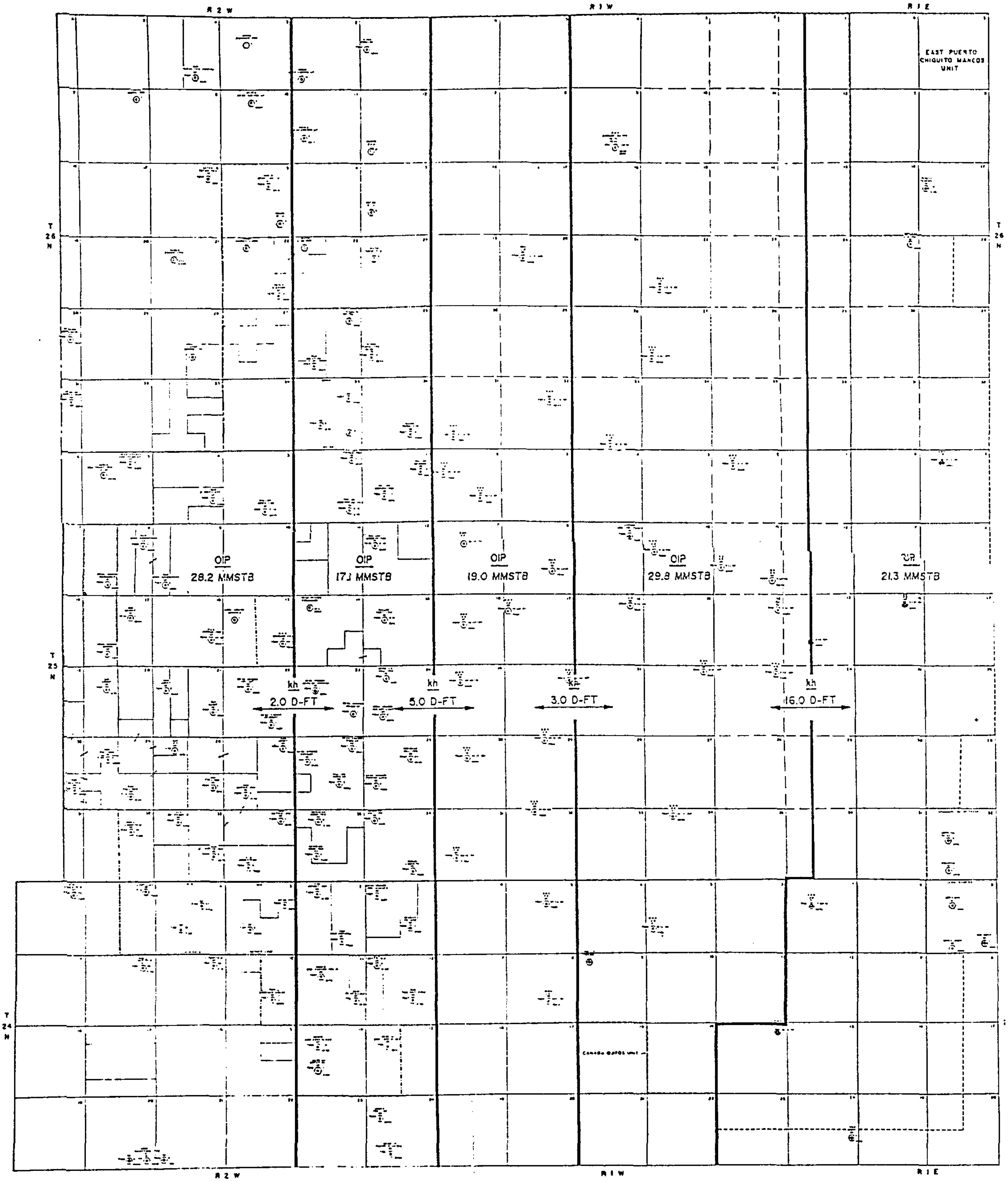
Sun Exploration and Production Company
Exhibits in Case Nos. 7980, 8946, 8950, and 9111
Before the Oil Conservation Commission of the
New Mexico Department of Energy and Minerals

June 13, 1988

MULTITANK MATERIAL BALANCE
AREAL DISTRIBUTION OF ORIGINAL OIL IN PLACE AND PERMEABILITY- THICKNESS PRODUCT



SUN Sun Exploration and Production Company Rocky Mountain District

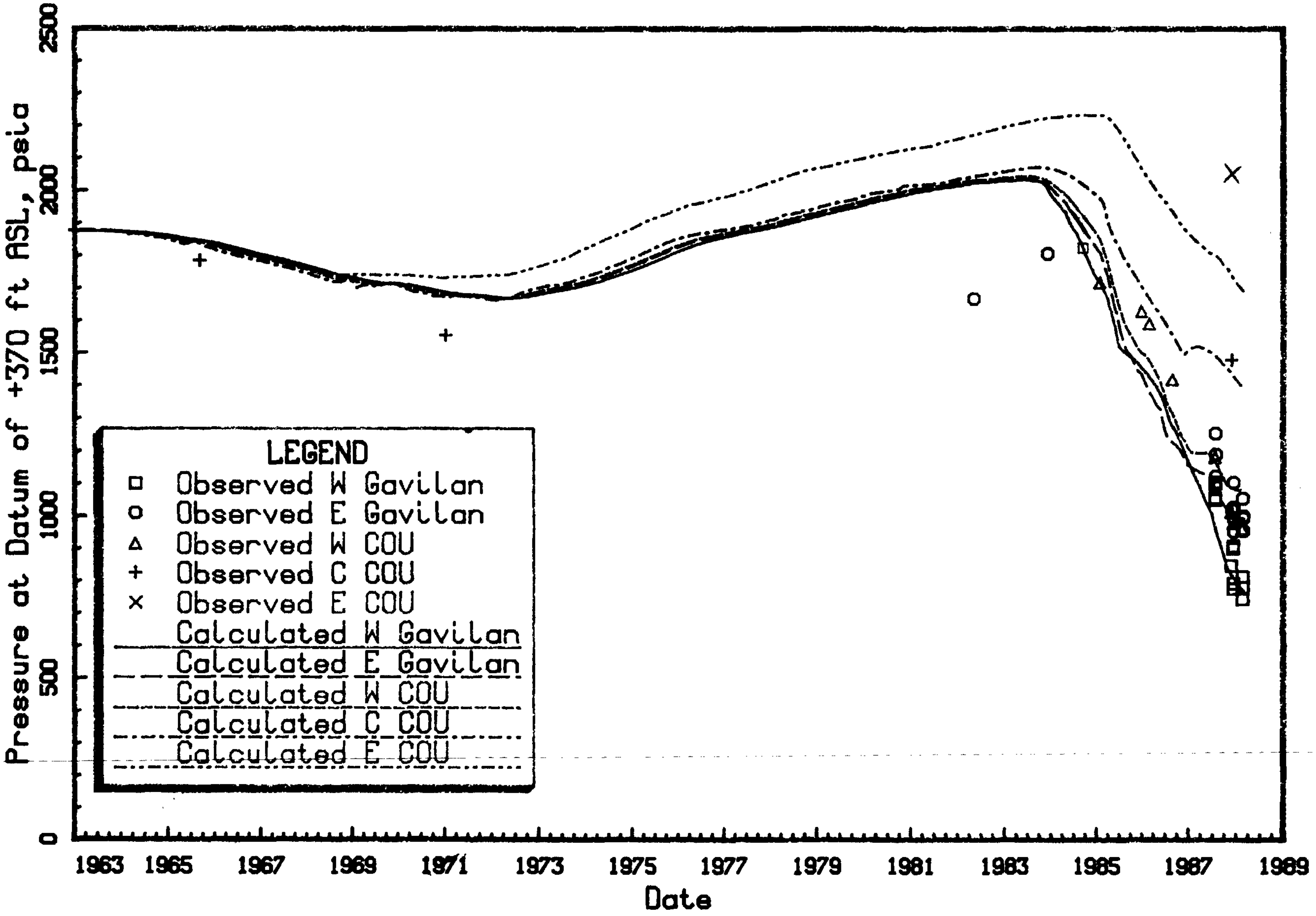
CANADA OJITOS & GAVILAN AREAS

TYPE:

DATUM:

Material Balance Verification

Comparison of Calculated and Measured Pressures



CONCLUSIONS BASED ON MATERIAL BALANCE CALCULATIONS

There is no flow barrier at the edge of the current pressure maintenance area in the Canada Ojitos Unit

* Observed pressure drops in the field can be explained by permeability **variations** rather than permeability **barriers**

Effect of Pressure Maintenance and Allowable On Cumulative Recovery From Gavilan

Effect of Pressure Maintenance

Current Oil and Gas Allowables (800 BOPD, 480 MCFPD for 640 acres)

Pressure Maintenance Starts 8/89

Case	Ultimate Recovery, MSTB
No Pressure Maintenance	5,439
Pressure Maintenance	10,215

Effect of Allowables

Allowables changed from 7/88 to 8/89

Pressure Maintenance starts in 8/89, with current allowables and gas injection credit

Allowables in Case (for 640 acres)	Ultimate Recovery, MSTB
800 BOPD, 188 MCFPD gas	11,063
800 BOPD, 480 MCFPD gas	10,215
1280 BOPD, 2560 MCFPD gas	7,375

CONCLUSION BASED ON FUTURE PERFORMANCE PROJECTIONS

Ultimate recovery from Gavilan will be increased by minimizing oil and gas withdrawals now, conserving reservoir energy for additional recovery with pressure maintenance later.

RECOMMENDATIONS

* Maintain the West Puerto Chiquito - Gavilan Boundary at its current position

* The lowest oil rates and the minimum gas production possible are desirable from a reservoir standpoint because they will conserve reservoir energy and can lead to improved recovery if a pressure maintenance project is installed in Gavilan

* Gavilan Operators should be encouraged to implement a pressure maintenance project to improve recovery from the reservoir

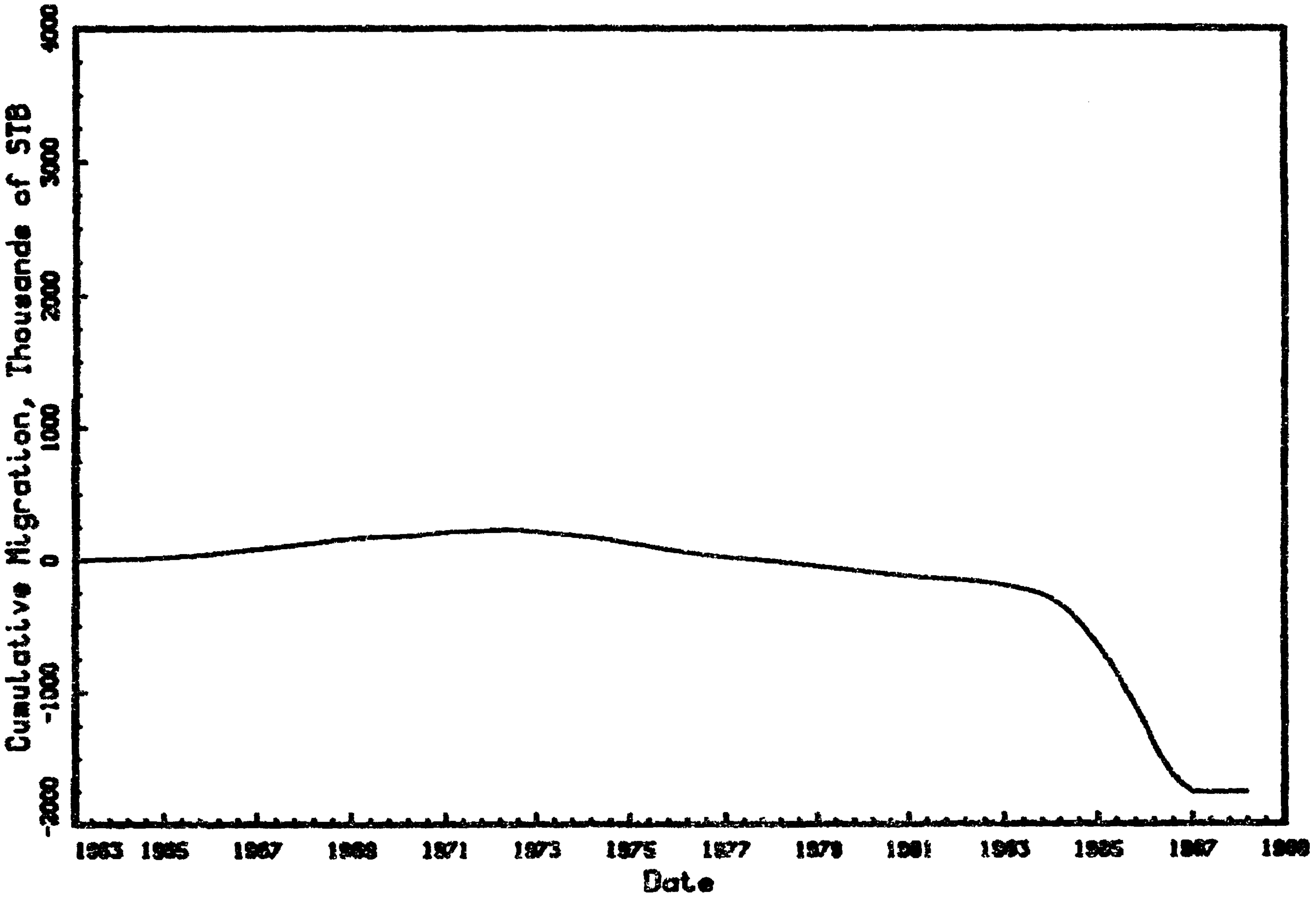
Sun Exploration and Production Company
Rebuttal Exhibits in Case Nos. 7980, 8946, 8950, and 9111
Before the Oil Conservation Commission of the
New Mexico Department of Energy and Minerals

June 13, 1988

REBUTTAL TESTIMONY

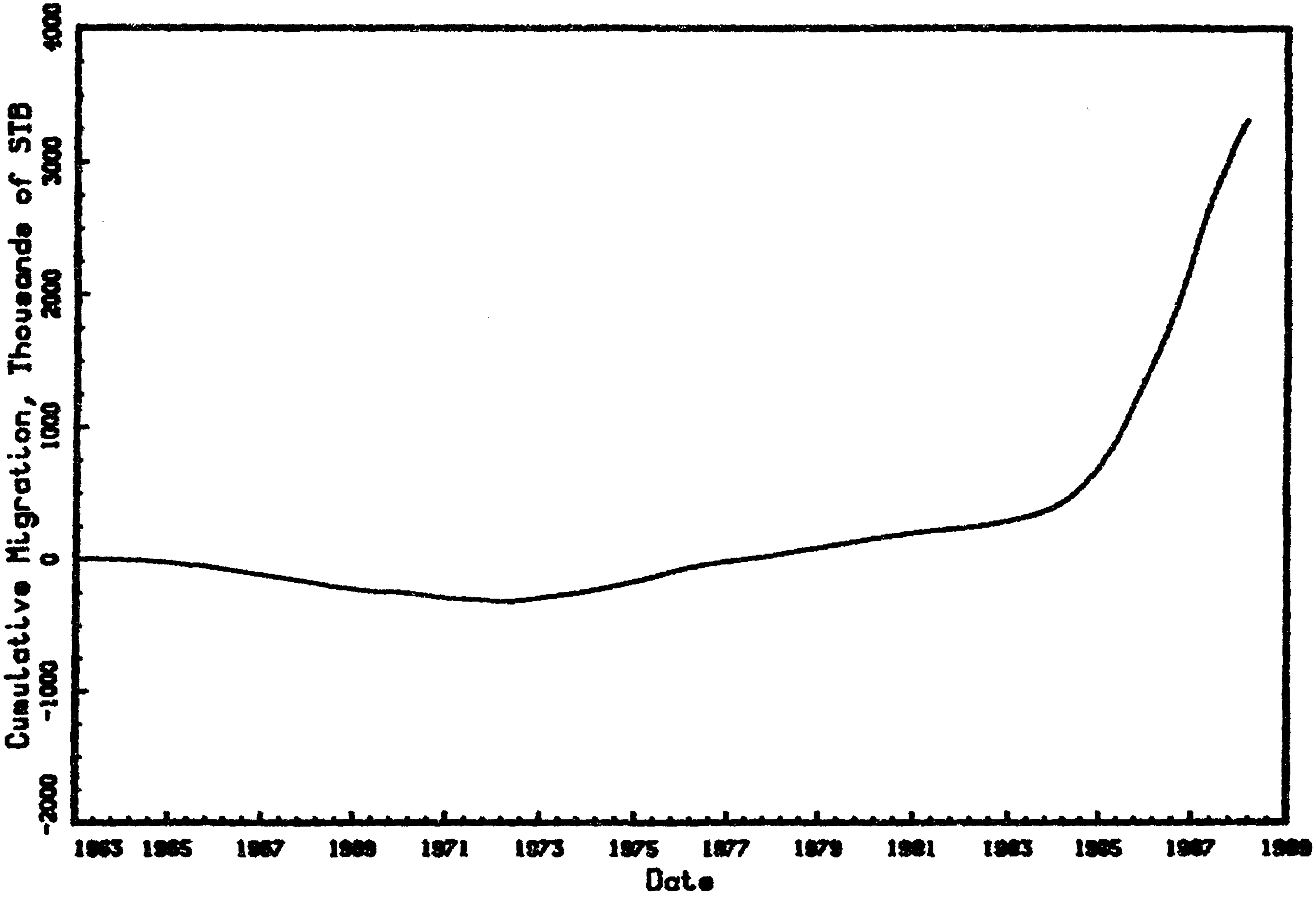
HISTORICAL MIGRATION

Historical Migration Into the Proposed Pressure Maintenance Expansion Area from Gavilan



