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Paramount et al Cameron M-73

AGAT Laboratories
Core Services Division

RESERVOIR ELECTRICAL HYROCARBON RESISTIVITY STUDY

June 1991

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EXECUTIVE SUMMARY

This report contains the results of a hydrocarbon resistivity index study on 6 samples drilled from core cut in the Cameron Hills area.

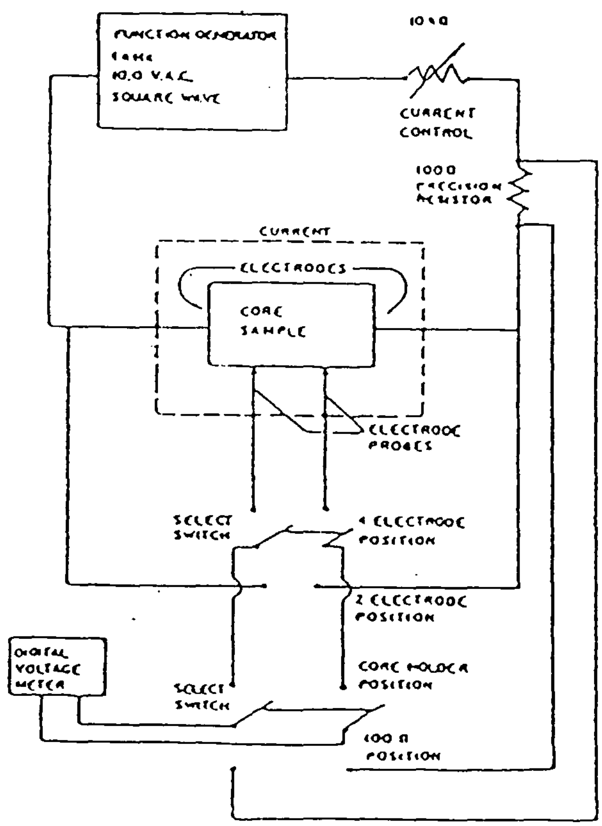
A previous report, dated May 8, 1991, contained the results of a formation resistivity factor study on these samples at net overburden pressure of 15,900 kPa, and reservoir temperature of 50oC. The Archie's relationship yielded an **m** (cementation exponent) of 2.19 and **a** (porosity constant) of 1.00 with a correlation coefficient of 0.4670 (See File No: 91-SC-4001-2).

Hydrocarbon resistivity indices on samples 7P, 10 and 84 yield saturation exponents (**n**) of 1.68, 1.55 and 99 is problematic, as is evident from the variance in the experimental results of these samples. One possible cause of the problematic data may be dual porosity system. Unless the possibility of a dual porosity system is examined further, a conclusive interpretation is not possible. Therefore, the present report offers two possible interpretations, for samples 18P, 27P and 99 hydrocarbon resistivity index data, detailed in the discusion of results'.

EXPERIMENTAL PROCEDURE

A general description of reservoir electrical resistivity testing is given in the appendix. The following discussion details the experimental procedure used.

For the current study, six samples were tested for their hydrocarbon resistivity indices.



RESISTIVITY APPARATUS

After measuring the petrophysical properties of the six clean samples they were saturated to 100% of their pore volumes with filtered (0.45 micron) and deaerated brine. The resistivity of a sample was measured and the sample was desaturated in a stepwise manner. The desaturation was achieved by spinning the sample in the centrifuge, using centrifugal acceleration to drive brine from the sample. The saturation of the sample was determined after each spin, by subtracting the dry weight of the sample from the wet weight to determine the weight of the fluid remaining in the sample. This weight of the fluid was divided by the density of the fluid to determine the volume of the fluid remaining. This weight of the fluid was divided by the density of the fluid to determine the volume of the fluid remaining. This volume was divided by the pore volume of the sample to determine the saturation. The resistivity was measured by closing the four electrode circuit (see Resistivity Apparatus diagram). The hydrocarbon resistivity index was calculated using the following equation:

$$I = Rt/Ro$$

where

I = hydrocarbon resistivity index

Rt = resistivity measured at each saturaiton

Ro = resistivity measured at 100% saturation

The index was plotted versus the saturation on a log-log graph for each sample. The slope of the least-squares fit line is the saturation exponent **n**.

DISCUSSION OF RESULTS

The experimental results are presented in a series of tables and figures at the back of this report. These results consist of the following:

1. Detailed geological description of each sample tested (Table 1).

2. Sample summary (Table 2.) This summary contains the following information for all samples: grain density, gas permeability, porosity, and dimensions.

3. A composite hydrocarbon resistivity index plot for all samples (Figure 1).

4. A composite hydrocarbon resistivity index plot for samples 7P, 10 and 84 (Figure 2).

5. Tabular and graphical presentations of the hydrocarbon resistivity indices for each sample tested (Tables 3 to 8, Figures 3 to 8).

The six samples tested by this study range in porosity and permeability from 4.6% to 15.2% and from 0.07 md to 14.50 md respectively.

Hydrocarbon resistivity indices on samples 7P, 10 and 84 yield saturation exponents (**n**) of 1.68, 1.55 and 1.26 respectively. These samples yield a composite **n** value of 1.44 with a correlation coefficient of 0.9349.

An interpretation of the experimental results of the hydrocarbon resistivity indices of samples 18P, 27P and 99 is problematic, as is evident from the variance in the experimental results of these samples. One possible cause of the problematic data may be a dual porosity system. Dual porosity systems may cause systematic shifts in the slope of the index as a function of brine saturation because it effects desaturation and related fluid distribution. Consequently, the **n** values are variable.

Unless the possibility of a dual porosity system is examined further by a petrographic study, a conclusive interpretation of the indices data to obtain an **n** value for all the samples is not possible. Hence the present report offers two possible interpretaions for each sample's hydrocarbon resistivity index data.

The first approach ignores the high variance in the data for samples 18P, 27P and 99 and treats the data in a routine manner detailed in the experimental procedure. This appraoch yields **n** values of 1.52, 123 and 1.64 respectively.

However, the routine approach yields poor corrlation coefficients (between 0.5902 to 0.9701). Upon a cursory glance at the indices plots for the six samples one can notice that these poor correlaitons are a result of a systematic shift in the slope of the log index vs log saturation plots. The shift in the slope occurs between saturations of 68% to 81% for the three samples. Using the assumption of dual porosity system, one can take a second approach for the interpretation of the data. The data is separated into two groups, greater than and less than the point of shift in slope, and each group is analysed separately. The higher saturation data set approach yields **n** values of 2.79, 1.58 and 2.27 for the three samples. This approach yields relatively good correlations; however, the data population for saturations above 80% is small with as few as five data points to a maximum of seven data points.

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A composite **n** value of 1.49 (r^2 = 0.9027) obtained by analysing all the samples, is coincidentally very similar to the composite **n** value of 1.44 from samples 7P, 10 and 84. However, the validity of this routine approach is questionable in view of the possibility of a dual porosity system.

Finally, it seems that neither of the two approaches taken to analyse the indices of samples 18P, 27P and 99 may be exclusively used with confidence. An optimum combination of the two approaches based on detailed petrographic analyses may give the most representative answers.

GEOLOGICAL DESCRIPTIONS

HYCAL ENERGY RESEARCH LABORATORIES LTD.

File #: 91-SC-4001-3

SAMPLE	LITHOLOGY	DESCRIPTION
7P	Dolostone	- mottled cream-beige and medium grey-brow - moderately hard - micro to very fine crystalline, locally microsucrosic - cream coloured fossiliferous breccia consisting of stromatoporoid fragments in a dark, shaly, carbonaceous, dolomitic matrix - individual fossil fragments are occasionally draped by shale laminae - fair to good visible intercrystalline porosity
10	Dolostone	- beige-brown - moderately hard - fine crystalline to microcrystalline - sucrosic texture - highly recrystallized, no primary structures observed - occasional microcrystalline bands and patches (possible tabular stromatoporoids) - abundant pinpoint vugs (dissolution) - occasional patches anhydrite - numerous scattered calcite crystals - good visible intercrystalline porosity
18P	Dolostone	- grey-beige - moderately hard - fine crystalline, microsucrosic - highly recrystallized, massive - rare dark, argillaceous, shaly patch - scattered pinpoint vugs - rare argillaceous shaly microlaminae - fair to good visible intercrystalline porosity
27P	Dolostone	- medium to light grey brown - moderately hard - sucrosic texture - numerous pinpoint vugs (dissolution) - highly recrystallized, masking primary structures - weakly calcareous - weakly argillaceous locally, rare shaly microlaminae - fair to good visible intercrystalline porosity

Table 1

GEOLOGICAL DESCRIPTIONS

HYCAL ENERGY RESEARCH LABORATORIES LTD.

File #: 91-SC-4001-3

SAMPLE	LITHOLOGY	DESCRIPTION
84	Dolostone	- mottled cream-beige and grey - moderately hard - micro to fine crystalline - abundant bulbous stromatoporoid fragments in a shaly, crinoidal, pyritic matrix - fossils are weakly calcareous - scattered pinpoint vugs
99	Dolostone	- medium brown with cream coloration - moderately hard - fine crystalline - fossiliferous floatstone of branching stromatoporoid fragments in a sucrosic dolomite matrix - fossils are moderately leached, producing patches of fenestral and pinpoint vugs - occasional small moldic vugs - good visible intercrystalline and pinpoint porosity

Table 1 (cont'd)

SAMPLE SUMMARY

SAMPLE NUMBER	DEPTH (m)	GAS PERMEABILITY (md)	POROSITY* (%)	GRAIN DENSITY (kg/m3)	LENGTH (cm)	DIA. (cm)
			WELL: G-21			
7P	1422.5	0.21	9.5	2828	6.14	2.52
10	1423.9	5.23	15.2	2817	6.78	2.51
18P	1427.5	0.07	4.6	2830	4.31	2.53
27P	1431.6	0.94	7.1	2843	6.11	2.52
			WELL: M-73			
84	1411.2	0.30	12.6	2840	6.42	2.51
99	1417.1	14.50	12.0	2840	5.72	2.51

