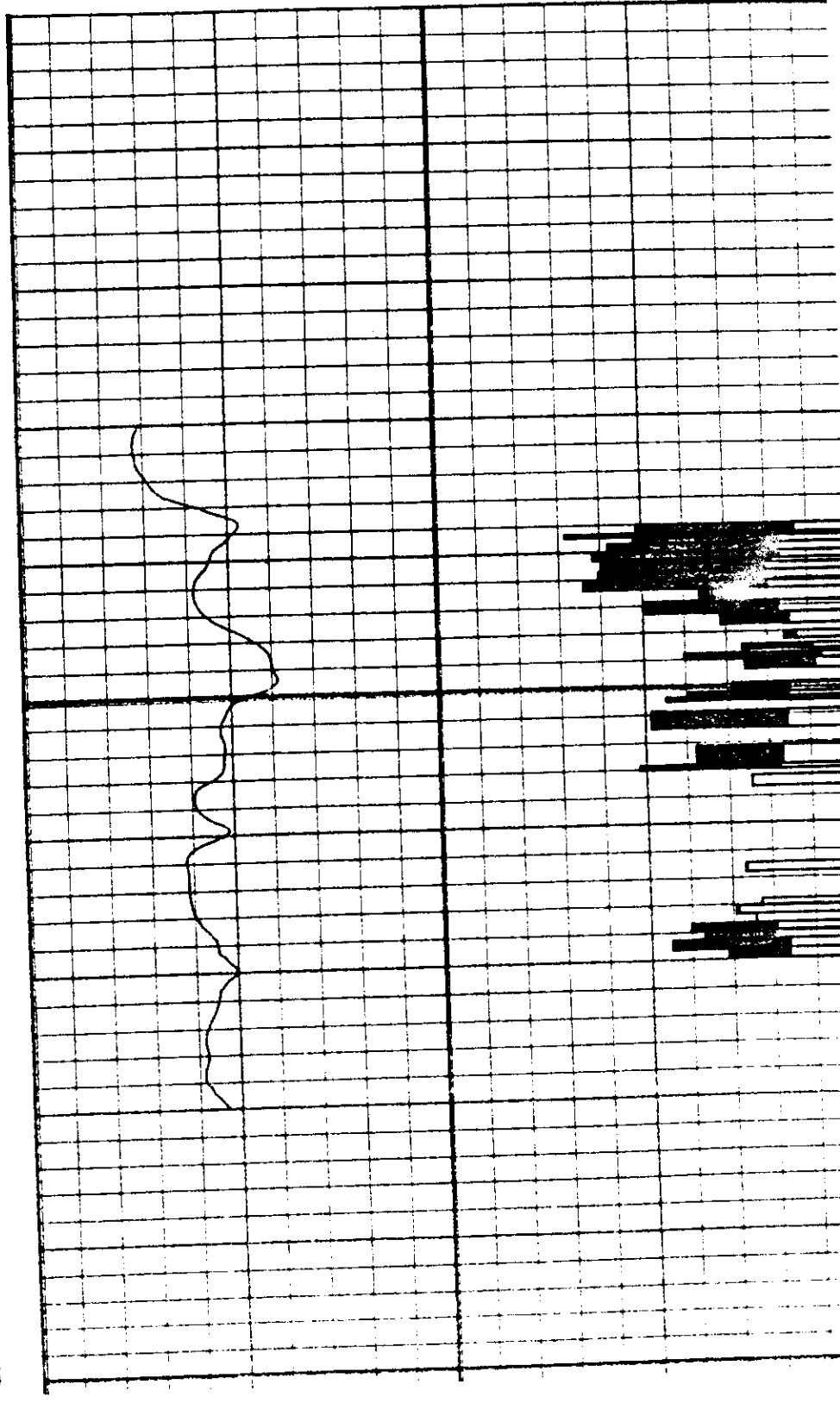
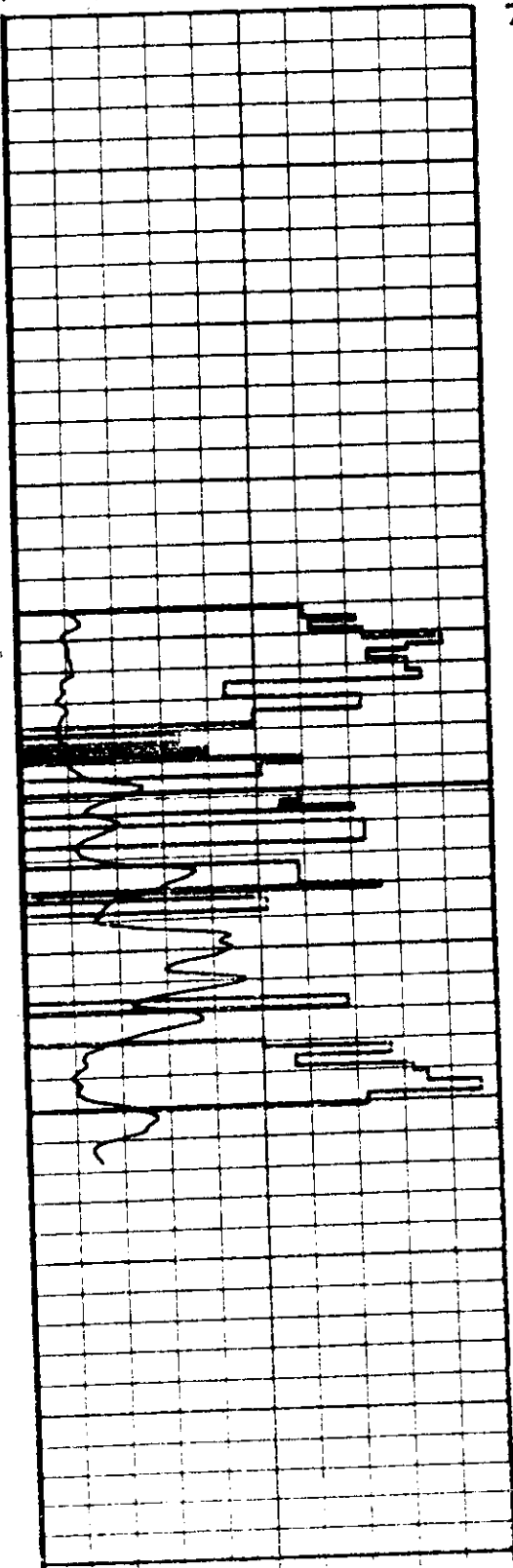
.2 Resistivity Log 200030 Formation Saturation 0

This figure shows a horizontal scale for a resistivity log. It includes a depth scale from 0 to 150 and a resistivity scale from 0.2 to 1000. The scale is marked with vertical lines and numerical values.