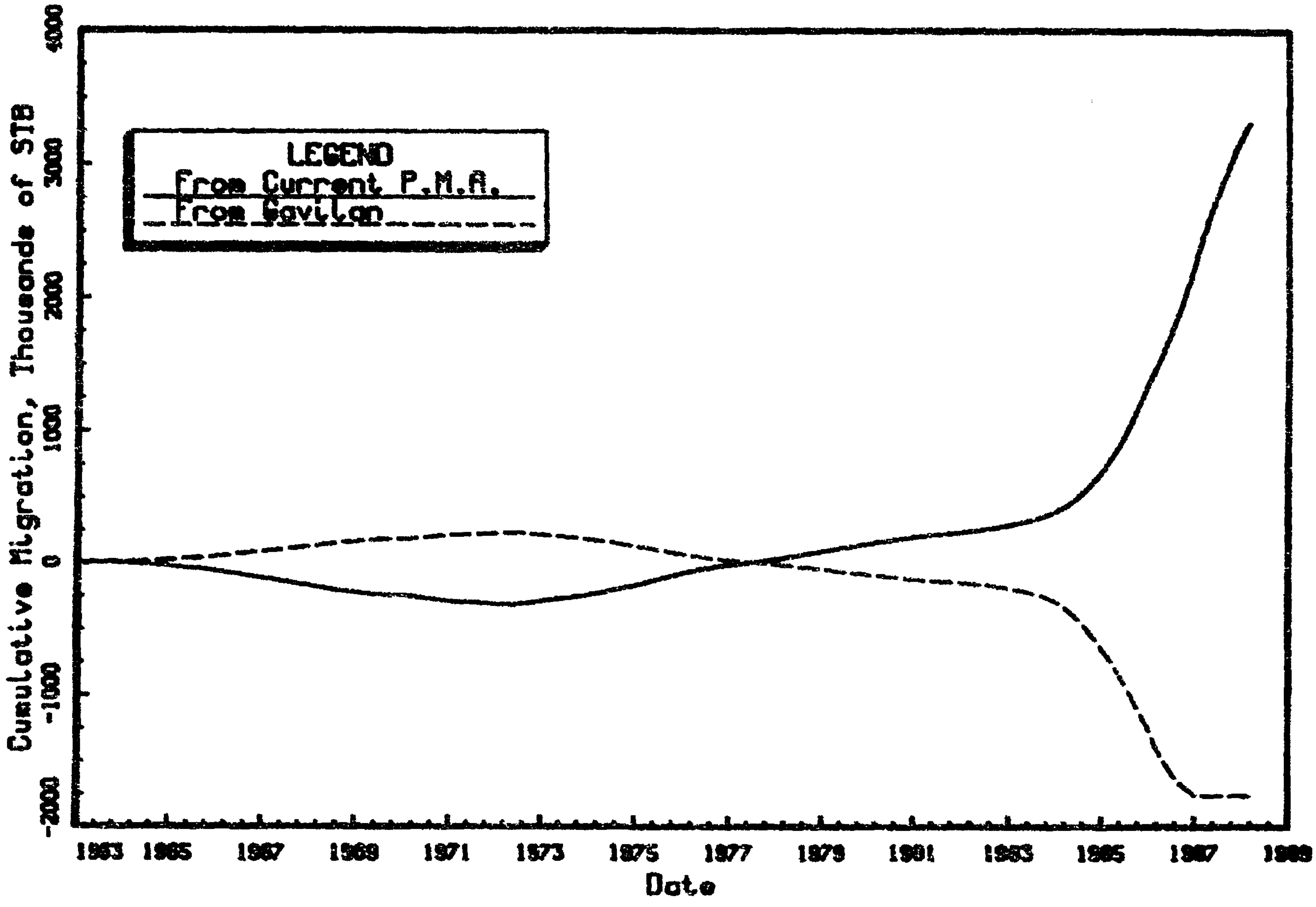
Historical Migration Into the Proposed

Pressure Maintenance Expansion Area from Current P.M.A.



Historical Migration Into the

Proposed Pressure Maintenance Expansion Area



REBUTTAL TESTIMONY

DUAL POROSITY RESERVOIR HYPOTHESIS

CORE DATA

* Average core data from the Mallon Davis Federal #3-15 Well indicate a geometric mean matrix permeability of less than 0.0164 md.

* Corrected for overburden pressure and water saturation, the average matrix permeability is less than 0.0000646 md.

  - Jones and Owens correlation used to correct permeability

* Not suprisingly, the cored well is a dry hole. This matrix is not productive.

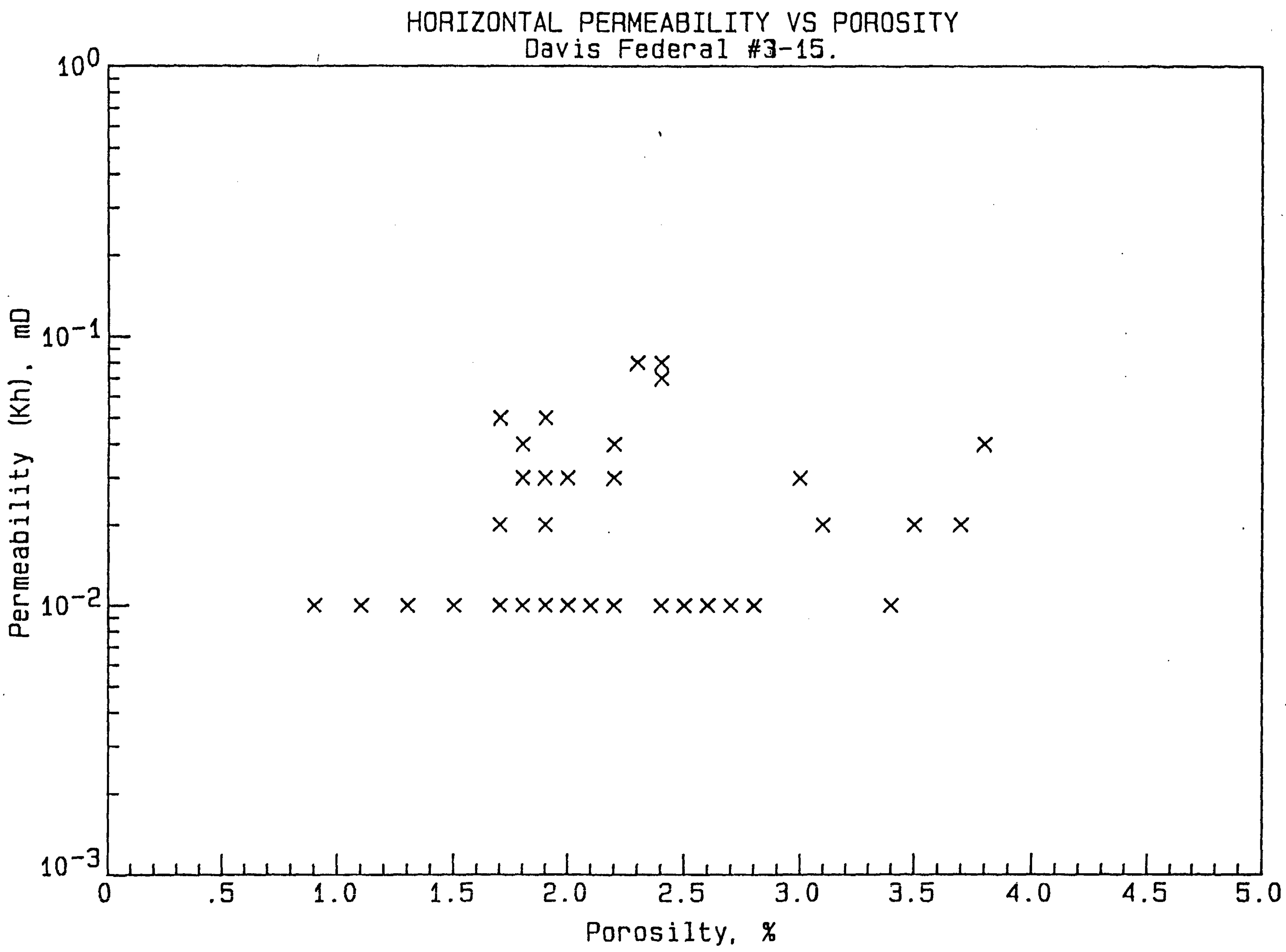
* Simulator results using observed matrix permeability indicates that only about 0.57% of the oil in place in the matrix would flow to the fractures even if there were no capillary forces retaining the oil in the matrix.

CORE ANALYSIS DATA FOR DAVIS FEDERAL #3-15.
RIO ARRIBA CO., NM

Depth, ft	Permeability, (md)	Porosity, %
7085.6	0.03	2.00
7086.6	0.01	0.9
7088.5	0.01	2.8
7091.5	0.08	2.4
7095.6	0.01	2.4
7103.6	0.01	1.1
7104.5	0.03	1.9
7105.5	0.08	2.3
7106.5	0.01	2.5
7109.2	0.05	1.7
7112.7	0.03	2.2
7113.5	0.01	1.9
7114.6	0.01	2.6
7120.7	0.03	1.8
7134.4	0.04	2.2
7148.5	0.01	1.7
7198.7	0.01	2.2
7201.8	0.03	1.8
7202.8	0.01	1.7
7207.3	0.01	2.2
7210.5	0.01	1.3
7211.0	0.01	2.0
7215.5	0.01	1.5
7262.9	0.01	2.0
7271.3	0.01	2.2
7274.8	0.01	1.7
7297.6	0.01	2.1
7302.4	0.01	2.8
7313.4	0.01	1.9
7331.4	0.01	2.6
7335.2	0.03	3.0
7337.4	0.02	3.1
7338.7	0.01	2.6
7340.7	0.01	2.7
7341.8	0.04	3.8
7342.8	0.02	3.5
7343.8	0.01	2.8
7350.7	0.01	1.9
7357.6	0.01	1.8
7358.4	0.01	2.5
7365.5	0.01	2.0
7367.4	0.01	1.7
7369.3	0.05	1.7
7376.4	0.01	2.1
7368.7	0.02	1.9
7081.7	0.01	3.4
7082.7	0.07	2.4
7084.7	0.02	3.7
7096.7	0.04	1.8
7098.3	0.05	1.9
7117.3	0.02	1.7

Geometric Mean = 0.0164

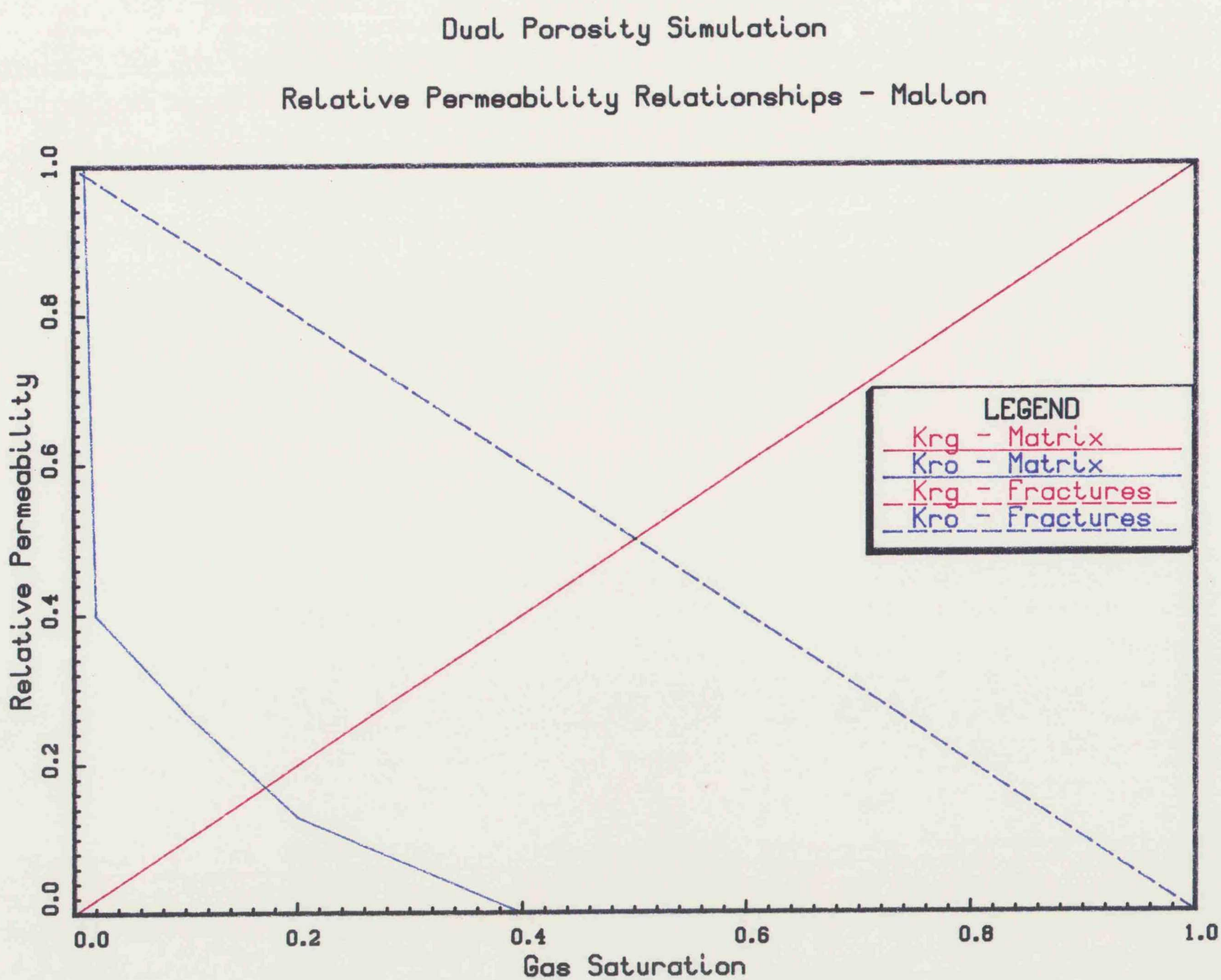
Permeability on 31 of 51 samples listed as 0.01 are actually <0.01 md.

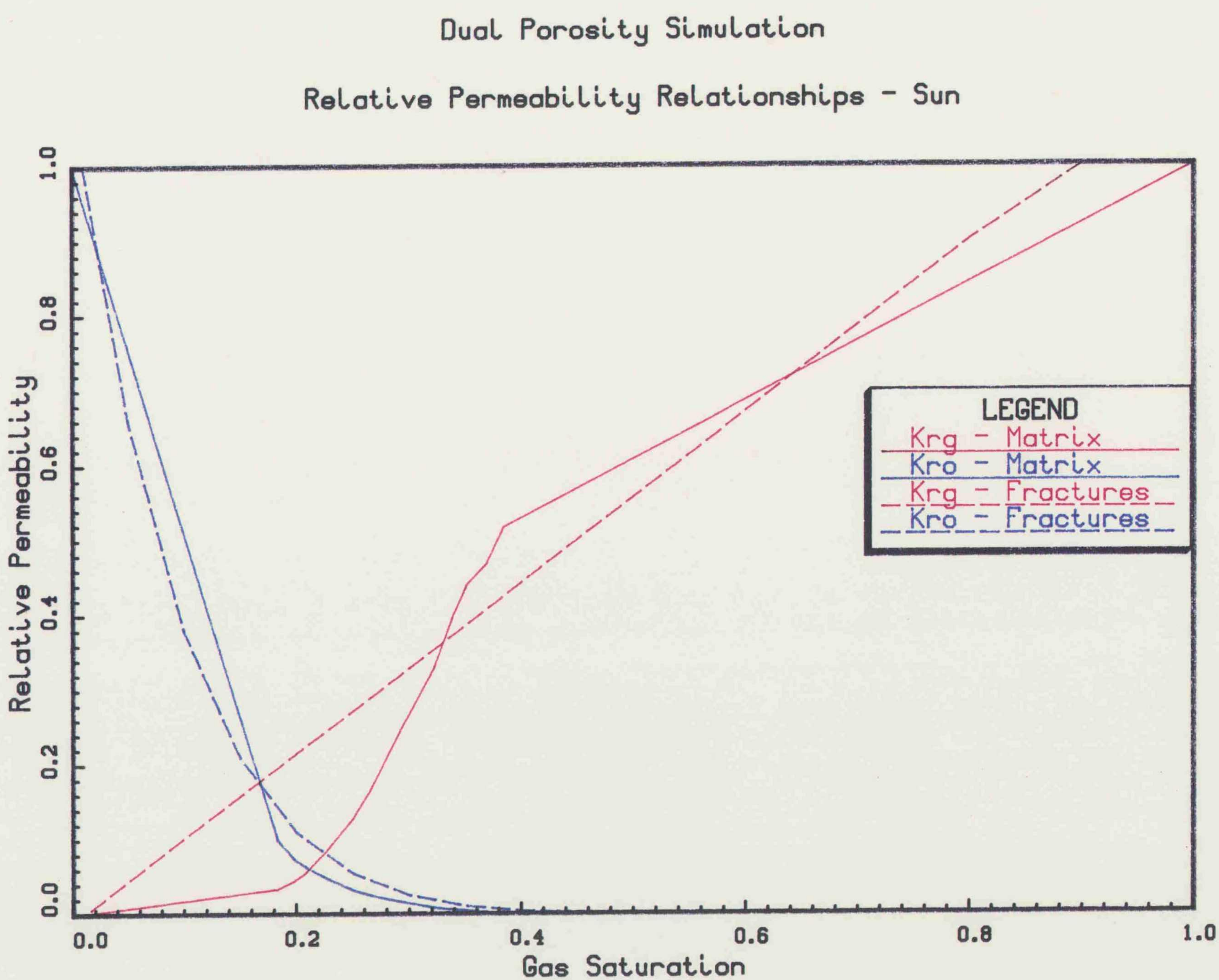

HORIZONTAL PERMEABILITY VS POROSITY
Davis Federal #3-15.
Permeability (Kh), mD
10^0
10^{-1}
10^{-2}
10^{-3}
0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Porosilty, %

SIMULTATION OF TWO-PHASE DUAL POROSITY RESERVOIR BEHAVIOR

COMPARISON OF SUN AND MALLON ASSUMPTIONS AND RESULTS

MODEL PARAMETER	DATA FOR SUN CASE	DATA FOR MALLON CASE
Reservoir Model	Dual Porosity	Dual Porosity
Matrix-Fracture Transer	Unsteady State	Pseudosteady State
Drainage Area, acres	640	640
Initial Pressure, psia	1600	1600
Net Pay, Ft	270	270
Fracture kh	400 md-ft	400 md-ft
Fracture HC Porosity, %	0.439	0.439
Interporosity Flow Coeff.	6.46×10^{-10}	3.00×10^{-9}
(Mallon Value Calculated from Sigma = 0.00004 = $1/Lz^2$)		
Matrix Permeability, md	0.0000646	0.00148
Storativity Ratio	0.10	0.10
Capillary Pressure	Zero	Zero
Relative Permeability	See Graphs	See Graphs
(Sun Matrix Rel. Perm. Data from Low Perm. Sand/Silt)		
(Mallon Rel. Perms. from Bergeson Report - ECLIPSE Data)		
Flowing BHP, psia	200	200
Matrix-to-Fracture Transfer at abandonment (10 BOPD), % OOIP in matrix	0.57	6.07


Dual Porosity Simulation
Relative Permeability Relationships - Mallon
Relative Permeability
0.0
0.2
0.4
0.6
0.8
1.0
Gas Saturation
LEGEND
Krg - Matrix
Kro - Matrix
Krg - Fractures
Kro - Fractures


Dual Porosity Simulation
Relative Permeability Relationships - Sun
Relative Permeability
0.0
0.2
0.4
0.6
0.8
1.0
Gas Saturation
LEGEND
Krg - Matrix
Kro - Matrix
Krg - Fractures
Kro - Fractures

