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QUARTERLY REPORT

TITLE: AN INTEGRATED STUDY OF THE GRAYBURG/SAN ANDRES RESERVOIR, FOSTER AND SOUTH COWDEN FIELDS, ECTOR COUNTY, TEXAS

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Objective

The principal objective of this research is to demonstrate in the field that 3D seismic data can be used to aid in identifying porosity zones, permeability barriers and thief zones and thereby improve waterflood design. Geologic and engineering data will be integrated with the geophysical data to result in a detailed reservoir characterization. Reservoir simulation will then be used to determine infill drilling potential and the optimum waterflood design for the project area. This design will be implemented and the success of the waterflood evaluated.

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SUMMARY OF TECHNICAL PROGRESS

GEOLOGY

Core K and ϕ for all cores

During the simulation, a question arose regarding the permeability and porosity of the different layers used in the model. A closer examination of the ϕ vs. K was undertaken and a series of plots (Fig. 1A-1T) were generated from the existing core reports. Although six wells were cored (Fig. 2) in sections 36, 31, and 32 (just to the east of section 31), only the cores taken in the Sun #6 Witcher still exist. The Sun #6 Witcher was cored in the Upper Grayburg (A1, A2, B1, and B2 zones, and basal Queen) and San Andres. The Arco #10 Brock was cored in the San Andres. The Arco #3-X Foster-Pegues was cored in the Upper Grayburg (A1, A2, B1, B2, and Upper C zones). The General American #7 Maurice was cored in the Upper Grayburg (A1, A2, B1 and B2 zones). The Great Western #19 Johnson was cored in the Upper and Lower Grayburg (A1, A2, B1, B2, C, and partial D). The Richmond Drilling #3-A Maurice was cored in the Upper Grayburg (A1 only).

A description of the Grayburg and San Andres cores from the #6 Witcher was completed last spring, including a description of the slabbed core and thin sections taken approximately every 8-10 feet. This evaluation has provided much needed information relating to depositional environments and diagenetic overprinting. Unfortunately, the #6 Witcher core does not by itself provide enough information to adequately describe the entire reservoir. It is anticipated that the recovery of cores in three new drills will provide a framework to better describe the reservoir.

The All Wells All plot (Fig. 1A) of ϕ vs. K contains all the analyses from the six wells. The wide scatter of data initially appears to show no distinct trend. However, with further evaluation, there appears to be three distinct populations: a high permeability/low porosity "fracture field", a low permeability/high porosity "secondary or vugular field", and a permeability/porosity field which exhibits a "normal" distribution for shallow shelf carbonates. The fracture field is present in core from the Grayburg in the #6 Witcher (Fig. 1D), #19 Johnson (Fig. 1B), #7 Maurice (Fig. 1C), and #3-X Foster-Pegues (Fig. 1F). In each well, there are a limited number of values (2-3) indicating that fractures make only a minor contribution. In addition, there are two 4 to 5 feet thick intervals in the core taken from the #11 Foster-Pegues with oil staining in fractures. (This will be reported in detail in the next quarterly report.) The log analysis indicates these zones have less than 3% porosity and would not have been perforated without the core. The "secondary" porosity field is composed of San Andres in the #10 Brock (Fig. 1G) and #6 Witcher (Fig. 1K), and some of the Grayburg in the #7 Maurice (Fig. 1C). The San Andres in the #6 Witcher core is composed of clean, high energy grainstones and packstones with secondary inter-particle porosity. The porosity in thin section looks well connected but the core analysis indicates low permeability. The fact that the core analyses from the #10 Brock (Fig. 1G) and #6 Witcher (Fig. 1K) San Andres match indicates that the San Andres is a poor water flood candidate. Although the logs and cores

indicate zones with 12 to 14% porosity, the low permeability (averaging 1 md at 10% ϕ) would preclude successful waterflooding on 20 acre spacing, and raise the risk of successfully waterflooding on 10 acres.

There are few Grayburg analyses which fall in the secondary range, leading to the conclusion that most of the Grayburg reservoir is composed of connected inter-particle porosity with good permeability. The plots of zones A-1 (Fig. 1M) and A-2 (Fig. 1N) indicate the uppermost Grayburg is composed almost entirely of the "typical" primary porosity. The plots of zone B1 (Fig. 1O) and B2 (Fig. 1P) indicate some points fall in the secondary porosity field. These analyses are mostly from the B1 and B2 zones in the #7 Maurice. This indicates a potentially different depositional or diagenetic environment in the #7 Maurice, and may represent the "wedge" seen in the Upper Grayburg in this area on the seismic. The data sets for C (Fig. 1Q) and D (Fig. 1R) zones are too small to draw any conclusion, as are the data sets for different facies identified in the Grayburg in the #6 Witcher. When the cores taken in the three new drills are evaluated, there will be an adequate data set available to draw facies based conclusions.