775

800

825



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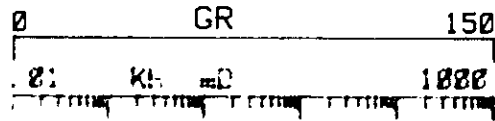
SATLOG

17 JUL 1984

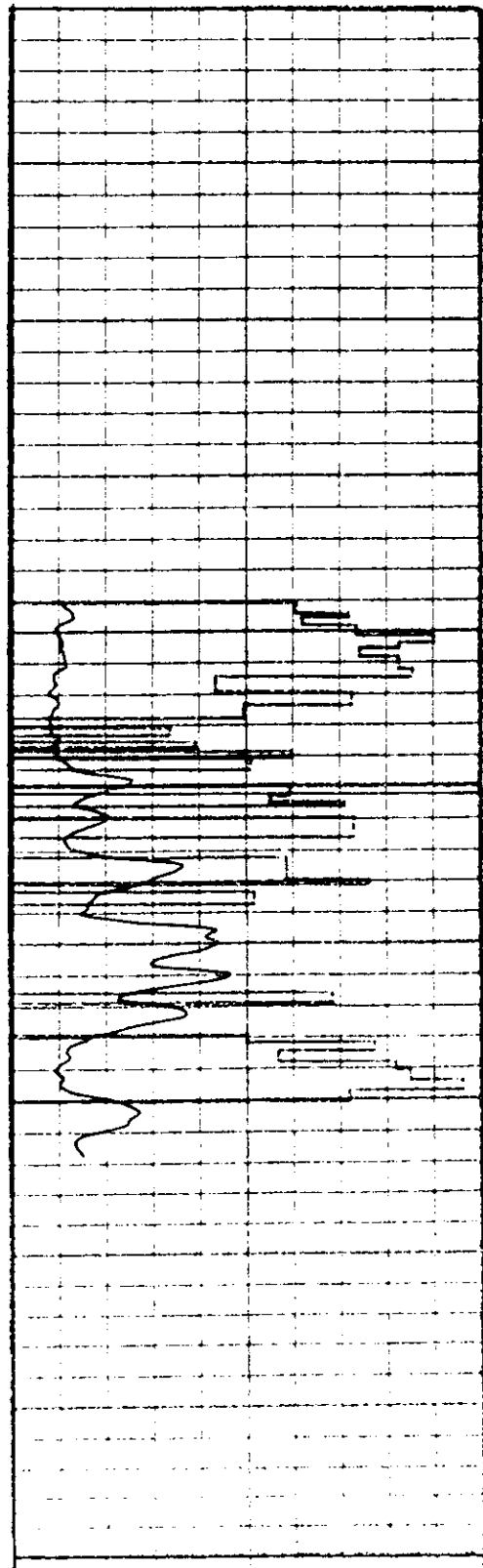
$S_o + S_g$

$S_w - S_{wr}$

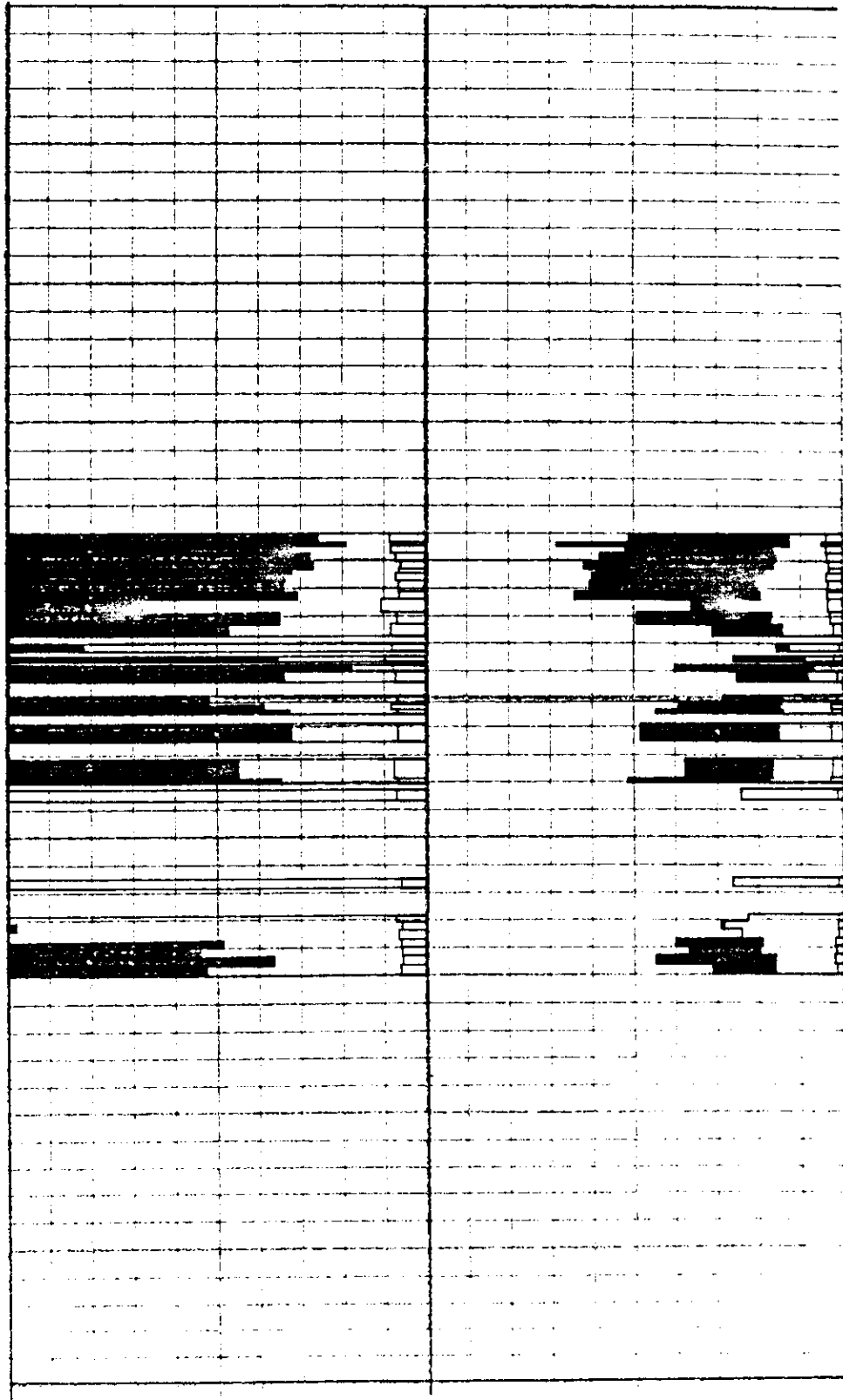
S_{wr}



100 Fluid Saturation 0 30 Absolute Saturations 0



775



800

825

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PROLOG

18 JUL 1984

f_o

f_w

f_o

f_w

GR

150

100 Fractional Production 0.01 Production Indicator 1000

775

800

825

RELATIVE PERMEABILITY

A general description of Relative Permeability testing is provided in the Appendix. The experimental data and results are presented in the following tables. The table containing the experimental data also includes the predictions of the "best-fit" history match.

When the oil production data was calculated, it was found that a good mass balance between injected fluids and produced fluids did not obtain. This problem was traced to a loss of oil during the separation of produced fluids; as much as 30% of the oil evaporated during this process alone, even though the separation was performed at ambient conditions. The oil production data was therefore corrected based on total injected fluids and produced water data. In the original set of experiments reported in June 1984, this correction was satisfactory for all samples except Sample #5A for which the correction was at best approximate. Because of the uncertainty in the data, this test was repeated. The results for the repeated test (Sample #5B) are contained in the present report.

For Sample #5B, a good match was obtained between the experimental and simulated data. The disagreements at early times for the pressure history are due to uncertainties in the boundary condition at time zero; the time zero point is not used in determining the quality of the history match.

The first table in the following collection of data contains a revised summary of the final results, including those already reported. The irreducible water saturations are based on the oil/brine capillary pressure tests performed in conjunction with the relative permeability tests. The residual oil saturations and end-point relative permeabilities were measured during the relative permeability tests and the relative permeability exponents were determined by history matching the experiment. Because of the very small amount of oil produced from Sample #14B and the very high pressure drop across the sample (at times the pressure drop was outside the range of the pressure transducer) no attempt was made to produce the relative permeability exponents. Sample #14B proved to have a considerably lower liquid permeability than originally suspected.