Table 2

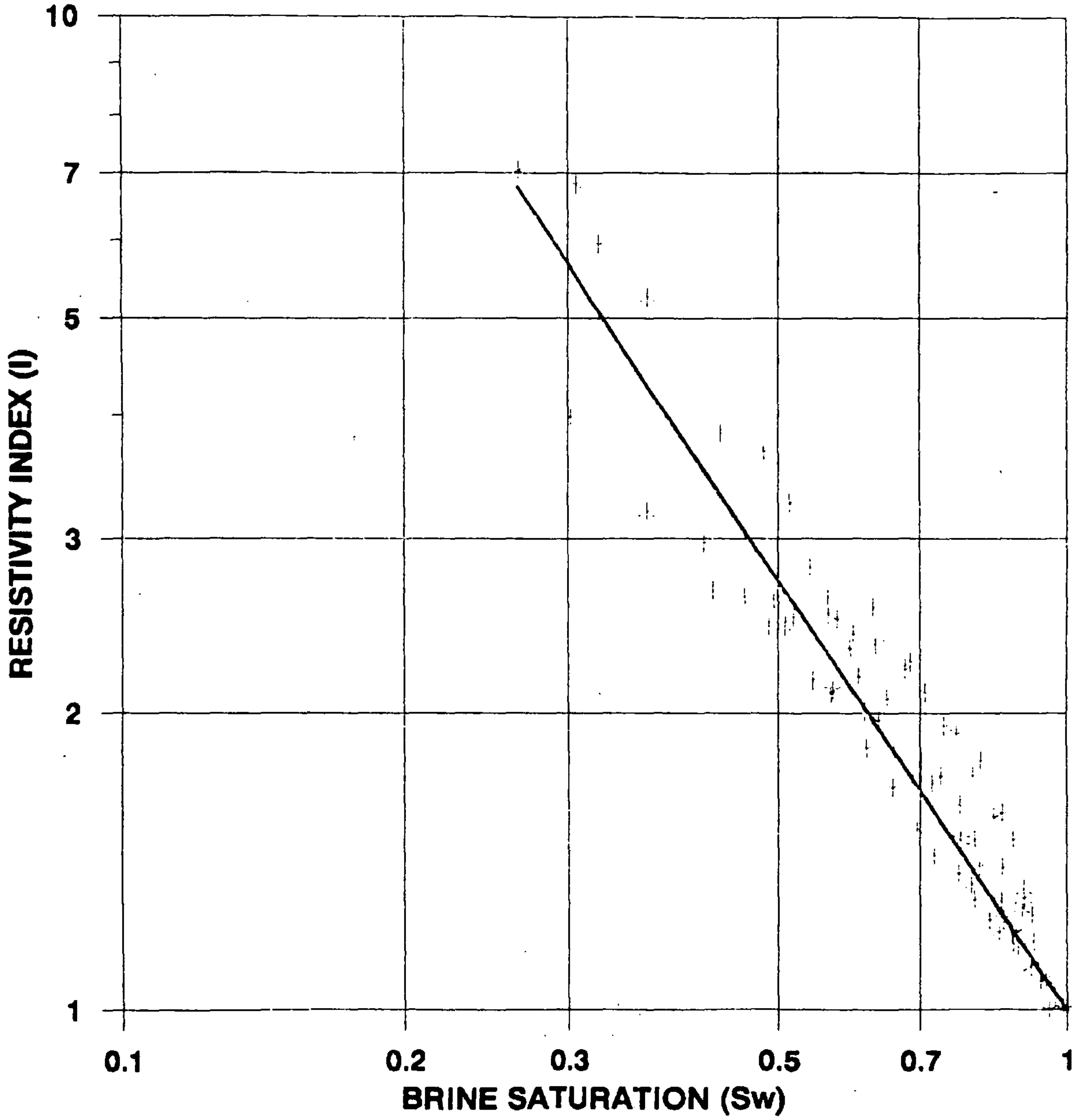
HYCAL ENERGY RESEARCH LABORATORIES LTD.

ALL SAMPLES | FILE: 91SC4001-3

$I = 1.00/Sw^{1.49}$ For entire Sw range tested $r^2 = 0.9027$

FIGURE 1

COMPOSITE HYDROCARBON RESISTIVITY INDEX



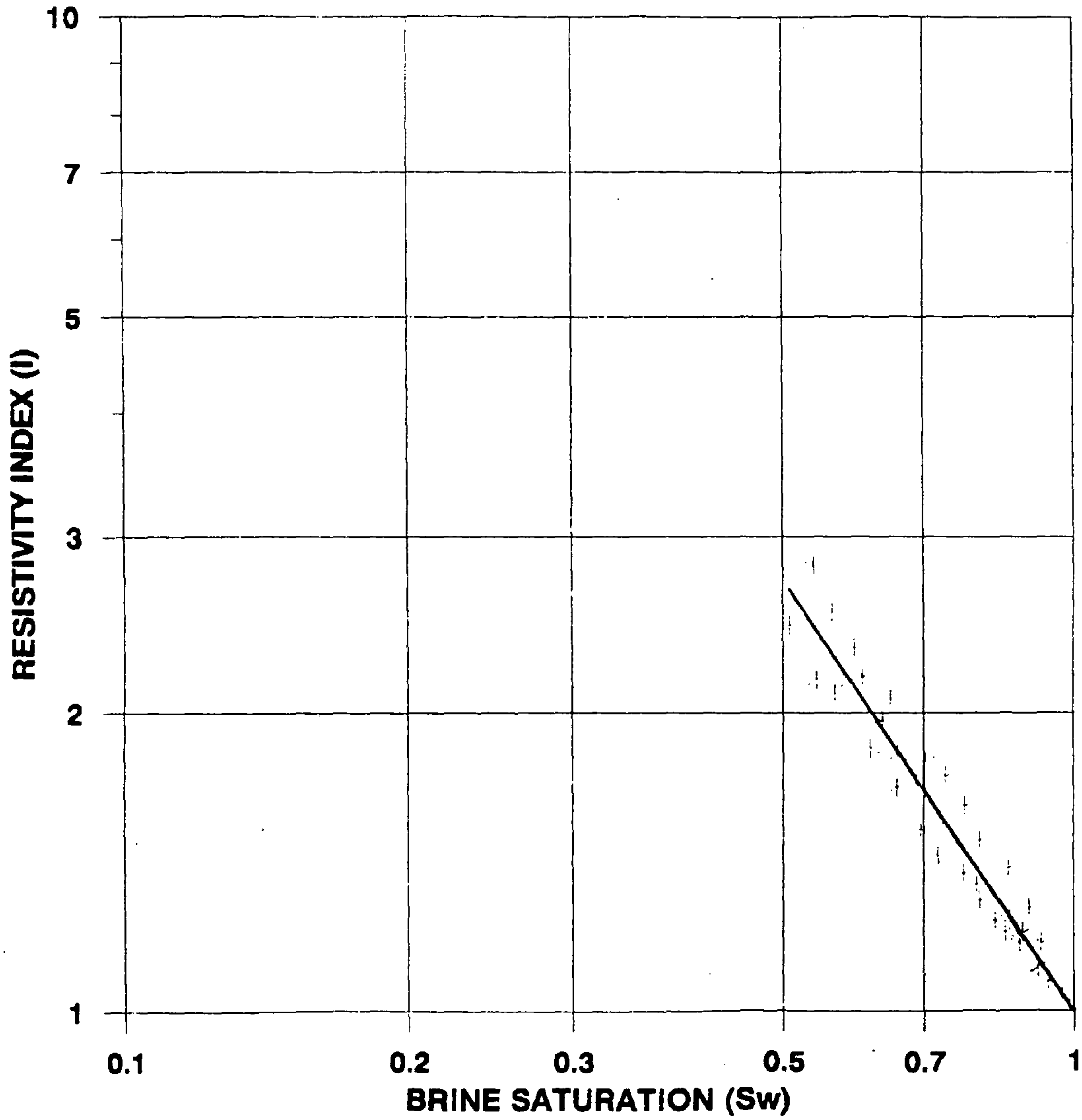
HYCAL ENERGY RESEARCH LABORATORIES LTD.

SAMPLES: 7P, 10& 84 **FILE: 91SC4001-3**

$I = 1.00/Sw^{1.44}$ **For entire Sw range tested** **$r^2 = 0.9349$**

FIGURE 2

COMPOSITE HYDROCARBON RESISTIVITY INDEX



June 8, 1991

HYCAL ENERGY RESEARCH LABORATORIES LTD. **SAMPLE #7P**

Depth: 1422.5 m

Porosity (phi):	9.5%	Saturation Exponent (**n**):	1.68
Gas Permeability (k):	0.21 md	Correlation Coefficient:	0.9682
Grain density (rho):	2828 kg/m3	Data Population:	10

HYDROCARBON RESISTIVITY INDEX DATA

Fractional Brine Saturation	Hydrocarbon Resistivity Index
1.000	1.00
0.924	1.17
0.896	1.27
0.855	1.40
0.799	1.49
0.771	1.61
0.736	1.73
0.702	1.79
0.646	2.06
0.604	2.17

$I = 1.0/Sw^{1.68}$

Table 3

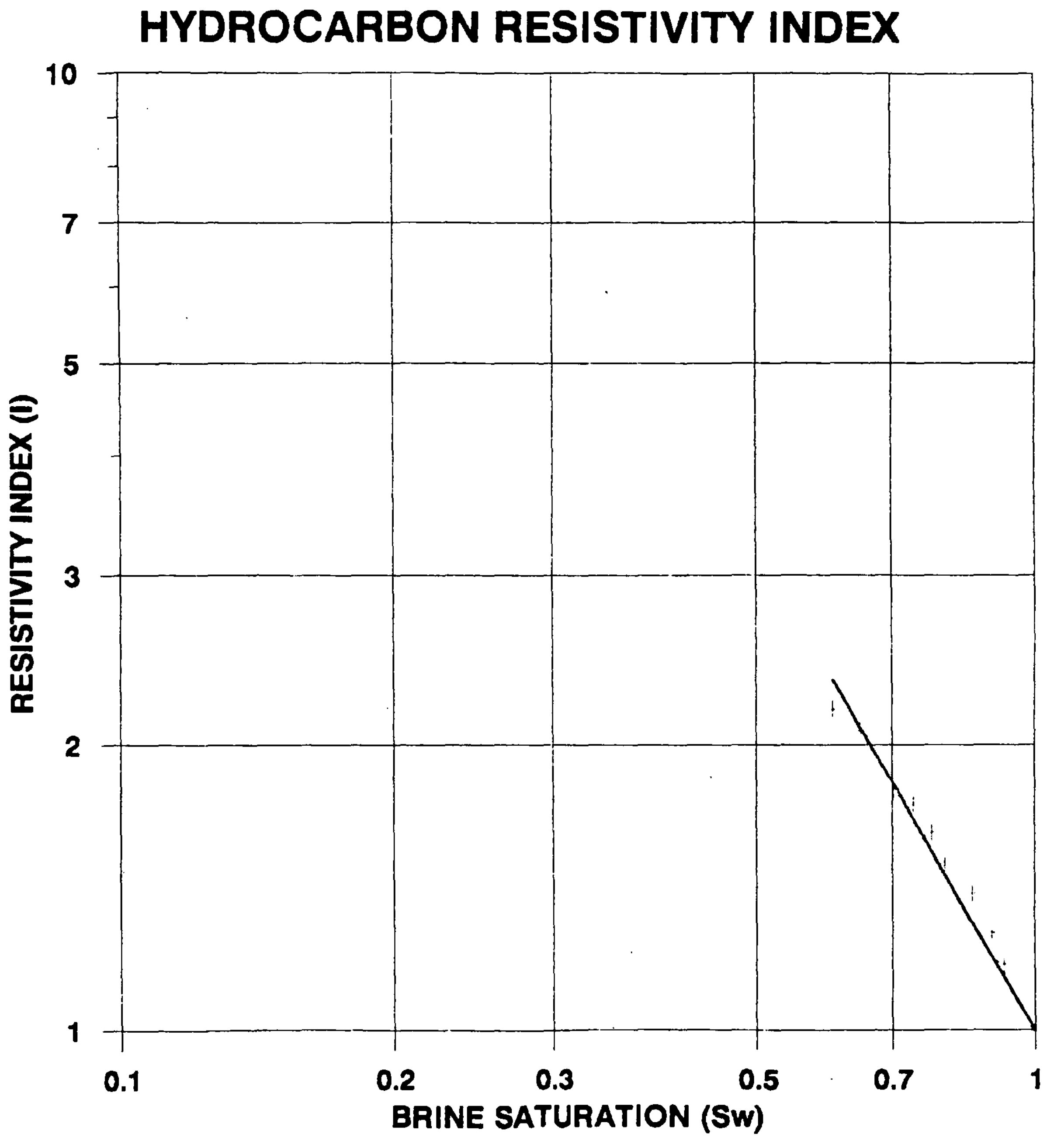
HYCAL ENERGY RESEARCH LABORATORIES LTD.

