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Reserve and Production Data for the Andector Field Area, Central Basin Platform, West Texas: Data for Model Constraint and Development

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RESERVE AND PRODUCTION DATA FOR THE ANDECTOR FIELD AREA, CENTRAL BASIN PLATFORM, WEST TEXAS: DATA FOR MODEL CONSTRAINT AND DEVELOPMENT

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Summary

The integrated model under development will ultimately predict reservoir properties, volumes, fluid content, and fluid composition (water, oil, and gas). Oil properties are presented here for use in subsequent flow models. To further constrain and verify these predictions, production history data, reservoir geometry, and well test data are used to map the initial potential, remaining reserves, and maximum non allowable limited production rates of the Andector Field. Historic bottom hole pressure data illustrate early production interference and boundary effects.

RESERVE AND PRODUCTION DATA FOR THE ANDECTOR FIELD AREA, CENTRAL BASIN PLATFORM, WEST TEXAS: DATA FOR MODEL CONSTRAINT AND DEVELOPMENT

Reservoir data related to the CIRF.B model concerns the ability of the rocks in a field to deliver oil. Naturally, the flow properties of the fluids bear on this problem as do the flow characteristics of the rocks. In addition, for matching purposes, we include data on

- (1) the maximum observed production rate for the field in pseudo-steady-state decline,
- (2) the initial potential as determined in well tests, and
- (3) a characterization of the pseudo-steady-state decline rates over the field.

The potential and rate data are interpretations of commercially available data [Petroleum Information Industry Client Server (PIICS, 1997)]. The rock and fluid data are from corporate documents (Technical Committee, 1972).

ROCK AND RESERVOIR PROPERTIES

The Andector reservoir rocks are in the Ellenburger Group of West Texas. Table 1 summarizes their physical properties.

Table 1. General rock properties for the study area of West Texas.

Property	Value	Condition
Porosity (%)	0-3 %	150 ft Phillips Alma # 7
	3-5 %	173 ft 9,468 ft to 9,872 ft
	5-8 %	63 ft
	8-10 %	11 ft
	10-15 %	4 ft
	15+%	1 ft
	3.8 %	Average
Permeability	Unknown	
So	0.7	
Pressure	3485	psi 5120 ft datum

This reservoir rock is a fractured dolomite. The fractures are of karst and subsequent tectonic origin and are highly cemented (see fracture report section of this document).

OIL PROPERTIES

The Andector oils are typical of the Ellenburger Group of West Texas. Table 2 summarizes their physical properties.

Table 2. General oil properties for the study area of West Texas.

Property	Value	Condition
Oil gravity	44° API	60°F
Gas Gravity	1.05	
Water Salinity	21,736 ppm Cl ⁻	
Saturation Pressure	1105 psi	132 °F
Gas Solubility	600 scf/bbl	
Formation Volume Factor	1.325	3,407 psi
	1.355	1,105 psi
	1.258	500 psi
Oil Viscosity at 132°F	0.67 cps	3,407 psi
	0.56 cps	1,105 psi
	1.56 cps	500 psi
Oil Composition	0.1872	Methane
	0.1139	Ethane
	0.1111	Propane
	0.0135	i-Butane
	0.0645	n-Butane
	0.0106	i-Pentane
	0.0510	n-Pentane
	0.0491	Hexane
	0.3838	C ₆ + (Hexane+)
	0.0004	Hydrogen Sulfide
	0.0059	Nitrogen
	0.0090	Carbon Dioxide
Molecular Weight	102.64	
Molecular Weight C ₆ +	202.00	

This oil is approximately a black oil, and it will be treated as such in the model studies of this project.

RESERVOIR OIL VOLUME

The Andector reservoir was predicted to ultimately produce the oil volumes shown below.

Table 3. Produced oil from Andector area leases, see Figure 1 for locations, and predictions of producible oil from previous work.