WATER ANALYSES

The pressure data collected during this Quarter indicates that many of the producing wells are not "seeing" the flood. As part of the effort to determine which zones have received water flood support, all available water analyses are being collected, and water samples from producing wells and injection stations collected and analyzed. The analyses will be plotted on piper diagrams and the results reported next quarter.

GEOLOGY OF WORKOVERS AND NEW DRILLS

Considerable time has been spent this quarter working with Richard Weinbrandt and Jack Brock, Laguna Field Engineer, on preparing the new drill and workover recommendations. This was to ensure that the zones identified as having potential during the simulation were adequately tested. Cores in the Foster-Pegues #11 were taken in the Lower Grayburg in an effort to confirm the results of the simulation.

ENGINEERING

SUMMARY OF RESERVOIR SIMULATION - JANUARY 1996

In Laguna's Section 36 property, forty six wells have produced from the Upper Grayburg, Lower Grayburg, and San Andres. Production from these zones has been commingled and wells have been recompleted over time. Hydraulic fracturing was effective and may have allowed the zones to communicate vertically. A number of layering strategies and areal grids were evaluated leading up to a five layer model using as layers the A, B, and C zones, the Lower Grayburg and the San Andres. The model results are presented here.

As a preliminary step, a large areal grid, Upper Grayburg, five layer model showed early migration in the A zone to the Northwest due to the original four injectors. This grid extended two locations past the edges of Section 36. There are several good wells in the Amoco property to the Northwest that probably benefited from the migration.

Understanding the vertical distribution of production was the next step. Detailed analysis of each well's production history was undertaken to allocate production to each zone. Open net thickness compared to total net, time of completion, and well tests were used to calculate each zone's contribution. The distribution of cumulative production is as follows: Upper Grayburg, 81%; Lower Grayburg, 5%; San Andres, 14%.

Early 40-acre wells (pre 1970) of the Brock and Witcher Leases produced from the A, B, and C zones only. Six of the eight 40-acre wells of the Foster and Pegues Leases also produced from the Lower Grayburg and San Andres.

The 40-acre wells tended to be open hole, shot with nitro. Hydraulic fracturing of these wells in 1955 increased the Section 36 production from 150 to 40 STB/D. Subsequent frac jobs were also successful with some wells fraced three times.

Water injection was initiated in 1962 by converting four old producers to injection. The injection was into the depleted upper zones on a vacuum. Thirteen injection profiles obtained from 1962 to 1980 were analyzed. These profiles showed that most of the injection water went into the A zone with a small amount into the B zone and almost nothing lower. Fill in the post 1980 period has probably insured that injection has not reached the deeper zones. The profiles also showed that in the three original injectors, FP-1, FP-2, and FS-1, the Queen Sand was in the open hole section and took 15 to 35% of the water. In the model, the pre waterflood depletion was combined with these injection profiles. The model results showed that 71% of the cumulative injection went into the A zone, 20% into the B zone, 5% into the C zone, 4% into the Lower Grayburg and essentially no injection into the San Andres.

The model's response to the oil production increase observed after the frac jobs provides an insight into the production mechanisms observed in the field. With a horizontal permeability of 5 md in all layers, vertical permeability of zero and calculated completion kh, the model was unable to produce the reported production. This observation led to a series of sensitivity runs aimed at matching the frac oil production. It was hypothesized that the fracs established communication horizontally and vertically with natural fracture systems that did not contribute before. This was modeled by changing horizontal and vertical permeabilities to the levels shown below:

Layer	Horizontal Perm., md.	Vertical Perm., md.
A	10	10-5
B	5	10-5
C	5	10-5
LG	3	10-9
SA	10	10-9

In addition, completion kh was increased by a factor of ten and the wells were fully completed in the C zone even though they were partially penetrating. The effect of these changes was to produce about 400,000 STB of Lower Grayburg oil through the Upper Grayburg perfs.

RESULTS OF WORKOVERS AND NEW DRILLS

The results of the simulation led to recommendations (Fig. 3) of high priority workover candidates. Each well was chosen to test parts of the simulation results. The workovers completed by the end of March were the Foster #3, Brock #12, and Brock #13 (Fig. 2). The Foster-Pegues #11, a new drill, was also recommended to test the potential primary reserves in the Lower Grayburg in Section 36 (the well spud in March, but at the end of the Quarter had not reached TD). The Foster #3 was chosen to determine if a gas cap, or isolated gas zone, existed as postulated based on old drilling records, in the A zone on the Foster lease. The Brock #12 workover would test the possible presence of a highly permeable zone channeling water from an injection (Witcher #3-WI) to the producer. The Brock #13 was tested to determine if the simulation had correctly identified that the water being injected into the Upper Grayburg was sweeping oil into that area.