SAMPLE # 7P

FILE: 91SC4001-3

$I = 1.00/Sw^{1.68}$ **For entire Sw range tested** **$r^2 = 0.9682$**

FIGURE 3



June 8, 1991

HYCAL ENERGY RESEARCH LABORATORIES LTD. **SAMPLE #10**

Depth: 1423.9 m

Porosity (phi):	15.2%	Saturation Exponent (n):	1.55
Gas Permeability (k):	5.23 md	Correlation Coefficient:	0.9833
Grain density (rho):	2817 kg/m3	Data Population:	14

HYDROCARBON RESISTIVITY INDEX DATA

Fractional Brine Saturation	Hydrocarbon Resistivity Index
1.000	1.00
0.972	1.03
0.940	1.07
0.916	1.10
0.884	1.20
0.876	1.20
0.856	1.24
0.829	1.23
0.793	1.34
0.701	1.71
0.657	1.82
0.633	1.96
0.593	2.32
0.561	2.52
0.538	2.81

$I = 1.0/Sw^{1.55}$

Table 4

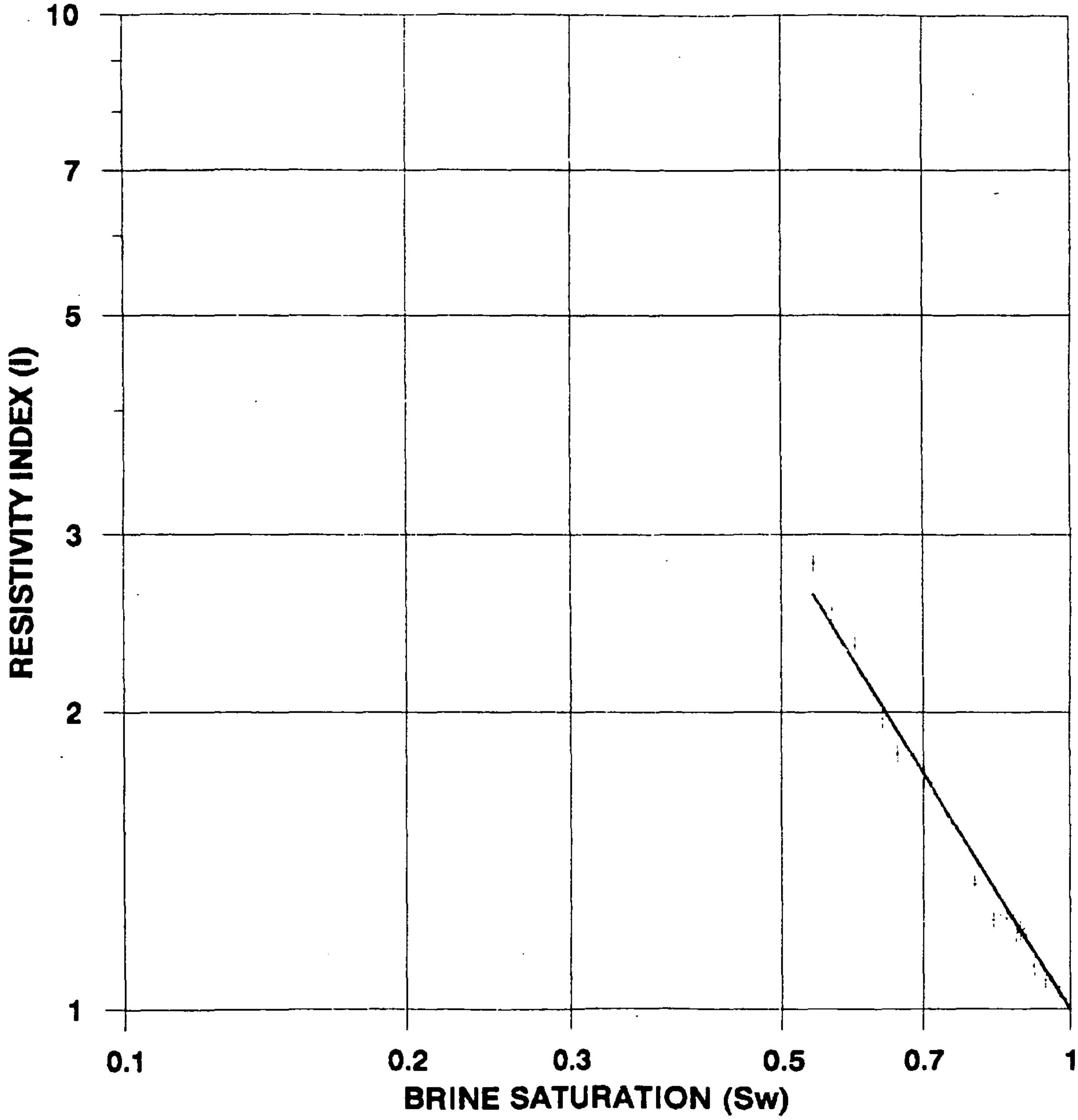
HYCAL ENERGY RESEARCH LABORATORIES LTD.

SAMPLE # 10 **FILE: 91SC4001-3**

$I = 1.00/Sw^{1.55}$ **For entire Sw range tested** **$r^2 = 0.9833$**

FIGURE 4

HYDROCARBON RESISTIVITY INDEX



June 8, 1991

HYCAL ENERGY RESEARCH LABORATORIES LTD. **SAMPLE #18P**

Depth: 1427.5 m

Porosity (phi):	4.6%	
Gas Permeability (k):	md	
Grain density (rho):	kg/m3	
Saturation Exponent (**n**):	1.52 for entire Sw range tested	; r^2 = 0.5902, n = 16
Saturation Exponent (**n**):	2.79 for Sw ≥ 0.81	; r^2 = 0.9104, n = 5
Saturation Exponent (**n**):	0.61 for Sw ≤ 0.81	; r^2 = 0.8636, n = 12

HYDROCARBON RESISTIVITY INDEX DATA

Fractional Brine Saturation	Hydrocarbon Resistivity Index
1.000	1.00
0.957	1.01
0.901	1.30
0.878	1.49
0.856	1.59
0.811	1.79
0.766	1.90
0.709	2.10
0.676	2.21
0.631	2.34
0.597	2.40
0.574	2.48
0.563	2.62
0.518	2.49
0.496	2.60
0.462	2.62
0.428	2.66

$I = 1.00/Sw^{1.52}$ for entire Sw range tested
$I = 1.00/Sw^{2.79}$ for Sw ≥ 0.81
$I = 1.36/Sw^{0.61}$ for Sw ≤ 0.81

Table 5

HYCAL ENERGY RESEARCH LABORATORIES LTD.

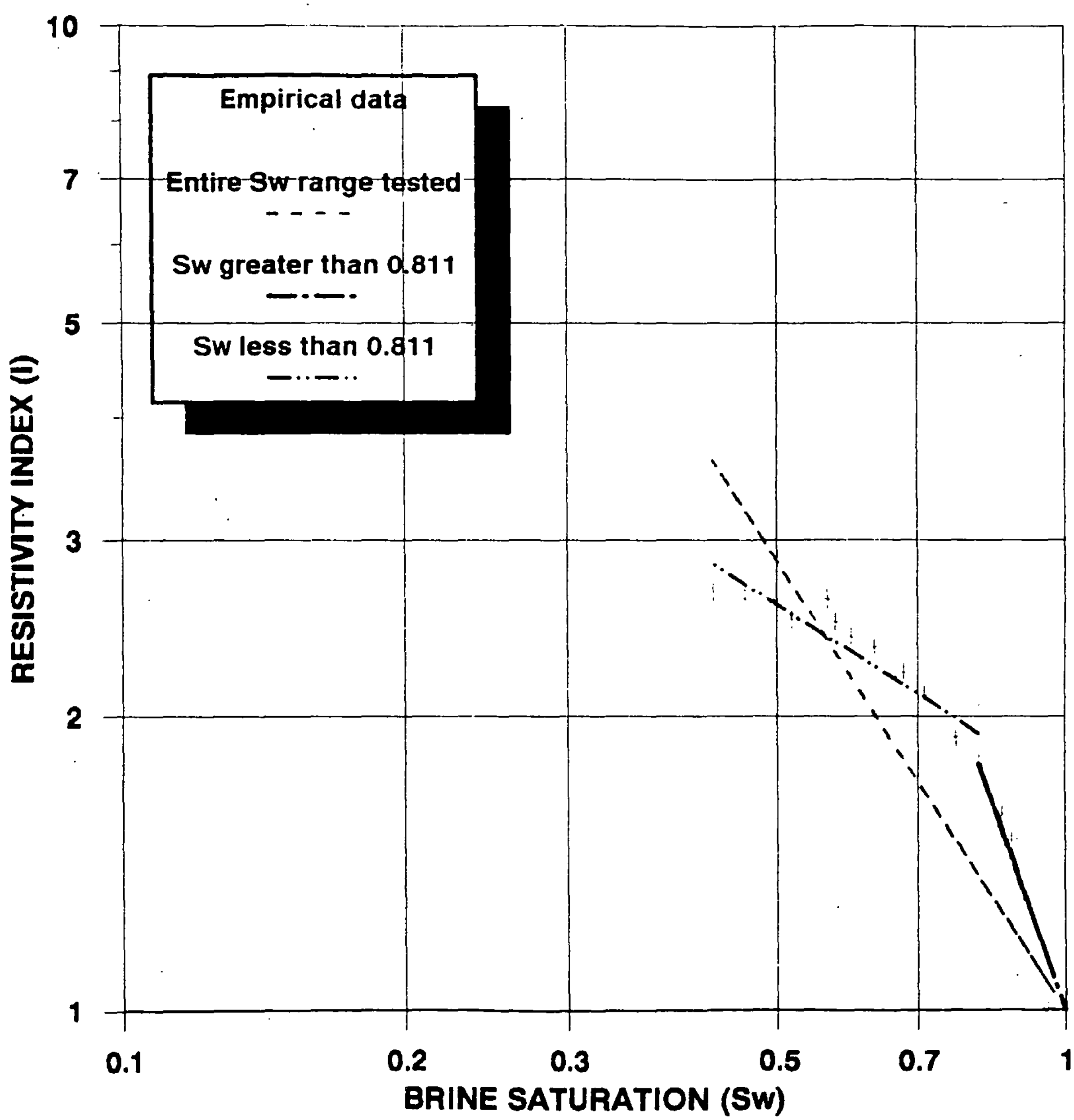
SAMPLE # 18P

FILE: 91SC4001-3

$I = 1.00/Sw^{1.52}$	For entire Sw range tested	$r^2 = 0.5902$
$I = 1.00/Sw^{2.79}$	For Sw > 0.81	$r^2 = 0.9104$
$I = 1.69/Sw^{0.61}$	For Sw < 0.81	$r^2 = 0.8636$

FIGURE 5

HYDROCARBON RESISTIVITY INDEX



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HYCAL ENERGY RESEARCH LABORATORIES LTD. **SAMPLE #27P**

Depth: 1431.6 m

Porosity (phi):	7.1%
Gas Permeability (k):	0.94 md
Grain density (rho):	2843 kg/m3

Saturation Exponent (**n**):	1.23 for entire Sw range tested	; r^2 = 0.9701, n =	12
Saturation Exponent (**n**):	1.58 for Sw ≥ 0.72	; r^2 = 0.9888, n =	6
Saturation Exponent (**n**):	0.97 for Sw ≤ 0.72	; r^2 = 0.9959, n =	7

HYDROCARBON RESISTIVITY INDEX DATA

Fractional Brine Saturation	Hydrocarbon Resistivity Index
1.000	1.00
0.951	1.07
0.889	1.16
0.853	1.29
0.809	1.40
0.773	1.49
0.720	1.70
0.613	2.00
0.569	2.10
0.489	2.44
0.417	2.96
0.364	3.19
0.302	3.98

$I = 1.00/Sw^{1.23}$ for entire Sw range tested
$I = 1.00/Sw^{1.58}$ for Sw ≥ 0.72
$I = 1.36/Sw^{0.87}$ for Sw ≤ 0.72