The relative permeability results are representative of a strongly water wet rock, with the end-point oil values being 3.5 to 8 times larger than the end-point water values. All samples had medium to high end-point oil relative permeabilities (0.389 to 0.719) and low end-point water relative permeabilities (0.069 to 0.159). The water relative permeabilities however are still sufficient to allow a waterflood to be performed. Comparing the data for samples from the two wells tested, there appears to be no systematic differences.

The relative permeability exponents for oil are all approximately 2; however, those for water vary from approximately 0.5 to 2. As described in the original report, the lowest exponent (Sample #13B) was probably caused by a small fracture.

Following the relative permeability data are tables and graphs containing the oil/brine capillary pressure results used in the history matching simulations. These curves were determined by means of centrifugal techniques. Again these curves suggest a strongly water wet reservoir.

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ROXY ANDEX WHITEWATER

3-2-3-21W1

13-2-3-21W1

SUMMARY OF RELATIVE PERMEABILITY DATA

| Sample # | Irreducible Water Saturation (S_w) | Residual Oil Saturation (S_o) | End-Point Water Rel. Perm. (K_{we}) | End-Point Oil Rel. Perm. (K_{oe}) | Rel. Water Perm. Exponent (n_w) | Rel. Oil Perm. Exponent (n_o) |
|-------------|---|--|--|--|--|--|
| 5B | 0.340 | 0.324 | 0.1590 | 0.5780 | 1.0784 | 1.9928 |
| 9A | 0.256 | 0.254 | 0.1340 | 0.7192 | 2.0680 | 2.3240 |
| 13B | 0.294 | 0.256 | 0.0709 | 0.5711 | 0.4800 | 2.3448 |
| 14B | 0.578 | 0.404 | 0.0685 | 0.3892 | N/A | N/A |

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ROXY ANDEX WHITEWATER
3-2-3-21W1

SAMPLE #5B

Depth: 810.17 m
Formation: Upper Whitewater

RELATIVE PERMEABILITY DATA

Core Parameters

| | |
|----------------------|----------------------|
| Length | 7.36 cm |
| Diameter | 2.47 cm ₂ |
| Cross-Sectional Area | 4.79 cm ² |
| Porosity | 0.154 |
| Pore Volume | 5.43 cm ³ |
| Liquid Permeability | 46.62 mD |

Fluid Properties

| | Water | Oil |
|----------------------|-----------------------------|---------------------------|
| Density | 1.079 gm/cm ³ | 0.8576 gm/cm ³ |
| Viscosity | 1.100 cp | 7.100 cp |
| Residual Saturation | 0.3400 | 0.3240 |
| End-Point Rel. Perm. | 0.1590 | 0.5780 |
| Rel. Perm. Exponent | 1.0784 | 1.9928 |
| Water Injection Rate | 0.200 cm ³ /min. | |