The Foster #3 tested two porous intervals that had not been included in the original completion in 1941. The original drilling report indicated that these zones produced gas during drilling at rates as high as 2MMCF/GPD. These zones were not shot during the initial completion, nor at any later date. All wells in the southwest part of the project area indicate gas present above +/-900 feet, with the first show of oil below that depth. These wells, the Foster #3, Foster #4, and Brock #1, and wells to the west were not completed above -900'. The Foster #3 was chosen to workover because of its accessibility. It was TA'd but re-enterable. The A2 zone was tested first and swabbed 100% water. It appears that this water is flood water, most likely from the Foster #5 or the Brock #9. The A1 zone was tested next and swabbed oil, gas, and water. At the end of the Quarter, the well was pumping 27 BO, 182 BW, 14 MCF/GPD. These results indicate that the water flood is pushing water into areas that had not previously been considered to have potential. This will necessitate a change in the simulation, adding pay in the A1 and A2 zones in the Brock and Foster leases.

The Brock #12 was chosen for workover because it had gone from making 27 BO and 230 BW to 0 BO, and 400 BW in five months at the end of 1995. Upon entering the well, it was determined that the water was not flood water entering from the Grayburg but was, instead, coming from the deeper Holt (1,500 feet below the Grayburg) past a leaking bridge plug. After the bridge plug was cemented in, the Grayburg began making oil and water. It is believed that the Holt water was entering the lower pressure Grayburg and some formation damage (scaling) may have occurred. At the end of the Quarter, the Brock #12 was pumping 8 BO, 202 BW, and 4 MCF/GPD. When this well stabilizes, a tracer survey will be run to determine the origination of the water, and a stimulation will be attempted.

The Brock #13 had been producing from the Lower Grayburg and San Andres and was pumping 32 BO, 15 BW, and 4 MCFGPD. The Upper Grayburg (A, B, C, D) was completed and, at the end of the quarter, was pumping 61 BO, 254 BW, and 6 MCFGPD. The Lower Grayburg and San Andres will be added back when the well stabilizes.

Each of these wells was a success. The Foster #3 had been TA'd with no reentry plans. The Brock #12 was thought to be behind the flood front and might soon have been abandoned. The Brock #13 Upper Grayburg production replaced the production from the Brock #2 (which was an Upper Grayburg only well making 3 BO, and 35 BW, 210 feet to the west).

PRODUCTION RATES

Obtaining production data for this project area was complicated by the fact that sixteen different companies had operated in the project area over sixty years. Production in many wells was commingled Grayburg and San Andres.

A program was initiated in December, 1995, and continued in the first quarter of 1996 to obtain accurate measurements of oil, gas and water production rates on all wells in the project area. A Portachek was used where a test separator was not available.

The current production measurements plus the completed net thickness from logs were used to allocate the entire production history back to the zones where it originated.

PRESSURE DATA

A program was initiated to conduct pressure buildups and falloffs on every well in the project area. The objectives of this program were

1. Pressures for history matching,
2. Skin damage to identify stimulation candidates,
3. Permeability for simulation, and
4. Identification of flow barriers in the reservoir.

Flow barriers were seen in two injectors. The injectors have reservoir pressures in the range of 1,500-2,200 PSI. The producers have some damage with reservoir pressures in the range of 200-500 PSI. The conclusion is that the injectors and producers are poorly connected.

The following table summarizes the tests for which analysis has been completed.