Table 6

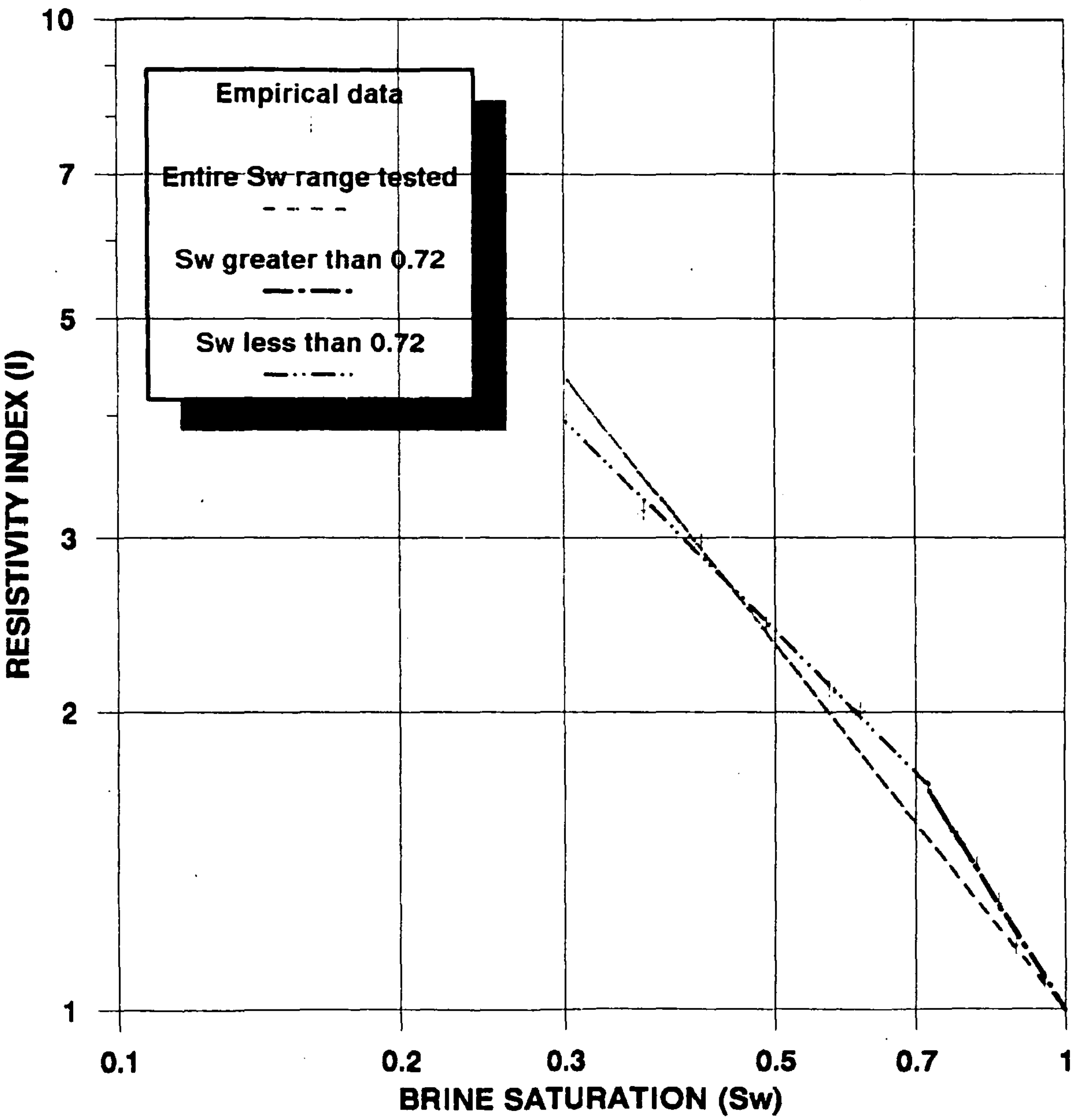
HYCAL ENERGY RESEARCH LABORATORIES LTD.

SAMPLE # 27P | FILE: 91SC4001-3

$I = 1.00/Sw^{1.23}$	For entire Sw range tested	$r^2 = 0.9701$
$I = 1.00/Sw^{1.58}$	For Sw > 0.72	$r^2 = 0.9888$
$I = 1.23/Sw^{0.97}$	For Sw < 0.72	$r^2 = 0.9959$

FIGURE 6

HYDROCARBON RESISTIVITY INDEX



Depth: 1411.2 m

Porosity (phi):	12.6%	Saturation Exponent (**n**):	1.26
Gas Permeability (k):	0.30 md	Correlation Coefficient:	0.9910
Grain density (rho):	2840 kg/m3	Data Population:	12

HYDROCARBON RESISTIVITY INDEX DATA

Fractional Brine Saturation	Hydrocarbon Resistivity Index
1.000	1.00
0.917	1.11
0.877	1.17
0.848	1.20
0.798	1.30
0.769	1.38
0.724	1.44
0.695	1.53
0.655	1.68
0.616	1.84
0.567	2.09
0.542	2.15
0.507	2.45

$I = 1.0/Sw^{1.26}$

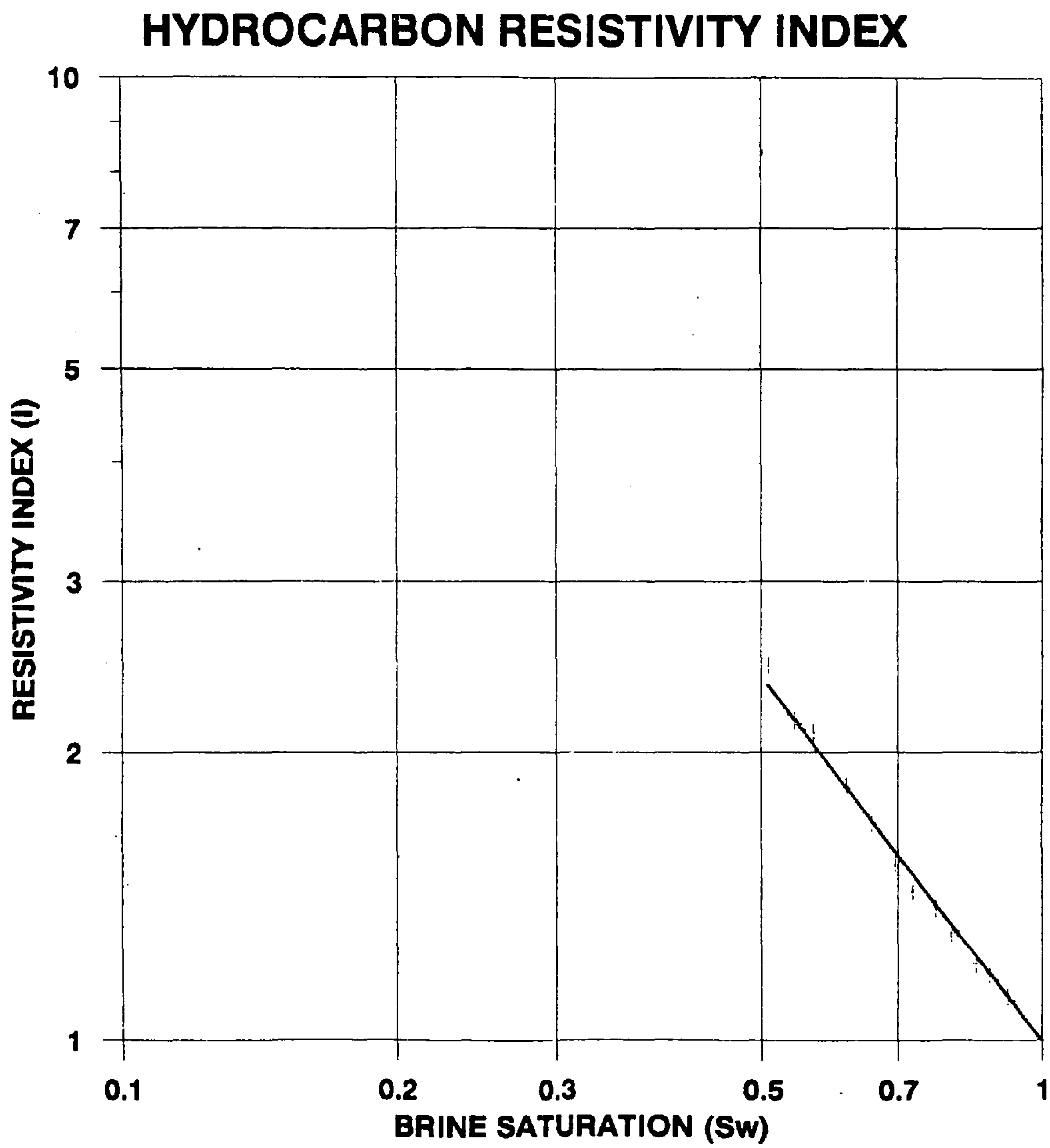
Table 7

HYCAL ENERGY RESEARCH LABORATORIES LTD.

SAMPLE # 84 — FILE: 91SC4001-3

$I = 1.00/Sw^{1.26}$ — For entire Sw range tested — $r^2 = 0.9910$

FIGURE 7



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HYCAL ENERGY RESEARCH LABORATORIES LTD. **SAMPLE #99**

Depth: 1417.1 m

Porosity (phi): 12.0%
Gas Permeability (k): 14.50 md
Grain density (rho): 2840 kg/m3

Saturation Exponent (**n**): 1.64 for entire Sw range tested ; r^2 = 0.9582, n = 15
Saturation Exponent (**n**): 2.27 for Sw ≥ 0.68 ; r^2 = 0.9782, n = 7
Saturation Exponent (**n**): 1.28 for Sw ≤ 0.68 ; r^2 = 0.9874, n = 9

HYDROCARBON RESISTIVITY INDEX DATA

Fractional Brine Saturation	Hydrocarbon Resistivity Index
1.000	1.00
0.990	1.01
0.919	1.25
0.901	1.33
0.837	1.57
0.795	1.73
0.742	1.94
0.683	2.25
0.624	2.55
0.512	3.26
0.483	3.68
0.436	3.83
0.365	5.26
0.324	5.95
0.306	6.84
0.265	7.05

$I = 1.00/Sw^{1.64}$ for entire Sw range tested
$I = 1.00/Sw^{2.27}$ for Sw ≥ 0.68
$I = 1.36/Sw^{1.28}$ for Sw ≤ 0.68