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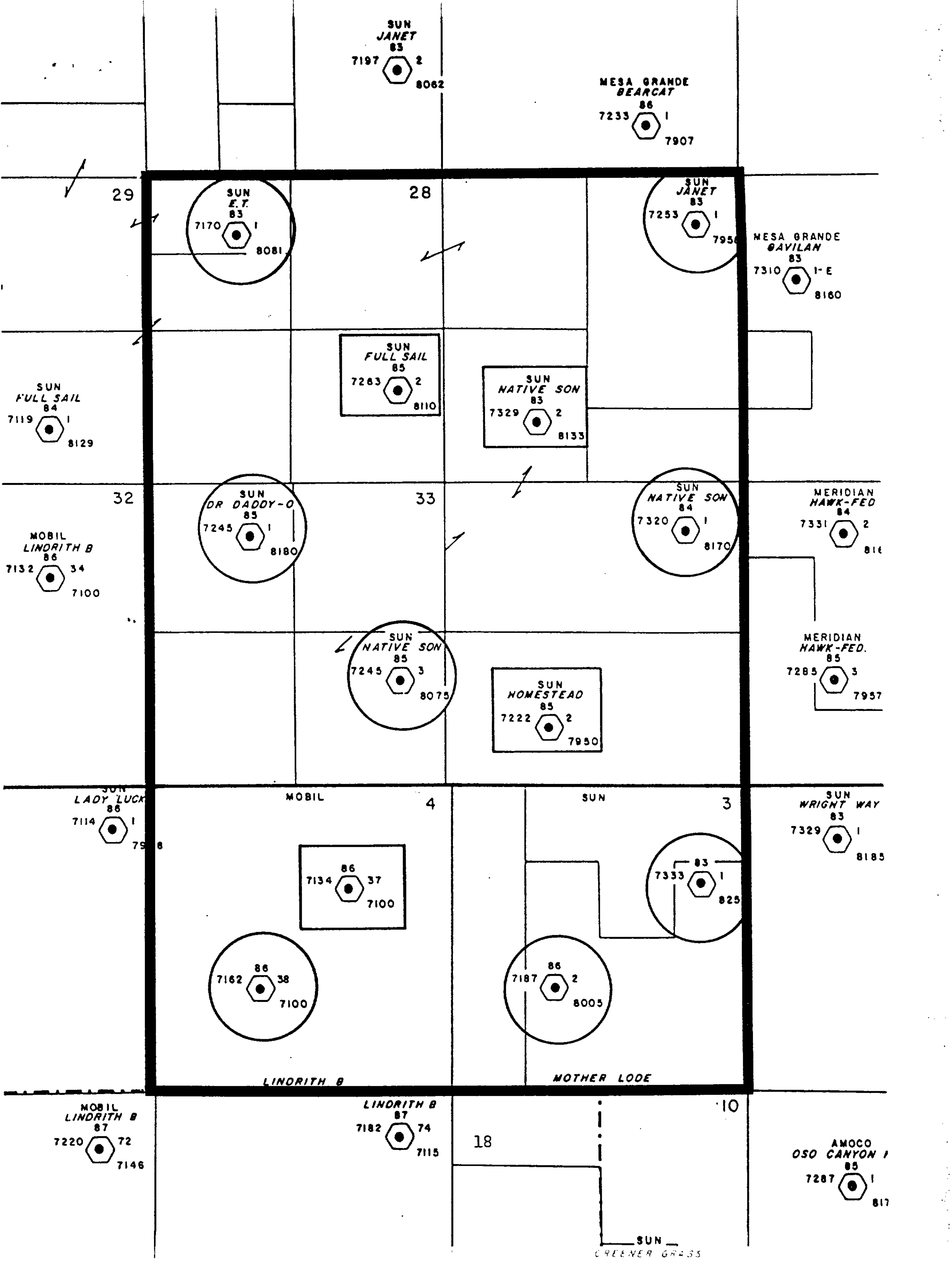
REBUTTAL TESTIMONY

DUAL POROSITY RESERVOIR HYPOTHESIS

FIELD OBSERVATIONS

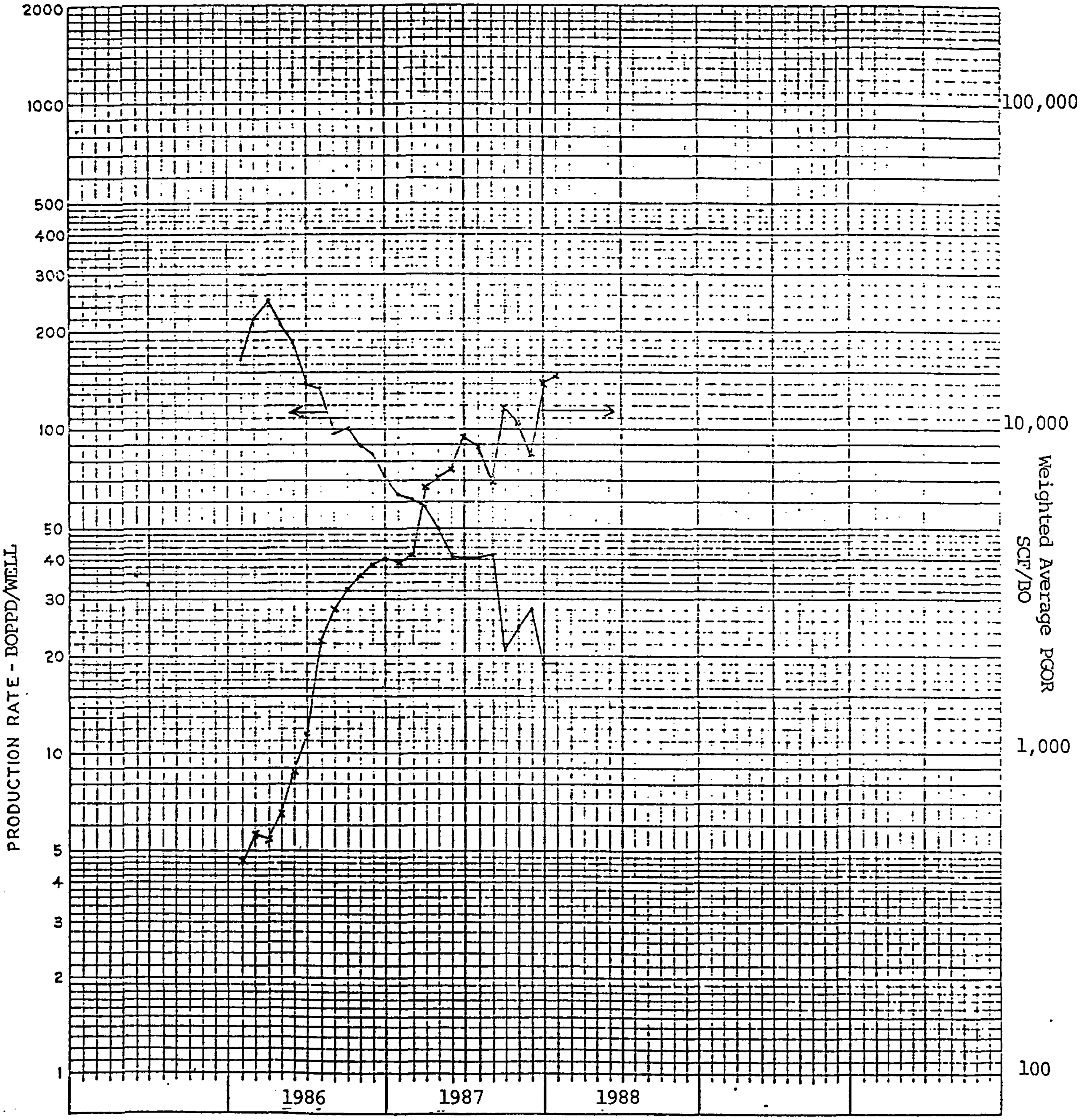
* Eight wells in a six-section area of Gavilan, amid some of the best wells in the field, are nearing depletion (map, production statistics attached).

- Despite the low pressure in the fractures (about 1,000 psia below initial reservoir pressure), matrix oil is not flowing in any significant way into the fracture system. If the matrix is not contributing now, why should we believe that it will <u>ever</u> contribute?



SUN
JANET
83
7197
2
8062
MESA GRANDE
BEARCAT
86
7233
1
7907
29
SUN
E.T.
83
7170
1
8081
28
SUN
JANET
83
7253
1
MESA GRANDE
GAVILAN
83
7310
1-E
8160
SUN
FULL SAIL
85
7263
2
8110
SUN
NATIVE SON
83
7329
2
8133
SUN
FULL SAIL
84
7119
1
8129
32
SUN
DR DADDY-O
85
7245
1
8180
33
SUN
NATIVE SON
84
7320
1
8170
MERIDIAN
HAWK-FED
84
7331
2
MOBIL
LINDRITH B
86
7132
34
7100
SUN
NATIVE SON
85
7245
3
8075
SUN
HOMESTEAD
85
7222
2
7950
MERIDIAN
HAWK-FED.
85
7285
3
7957
LADY LUCK
86
7114
1
MOBIL
4
SUN
3
SUN
WRIGHT WAY
83
7329
1
8185
86
7134
37
7100
83
7333
1
86
7162
38
7100
86
7187
2
8005
LINDRITH B
MOTHER LODE
MOBIL
LINDRITH B
87
7220
72
7146
LINDRITH B
87
7182
74
7115
18
10
AMOCO
OSO CANYON
85
7287
1
SUN

Production Data From Declining Wells Near High Capacity Wells In Gavilan



Year	Month		ET #1 (days)	ET #1	Janet #1 (days)	Janet #1	Native Son #1 (days)	Native Son #1	Dr. Daddy O (days)	Dr. Daddy O	Native Son 3 (days)	Native Son 3	Lindrith B-38 (days)	Lindrith B-38	Mother Lode 2 (days)	Mother Lode 2	Mother Lode 1 (days)	Mother Lode 1	Total	GOR	Total Prod. Days	
1987	Jan	Oil	14	785	23	567	27	3618	31	2543	19	714	23	348	11	1377	29	1760	11742	3918	187	63
	Feb		26	572	24	644	28	2783	28	2374	12	724	26	491	24	2908	27	1420	11866	4183	195	61
	Mar		19	435	20	444	26	2567	31	2577	10	559	26	517	12	1389	26	1346	9854	6830	170	58
	Apr		18	449	19	273	23	1778	30	2637	11	723	26	434	11	762	23	1055	8115	7139	161	50
	May		19	339	20	444	31	1383	31	2567	10	625	27	410	11	710	31	912	7420	7560	180	41
	June		19	300	19	300	23	1928	27	2181	15	608	21	349	10	357	27	552	6557	9572	161	41
	July		30	405	29	423	31	2012	30	2064	26	1328	31	405	31	2215	31	935	9797	8951	239	41
	Aug		27	169	27	318	27	2710	27	1018	27	1025	28	471	28	2444	27	794	9021	6969	217	42
	Sept		30	154	30	387	28	208	30	923	29	863	30	240	28	1417	8	224	4396	11810	213	21
	Oct.		31	98	31	425	31	846	31	709	31	912	31	228	31	1523	31	1445	6234	10399	248	25
	Nov		30	69	16	—	24	1522	24	359	24	341	16	90	24	1725	24	934	5112	8427	182	25
	Dec		27	72	26	—	28	690	28	684	27	316	—	—	18	827	18	643	3202	14108	172	19
1988	Jan		19	13	26	154	29	711	31	1135	28	157	—	—	29	776	28	737	3689	14857	190	19
1987	Jan	GAS		7139		7381		8133		5984		3175		8034		4567		3587	46000			
	Feb			8089		5879		6784		3350		4911		7021		6288		4312	49634			
	Mar			9578		6762		6710		4752		10725		9394		11192		7987	67300			
	Apr			7178		7967		6914		5433		7711		7717		7890		6938	58048			
	May			7199		7385		4552		7104		7327		9858		7068		5600	56093			
	June			7212		7074		7200		7604		8909		7197		3484		13693	62323			
	July			11177		10879		7865		6881		20817		5921		22935		1184	87689			
	Aug			8523		8560		1948		6541		10449		6794		7546		6505	62866			
	Sept			8436		8412		325		8627		7850		5920		9545		2713	51916			
	Oct			6948		8233		1513		8756		6729		5951		12758		12207	66095			
	Nov			4025		4523		4500		5874		3952		1684		9543		8627	43080			
	Dec			4364		3914		7470		7561		8573		—		2967		10324	45123			
1988	Jan			3092		7530		8140		6462		4159		—		10015		15290	54688			

			ET#1		Janet #1		NS#1		Dr. Dolly		NS 3		Lind B 38		Mother Lode 2		Mother Lode 1		Total		GOR	Total Prod. Days	Total Oil Per Prod. Day
1986	Jan	OIL	31	2259	31	3555	31	1154				-				-	30	3344	20679		469	123	168
	Feb		27	5405	27	3145	27	1750		-		-		-		-	27	3461	23761		567	108	220
	Mar		31	7313	31	3292	31	1776		-		-		-		-	30	8709	31090		542	123	253
	Apr		30	6000	29	3183	30	4136		-		-		-		-	29	7464	25283		656	118	214
	May		31	5168	26	2463	31	4370	11	783		-		-	10	1042	31	7778	27604		878	148	187
	June		30	3128	30	2834	30	[illegible]	7	69	7	2049	11	918	30	1482	30	6666	25679		1171	183	140
	July		31	2024	31	2310	31	7387	-	-	17	4665	31	1165	5	241	31	6312	24154		2271	177	136
	Aug		29	1146	29	2199	31	2077	-	-	29	7248	29	1009	-	-	26	3109	16788		2811	173	97
	Sept		2	264	2	1757	12	2448	6	339	6	3105	20	338	2	135	20	1217	6983		3266	70	100
	Oct		19	527	28	1514	28	4266	31	2558	11	1758	21	458	27	4389	25	1808	17108		3522	123	89
	Nov		18	660	21	674	22	3206	30	2137	9	816	23	399	19	3863	23	1798	13853		3709	165	84
	Dec		20	665	20	639	21	3242	31	2818	8	780	23	443	18	1966	27	1548	12101		4068	168	72
1986	Jan			1031		2125		3625		-		-		-		-		2927	9706				
	Feb			2371		1777		4851		-		-		-		-		4263	13464				
	Mar			3883		2244		4216		-		-		-		-		6494	16837				
	Apr			4170		1961		2432		-		-		-		-		8025	16588				
	May			7423		1722		1712		118		-		-		-		13021	24246				
	June			10229		2318		4633		32		674		2670		631		8927	30058				
	July			15164		6079		940		-		12043		7893		101		12324	54844				
	Aug			12872		5420		904		-		16153		7264		-		4578	47196				
	Sept			1569		5781		3054		147		1904		4912		48		5388	22843				
	Oct			7741		8499		8001		5848		10443		7504		4775		8460	61201				
	Nov			3397		9175		7554		5300		7113		6772		6806		6418	53737				
	Dec			9116		7559		4911		3510		7295		3958		6591		6285	49225				

REBUTTAL TESTIMONY
DUAL POROSITY RESERVOIR HYPOTHESIS
INFERENCES FROM PRESSURE BUILDUP TEST PLOT SHAPES

• The shape of the pressure buildup test plot for the mid-1987 test of the Mobil Lindreth B-37 well is similar to the characteristic shapes of buildup test plots from dual porosity reservoirs.

• This shape, on the tests from one well, hardly "proves" the dual porosity hypothesis.

- This shape is the exception, rather than the rule, and it is more common in recent tests than in earlier tests.

- Other phenomena--notably phase redistribution in the wellbore (gas rising to the top and liquid falling to the bottom of the wellbore following shut-in)--can cause the same shape.

- Phase redistribution is clearly occurring in the field. Extreme cases result in a pressure "hump," which has virtually no other causes. Pressure humps are present in several test plots (graphs attached).

- The attached SPE paper points out the similarity in test plot shapes for dual-porosity reservoirs and wells with phase redistribution in the wellbore.

SPE

Society of Petroleum Engineers

SPE 16763

An Analytical Model for Composite Reservoirs Produced at Either Constant Bottomhole Pressure or Constant Rate

by J.S. Olarewaju and W.J. Lee, Texas A&M U.

SPE Members

This paper was prepared for presentation at the 62nd Annual Technical Conference and Exhibition of the Society of Petroleum Engineers held in Dallas, TX September 27-30, 1987.

ABSTRACT

In this paper, we present a model of the complete characteristic transient response from a composite reservoir including the effects of skin, wellbore storage and phase redistribution at the well. We present six flow regimes and the combined effects of wellbore storage and phase redistribution on pressure behavior in composite reservoirs.

Using an automatic history matching approach, we analyzed three buildup tests and a pressure falloff test. This method eliminated the serious uniqueness problem associated with type curve analysis. We demonstrate that incorrect reservoir parameter estimates and incorrect production performance predictions would result from the use of any model that lacks the capabilities of the model we present in this paper. We also demonstrate possible misinterpretations of pressure data that may result from not recognizing the presence of phase redistribution in the buildup test data or not recognizing the composite reservoir behavior.

INTRODUCTION

Numerous analytical models have been presented in recent years to describe the pressure behavior of composite reservoir systems.[1-8] Composite reservoirs are encountered in a wide variety of reservoir situations. In a composite reservoir there is a circular inner region with fluid and rock properties different from those in the outer region. Reservoirs damaged because of fluid invasion during drilling or completion; stimulated reservoirs; reservoirs being waterflooded or undergoing insitu combustion are examples of the reservoir types that can be described by a composite reservoir model. The inner zone represents the invaded or altered zone while the outer zone represents the uninvaded zone. The two zones are separated by a sharp radial discontinuity. This idealized interface may be a permeability, mobility, saturation or thermal discontinuity.

During the 1960's there was great interest in the composite reservoir flow problem. Hurst[1] discussed in detail the "sand in series" problem and presented formulas to describe unsteady state pressure behavior of fluid movement through two sands in series in a radial configuration. Loucks and Guerrero[2] presented a theoretical study of the pressure distribution in an infinite composite reservoir. They found that under certain conditions the permeability in both zones as well as the size of the inner zone can be determined from pressure transient test data. Wattenbarger and Ramey[3] presented a finite difference solution for the infinite composite reservoir. Other early investigators include Merrill et al.,[4] Clossmann and Ratliff,[5] and Bixel and Van Poollen.[6]

Recently Satman[7] presented an analytical study of interference in a composite reservoir which accounts for wellbore storage and skin at the active well. Brown[8] presented a graphical approach for calculating mobility of the altered and unaltered zones and the radius of the altered zone. DaPrat et al.[9] presented an application of a composite reservoir model to interpret falloff tests in an insitu combustion project.