Tract	Lease	Production in Barrels (000)				
		Cum to '72 [#]	Primary to '72	Cum to '98 [#]	Predicted Tot	Differ- ence
1	R. B Cowden E	2130	781	2223	2911	688
2	R. B. Cowden B	257	37	257	294	37
3	R. B. Cowden 12	3892	857	4440	4749	309
4	Limpia	4228	2932	7034	7160	126
5	Nobles	2645	1338	3925	3983	58
6	Cowden A	2670	14	2674	2684	10
7	Abell	3974	1582	4809	5556	747
8	Cowden H	2443	20	2444	2463	19
9	Frank B	9365	9274	18291	18639	348
10	Cummins 12	11399	5516	16074	16915	841
11	J. F. Cowden	13558	16164	22661	29722	7061
13	Cummins 13	2077	297	2225	2374	149
14	Frank A	8080	4083	10883	12163	1280
15	McEntire	4195	4720	7383	8915	1532
12	Embar 9					
16	Embar 17*	17457	35038	36906	52495	15589
17	Embar 16					
18	Cowden C	6753	156	7703	2304	-794
19	Cowden C	8658	4153	10507	12811	2304
20	Schar	748	8	748	756	8
Total		104529	86970	161187	191499	30312

[#] Data are derived from PIICS.

*Embar 17 represents the sum of contributions for Embar 9, 16, and 17. This gives consistency between the commercial and corporate data.

Two things are apparent. First, the overall quality of the 1972 predictions of the Andector engineering team is exceptionally good. One can see where additional potential lies, and can begin to engineer the final production of the reservoir using these data. Second, the reservoir is near ultimate depletion. For purposes of the basin analysis here,

we can take the reservoir volume to be equal to the pre 1971 cumulative production plus the cumulative total prediction in tables 3. This value is expressed as

$$\begin{aligned} \text{Volume Recoverable Oil in Place (barrels)} &= \\ 100,870,000 \text{ cumulative to '71} &+ 86,970,000 \text{ predicted remaining post '71} \\ &= \\ 190,840,000 \end{aligned}$$

This figure includes the volume of oil produced between 1949 (start of production) and 1958 (start of commercial data). The pre 1958 production has not been allocated to leases. Reservoir pore volume is approximately 500×10^6 barrels, so the overall recovery is expected to be 38%.

DISTRIBUTION OF MAXIMUM RATE

The leases in the Andector area have undergone a complicated production history. A typical production rate curve has the form shown below.

Figure 1. Pressure and production rate histories of a portion of the Andector Field. The pressure data are from corporate sources, the rate data are from PIICS. The commercial rate data are not available for the times before 1958.

In light of these curves, we can assume:

- (1) Before 1965, the production was limited, and the field was undergoing transient decline or near transient decline.
- (2) After 1968, the field production practices radically changed. The pressure decline became more rapid, and the production rose to a maximum and went into a steep decline. Portions of the early part of this second decline are probably simple pseudo-steady-state, and decline parameters may be estimated.
- (3) It is likely that only a few and relatively minor modifications to production practices were made during the early part of this decline during the pre-1968 period.
- (4) The field was developed on a constant 40 acre spacing, so the pre-1968 portion of the pressure curve is the field's response to a uniform depletion over its entire area. After this period, wells are being shut in, rates are changing, and the analysis would require a great deal of complicated reinitialization.

REMAINING HYDROCARBON POTENTIAL OR PRIMARY RESERVES

Figure 2 below shows the remaining hydrocarbon potential for this area. Not surprisingly, this distribution follows structure. The largest reserves are just located where the oil saturated reservoir formation is thickest.

MAXIMUM PRODUCTION RATE

Figure 3 below shows the maximum production rates by lease observed over the area. One can see the field divides into North and South Fault blocks. The numbers are early production rates in barrels of oil per year for selected leases in the Andector area. The values are normalized to 1 mi² of lease area. The posted values are the annual rates for the first year of commercial data, 1958. This year is in the transient flow period, and all the subsequent transient flow rates (that is, rates prior to 1965) are less than those for 1958. Therefore, we take the 1958 rates to represent our best view of the reservoir's early rate potential. The well spacing in this field is 40 acres, and it is quite uniform over the area. The area normalization produces a property characteristic of the producing formation.