Table 8

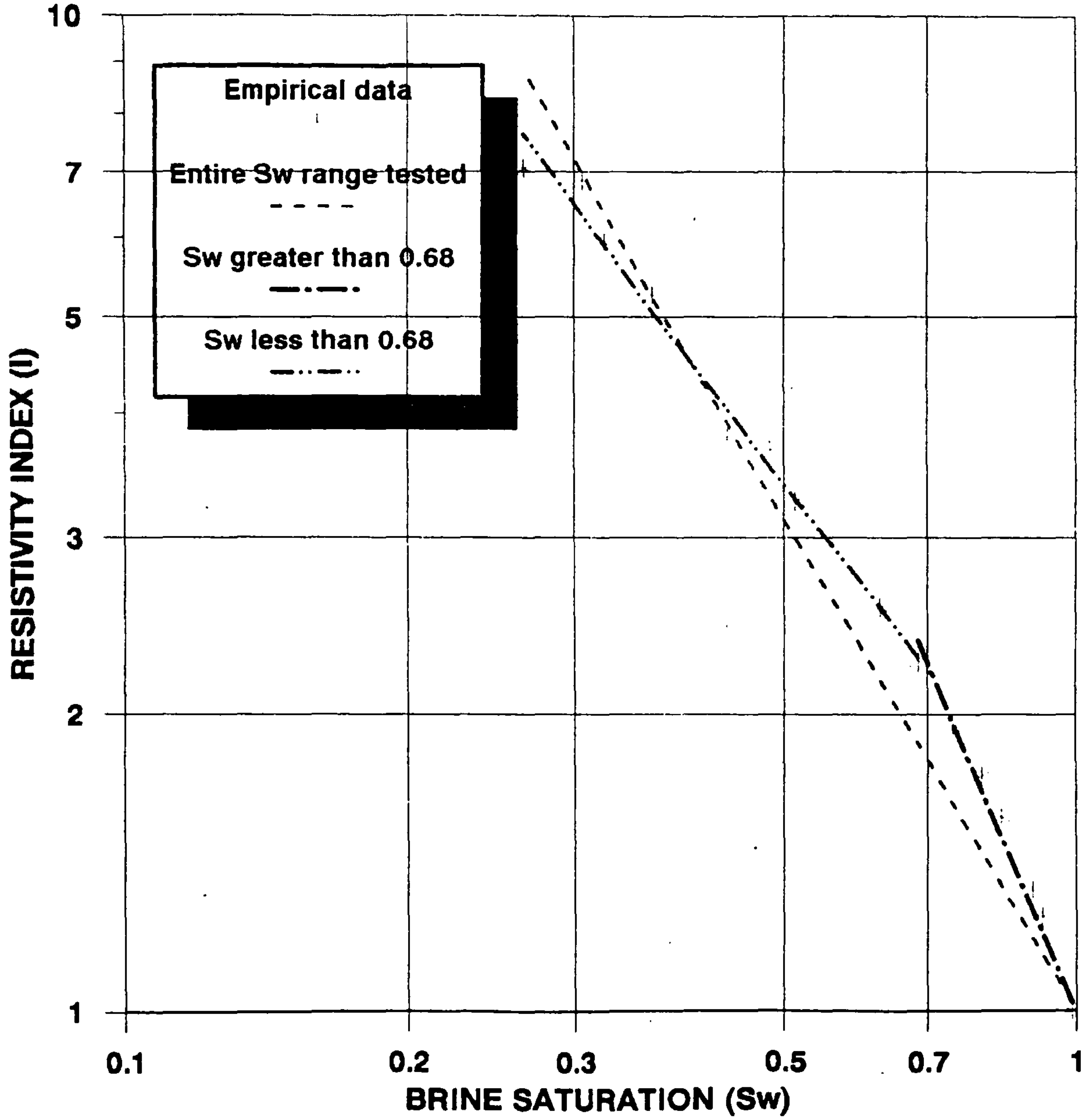
HYCAL ENERGY RESEARCH LABORATORIES LTD.

SAMPLE # 99 **FILE: 91SC4001-3**

$I = 1.00/Sw^{1.64}$	For entire Sw range tested	$r^2 = 0.9582$
$I = 1.00/Sw^{2.27}$	For Sw > 0.68	$r^2 = 0.9782$
$I = 1.40/Sw^{1.28}$	For Sw < 0.68	$r^2 = 0.9874$

FIGURE 8

HYDROCARBON RESISTIVITY INDEX



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RESERVOIR ELECTRICAL RESISTIVITY STUDY
(HYDROCARBON)

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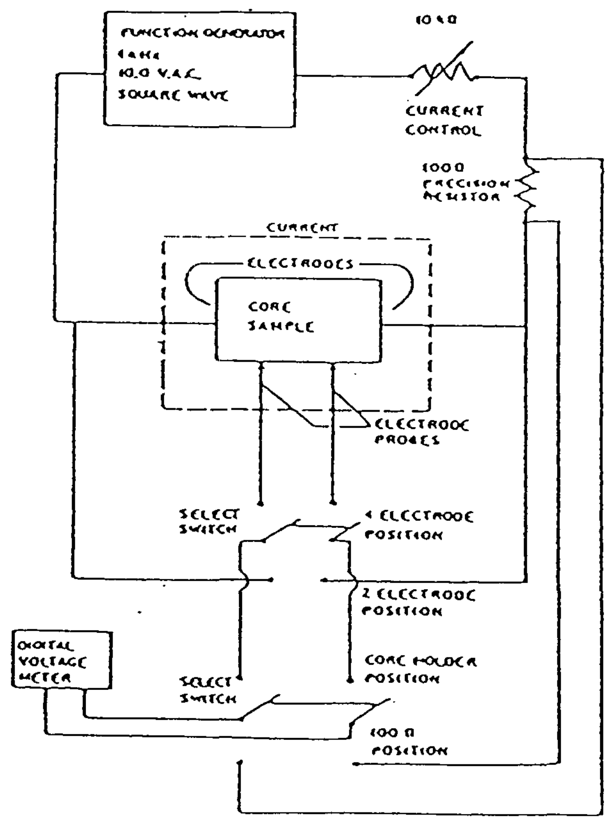

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EXPERIMENTAL PROCEDURE

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HYCAL ENERGY RESEARCH LABORATORIES LTD.

File #: 91-SC-4001-3

SAMPLE	LITHOLOGY	DESCRIPTION
7P	Dolostone	- mottled cream-beige and medium grey-brow - moderately hard - micro to very fine crystalline, locally microsucrosic - cream coloured fossiliferous breccia consisting of stromatoporoid fragments in a dark, shaly, carbonaceous, dolomitic matrix - individual fossil fragments are occasionally draped by shale laminae - fair to good visible intercrystalline porosity
10	Dolostone	- beige-brown - moderately hard - fine crystalline to microcrystalline - sucrosic texture - highly recrystallized, no primary structures observed - occasional microcrystalline bands and patches (possible tabular stromatoporoids) - abundant pinpoint vugs (dissolution) - occasional patches anhydrite - numerous scattered calcite crystals - good visible intercrystalline porosity
18P	Dolostone	- grey-beige - moderately hard - fine crystalline, microsucrosic - highly recrystallized, massive - rare dark, argillaceous, shaly patch - scattered pinpoint vugs - rare argillaceous shaly microlaminae - fair to good visible intercrystalline porosity
27P	Dolostone	- medium to light grey brown - moderately hard - sucrosic texture - numerous pinpoint vugs (dissolution) - highly recrystallized, masking primary structures - weakly calcareous - weakly argillaceous locally, rare shaly microlaminae - fair to good visible intercrystalline porosity

Table 1

GEOLOGICAL DESCRIPTIONS

HYCAL ENERGY RESEARCH LABORATORIES LTD.

File #: 91-SC-4001-3

SAMPLE	LITHOLOGY	DESCRIPTION
84	Dolostone	- mottled cream-beige and grey - moderately hard - micro to fine crystalline - abundant bulbous stromatoporoid fragments in a shaly, crinoidal, pyritic matrix - fossils are weakly calcareous - scattered pinpoint vugs
99	Dolostone	- medium brown with cream coloration - moderately hard - fine crystalline - fossiliferous floatstone of branching stromatoporoid fragments in a sucrosic dolomite matrix - fossils are moderately leached, producing patches of fenestral and pinpoint vugs - occasional small moldic vugs - good visible intercrystalline and pinpoint porosity

Table 1 (cont'd)

SAMPLE SUMMARY

SAMPLE NUMBER	DEPTH (m)	GAS PERMEABILITY (md)	POROSITY* (%)	GRAIN DENSITY (kg/m3)	LENGTH (cm)	DIA. (cm)
			WELL: G-21			
7P	1422.5	0.21	9.5	2828	6.14	2.52
10	1423.9	5.23	15.2	2817	6.78	2.51
18P	1427.5	0.07	4.6	2830	4.31	2.53
27P	1431.6	0.94	7.1	2843	6.11	2.52
			WELL: M-73			
84	1411.2	0.30	12.6	2840	6.42	2.51
99	1417.1	14.50	12.0	2840	5.72	2.51

Table 2

HYCAL ENERGY RESEARCH LABORATORIES LTD.