EXPERIMENTAL DATA

PREDICTION

| Time (min) | Water Production (cm ³) | Oil Production (cm ³) | Diff. Pressure (kPa) | Water Production (cm ³) | Oil Production (cm ³) | Diff. Pressure (kPa) |
|---------------|---|---|----------------------------|---|---|----------------------------|
| 4.0 | 0.09 | 0.70 | 117 | 0.00 | 0.79 | 116 |
| 12.0 | 1.35 | 1.04 | 104 | 1.09 | 1.30 | 97 |
| 20.0 | 2.63 | 1.36 | 90 | 2.53 | 1.45 | 90 |
| 28.0 | 4.02 | 1.58 | 81 | 4.05 | 1.54 | 85 |
| 36.0 | 5.55 | 1.64 | 80 | 5.59 | 1.59 | 83 |
| 44.0 | 6.97 | 1.83 | 78 | 7.15 | 1.63 | 81 |

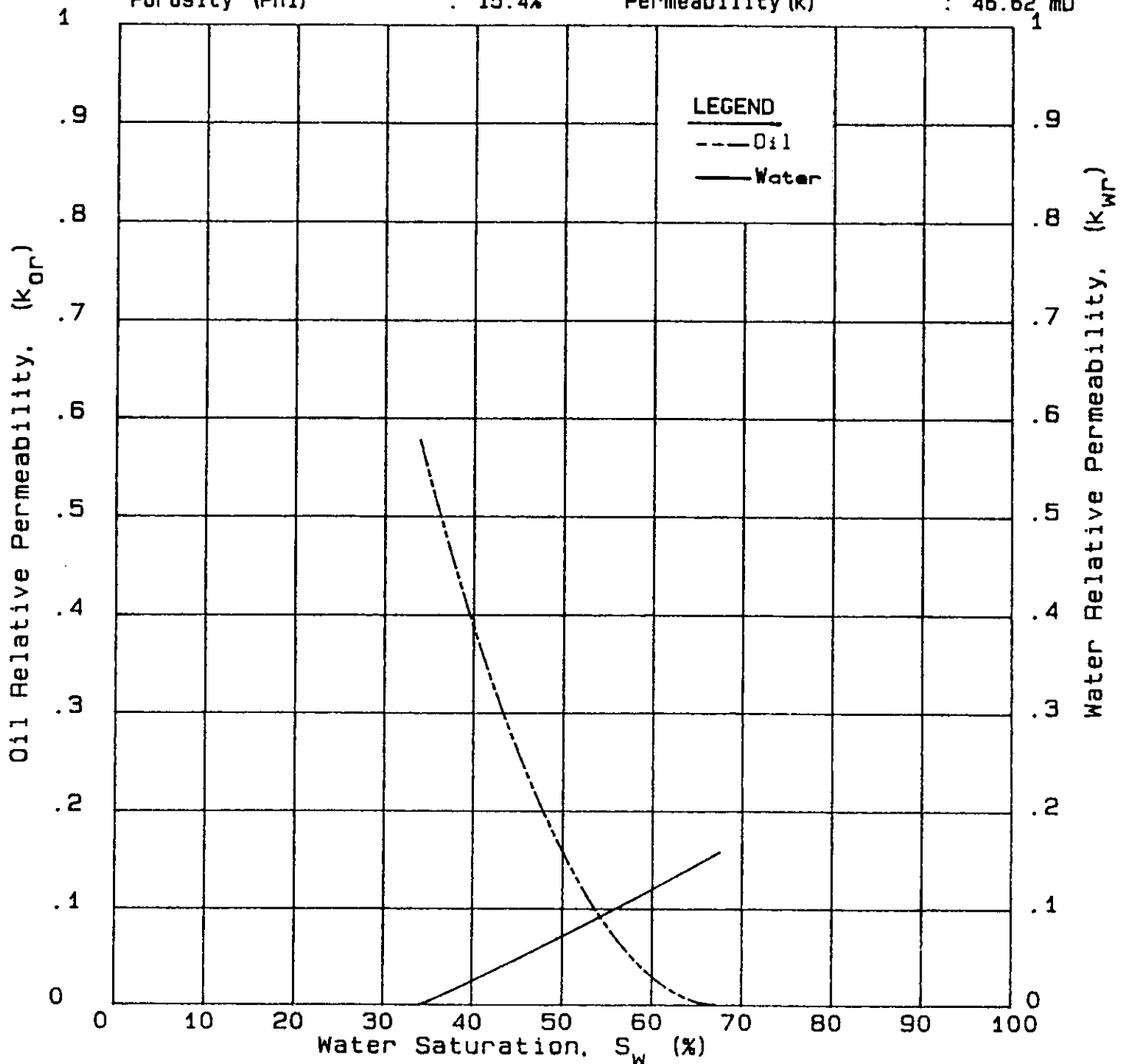
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3-2-3-21W1

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RELATIVE PERMEABILITY
(Standard Plot)

| | | | |
|-----------------------------|--------------------|----------------------------|------------|
| DEPTH | : 810.17 m | SAMPLE # | 5B |
| FORMATION | : Upper Whitewater | | |
| Irr. Wat. Sat. (S_{wr}) | : 0.340 | Res. Oil Sat. (S_{or}) | : 0.324 |
| End Wat. Perm. (k_{we}) | : 0.159 | End Oil Perm. (k_{pe}) | : 0.578 |
| Wat Exponent (n_w) | : 1.078 | Oil Exponent (n_o) | : 1.993 |
| Porosity (Φ) | : 15.4% | Permeability (k) | : 46.62 mD |