Figure 4 is similar to Figure 3. However, we plot the maximum post 1969 rate divided by the area of the lease. This is the rate achieved after the field was worked over from 1965 to 1970 and production practices changed to maximize yield. These numbers approximate the maximum rate the reservoir could produce at the onset of pseudo-steady-state flow. As for Figure 3, the area normalization produces a property characteristic of the producing formation.

Figure 5 shows the rates of Figure 4 normalized by the volume of the original oil in place. These numbers give an indication of the lifetime one might expect of the lease. The higher the rate relative to the oil present, the shorter the lifetime.

The maximum rates in both Figures 3 and 4 naturally occur on the culminations of the structures. High rates are also seen in areas near the major bounding faults. The lowest rates are seen on the edges of the reservoir near the oil-water contact. In Figures 4 and 5, some of the rates are zero. These leases are marginal, small, and near the oil water contact. They tend to deplete before the larger, more important leases in the area go into true decline. These relations are not surprising, but they do suggest some structural control over the development of permeability.

The data on these maps is summarized in Table 3.

Table 3. Andector production data. Areas, isopachs, and production data are approximate from corporate data and commercial data sources. Isopachs are from visual averages of an isopach map. Areas are from graphic integration of area in lease boundaries. Approximate data are sufficient to constrain a basin model.

Lease	Area mi2	Isopach ft	Tot Vol acre	Vol acre*ft	OOIP bbl	Max BOPY	MaxRate /mi2	Rate/ Vol	MaxRate /OOIP	Rate'58/ Area
R B COWDEN	0.25	375	60000	2280	9.34E+06	0	0	0	0.000	115932
CUMMINS-12	0.95	300	182400	6931	2.84E+07	501764	528173	72	0.018	449508
CUMMINS-13	0.30	200	38400	1459	5.98E+06	66076	220253	45	0.011	305327
COWDEN, R.B.-E	0.20	300	38400	1459	5.98E+06	110562	552810	76	0.018	305425
COWDEN, H. B. -H-	0.25	225	36000	1368	5.61E+06	0	0	0	0.000	278928
ABELL	0.25	300	48000	1824	7.48E+06	245239	980956	134	0.033	490300
BLAKENEY	0.20	100	12800	486	1.99E+06	0	0	0	0.000	140250
EMBAR	1.25	625	500000	19000	7.79E+07	1824002	1459202	96	0.023	465898
FRANK-A-	0.65	210	87360	3320	1.36E+07	519129	798660	156	0.038	426206
FRANK -B-	0.55	475	167200	6354	2.60E+07	914690	1663073	144	0.035	561764
LIMPIA	0.25	425	68000	2584	1.06E+07	372880	1491520	144	0.035	495744
MCENTIRE	0.25	475	76000	2888	1.18E+07	370938	1483752	128	0.031	498488
NOBLES	0.20	350	44800	1702	6.98E+06	191364	956820	112	0.027	444040
SCHAR-B	0.06	200	8006.4	304	1.25E+06	41021	655811	135	0.033	492134
COWDEN, R. B.12	0.03	200	3200	122	4.98E+05	186751	7470040	1536	0.375	4894880
COWDEN-A	0.25	200	32000	1216	4.98E+06	0	0	0	0.000	279276
COWDEN-B	0.06	300	12000	456	1.87E+06	38563	617008	85	0.021	482256
COWDEN, W. F. C.-DEEP R/A	0.75	150	72000	2736	1.12E+07	548822	731763	201	0.049	305511
COWDEN, W. F. C.-DEEP R/A	0.50	125	40000	1520	6.23E+06	90562	181124	60	0.015	204836
COWDEN, J. F.	0.60	250	96000	3648	1.50E+07	1152952	1921587	316	0.077	711443
Total, Average	7.80	145	1.62E+06	61658	2.53E+08

Figure 2. Remaining hydrocarbon reserves for selected wells in the Andector area. The map also shows the Ellenburger contours at sea level datum.