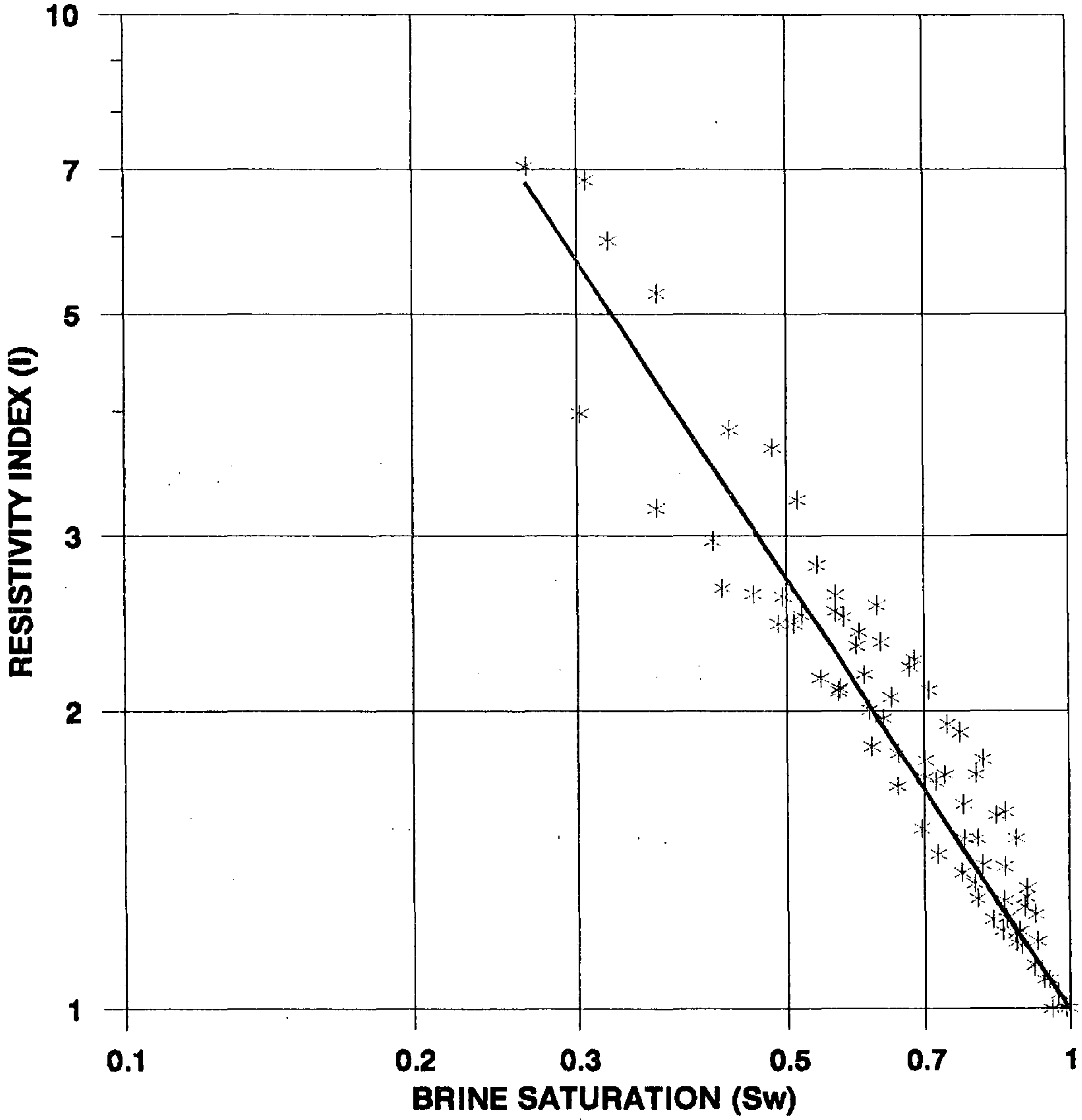
ALL SAMPLES

FILE: 91SC4001-3

$I = 1.00/Sw^{1.49}$ **For entire Sw range tested** **$r^2 = 0.9027$**

FIGURE 1

COMPOSITE HYDROCARBON RESISTIVITY INDEX



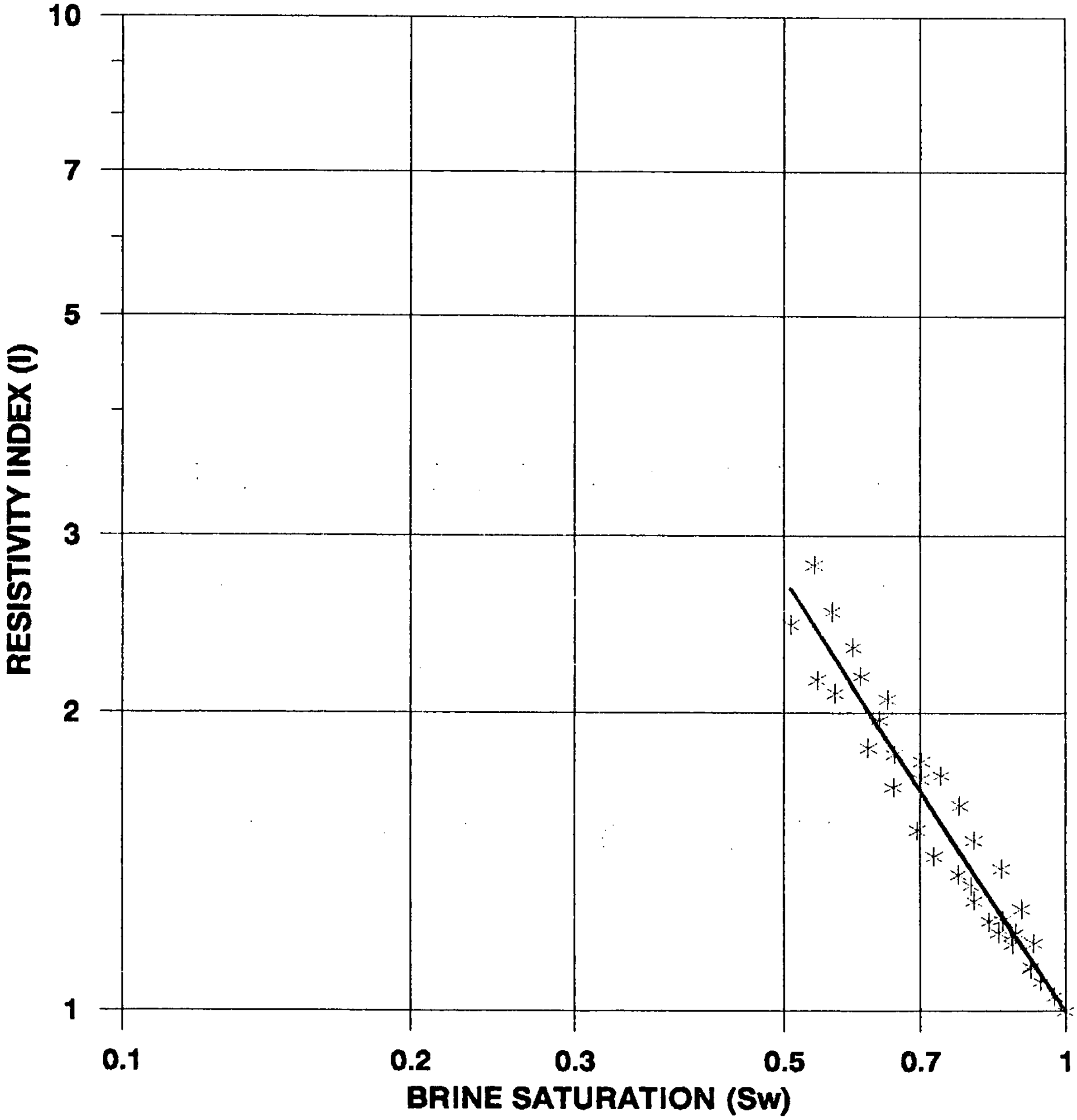
HYCAL ENERGY RESEARCH LABORATORIES LTD.

SAMPLES: 7P, 10& 84 **FILE: 91SC4001-3**

$I = 1.00/Sw^{1.44}$ **For entire Sw range tested** **r^2 = 0.9349**

FIGURE 2

COMPOSITE HYDROCARBON RESISTIVITY INDEX



June 8, 1991

HYCAL ENERGY RESEARCH LABORATORIES LTD. **SAMPLE #7P**

Depth: 1422.5 m

Porosity (phi):	9.5%	Saturation Exponent (**n**):	1.68
Gas Permeability (k):	0.21 md	Correlation Coefficient:	0.9682
Grain density (rho):	2828 kg/m3	Data Population:	10

HYDROCARBON RESISTIVITY INDEX DATA

Fractional Brine Saturation	Hydrocarbon Resistivity Index
1.000	1.00
0.924	1.17
0.896	1.27
0.855	1.40
0.799	1.49
0.771	1.61
0.736	1.73
0.702	1.79
0.646	2.06
0.604	2.17

$I = 1.0/Sw^{1.68}$

Table 3

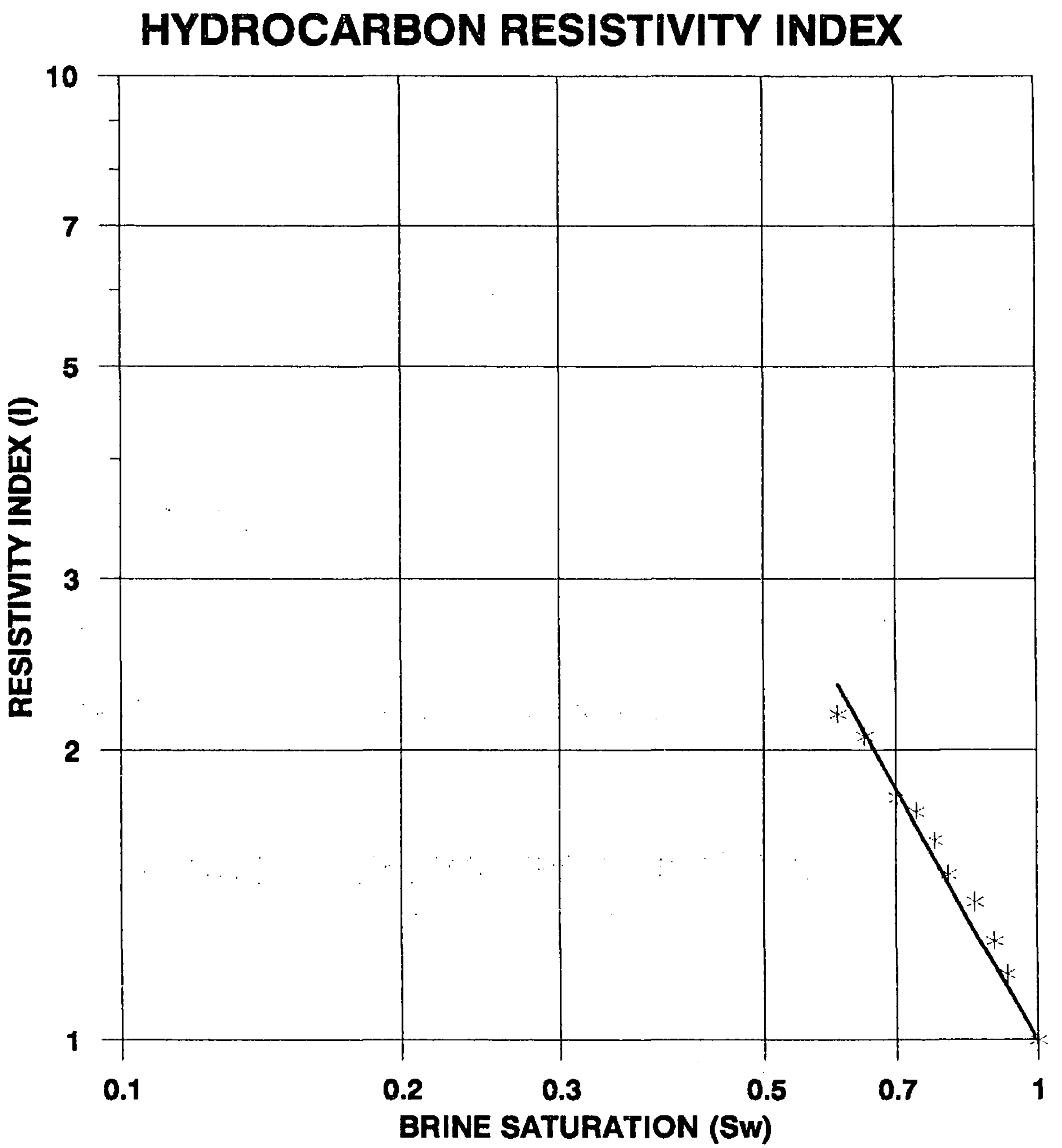
HYCAL ENERGY RESEARCH LABORATORIES LTD.

SAMPLE # 7P

FILE: 91SC4001-3

$I = 1.00/Sw^{1.68}$ **For entire Sw range tested** $r^2 = 0.9682$

FIGURE 3



June 8, 1991

HYCAL ENERGY RESEARCH LABORATORIES LTD. **SAMPLE #10**

Depth: 1423.9 m

Porosity (phi):	15.2%	Saturation Exponent (**n**):	1.55
Gas Permeability (k):	5.23 md	Correlation Coefficient:	0.9833
Grain density (rho):	2817 kg/m3	Data Population:	14

HYDROCARBON RESISTIVITY INDEX DATA

Fractional Brine Saturation	Hydrocarbon Resistivity Index
1.000	1.00
0.972	1.03
0.940	1.07
0.916	1.10
0.884	1.20
0.876	1.20
0.856	1.24
0.829	1.23
0.793	1.34
0.701	1.71
0.657	1.82
0.633	1.96
0.593	2.32
0.561	2.52
0.538	2.81

$I = 1.0/Sw^{1.55}$

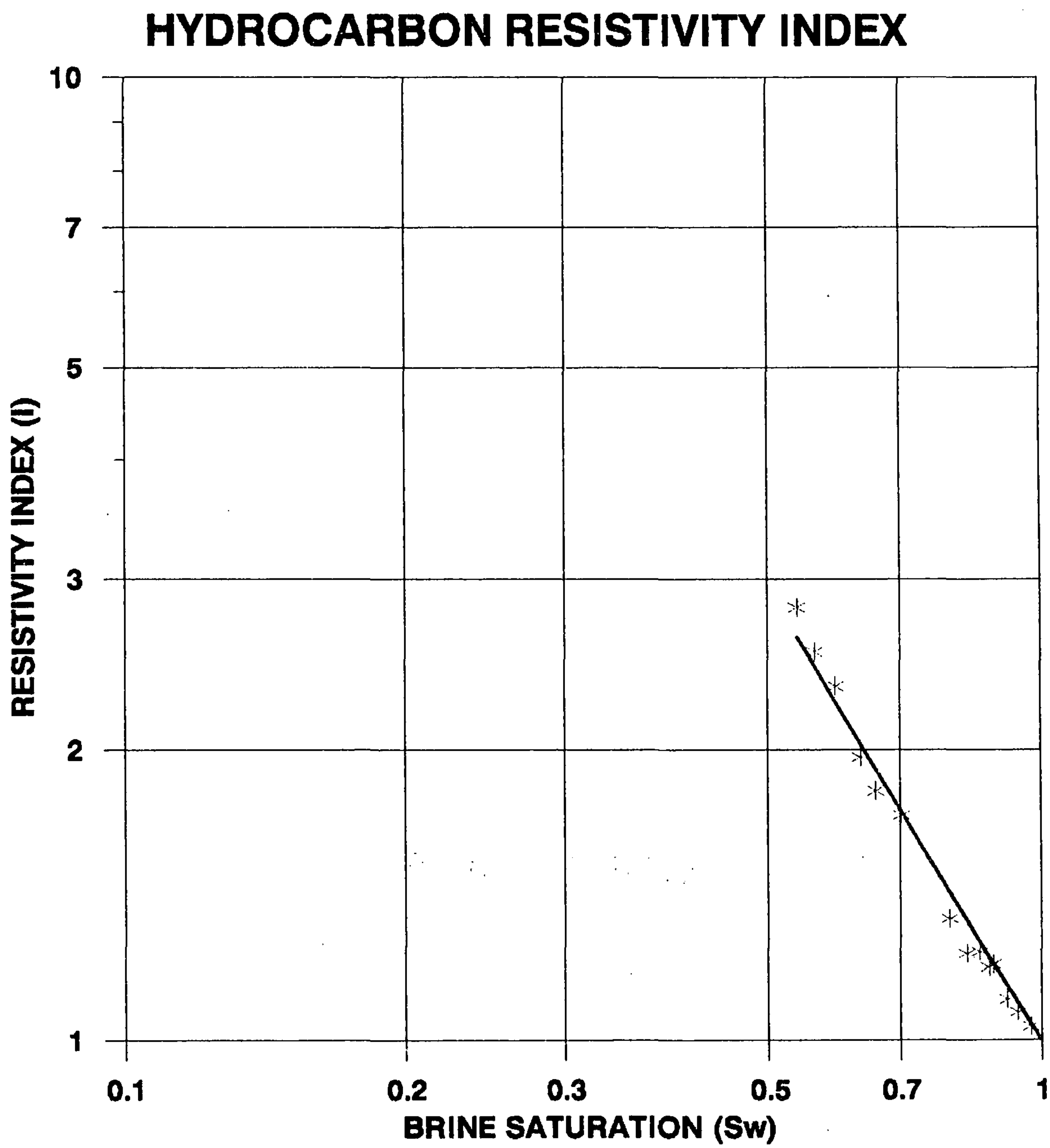
Table 4

HYCAL ENERGY RESEARCH LABORATORIES LTD.