The major contribution of this paper is the presentation of the combined effects of skin, wellbore storage and phase segregation on pressure transient tests in composite reservoir systems. We also present the six flow regimes possible in a finite composite reservoir and show how the characteristic influence of wellbore storage and phase segregation may case a misinterpretation of pressure transient tests. The rate solution in a composite model with an inner steady state skin is also presented. This solution is useful for

References and illustrations at end of paper.

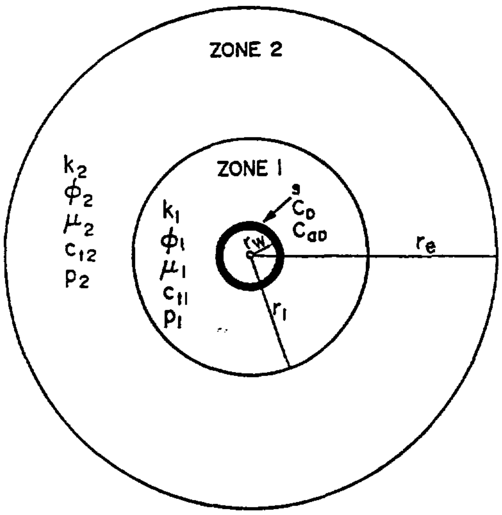


Fig. 1—Schematic diagram of composite reservoir system.

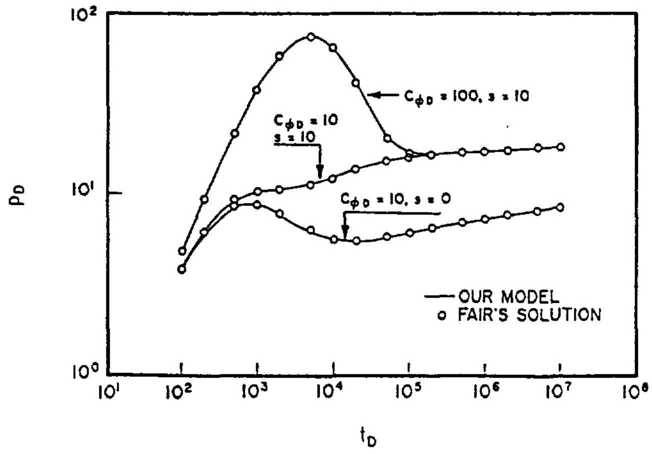


Fig. 2—Comparison of solutions developed in this study with Fair's solution, $\eta_1/\eta_2 = 1.0$, $r_i/r_w = 1$, $C_D = 1{,}000$, $C_{aD} = 20$.

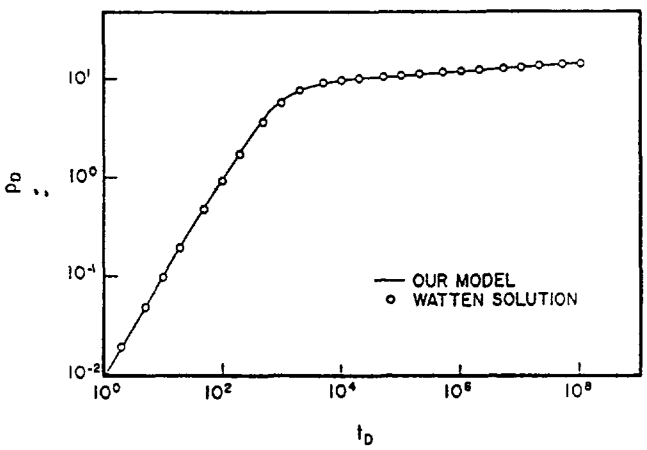


Fig. 3—Comparison of solution developed in this study with Wattenbarger and Ramey's solution, $s = 5$, $C_D = 1{,}000$.

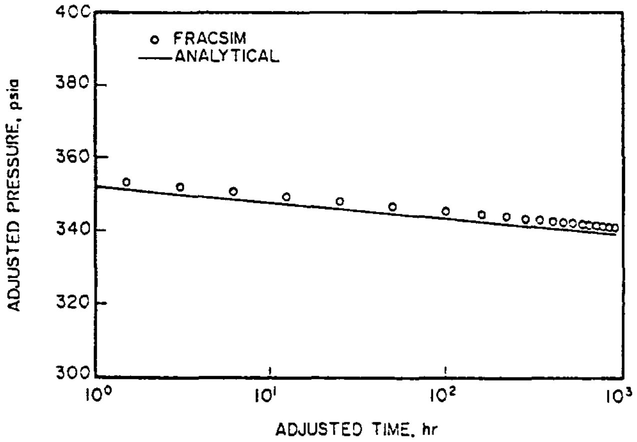


Fig. 4—Comparison with simulator solution for fractured gas well, pressure drawdown test, $k_1 = 0.029$, $k_2 = 0.0029$, $r_i/r_w = 100$.

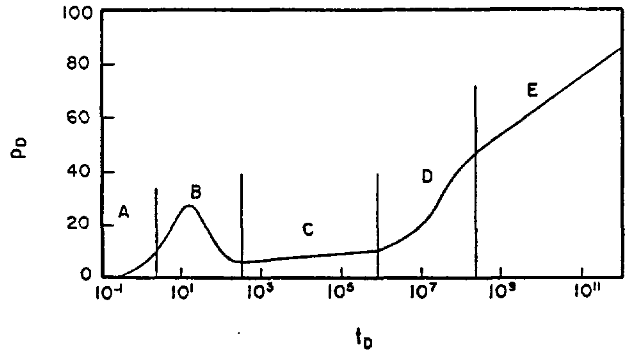


Fig. 5—Flow regimes in an infinite composite reservoir, $\eta_1/\eta_2 = 10$, $r_i/r_w = 500$, $s = 0$, $C_D = 100$, $C_{\phi D} = 50$, $s = 10$.

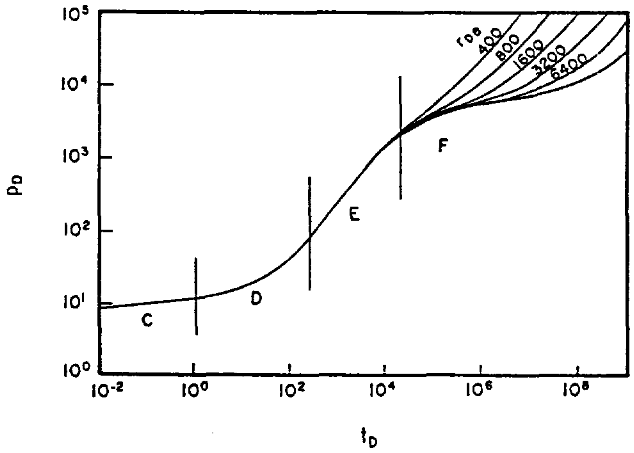


Fig. 6—Pressure flow regimes in a finite composite reservoir, $\eta_1/\eta_2 = 1{,}000$, $r_i/r_w = 100$, $C_D = 0$, $s = 5$, $C_{aD} = 0$.

CONCLUSIONS

1. We have demonstrated in this paper the danger of misinterpretation that may result from applying an incomplete model to buildup test data where pressure distortion caused by phase redistribution is not large enough to show the classical hump. The analysis of such buildup data with techniques that do not account for phase redistribution can lead to incorrect reservoir property estimates and incorrect predictions of production.

2. We have applied an automatic history matching technique and our new composite model to analysis of buildup and falloff tests. This technique is superior to available type curve and semilog analysis methods because of the reduction of the uniqueness problem, ability to estimate many important reservoir parameters and a correct representation of the skin zone.

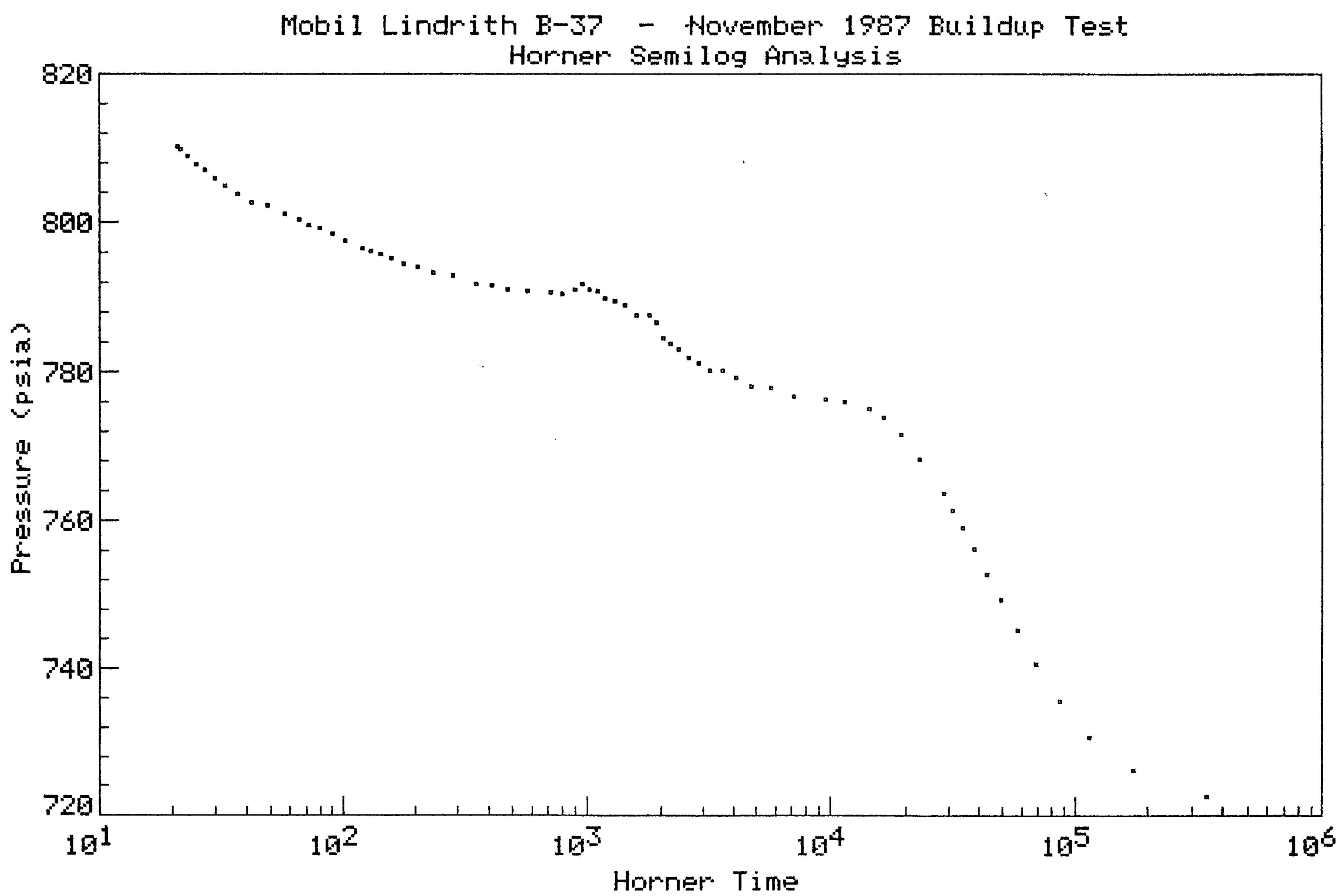
3. When the diffusivity of the inner zone of a composite system is less than that of the outer zone, as in a damaged system, the pressure humps caused by phase redistribution are both larger and last longer than when the diffusivity of the inner zone is greater. The presence of wellbore storage and phase redistribution will usually mask the first semilog straight line, thereby, in such damaged systems, rendering conventional semilog analysis useless in evaluating the properties of the inner zone. Such test data can be analyzed with the model presented in this paper.

4. When the distortion caused by phase redistribution is not severe enough to cause a hump, the characteristic shape of the pressure behavior could be misinterpreted as that from a dual porosity reservoir. The composite reservoir behavior could also be misinterpreted as an effect caused by the reservoir drainage boundary. When such a characteristic shape is displayed in a transient test, more information should be sought about the reservoir geology, reservoir fluid phase behavior and fluid properties before a model is chosen.

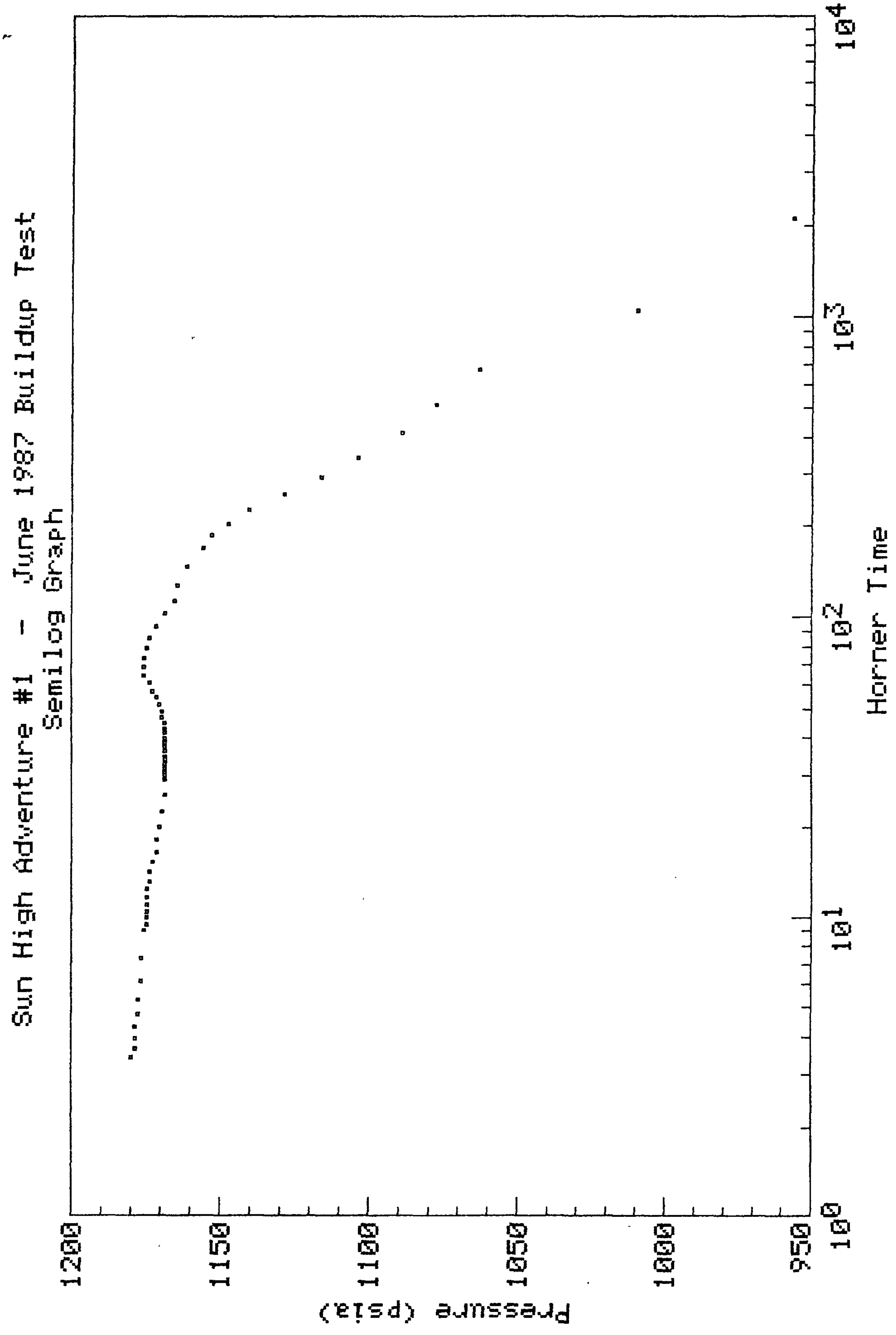
5. The transition flow regime of a composite model lasts about 2-1/2 log cycles if the diffusivity of the inner zone is greater than that of the outer zone. When the diffusivity of the inner zone is smaller, the transition flow regime lasts approximately 1 log cycle.

NOMENCLATURE

Symbol	Meaning
B	Formation volume factor, Rb/Mscf for gas and RB/STB for oil
C_{aD}	$\frac{1}{C_D} + \frac{C_{\phi D}}{\alpha_D}$, dimensionless apparent wellbore storage coefficient
c_t	Total compressibility, psia^{-1}
C_D	$\frac{0.894\ C_s}{c_t\ h\ r_w^2}$, dimensionless wellbore storage coefficient
C_s	Wellbore storage coefficient, bbl/psi
C_ϕ	Phase redistribution pressure parameter, psi
$C_{\phi D}$	$\frac{kh\ C_\phi}{141.2\ q \mu B}$, dimensionless phase redistribution parameter
h	Net pay thickness, ft
I_o	Modified Bessel function of the first kind, zero order
k	Permeability, md
K_o	Modified Bessel's function of the second kind, zero order
L_f	Fracture half length, ft
p	Pressure, psia
p_a	$\frac{\bar{\mu}}{\bar{\rho}} \int_{p_o}^{p} \frac{\rho}{\mu} dp$, adjusted pressure, psia
p_D, p_{Dw}	$\frac{k_2\ h\ (p_i - p_{wf})}{141.2\ q \mu B}$, dimensionless pressure
p_i	Initial reservoir pressure, psia
p_ϕ	Phase redistribution pressure, psi
$p_{\phi D}$	$\frac{k\ h\ p_\phi}{141.2\ q \mu B}$, dimensionless phase redistribution pressure
p_{gef}	Flowing pressure at point of gas entry, psi
p_{whf}	Flowing wellhead pressure, psi
p_{wf}	Flowing wellbore pressure, psia
q	Flow rate, Mscf/D for gas, and b/d for oil
r_D	Dimensionless radius, r/r_w
r_e	Drainage radius, ft
r_w	Wellbore radius, ft
s	Laplace transform parameter (in the Appendices); in text, skin factor, dimensionless
S	Skin factor, dimensionless (in the Appendices)
t	Time, hr
t_a	$t(p) \times \bar{\mu}\ \bar{c}_t$, adjusted time, hr



Mobil Lindrith B-37 - November 1987 Buildup Test
Horner Semilog Analysis
820
800
780
760
740
720
Pressure (psia)
10^1
10^2
10^3
10^4
10^5
10^6
Horner Time


Sun High Adventure #1 - June 1987 Buildup Test
Semilog Graph
Pressure (psia)
1200
1150
1100
1050
1000
950
Horner Time
10^0
10^1
10^2
10^3
10^4

REBUTTAL TESTIMONY
DUAL POROSITY RESERVOIR HYPOTHESIS
CONCLUSIONS

- Available core data indicates the matrix permeability is extremely low.

- Reservoir simulation using available core data indicates that the matrix will not contribute significantly to pool reserves.