Figure 3. Early production rate in barrels of oil per year per mi² of lease area for selected leases in the Andector area. The posted values are the annual rates divided by the lease area for the first year of commercial data, 1958. This year is in the transient flow period, and all the subsequent transient flow rates (that is, rates prior to 1965) are less than those for 1958. Therefore, we take the 1958 rates to represent our best view of the reservoir's initial rate potential.

Figure 4. . Maximum apparent pseudo-steady-state rate in 1.0×10^6 barrels of oil per year per mi^2 reservoir area for selected leases in the Andector area. The posted values are highest the annual rates of production in the early 1970's divided by the reservoir area. The wells had all gone into pseudo-steady-state production at this time. The field was fully developed at a 40 acre spacing. This year is in the pseudo-steady-state when the pressure transients have definitely touched the reservoir walls and are in active interference.

Figure 5. Maximum apparent pseudo-steady-state rate in 1.0×10^6 barrels of oil per year per acre*ft reservoir volume for selected leases in the Andector area. The posted values are the highest annual rate of production in the early 1970's divided by the reservoir volume. The wells had all gone into pseudo-steady-state production at this time. The field was fully developed at a 40 acre spacing. This year is in the pseudo-steady-state when the pressure transients have definitely touched the reservoir walls and are in active interference.

LARGE SCALE PRESSURE HISTORY

The following graphs show Cartesian plots of the pressure and rate history in an Andector Block. Figure 1 gives the pressure history for and average of several wells in the North Fault Block area. Similar curves are available for other locations, and these curves are collected in Appendix I. The curves all have this basic form.

Figure 6. The curves at left show the logarithmic appearing pressure decline characteristic of transient production. There are changes in slope that may indicate interference. These changes seem to take place as the production reaches a maximum, and we take this to indicate the onset of pseudo-steady-state flow. See Raghavan (1993), Lee (1982), Horne (1995).

Figure 7. Log-log plot presentation common in well test diagnosis. $\log(\Delta P)$ and the $\log(t)$ derivative of P tend to confirm the semi-log linear character and slope doubling we saw in Figure 6. The slope doubling indicates interference with a neighbor well or an impermeable barrier. T is days post 1949. The ticks on the horizontal axes indicate the years 1949, 1958, 1960, 1965, 1970, 1980, 1990, and 1998.

The derivative shows two possible slope doubling or interference regions and a region of slope decline. In draw-down tests, this decline could be an indication of support from an active aquifer. It is significant that the first doubling takes place before the sharp increase in production after 1968. The reduction of slope takes place between 1970 and 1980, when actual production was at a maximum. The apparent pressure support is

unlikely to be an effect of shut-in wells. This is when production was at its highest. We think the reduction in slope is aquifer support and indicates a strong water drive. This is consistent with the classic aquifer studies on this system (Moore and Truby, 1952), where boundary/closed aquifer effects were seen in the first years of production.

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APPENDIX I: PRESSURE EVOLUTION DURING THE INITIAL PRODUCTION PHASE IN ANDECTOR FIELD

North Fault Block

Abell Lease Production and Pressure

Nobles Lease Production and Pressure

South Fault Block

Embar Lease Production and Pressure

McEntire Lease Production and Pressure

PRESSURE HISTORY DIAGNOSTIC PLOTS

The derivatives of pressure with respect to $\log T$ were obtained in two steps. First, the pressure change, ΔP , was convolved with the series of weights (1,2,3,2,1) and the result divided by 9 to produce a moving average. Then a second order formula for the first derivative was applied to the smoothed data. The results are the lightly shaded curve above. The following graphs present diagnostic plots for the Andector leases in this study.

North Fault Block

South Fault Block