SAMPLE # 10 **FILE: 91SC4001-3**

$I = 1.00/Sw^{1.55}$ **For entire Sw range tested** **r^2 = 0.9833**

FIGURE 4



June 8, 1991

HYCAL ENERGY RESEARCH LABORATORIES LTD. **SAMPLE #18P**

Depth: 1427.5 m

Porosity (phi):	4.6%
Gas Permeability (k):	md
Grain density (rho):	kg/m3

Saturation Exponent (**n**):	1.52 for entire Sw range tested	; r^2 = 0.5902, n = 16
Saturation Exponent (**n**):	2.79 for Sw ≥ 0.81	; r^2 = 0.9104, n = 5
Saturation Exponent (**n**):	0.61 for Sw ≤ 0.81	; r^2 = 0.8636, n = 12

HYDROCARBON RESISTIVITY INDEX DATA

Fractional Brine Saturation	Hydrocarbon Resistivity Index
1.000	1.00
0.957	1.01
0.901	1.30
0.878	1.49
0.856	1.59
0.811	1.79
0.766	1.90
0.709	2.10
0.676	2.21
0.631	2.34
0.597	2.40
0.574	2.48
0.563	2.62
0.518	2.49
0.496	2.60
0.462	2.62
0.428	2.66

$I = 1.00/Sw^{1.52}$ for entire Sw range tested
$I = 1.00/Sw^{2.79}$ for Sw ≥ 0.81
$I = 1.36/Sw^{0.61}$ for Sw ≤ 0.81

Table 5

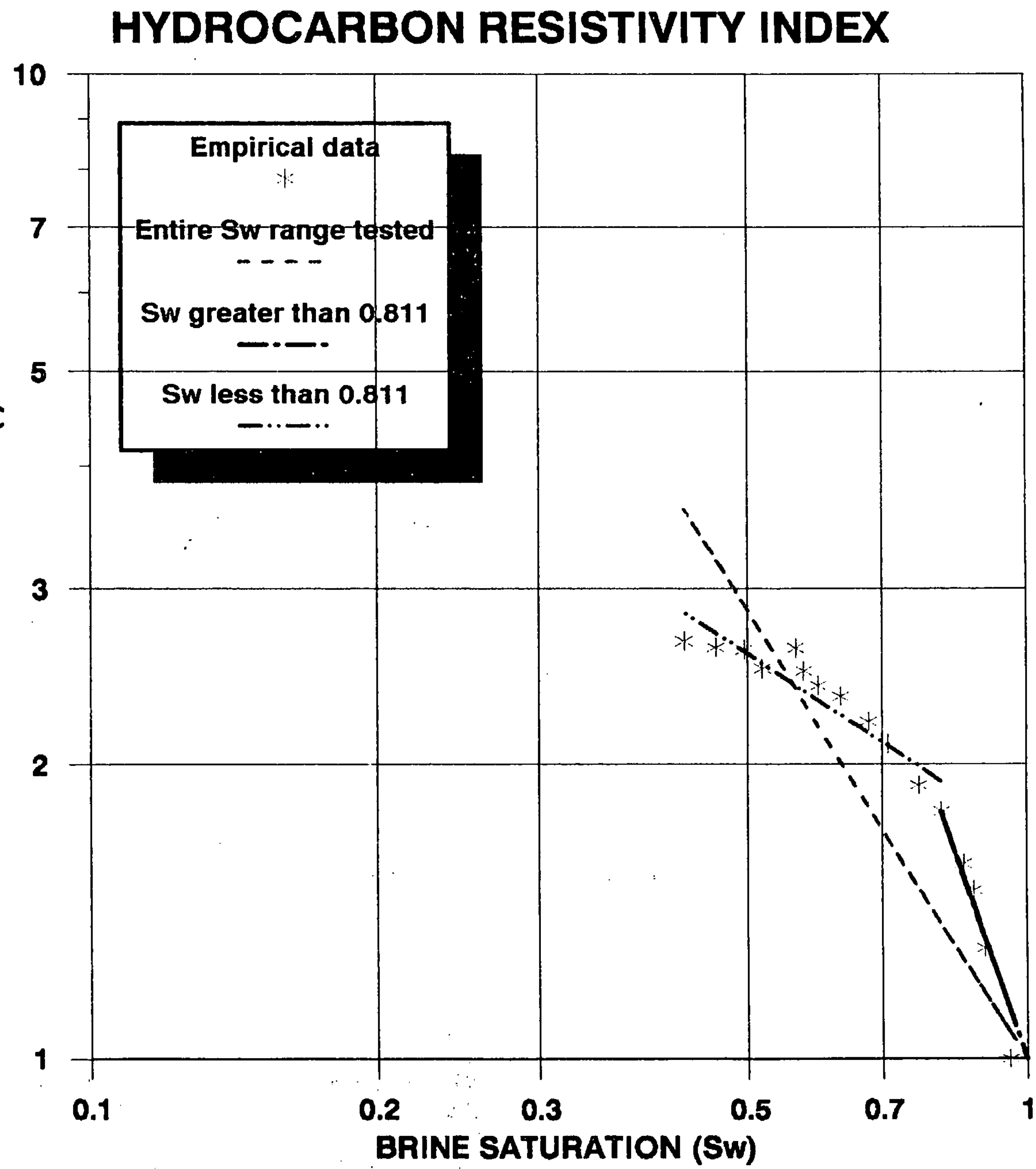
HYCAL ENERGY RESEARCH LABORATORIES LTD.

SAMPLE # 18P

FILE: 91SC4001-3

$I = 1.00/Sw^{1.52}$	For entire Sw range tested	r^2 = 0.5902
$I = 1.00/Sw^{2.79}$	For Sw > 0.81	r^2 = 0.9104
$I = 1.69/Sw^{0.61}$	For Sw < 0.81	r^2 = 0.8636

FIGURE 5



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HYCAL ENERGY RESEARCH LABORATORIES LTD. **SAMPLE #27P**

Depth: 1431.6 m

Porosity (phi): 7.1%
Gas Permeability (k): 0.94 md
Grain density (rho): 2843 kg/m3

Saturation Exponent (**n**): 1.23 for entire Sw range tested ; r^2 = 0.9701, n = 12
Saturation Exponent (**n**): 1.58 for Sw ≥ 0.72 ; r^2 = 0.9888, n = 6
Saturation Exponent (**n**): 0.97 for Sw ≤ 0.72 ; r^2 = 0.9959, n = 7

HYDROCARBON RESISTIVITY INDEX DATA

Fractional Brine Saturation	Hydrocarbon Resistivity Index
1.000	1.00
0.951	1.07
0.889	1.16
0.853	1.29
0.809	1.40
0.773	1.49
0.720	1.70
0.613	2.00
0.569	2.10
0.489	2.44
0.417	2.96
0.364	3.19
0.302	3.98

$I = 1.00/Sw^{1.23}$ for entire Sw range tested
$I = 1.00/Sw^{1.58}$ for Sw ≥ 0.72
$I = 1.36/Sw^{0.97}$ for Sw ≤ 0.72

Table 6

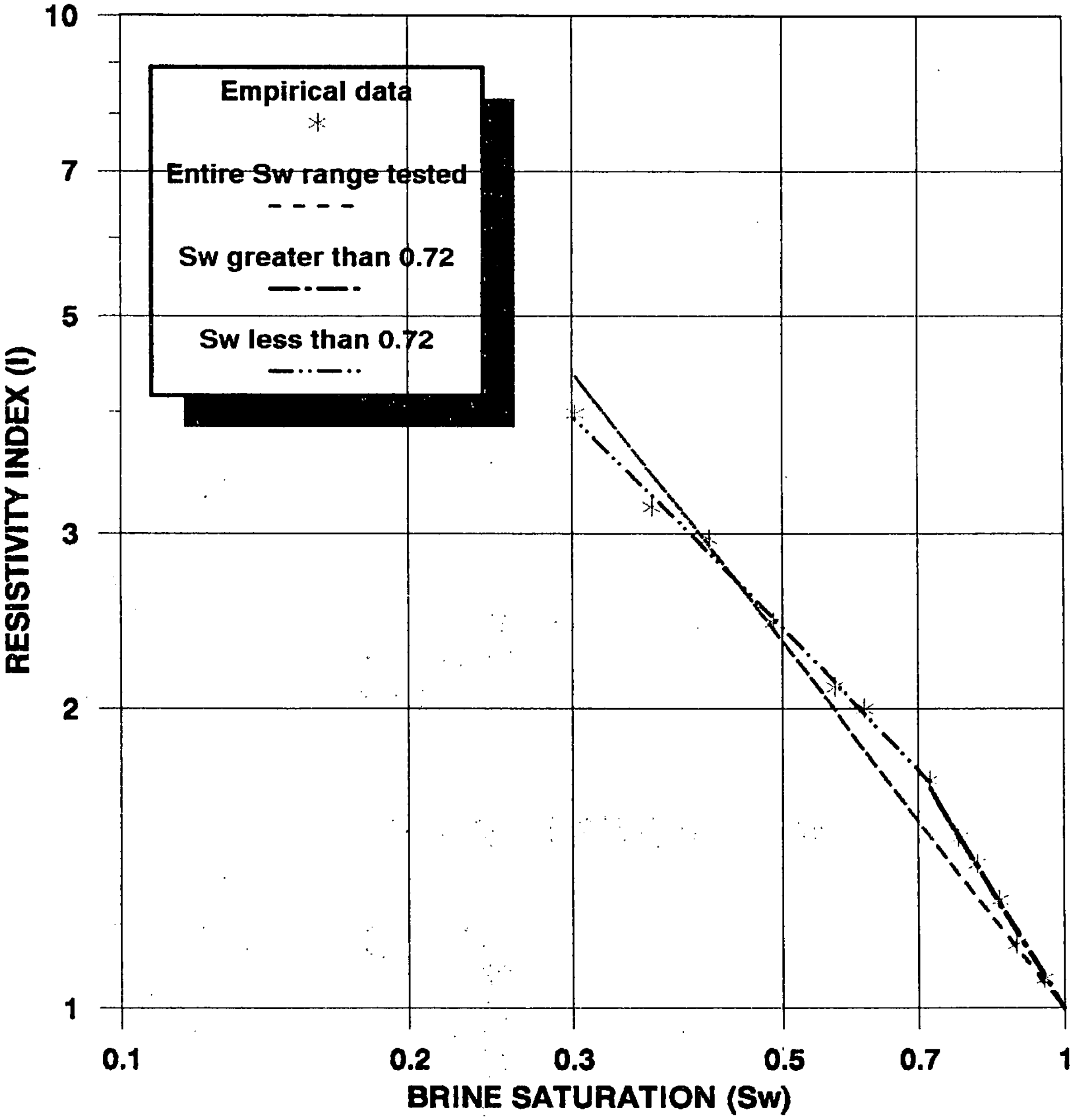
HYCAL ENERGY RESEARCH LABORATORIES LTD.