- Actual field performance indicates no support from the matrix in declining wells.

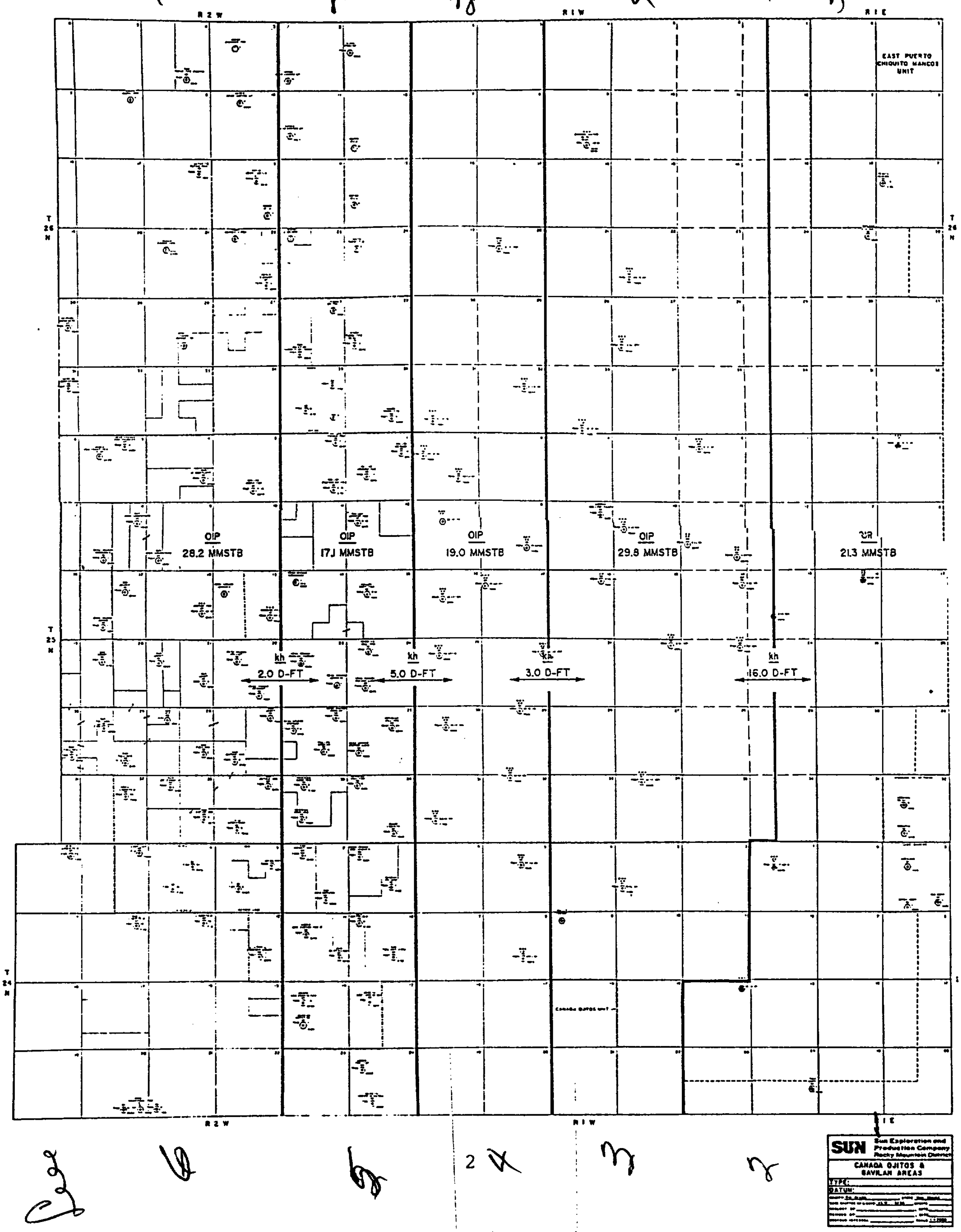
- The buildup curve shape on the Mobil Lindreth B-37 well does not prove dual porosity behavior. Phase redistribution in the wellbore is a more likely explanation.

Sun Exploration and Production Company
Exhibits in Case Nos. 7980, 8946, 8950, and 9111
Before the Oil Conservation Commission of the
New Mexico Department of Energy and Minerals

June 13, 1988

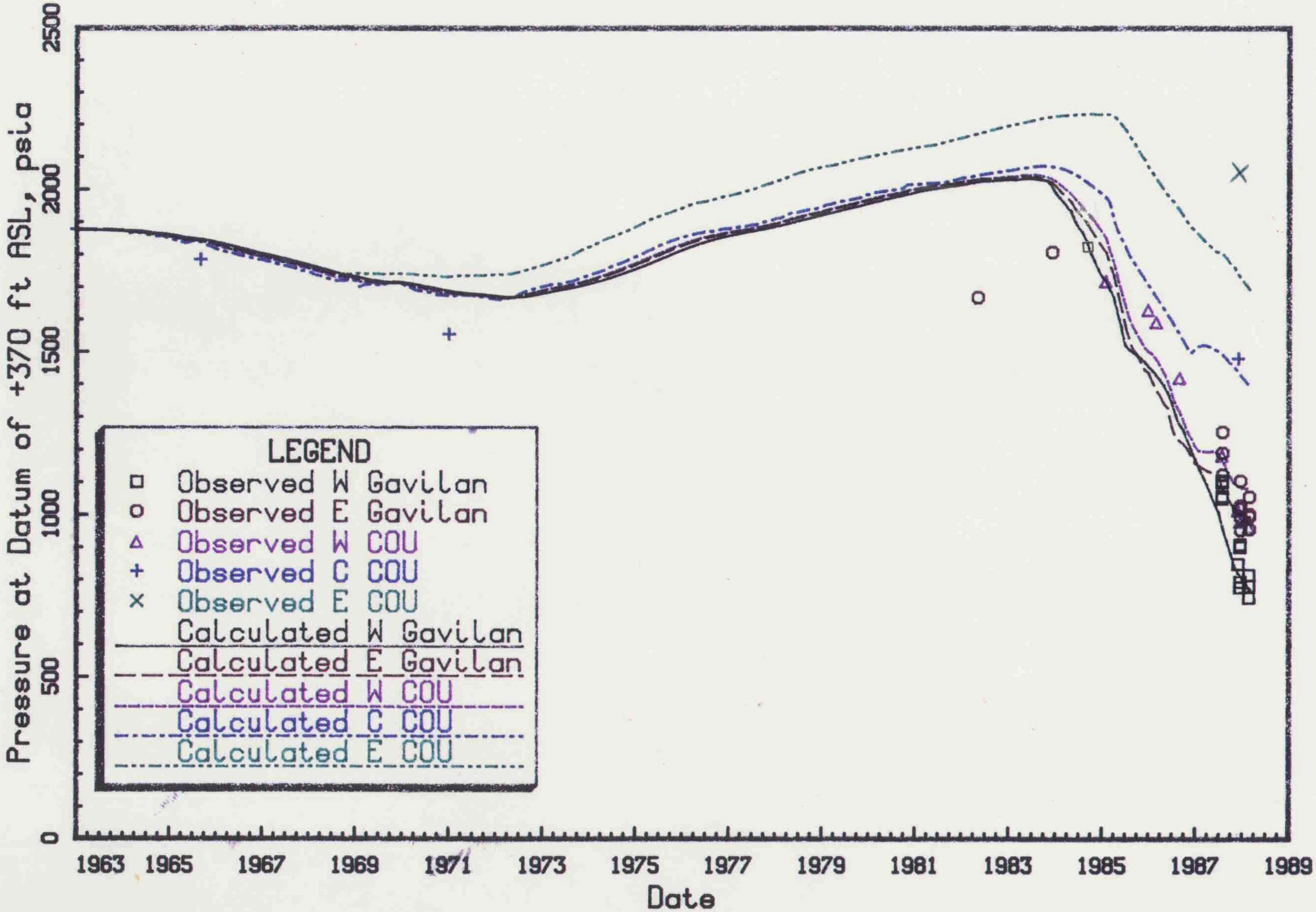
BEFORE THE
OIL CONSERVATION COMMISSION
Santa Fe, New Mexico
Case No.________ Exhibit No. 1
Submitted by Sun
Hearing Date 6/13/88

MULTITANK MATERIAL BALANCE
AREAL DISTRIBUTION OF ORIGINAL OIL IN PLACE AND PERMEABILITY- THICKNESS PRODUCT



Material Balance Verification

Comparison of Calculated and Measured Pressures



CONCLUSIONS BASED ON MATERIAL BALANCE CALCULATIONS

There is no flow barrier at the edge of the current pressure maintenance area in the Canada Ojitos Unit

* Observed pressure drops in the field can be explained by permeability **variations** rather than permeability **barriers**

Effect of Pressure Maintenance and Allowable On Cumulative Recovery From Gavilan

Effect of Pressure Maintenance

Current Oil and Gas Allowables (800 BOPD, 480 MCFPD for 640 acres)

Pressure Maintenance Starts 8/89

Case	Ultimate Recovery, MSTB
No Pressure Maintenance	5,439
Pressure Maintenance	10,215

Effect of Allowables

Allowables changed from 7/88 to 8/89

Pressure Maintenance starts in 8/89, with current allowables and gas injection credit

Allowables in Case (for 640 acres)	Ultimate Recovery, MSTB
800 BOPD, 188 MCFPD gas	11,063
800 BOPD, 480 MCFPD gas	10,215
1280 BOPD, 2560 MCFPD gas	7,375

CONCLUSION BASED ON FUTURE PERFORMANCE PROJECTIONS

Ultimate recovery from Gavilan will be increased by minimizing oil and gas withdrawals now, conserving reservoir energy for additional recovery with pressure maintenance later.

RECOMMENDATIONS

* Maintain the West Puerto Chiquito - Gavilan Boundary at its current position

* The lowest oil rates and the minimum gas production possible are desirable from a reservoir standpoint because they will conserve reservoir energy and can lead to improved recovery if a pressure maintenance project is installed in Gavilan

* Gavilan Operators should be encouraged to implement a pressure maintenance project to improve recovery from the reservoir

Sun Exploration and Production Company
Rebuttal Exhibits in Case Nos. 7980, 8946, 8950, and 9111
Before the Oil Conservation Commission of the
New Mexico Department of Energy and Minerals