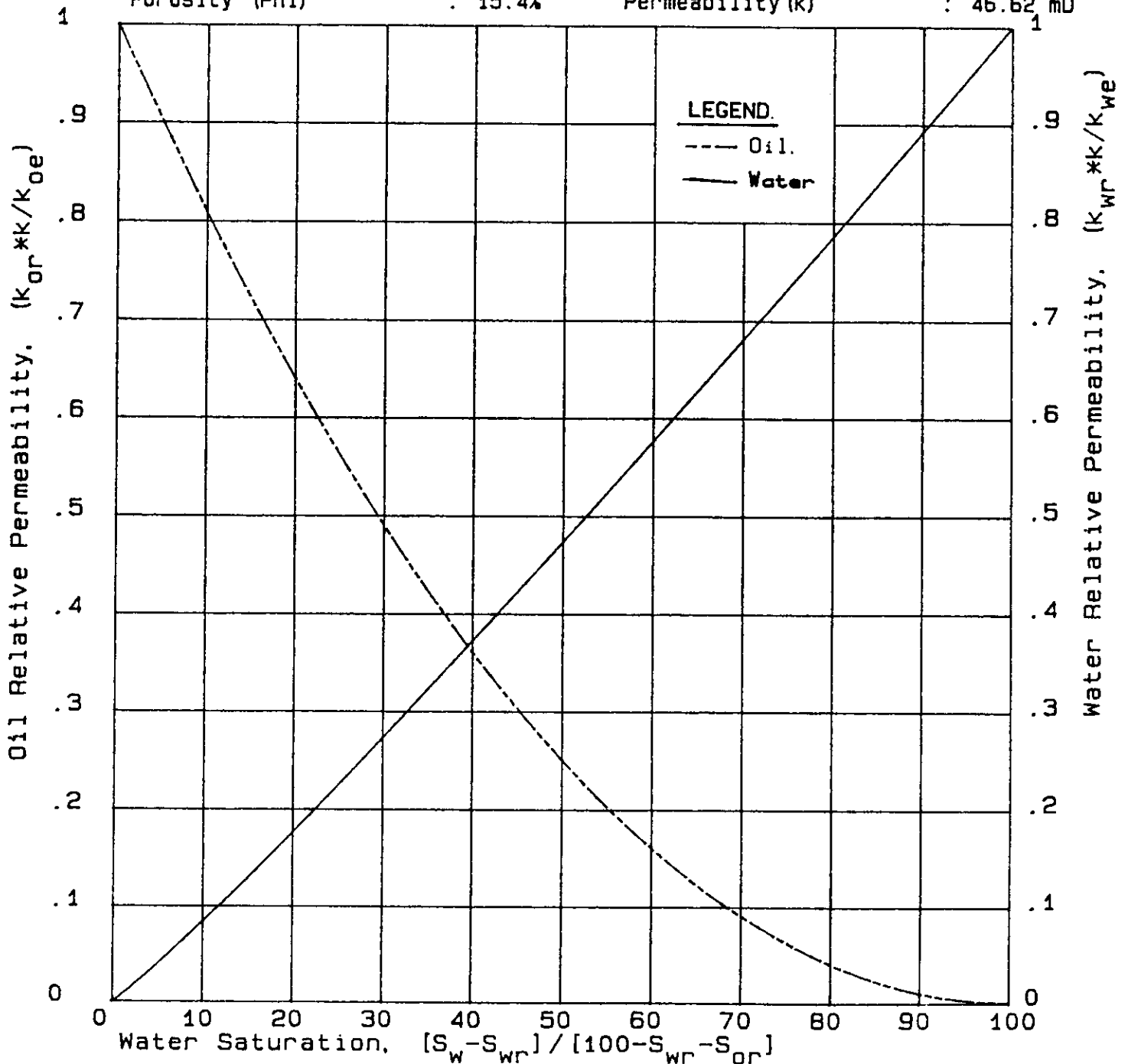
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RELATIVE PERMEABILITY
(Normalized Plot)

| | | | |
|-----------------------------|--------------------|----------------------------|------------|
| DEPTH | : 810.17 m | SAMPLE # | 5B |
| FORMATION | : Upper Whitewater | | |
| Irr. Wat. Sat. (S_{wr}) | : 0.340 | Res. Oil Sat. (S_{or}) | : 0.324 |
| End Wat. Perm. (k_{we}) | : 0.159 | End Oil Perm. (k_{pe}) | : 0.578 |
| Wat Exponent (n_w) | : 1.078 | Oil Exponent (n_o) | : 1.993 |
| Porosity (Φ) | : 15.4% | Permeability (k) | : 46.62 mD |