SAMPLE # 27P | | FILE: 91SC4001-3

$I = 1.00/Sw^{1.23}$	For entire Sw range tested	$r^2 = 0.9701$
$I = 1.00/Sw^{1.58}$	For Sw > 0.72	$r^2 = 0.9888$
$I = 1.23/Sw^{0.97}$	For Sw < 0.72	$r^2 = 0.9959$

FIGURE 6

HYDROCARBON RESISTIVITY INDEX



June 8, 1991

HYCAL ENERGY RESEARCH LABORATORIES LTD. **SAMPLE #84**

Depth: 1411.2 m

Porosity (phi):	12.6%	Saturation Exponent (**n**):	1.26
Gas Permeability (k):	0.30 md	Correlation Coefficient:	0.9910
Grain density (rho):	2840 kg/m3	Data Population:	12

HYDROCARBON RESISTIVITY INDEX DATA

Fractional Brine Saturation	Hydrocarbon Resistivity Index
1.000	1.00
0.917	1.11
0.877	1.17
0.848	1.20
0.798	1.30
0.769	1.38
0.724	1.44
0.695	1.53
0.655	1.68
0.616	1.84
0.567	2.09
0.542	2.15
0.507	2.45

$I = 1.0/Sw^{1.26}$

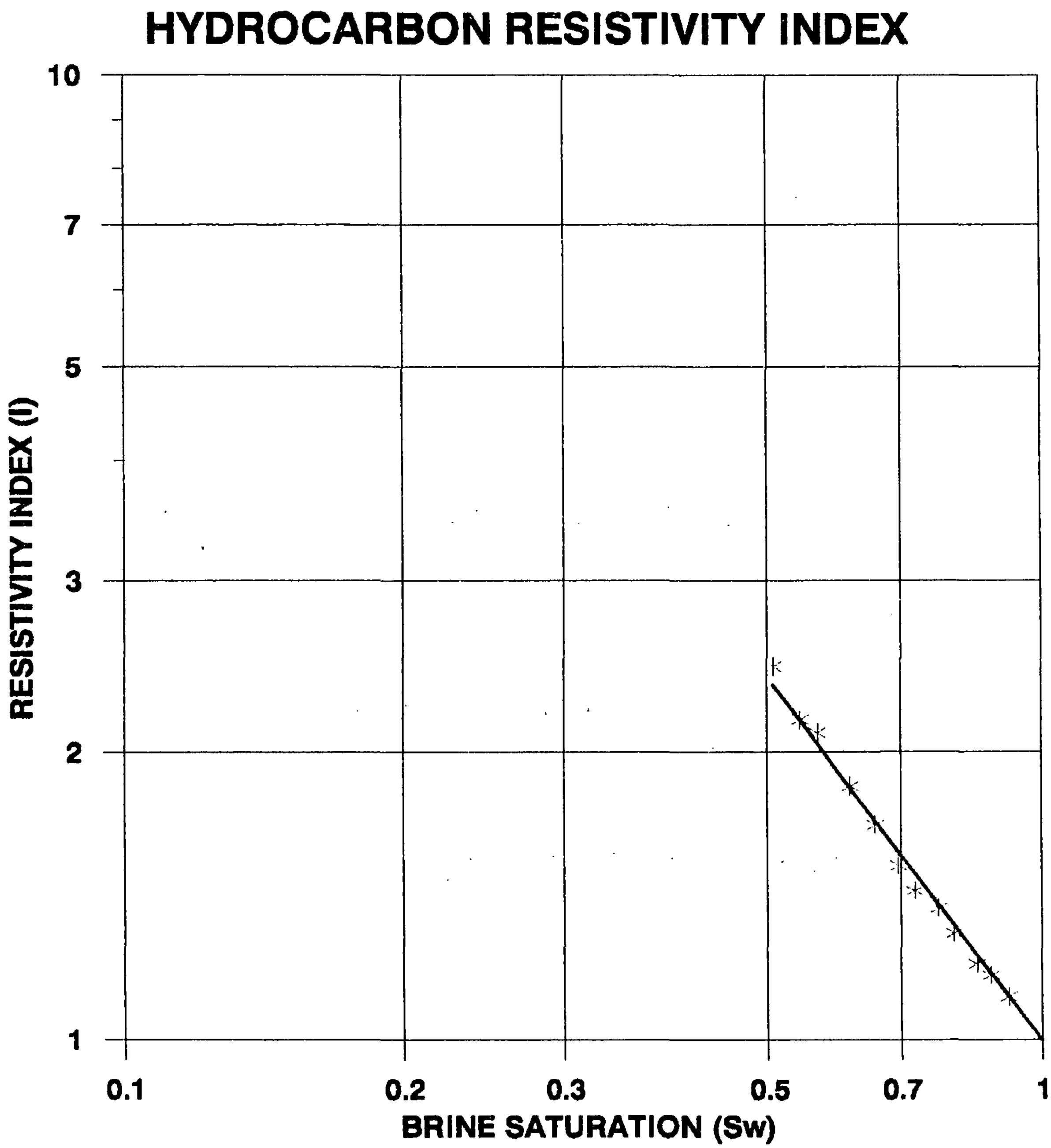
Table 7

HYCAL ENERGY RESEARCH LABORATORIES LTD.

SAMPLE # 84 **FILE: 91SC4001-3**

$I = 1.00/Sw^{1.26}$ **For entire Sw range tested** **r^2 = 0.9910**

FIGURE 7



June 8, 1991

HYCAL ENERGY RESEARCH LABORATORIES LTD. **SAMPLE #99**

Depth: 1417.1 m

Porosity (phi):	12.0%
Gas Permeability (k):	14.50 md
Grain density (rho):	2840 kg/m3

Saturation Exponent (**n**):	1.64 for entire Sw range tested	; r^2 = 0.9582, n = 15
Saturation Exponent (**n**):	2.27 for Sw ≥ 0.68	; r^2 = 0.9782, n = 7
Saturation Exponent (**n**):	1.28 for Sw ≤ 0.68	; r^2 = 0.9874, n = 9

HYDROCARBON RESISTIVITY INDEX DATA

Fractional Brine Saturation	Hydrocarbon Resistivity Index
1.000	1.00
0.990	1.01
0.919	1.25
0.901	1.33
0.837	1.57
0.795	1.73
0.742	1.94
0.683	2.25
0.624	2.55
0.512	3.26
0.483	3.68
0.436	3.83
0.365	5.26
0.324	5.95
0.306	6.84
0.265	7.05

$I = 1.00/Sw^{1.64}$ for entire Sw range tested
$I = 1.00/Sw^{2.27}$ for Sw ≥ 0.68
$I = 1.36/Sw^{1.28}$ for Sw ≤ 0.68

Table 8

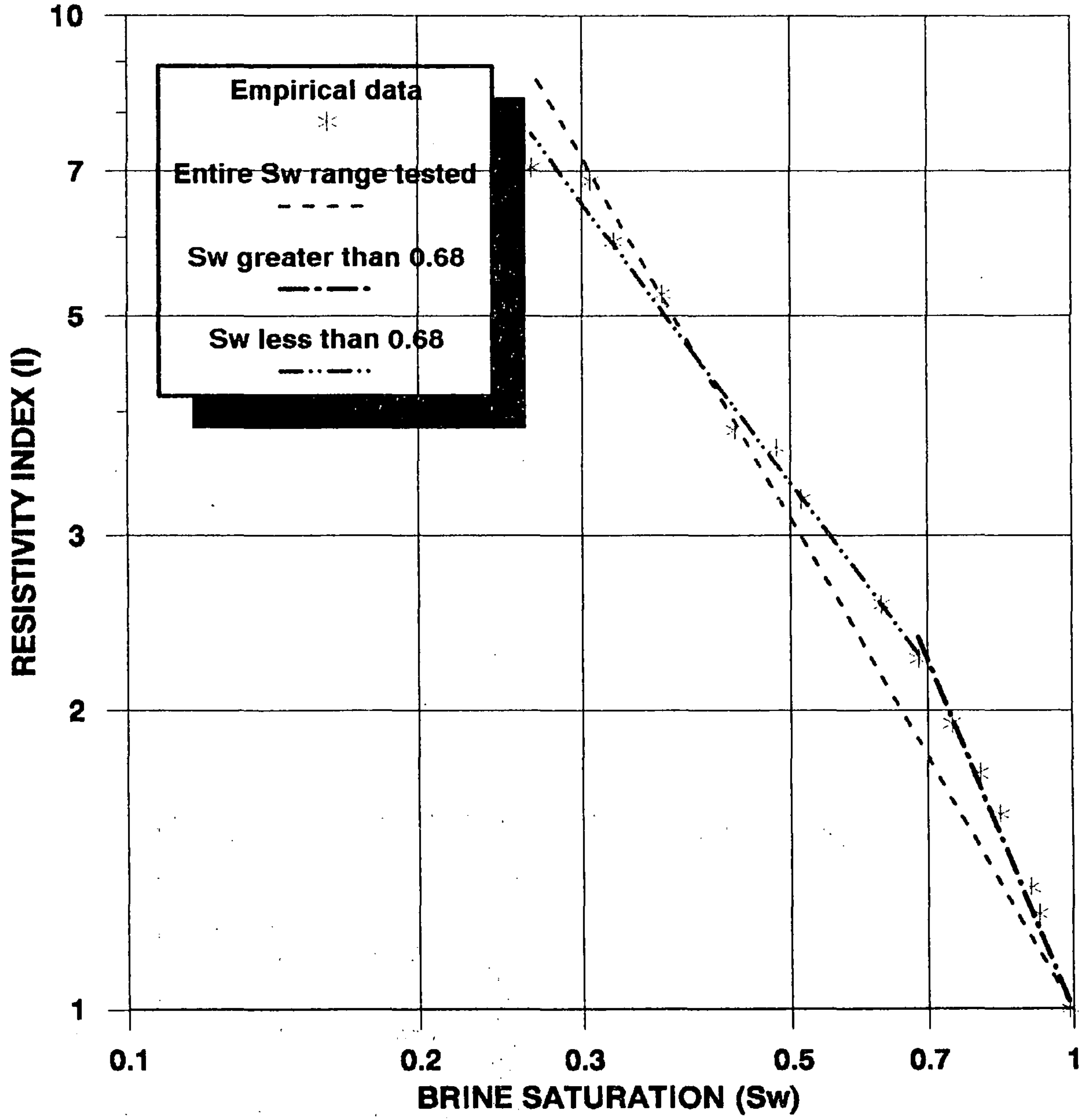
HYCAL ENERGY RESEARCH LABORATORIES LTD.

SAMPLE # 99 | FILE: 91SC4001-3

$I = 1.00/Sw^{1.64}$	For entire Sw range tested	$r^2 = 0.9582$
$I = 1.00/Sw^{2.27}$	For Sw > 0.68	$r^2 = 0.9782$
$I = 1.40/Sw^{1.28}$	For Sw < 0.68	$r^2 = 0.9874$

FIGURE 8

HYDROCARBON RESISTIVITY INDEX



PLOTS & GRAPHS