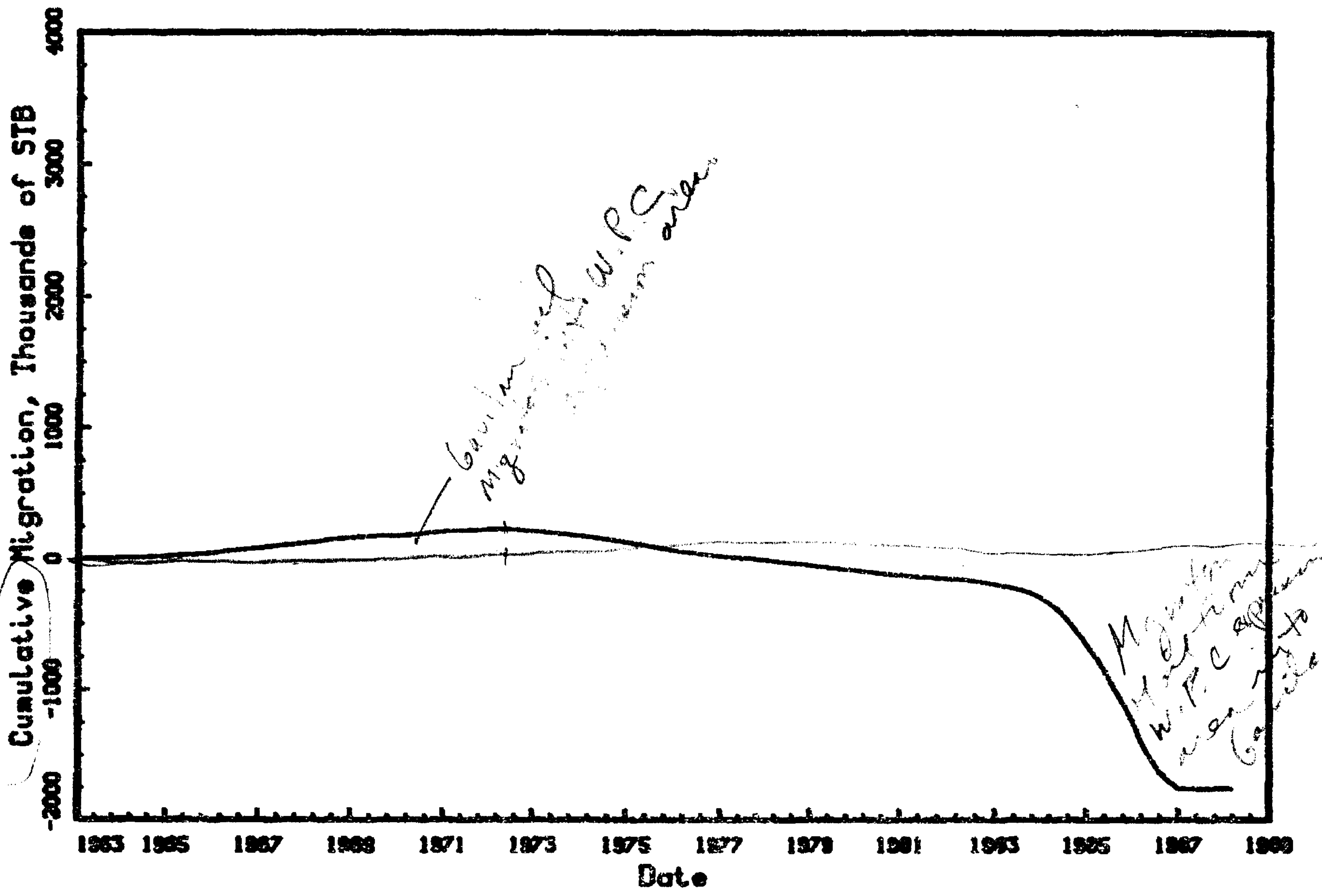
June 13, 1988

REBUTTAL TESTIMONY

HISTORICAL MIGRATION

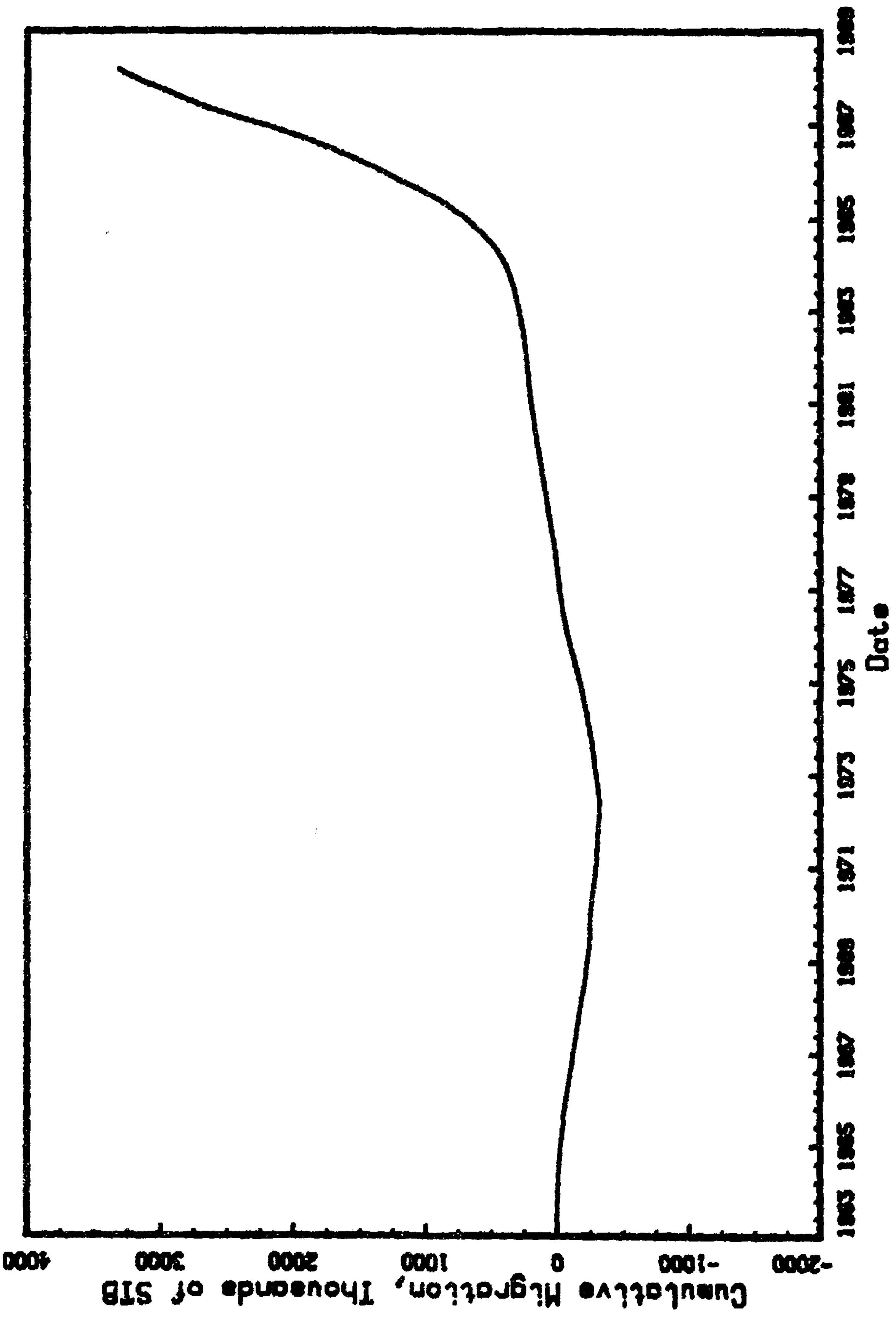
Historical Migration Into the Proposed

Pressure Maintenance Expansion Area from Gavilan



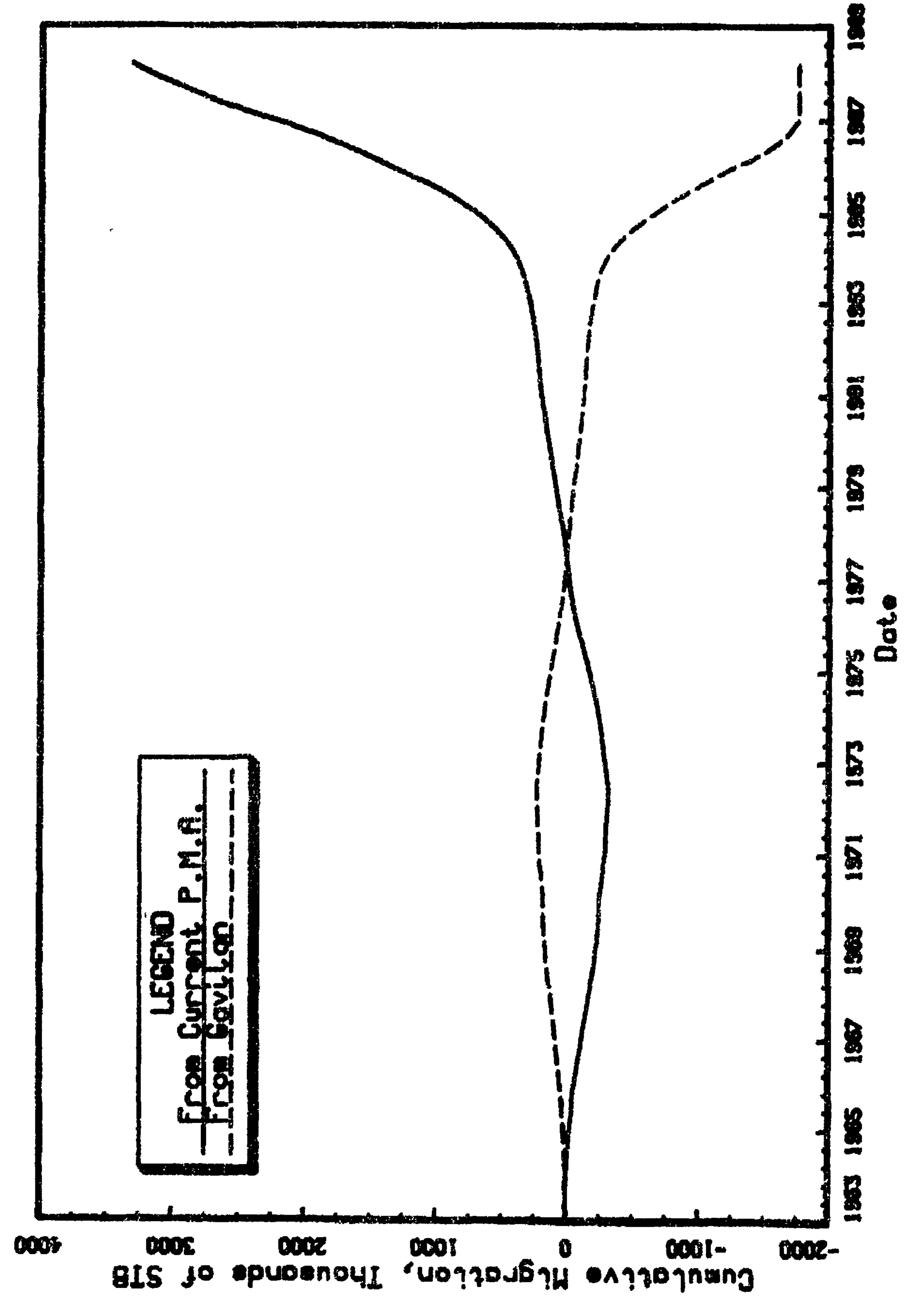
Historical Migration Into the Proposed

Pressure Maintenance Expansion Area from Current P.M.A.



Historical Migration Into the

Proposed Pressure Maintenance Expansion Area



REBUTTAL TESTIMONY

DUAL POROSITY RESERVOIR HYPOTHESIS

CORE DATA

* Average core data from the Mallon Davis Federal #3-15 Well indicate a geometric mean matrix permeability of less than 0.0164 md.

* Corrected for overburden pressure and water saturation, the average matrix permeability is less than 0.0000646 md.

  - Jones and Owens correlation used to correct permeability

* Not suprisingly, the cored well is a dry hole. This matrix is not productive.

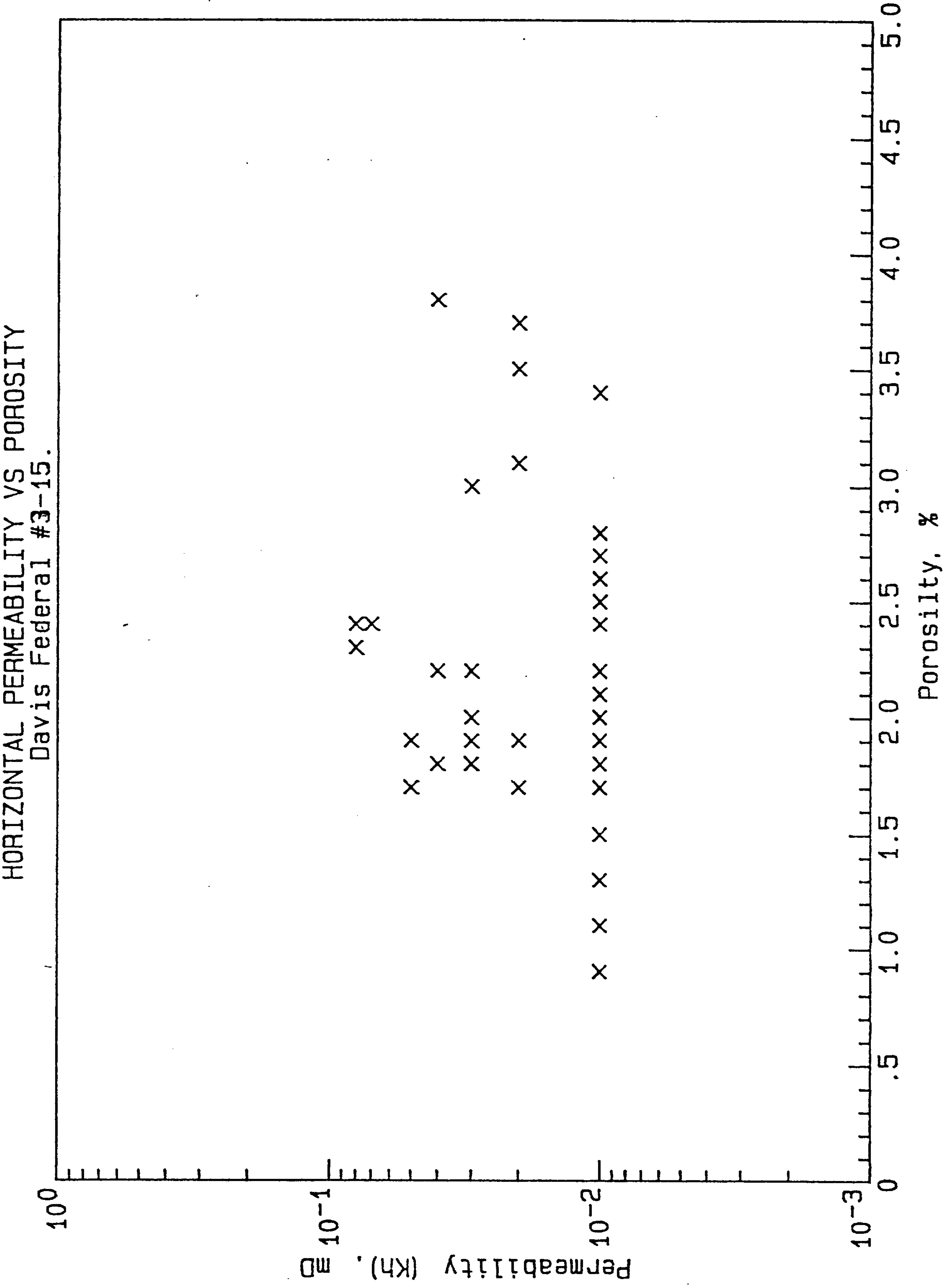
* Simulator results using observed matrix permeability indicates that only about 0.57% of the oil in place in the matrix would flow to the fractures even if there were no capillary forces retaining the oil in the matrix.

CORE ANALYSIS DATA FOR DAVIS FEDERAL #3-15.
RIO ARRIBA CO., NM

Depth, ft	Permeability, (md)	Porosity, %
7085.6	0.03	2.00
7086.6	0.01	0.9
7088.5	0.01	2.8
7091.5	0.08	2.4
7095.6	0.01	2.4
7103.6	0.01	1.1
7104.5	0.03	1.9
7105.5	0.08	2.3
7106.5	0.01	2.5
7109.2	0.05	1.7
7112.7	0.03	2.2
7113.5	0.01	1.9
7114.6	0.01	2.6
7120.7	0.03	1.8
7134.4	0.04	2.2
7148.5	0.01	1.7
7198.7	0.01	2.2
7201.8	0.03	1.8
7202.8	0.01	1.7
7207.3	0.01	2.2
7210.5	0.01	1.3
7211.0	0.01	2.0
7215.5	0.01	1.5
7262.9	0.01	2.0
7271.3	0.01	2.2
7274.8	0.01	1.7
7297.6	0.01	2.1
7302.4	0.01	2.8
7313.4	0.01	1.9
7331.4	0.01	2.6
7335.2	0.03	3.0
7337.4	0.02	3.1
7338.7	0.01	2.6
7340.7	0.01	2.7
7341.8	0.04	3.8
7342.8	0.02	3.5
7343.8	0.01	2.8
7350.7	0.01	1.9
7357.6	0.01	1.8
7358.4	0.01	2.5
7365.5	0.01	2.0
7367.4	0.01	1.7
7369.3	0.05	1.7
7376.4	0.01	2.1
7368.7	0.02	1.9
7081.7	0.01	3.4
7082.7	0.07	2.4
7084.7	0.02	3.7
7096.7	0.04	1.8
7098.3	0.05	1.9
7117.3	0.02	1.7

Geometric Mean = 0.0164

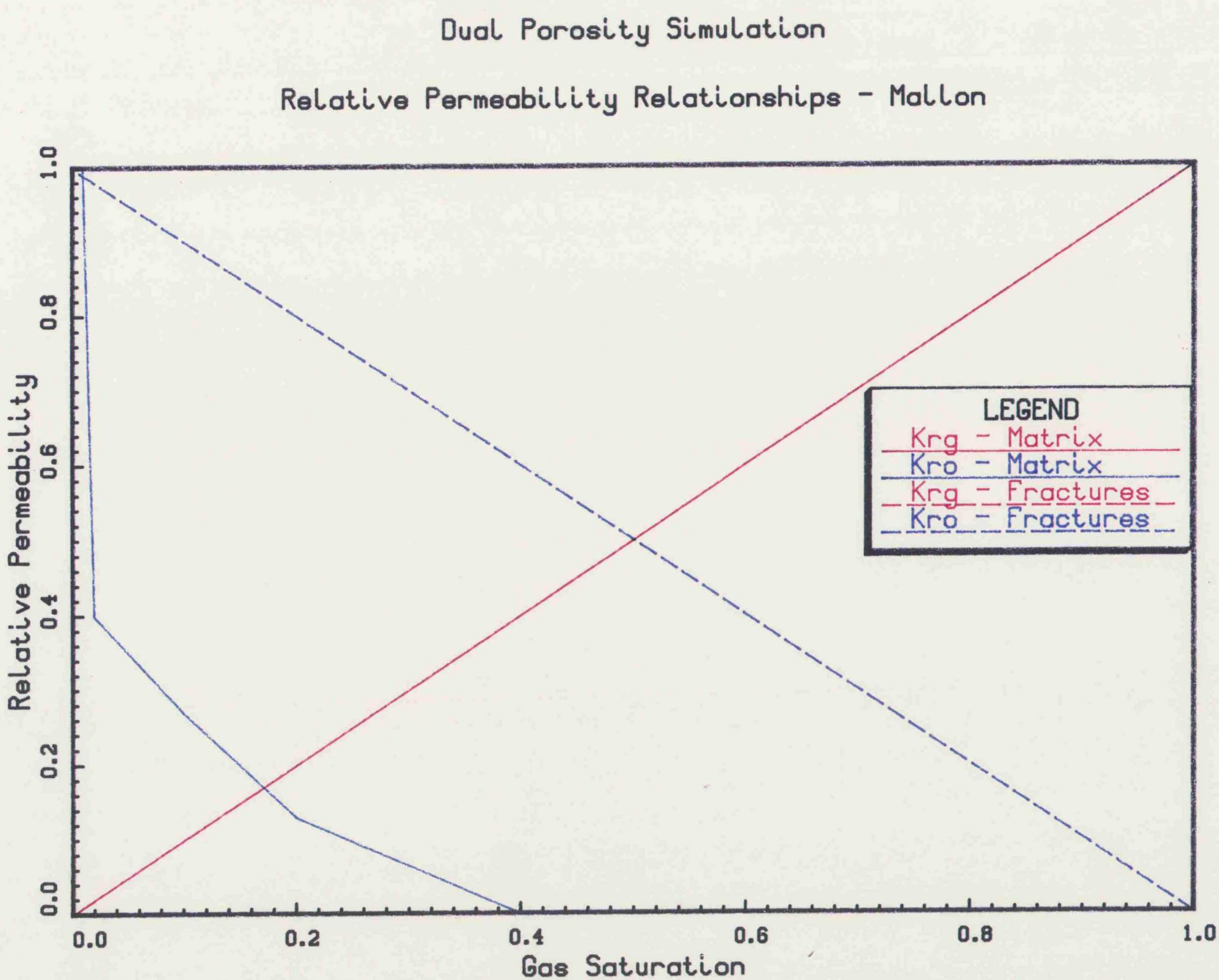
Permeability on 31 of 51 samples listed as 0.01 are actually <0.01 md.


HORIZONTAL PERMEABILITY VS POROSITY
Davis Federal #3-15.
Permeability (Kh), mD
10^0
10^{-1}
10^{-2}
10^{-3}
Porosity, %
0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0

SIMULTATION OF TWO-PHASE DUAL POROSITY RESERVOIR BEHAVIOR

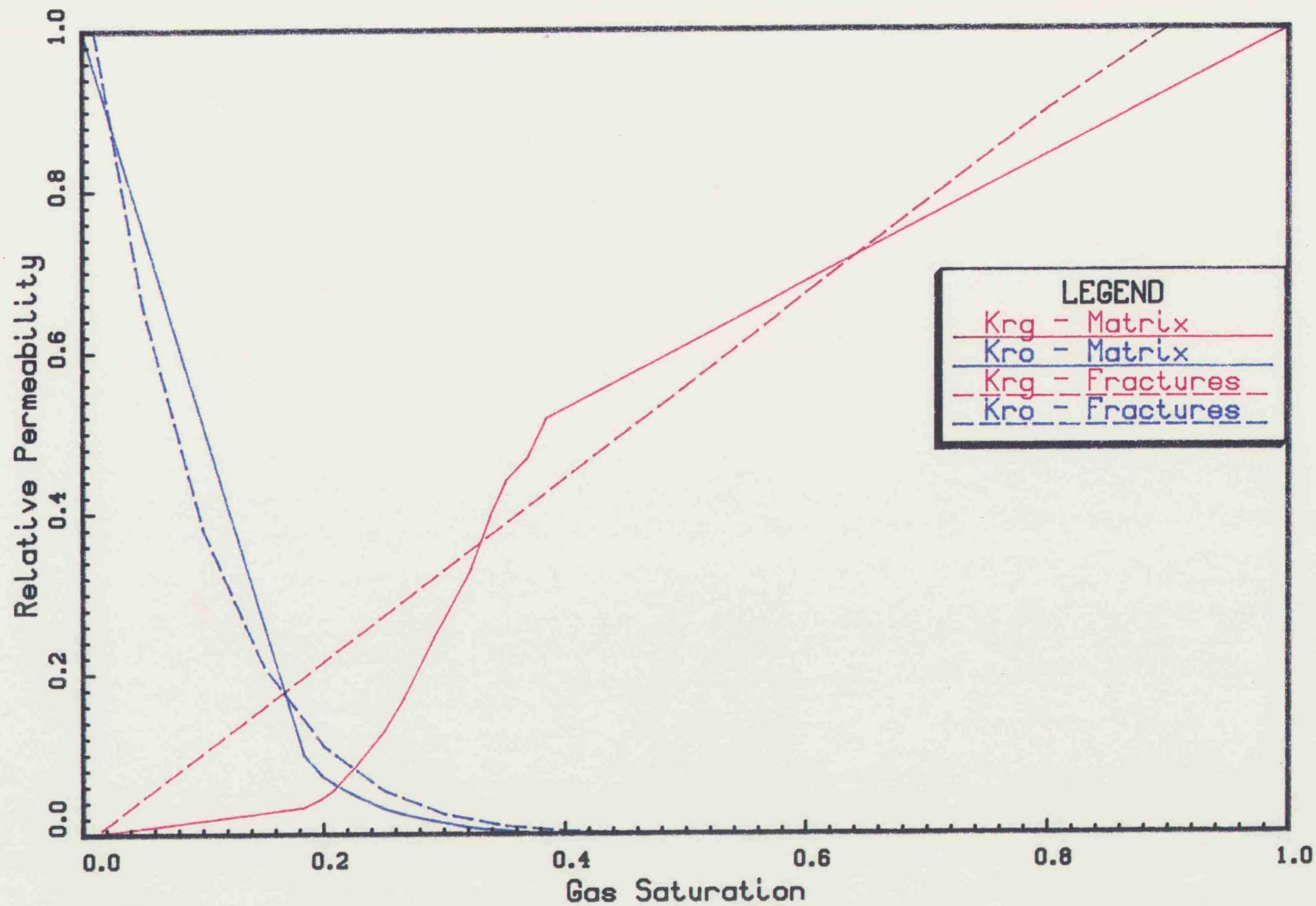
COMPARISON OF SUN AND MALLON ASSUMPTIONS AND RESULTS

MODEL PARAMETER	DATA FOR SUN CASE	DATA FOR MALLON CASE
Reservoir Model	Dual Porosity	Dual Porosity
Matrix-Fracture Transer	Unsteady State	Pseudosteady State
Drainage Area, acres	640	640
Initial Pressure, psia	1600	1600
Net Pay, Ft	270	270
Fracture kh	400 md-ft	400 md-ft
Fracture HC Porosity, %	0.439	0.439
Interporosity Flow Coeff.	6.46×10^{-10}	3.00×10^{-9}
(Mallon Value Calculated from Sigma = 0.00004 = $1/Lz^2$)		
Matrix Permeability, md	0.0000646	0.00148
Storativity Ratio	0.10	0.10
Capillary Pressure	Zero	Zero
Relative Permeability	See Graphs	See Graphs
(Sun Matrix Rel. Perm. Data from Low Perm. Sand/Silt)		
(Mallon Rel. Perms. from Bergeson Report - ECLIPSE Data)		
Flowing BHP, psia	200	200
Matrix-to-Fracture Transfer at abandonment (10 BOPD), % OOIP in matrix	0.57	6.07


Dual Porosity Simulation
Relative Permeability Relationships - Mallon
Relative Permeability
0.0
0.2
0.4
0.6
0.8
1.0
Gas Saturation
LEGEND
Krg - Matrix
Kro - Matrix
Krg - Fractures
Kro - Fractures