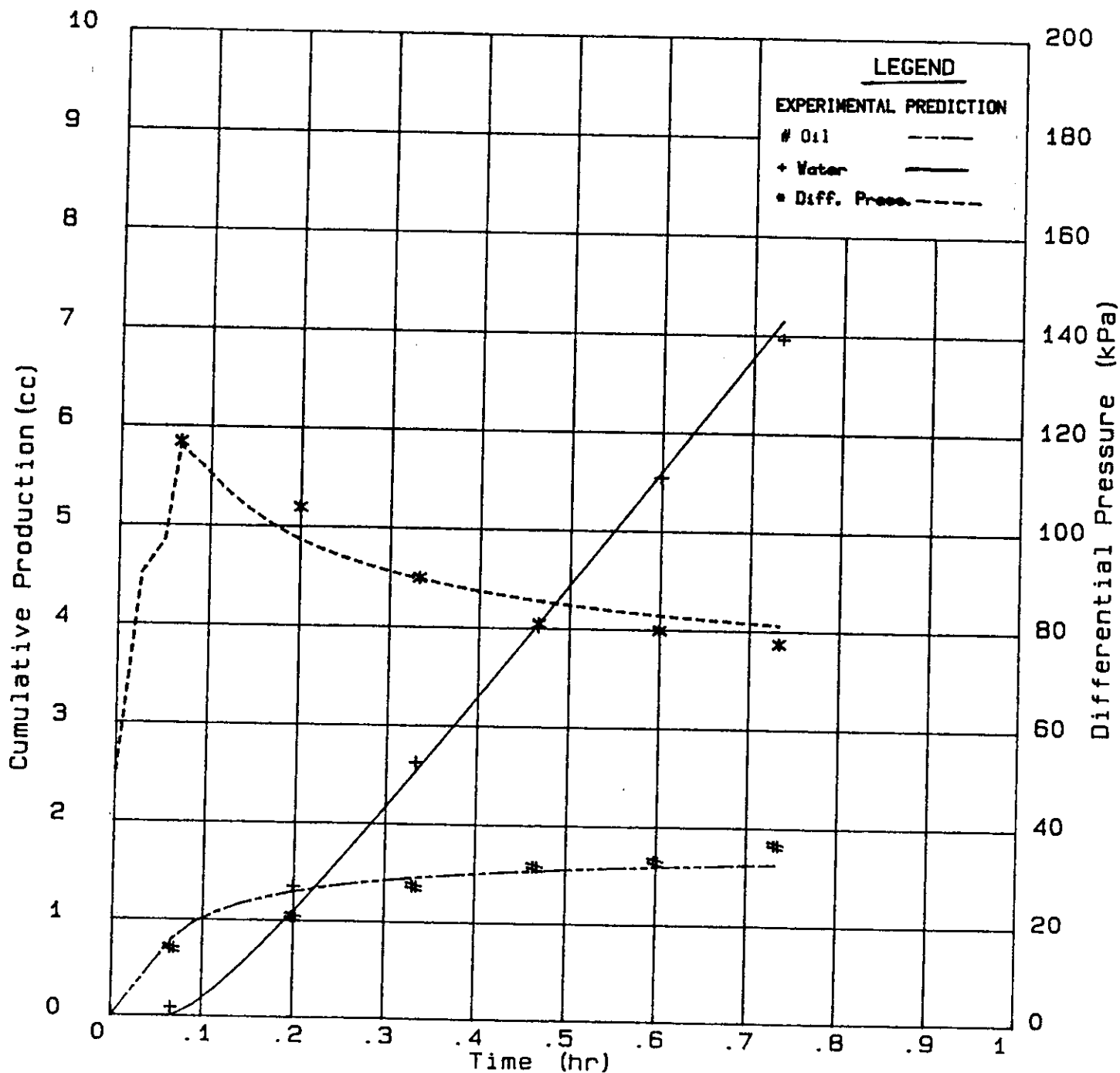
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HISTORY MATCH

| | | | |
|----------------|--------------------|------------------|------------|
| DEPTH | : 810.17 m | SAMPLE # | 5B |
| FORMATION | : Upper Whitewater | | |
| Porosity (Phi) | : 15.4% | Permeability (k) | : 46.62 mD |



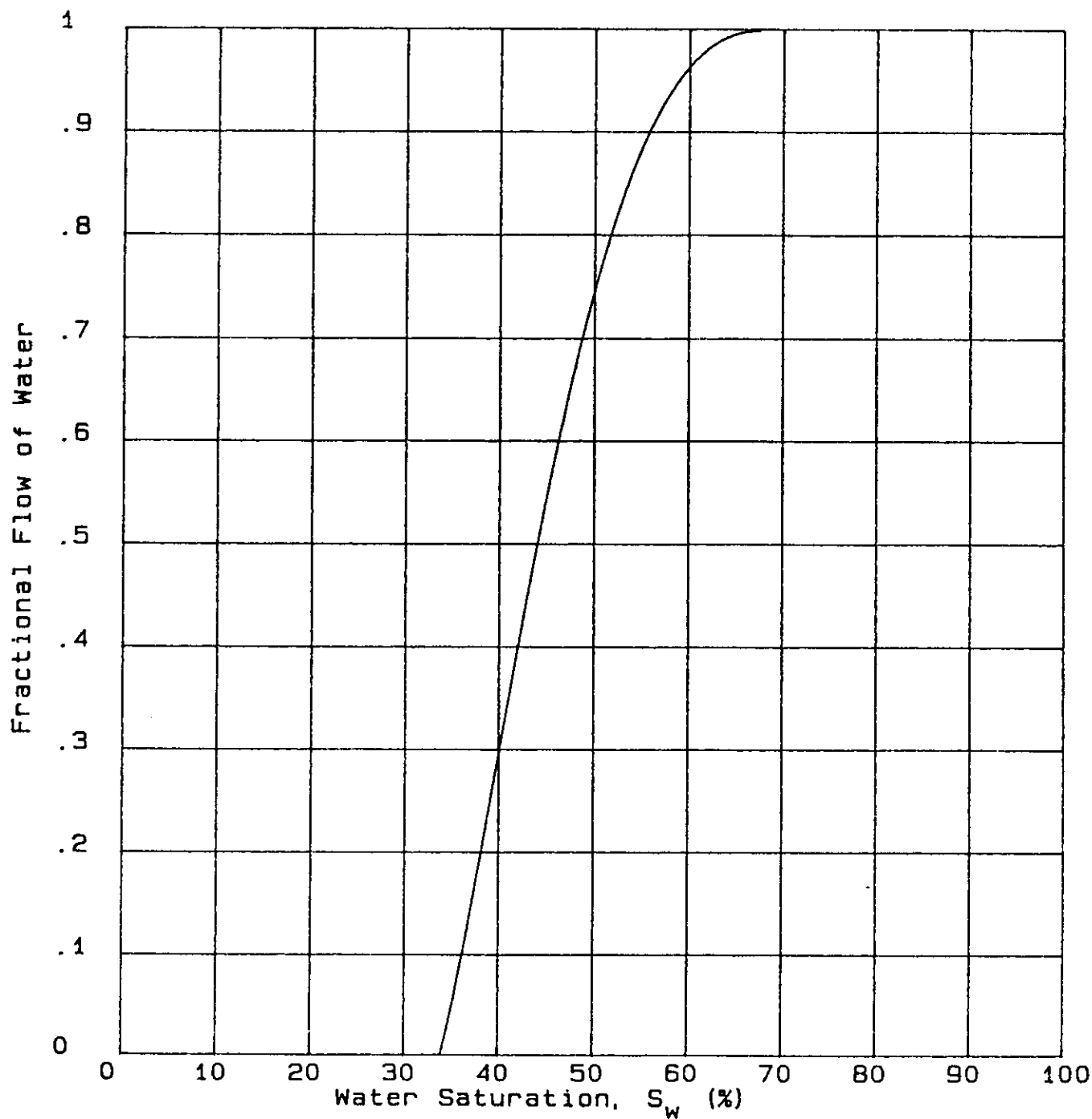
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FRACTIONAL FLOW

| | | | |
|-----------------------------|--------------------|----------------------------|------------|
| DEPTH | : 810.17 m | SAMPLE # | 5B |
| FORMATION | : Upper Whitewater | | |
| Irr. Wat. Sat. (S_{wr}) | : 0.340 | Res. Oil Sat. (S_{or}) | : 0.324 |
| Porosity (Φ) | : 15.4% | Permeability (k) | : 46.62 mD |