Dual Porosity Simulation

Relative Permeability Relationships - Sun



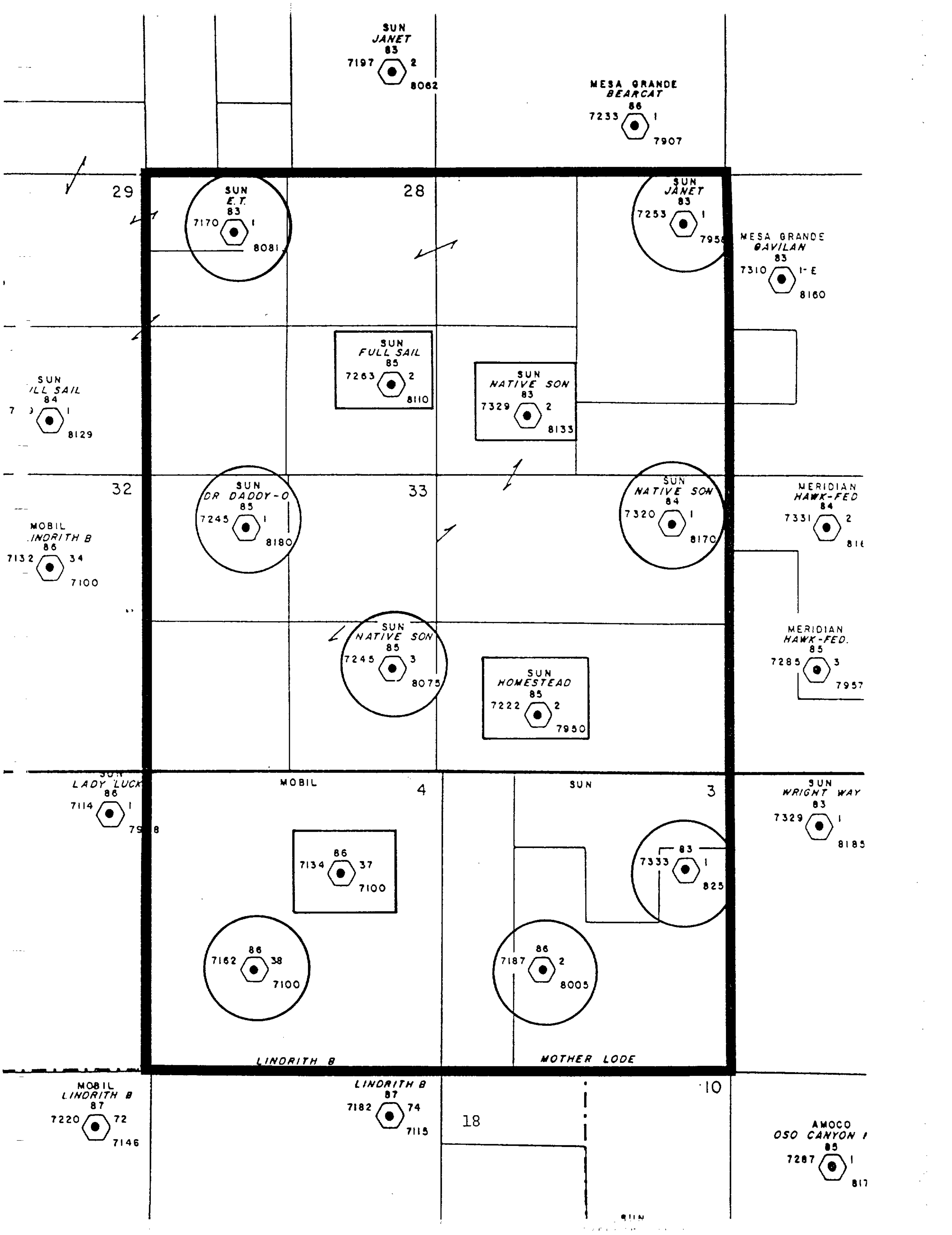
REBUTTAL TESTIMONY

DUAL POROSITY RESERVOIR HYPOTHESIS

FIELD OBSERVATIONS

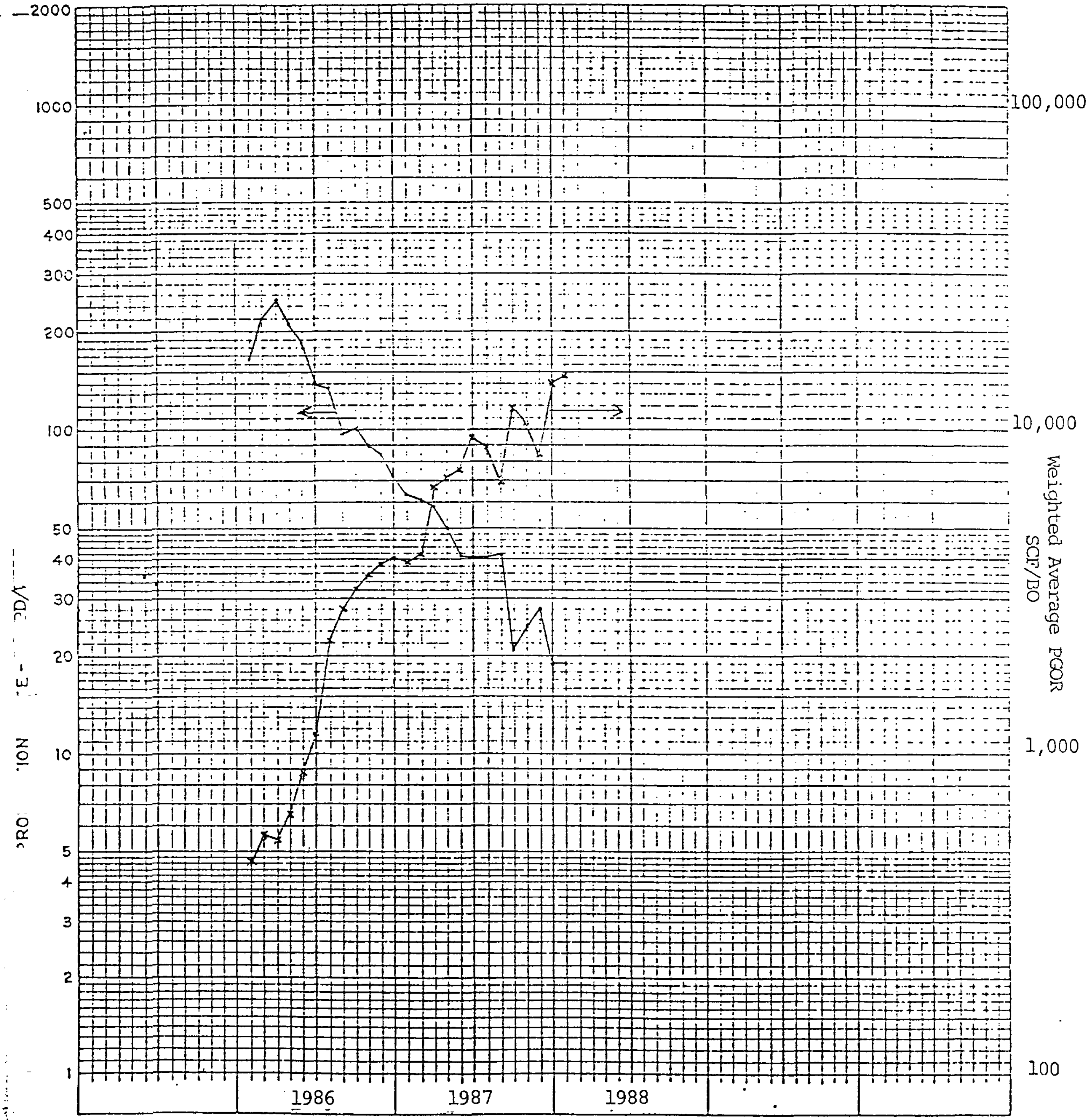
* Eight wells in a six-section area of Gavilan, amid some of the best wells in the field, are nearing depletion (map, production statistics attached).

- Despite the low pressure in the fractures (about 1,000 psia below initial reservoir pressure), matrix oil is not flowing in any significant way into the fracture system. If the matrix is not contributing now, why should we believe that it will <u>ever</u> contribute?



SUN
JANET
83
7197
2
8062
MESA GRANDE
BEARCAT
86
7233
1
7907
29
28
SUN
E.T.
83
7170
1
8081
SUN
JANET
83
7253
1
MESA GRANDE
GAVILAN
83
7310
1-E
8160
SUN
FULL SAIL
85
7263
2
8110
SUN
NATIVE SON
83
7329
2
8133
SUN
84
1
8129
32
33
SUN
DR DADDY-O
85
7245
1
8180
SUN
NATIVE SON
84
7320
1
8170
MERIDIAN
HAWK-FED
84
7331
2
MOBIL
86
7132
34
7100
SUN
NATIVE SON
85
7245
3
8075
MERIDIAN
HAWK-FED.
85
7285
3
7957
SUN
HOMESTEAD
85
7222
2
7950
LADY LUCK
86
7114
1
MOBIL
4
SUN
3
SUN
WRIGHT WAY
83
7329
1
8185
86
7134
37
7100
83
7333
1
86
7162
38
7100
86
7187
2
8005
LINORITH B
MOTHER LODE
MOBIL
LINORITH B
87
7220
72
7146
LINORITH B
87
7182
74
7115
18
10
AMOCO
85
7287
1

Production Data
From Declining Wells Near
High Capacity Wells In Gavilan



Year	Month		ET #1 days	ET #1	Janet #1 days	Janet #1	Native Son #1 days	Native Son #1	Dr. Darley O days	Dr. Darley O	Native Son 3 days	Native Son 3	Lindrith B-38 days	Lindrith B-38	Mother Lode 2 days	Mother Lode 2	Mother Lode 1 days	Mother Lode 1	Total		GOR	Total Prod. Days	
1987	Jan	Oil	A	785	23	567	27	3618	31	2545	A	714	23	348	11	1377	29	1760	11742		3918	187	23
	Feb		26	572	24	644	28	2783	28	2324	12	724	26	491	24	2908	27	1920	11866		4183	195	61
	Mar		19	435	20	444	26	2567	31	2577	10	559	26	517	12	1389	26	1340	7854		6830	170	58
	Apr		18	449	19	273	23	1778	30	2137	11	723	26	434	11	762	23	1055	8115		7159	161	50
	May		19	339	20	444	31	1383	31	2567	10	625	27	410	11	710	31	942	7420		7560	180	41
	June		19	300	A	300	23	1948	27	2181	15	608	21	349	10	357	27	552	6557		9512	161	41
	July		30	405	29	423	31	2002	30	2064	26	1328	31	405	31	2215	31	955	9097		8951	239	41
	Aug		27	169	27	318	27	2710	17	1018	27	1025	28	471	21	2466	27	794	9021		6969	217	42
	Sept		30	154	30	387	28	208	30	923	29	863	30	240	26	1417	8	224	4396		11810	213	21
	Oct		31	98	31	425	31	846	31	709	31	912	31	228	31	1523	31	1445	6234		10599	248	25
	Nov		30	69	16	—	24	1522	24	359	24	341	16	90	24	1725	24	936	5112		8427	182	28
	Dec		27	72	26	—	28	690	28	684	27	316	-	—	18	827	18	643	3202		14108	172	19
1988	Jan		A	13	26	154	29	711	31	1135	28	157	/	—	29	776	28	737	3683		14849	190	19
1987	Jan	GAS		7139		7381		8133		3784		3175		8034		4567		3587	46000				
	Feb			8089		5879		6784		3350		4911		7021		6288		4312	49634				
	Mar			9578		6762		6710		4452		10725		9394		11192		7987	67300				
	Apr			7478		7967		6914		5423		7711		7717		7890		6938	58048				
	May			7199		7385		4552		7104		7327		9858		7068		5600	56093				
	June			7212		7074		7200		7604		8909		7197		3484		13683	62323				
	July			11197		10879		7865		6881		20817		5921		22935		1194	87689				
	Aug			8523		8560		1948		6541		10449		6744		7546		6505	62866				
	Sept			8436		8412		323		8627		7850		5920		9565		2713	51916				
	Oct			6948		8233		1513		8756		6729		8951		12758		12207	66095				
	Nov			4025		4523		4500		5874		3952		1684		9543		8627	43080				
	Dec			4364		3914		7470		7561		8573		—		2967		10324	45123				
1988	Jan			3092		7530		8140		6462		4159		—		10015		15290	54688				

National 45-613 Eye Ease 45-713 20-20 Buff Made in USA

Year	Month	OIL	ET#1 days	ET#1	Janet #1 days	Janet #1	NS#1 days	NS#1	Dr. Dolly days	Dr. Dolly	NS 3 days	NS 3	Lind B 38 days	Lind B 38	Mother Lode 2 days	Mother Lode 2	Mother Lode 1 days	Mother Lode 1	Total	GOR	Total Prod. Days	Total Oil Per Prod. Day
1986	Jan	OIL	31	2259	31	3555	31	11521				–		–		–	30	3344	20679	469	123	168
	Feb		27	5405	27	3145	27	11750				–		–		–	27	3461	23761	567	108	220
	Mar		31	7313	31	3292	31	11776				–		–		–	31	8709	31090	542	123	253
	Apr		30	6000	29	3183	30	8636				–		–		–	29	7464	25285	656	118	214
	May		31	3168	26	2463	31	12370	11	783		–		–	10	1042	31	7778	27604	878	148	187
	June		30	3128	30	2834	30	8423	7	69	7	2049	11	1328	30	1182	30	6666	25679	1171	183	140
	July		31	2074	31	2310	31	7387	–	–	17	4665	31	1165	5	241	31	6312	24154	2271	177	136
	Aug		29	1146	29	2199	31	2077	–	–	29	7248	29	1009	–	–	26	3109	16788	2811	173	97
	Sept		2	264	2	1757	12	2448	6	339	6	505	20	338	2	135	20	1217	6983	3266	70	100
	Oct		19	527	28	1544	28	4266	31	2558	11	1758	21	458	27	4389	25	1808	17108	3522	123	89
	Nov		18	660	21	674	22	3206	30	2137	9	816	23	399	19	3863	23	1798	13853	3979	165	84
	Dec		20	665	20	637	21	3242	31	2818	8	780	23	443	18	1966	27	1548	12101	4068	168	72
1986	Jan			1031		2125		3625		–		–		–		–		2927	9706			
	Feb			2371		1777		4851		–		–		–		–		4263	13464			
	Mar			3883		2244		4216		–		–		–		–		6494	16837			
	Apr			4170		1961		4432		–		–		–		–		6025	16588			
	May			7423		1722		1712		118		–		–		–		13021	24246			
	June			10225		2318		4633		32		624		2670		631		8927	30058			
	July			13464		6079		940		–		12043		9593		101		12324	54844			
	Aug			12872		5420		904		–		16153		7264		–		4578	47196			
	Sept			1569		5781		3554		147		1904		4912		48		5388	22803			
	Oct			7741		8499		8601		5808		10463		7504		4775		8460	61201			
	Nov			3397		6125		7554		5300		7143		6772		6896		6418	53737			
	Dec			9116		7559		4911		3510		7295		3958		6591		6285	49225			

REBUTTAL TESTIMONY
DUAL POROSITY RESERVOIR HYPOTHESIS
INFERENCES FROM PRESSURE BUILDUP TEST PLOT SHAPES

• The shape of the pressure buildup test plot for the mid-1987 test of the Mobil Lindreth B-37 well is similar to the characteristic shapes of buildup test plots from dual porosity reservoirs.

• This shape, on the tests from one well, hardly "proves" the dual porosity hypothesis.

- This shape is the exception, rather than the rule, and it is more common in recent tests than in earlier tests.

- Other phenomena--notably phase redistribution in the wellbore (gas rising to the top and liquid falling to the bottom of the wellbore following shut-in)--can cause the same shape.

- Phase redistribution is clearly occurring in the field. Extreme cases result in a pressure "hump," which has virtually no other causes. Pressure humps are present in several test plots (graphs attached).

- The attached SPE paper points out the similarity in test plot shapes for dual-porosity reservoirs and wells with phase redistribution in the wellbore.

SPE

Society of Petroleum Engineers

SPE 16763

An Analytical Model for Composite Reservoirs Produced at Either Constant Bottomhole Pressure or Constant Rate

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SPE Members

This paper was prepared for presentation at the 62nd Annual Technical Conference and Exhibition of the Society of Petroleum Engineers held in Dallas, TX September 27-30, 1987.

ABSTRACT

In this paper, we present a model of the complete characteristic transient response from a composite reservoir including the effects of skin, wellbore, storage and phase redistribution at the well. We present six flow regimes and the combined effects of wellbore storage and phase redistribution on pressure behavior in composite reservoirs.

Using an automatic history matching approach, we analyzed three buildup tests and a pressure falloff test. This method eliminated the serious uniqueness problem associated with type curve analysis. We demonstrate that incorrect reservoir parameter estimates and incorrect production performance predictions would result from the use of any model that lacks the capabilities of the model we present in this paper. We also demonstrate possible misinterpretations of pressure data that may result from not recognizing the presence of phase redistribution in the buildup test data or not recognizing the composite reservoir behavior.

INTRODUCTION

Numerous analytical models have been presented in recent years to describe the pressure behavior of composite reservoir systems.[1-8] Composite reservoirs are encountered in a wide variety of reservoir situations. In a composite reservoir there is a circular inner region with fluid and rock properties different from those in the outer region. Reservoirs damaged because of fluid invasion during drilling or completion; stimulated reservoirs; reservoirs being waterflooded or undergoing insitu combustion are examples of the reservoir types that can be described by a composite reservoir model. The inner zone represents the invaded or altered zone while the outer zone represents the uninvaded zone. The two zones are separated by a sharp radial discontinuity. This idealized interface may be a permeability, mobility, saturation or thermal discontinuity.

During the 1960's there was great interest in the composite reservoir flow problem. Hurst[1] discussed in detail the "sand in series" problem and presented formulas to describe unsteady state pressure behavior of fluid movement through two sands in series in a radial configuration. Loucks and Guerrero[2] presented a theoretical study of the pressure distribution in an infinite composite reservoir. They found that under certain conditions the permeability in both zones as well as the size of the inner zone can be determined from pressure transient test data. Wattenbarger and Ramey[3] presented a finite difference solution for the infinite composite reservoir. Other early investigators include Merrill et al.,[4] Clossmann and Ratliff,[5] and Bixel and Van Poollen.[6]

Recently Satman[7] presented an analytical study of interference in a composite reservoir which accounts for wellbore storage and skin at the active well. Brown[8] presented a graphical approach for calculating mobility of the altered and unaltered zones and the radius of the altered zone. DaPrat et al.[9] presented an application of a composite reservoir model to interpret falloff tests in an insitu combustion project.