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ROXY ANDEX WHITEWATER
3-2-3-21W1

SAMPLE #5B

Depth: 810.17 m
Formation: Upper Whitewater

RELATIVE PERMEABILITY DATA
(Rock Properties)

| Water Saturation S_w | Water Relative Permeability K_{wr} | Oil Relative Permeability K_{or} |
|---------------------------|---|---------------------------------------|
| 0.340 | 0.0000 | 0.5780 |
| 0.357 | 0.0063 | 0.5218 |
| 0.374 | 0.0133 | 0.4685 |
| 0.390 | 0.0206 | 0.4181 |
| 0.407 | 0.0280 | 0.3705 |
| 0.424 | 0.0357 | 0.3258 |
| 0.441 | 0.0434 | 0.2839 |
| 0.458 | 0.0513 | 0.2450 |
| 0.474 | 0.0592 | 0.2088 |
| 0.491 | 0.0672 | 0.1756 |
| 0.508 | 0.0753 | 0.1452 |
| 0.525 | 0.0834 | 0.1177 |
| 0.542 | 0.0917 | 0.0931 |
| 0.558 | 0.0999 | 0.0713 |
| 0.575 | 0.1082 | 0.0525 |
| 0.592 | 0.1166 | 0.0365 |
| 0.609 | 0.1250 | 0.0234 |
| 0.626 | 0.1334 | 0.0132 |
| 0.642 | 0.1419 | 0.0059 |
| 0.659 | 0.1504 | 0.0015 |
| 0.676 | 0.1590 | 0.0000 |

OIL/BRINE CAPILLARY PRESSURE

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3-2-3-21W1

SAMPLE #5B

| | | | |
|------------|------------------|-----------------------------------|-------|
| Formation: | Upper Whitewater | Porosity percent: | 15.4 |
| Depth: | 810.17 m | Permeability mD: | 46.62 |
| | | Grain Density kg/m ³ : | 2693 |

OIL/BRINE CAPILLARY PRESSURE DATA

| Capillary Pressure (PSIG) (kPa) | | Brine Saturation (%) |
|---|-------|-------------------------|
| <hr/> | | <hr/> |
| 0.00 | 0.00 | 99.05 |
| 0.25 | 1.72 | 89.28 |
| 0.50 | 3.45 | 71.24 |
| 1.00 | 6.89 | 59.00 |
| 3.00 | 20.68 | 49.50 |
| 5.00 | 34.47 | 43.50 |
| 9.00 | 62.05 | 36.50 |
| 12.00 | 82.74 | 33.47 |

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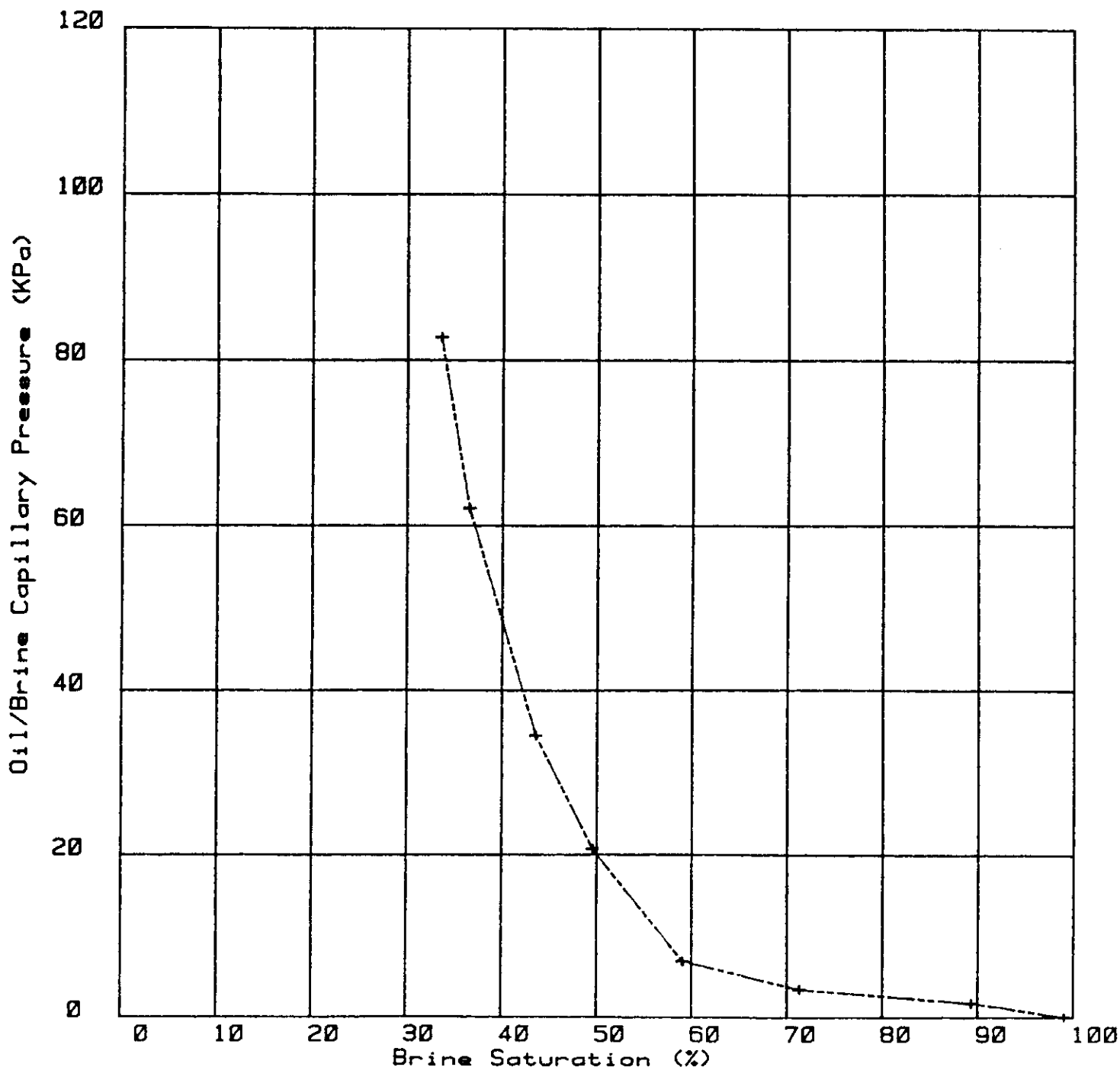
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RESTORED STATE CAPILLARY PRESSURE (OIL/BRINE)

| | | | |
|---------------------|--------------------|------------------------|------------|
| FORMATION | : Upper Whitewater | Liquid Permeability | : 46.62 mD |
| Sample #5B | | Porosity | : 15.4% |
| Depth | : 810.17m | Irreducible Brine Sat. | : 33% |
| Interfacial Tension | : 17.1mN/m | | |



APPENDIX

RELATIVE PERMEABILITY

EXPERIMENTAL PROCEDURE

The relative permeability is measured by means of an unsteady state experimental technique and a computer simulation interpretive method. The experimental procedure for restored core consists of the following basic steps:

1. A core plug is cut from a core sample, gently cleaned by recycling solvents through it, then dried in an oven. The porosity and gas permeability of the plugs are then measured using routine petrophysical techniques. In addition, routine densities and viscosities of all fluids are determined at the temperature and pore pressure used in the experiment.
2. The plug is mounted in a core holder and sleeved with either a flexible aluminum tube or plastic heat shrink tubing. The core holder is then placed in a pressure jacket and the jacket is placed in a temperature controlled chamber. The chamber is raised to the reservoir temperature and a pressure equal to the overburden pressure which is applied to the outside of the core sleeve by pressurizing the jacket.
3. The plug is evacuated, then saturated at the reservoir pore pressure with brine which simulates the connate reservoir brine. The amount of fluid required to saturate the core is measured and the porosity of the plug is calculated. The plug is then flooded with connate water and a permeability to water is calculated.
4. For a water/oil relative permeability, the plug is flooded with the specified flood water at field realistic flood rates and a study of permeability change with time is performed. If the permeability decreases with time, either a clay swelling problem or a fines mobilization problem is indicated and further testing is suspended until consultation can be held with the client. If no permeability degradation is noted, the core is then reflooded with connate brine until the initial conditions are restored. For a gas/oil or gas/water test, this step is not performed.
5. The plug is flooded with reservoir oil until a residual water saturation is obtained. The end point relative permeability to oil is measured at the end of this flooding procedure. By mass balance calculations, the residual water saturation, S_{wr} , and the initial oil in place, are obtained.

If desired, additional data can be collected during this step and oil-increasing, oil/brine relative permeability curves can be obtained.

6. The plug is flooded with the specified displacement fluid (water or gas) at field realistic flow rates. The produced fluids are collected and separated in order to determine cumulative production versus time data. In addition, the differential pressure across the cell is measured as a function of time. The flood proceeds until no more oil is being produced and at that time the end point permeability to water is measured. The residual oil saturation is determined by a mass balance calculation.
7. The plug is removed from its holder and recleaned. The mass of oil in the core is measured during this cleaning process in order to check the previously calculated residual oil value.
8. The capillary pressure characteristics of the plug are determined for the fluids used in the displacement.

INTERPRETING THE EXPERIMENTAL DATA

Direct computer simulation is used to interpret relative permeability data from the displacement experiments. The method is applied by assuming that relative permeability is related to saturation by means of expressions of the form (for a two phase system)

$$k_{or} = k_{oe} ((S_o - S_{or}) / (1 - S_{wr} - S_{or}))^{n_o}$$

and

$$k_{wr} = k_{we} ((S_w - S_{wr}) / (1 - S_{wr} - S_{or}))^{n_w},$$

where k_{or} and k_{wr} are the relative permeabilities, k_{oe} and k_{we} are the end point relative permeabilities (k_{or} at S_{wr} and k_{wr} at S_{or}), S_o and S_w are the saturations, S_{or} is the residual oil saturation, S_{wr} is the irreducible water saturation, and n_o and n_w are the saturation exponents. The "history" of the experiment

(i.e. the productions of the two phases and the pressure differential across the cell as functions of time) is matched by varying the n_o and n_w , and performing one-dimensional numerical simulations. The k_{oe} , k_{we} , S_{or} and S_{wr} are measured during the experiment. In order to properly account for capillary effects without going to the extreme step of increasing the pressure drop in order to make them negligible, capillary pressures are measured directly on reservoir plugs and input into the numerical simulator. In this way, all capillary pressure related phenomena, including core end effects, are properly accounted for.

USING THE RESULTS

The relative permeability results are presented in two forms: the standard plot, which shows the two relative permeability curves as functions of the brine saturation, and the normalized plot, which shows the two relative permeability curves as ratios of their respective end-point values plotted against a normalized brine saturation given by

$$S_w' = (S_w - S_{wr}) / (1 - S_{wr} - S_{or}).$$

In addition to the relative permeability curves, the "history" of the experiment is plotted along with the results of the "best fit" numerical simulation. The fractional flow of the brine as a function of brine saturation is also plotted.

The data may be input into reservoir simulators in two manners: if the simulator allows equation input, the k_{oe} , k_{we} , S_{or} , S_{wr} , n_o , and n_w can be input directly; since most simulators require tabular input, the relative permeability data is tabulated for your convenience.