The major contribution of this paper is the presentation of the combined effects of skin, wellbore storage and phase segregation on pressure transient tests in composite reservoir systems. We also present the six flow regimes possible in a finite composite reservoir and show how the characteristic influence of wellbore storage and phase segregation may case a misinterpretation of pressure transient tests. The rate solution in a composite model with an inner steady state skin is also presented. This solution is useful for

References and illustrations at end of paper.

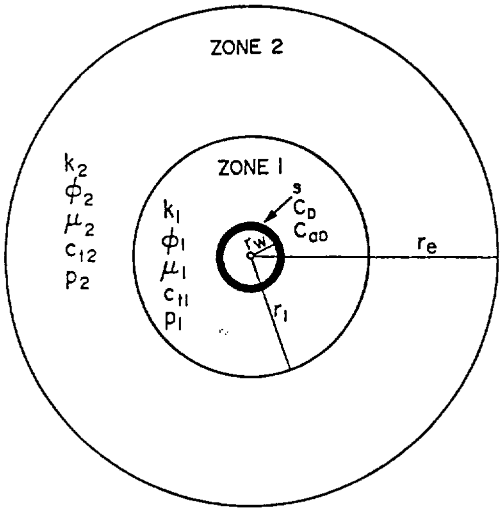


Fig. 1—Schematic diagram of composite reservoir system.

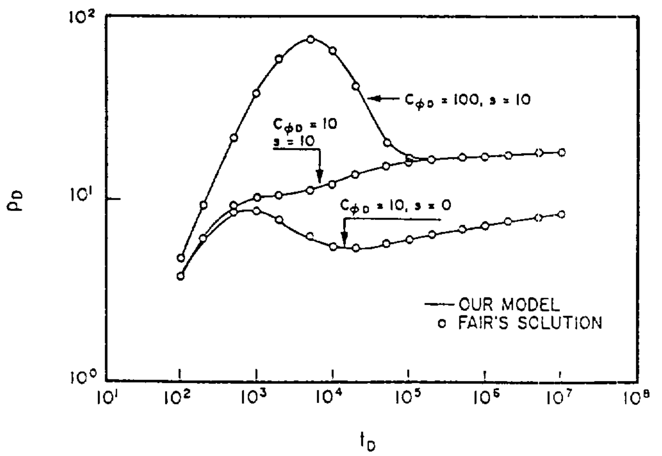


Fig. 2—Comparison of solutions developed in this study with Fair's solution, $\eta_1/\eta_2 = 1.0$, $r_1/r_w = 1$, $C_D = 1,000$, $C_{\phi D} = 20$.

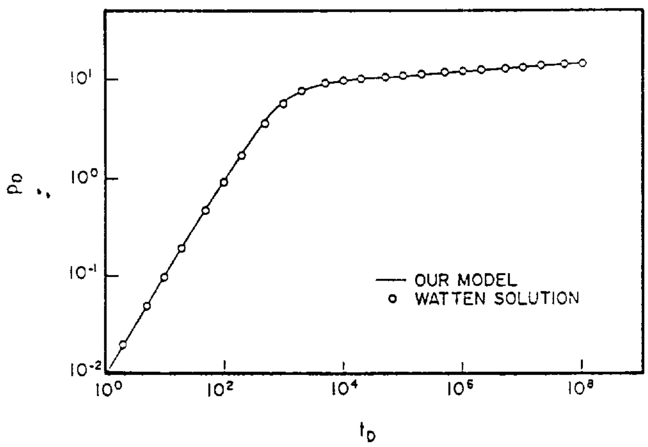


Fig. 3—Comparison of solution developed in this study with Wattenbarger and Ramey's solution, s = 5, $C_D = 1,000$.

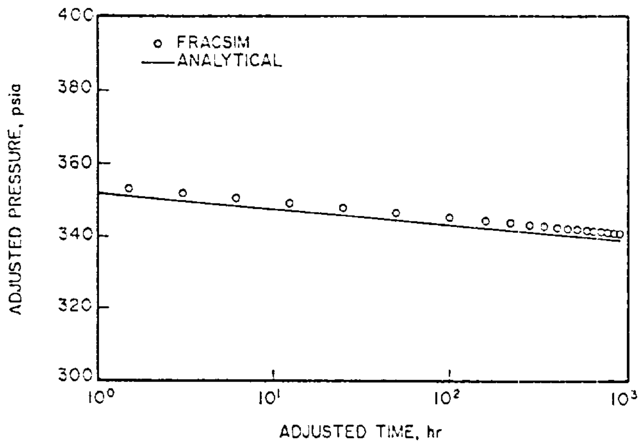


Fig. 4—Comparison with simulator solution for fractured gas well, pressure drawdown test, $k_1 = 0.029$, $k_2 = 0.0029$, $r_1/r_w = 100$.

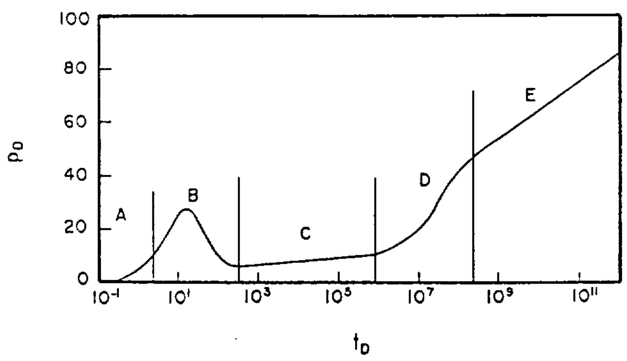


Fig. 5—Flow regimes in an infinite composite reservoir, $\eta_1/\eta_2 = 10$, $r_1/r_w = 500$, $s = 0$, $C_D = 100$, $C_{1D} = 50$, $\epsilon = 10$.

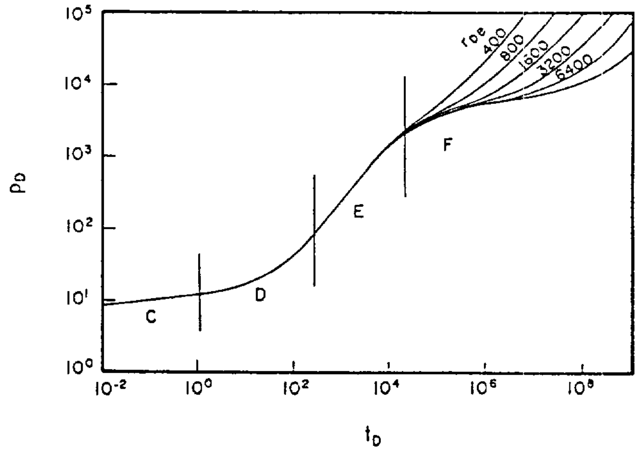


Fig. 6—Pressure flow regimes in a finite composite reservoir, $\eta_1/\eta_2 = 1,000$, $r_1/r_w = 100$, $C_D = 0$, $s = 5$, $C_{\phi D} = 0$.

CONCLUSIONS

1. We have demonstrated in this paper the danger of misinterpretation that may result from applying an incomplete model to buildup test data where pressure distortion caused by phase redistribution is not large enough to show the classical hump. The analysis of such buildup data with techniques that do not account for phase redistribution can lead to incorrect reservoir property estimates and incorrect predictions of production.

2. We have applied an automatic history matching technique and our new composite model to analysis of buildup and falloff tests. This technique is superior to available type curve and semilog analysis methods because of the reduction of the uniqueness problem, ability to estimate many important reservoir parameters and a correct representation of the skin zone.

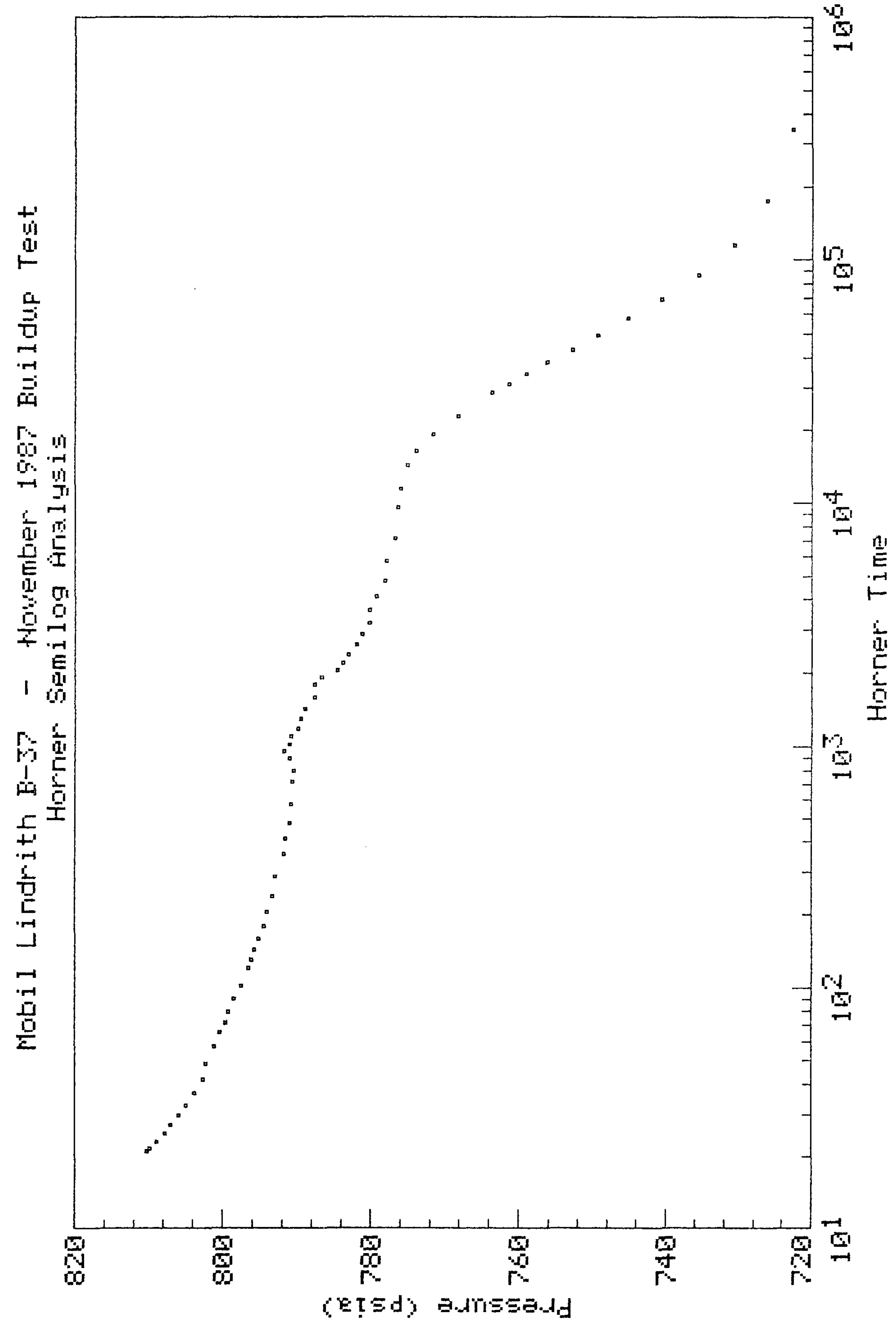
3. When the diffusivity of the inner zone of a composite system is less than that of the outer zone, as in a damaged system, the pressure humps caused by phase redistribution are both larger and last longer than when the diffusivity of the inner zone is greater. The presence of wellbore storage and phase redistribution will usually mask the first semilog straight line, thereby, in such damaged systems, rendering conventional semilog analysis useless in evaluating the properties of the inner zone. Such test data can be analyzed with the model presented in this paper.

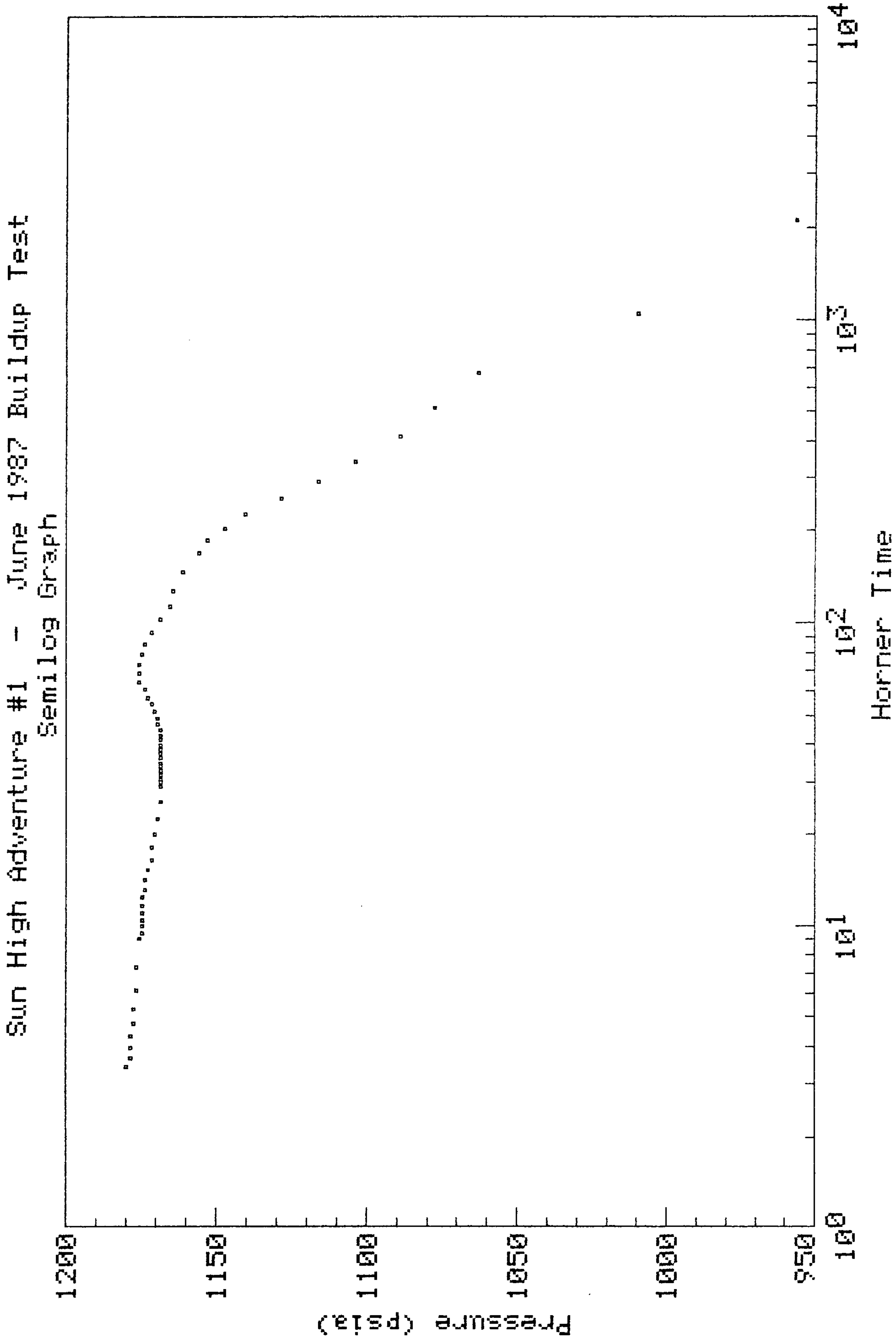
4. When the distortion caused by phase redistribution is not severe enough to cause a hump, the characteristic shape of the pressure behavior could be misinterpreted as that from a dual porosity reservoir. The composite reservoir behavior could also be misinterpreted as an effect caused by the reservoir drainage boundary. When such a characteristic shape is displayed in a transient test, more information should be sought about the reservoir geology, reservoir fluid phase behavior and fluid properties before a model is chosen.

5. The transition flow regime of a composite model lasts about 2-1/2 log cycles if the diffusivity of the inner zone is greater than that of the outer zone. When the diffusivity of the inner zone is smaller, the transition flow regime lasts approximately 1 log cycle.

NOMENCLATURE

Symbol	Meaning
B	Formation volume factor, Rb/Mscf for gas and RB/STB for oil
C_{aD}	$\frac{1}{C_D} + \frac{C_{\phi D}}{\alpha_D}$, dimensionless apparent wellbore storage coefficient
c_t	Total compressibility, psia^{-1}
C_D	$\frac{0.894\, C_s}{c_t h r_w^2}$, dimensionless wellbore storage coefficient
C_s	Wellbore storage coefficient, bbl/psi
C_ϕ	Phase redistribution pressure parameter, psi
$C_{\phi D}$	$\frac{kh\, C_\phi}{141.2\, q \mu B}$, dimensionless phase redistribution parameter
h	Net pay thickness, ft
I_o	Modified Bessel function of the first kind, zero order
k	Permeability, md
K_o	Modified Bessel's function of the second kind, zero order
L_f	Fracture half length, ft
p	Pressure, psia
p_a	$\frac{\bar{\mu}}{\bar{\rho}} \int_{p_o}^{p} \frac{\rho}{\mu}\, dp$, adjusted pressure, psia
p_D, p_{Dw}	$\frac{k_2 h (p_i - p_{wf})}{141.2\, q \mu B}$, dimensionless pressure
p_i	Initial reservoir pressure, psia
p_ϕ	Phase redistribution pressure, psi
$p_{\phi D}$	$\frac{k h\, p_\phi}{141.2\, q \mu B}$, dimensionless phase redistribution pressure
p_{gef}	Flowing pressure at point of gas entry, psi
p_{whf}	Flowing wellhead pressure, psi
p_{wf}	Flowing wellbore pressure, psia
q	Flow rate, Mscf/D for gas, and b/d for oil
r_D	Dimensionless radius, r/r_w
r_e	Drainage radius, ft
r_w	Wellbore radius, ft
s	Laplace transform parameter (in the Appendices); in text, skin factor, dimensionless
S	Skin factor, dimensionless (in the Appendices)
t	Time, hr
t_a	$t(p) \times \bar{\mu}\, \bar{c}_t$, adjusted time, hr


Mobil Lindrith B-37 – November 1987 Buildup Test
Horner Semilog Analysis
Pressure (psia)
Horner Time
820
800
780
760
740
720
10^1
10^2
10^3
10^4
10^5
10^6



Sun High Adventure #1 - June 1987 Buildup Test
Semilog Graph
Horner Time
Pressure (psia)

REBUTTAL TESTIMONY
DUAL POROSITY RESERVOIR HYPOTHESIS
CONCLUSIONS

- Available core data indicates the matrix permeability is extremely low.

- Reservoir simulation using available core data indicates that the matrix will not contribute significantly to pool reserves.

- Actual field performance indicates no support from the matrix in declining wells.

- The buildup curve shape on the Mobil Lindreth B-37 well does not prove dual porosity behavior. Phase redistribution in the wellbore is a more likely explanation.