PRODUCTION TEST DATA					PRESSURE TEST DATA				
WELL	DATE	DAYS ON TEST	OIL RATE B/D	WATER RATE	PRESS. AVE.	PERM	FRAC 1/2 LNG	SKIN DMG	RADIUS OF INV
BR-2	12/12/95	3	3.39	25.30	539.60	0.3996	5.20	0.42	288
BR-5	12/25/95	3	11.24	10.39	380.30	0.4802	40.30	0.31	150
BR-6	1/3/96	3	6.00	6.00	420.80	0.275	50.00	1.08	118
BR-7	12/11/95	5	9.64	4.80	548.70	1.163	4.10	0.18	273
BR-8	1/4/96	3	4.10	10.20	340.20	0.1857	103.50	0.73	128
BR-9	1/8/96	6		-207.00	2178.80	84.18	4.70	3.03	2763
BR-10	1/2/96	4	3.00	56.00	535.00	0.1411	3.50	0.80	259
BR-13	12/18/95	3	32.00	15.00	567.80	2.477	4.10	0.80	300
FP-3X	1/18/96			-150.00	2255.40	7	1.00	0.07	1391
FS-1	1/3/96	4		-231.00	2212.50	18.53	95.70	1.72	1401
FS-2	1/9/96	6	5.30	16.80	1477.01	0.816	4.50	1.86	288
FS-5	1/10/96	4		-107.00	-	3.096	16.50	2.56	-
FS-6	1/3/96	4		-230.00	2009.20	8.06	479.90	0.51	971
FS-7	1/10/96	3	1.40	3.00	187.60	0.1357	1.90	7.05	141
FS-8	1/15/96	3	5.00	40.00	3132.80	0.01648	49.00	0.00	61
JN-6	1/15/55	4			769.50	28.03	1.00	10.80	969

The three plots from the Brock 7 (Figs. 4, 5, 6) provide an example of a pressure buildup analysis in a producer while the three plots from the Foster WIW 5 (Figs. 7, 8, 9) provide an example of a pressure falloff in an injector. The analysis results are shown in boxes on the Figures.

GEOPHYSICS

A review of the Geoquest RM package, the Vest 3D interpretation package, and the Kingdom 3D Pack was begun to determine which system would provide the most cost effective method for integrating the 3D data into the reservoir simulation. This investigation is ongoing.

TECHNOLOGY TRANSFER

This quarter, methodologies on reservoir characterizations and waterflood design have been exchanged with Paul Hinds of Amoco Production, and Bob Ward, an independent Midland consultant working on a study of the terminal erosional event in the San Andres. Bob Lindsay, Chevron, U.S.A. exchanged ideas on sequence stratigraphy of the Grayburg and San Andres.

The technical team presented a paper and poster session at the Southwest Section AAPG meeting in El Paso in March, and a paper on seismic modeling at the RMAG/DGS 3D Seismic Symposium in Denver in March. Work is progressing on papers for presentation at the Southwestern Petroleum Short Course and a one day Southwest Section AAPG Short Course in April and the Annual SPE/DOE Conference in Tulsa in May.

FIGURE 1

FIGURE 1 (CONT)

FIGURE 1 (CONT)

FIGURE 1 (CONT)

FIGURE 1 (CONT)

FIGURE 2

Figure 3

LAGUNA PETROLEUM CORPORATION, DOE STUDY
FIELD DEVELOPMENT IMPLEMENTATION PLAN - PHASE II

A five layer model (A, B, C, Lower Grayburg and San Andres) for Laguna's Section 36 in the Foster Field has been constructed and history matched. Based on the model predictions, the following field development work schedule is recommended.

This plan of implementation will be revised on an ongoing basis as field operations and results dictate.

# WELL	RECOMMENDED WORK
1. BR-13	Perforate A, B, C zones and fracture to provide an effective Upper Grayburg completion in the northwest corner of Section 36 to prevent migration off lease. Date on production is March 1, 1990. Cumulative production in twenty years is 120 MSTB.
2. BR-12	Squeeze Upper Grayburg perfs that are channeling water from the AW3, leave Lower Grayburg open. Date on production is March 1, 1990. Cumulative production in twenty years is 45 MSTB.
3. FS-3	Perforate A1 and A2 for gas, if no gas, consider as injector.
4. WH-2	Original open hole well. Deepen to Lower Grayburg, recomplete A and B zones. Use experience gained in this work to evaluate deepening other older wells. A number of the original open hole wells can be deepened to the Lower Grayburg. Even BR-2 and BR-3 which are close to newer producers, should be considered for deepening and recompletion. Cumulative production in twenty years is 97 MSTB.
5. FP-11	Drill straight hole through Lower Grayburg. Date on production is May 1, 1996. Conduct VSP, RFT, Core, full log suite. Cumulative production in twenty years is 198 MSTB. FP-11 showed less decline and about twice the cumulative production as the other new wells, BR-14 and FS-11 for several reasons: <ul style="list-style-type: none">a. In the Upper Grayburg, the initial waterflood went north of this location, leaving it unswept.b. In the Lower Grayburg, the FP-2 has injected a small amount in the past. Currently, the FP-3X is injecting into the Lower Grayburg and this small amount of pressure support has flattened the decline at FP-11.c. The San Andres is expected to be wet at this location.

Figure 3 (Continued)

6. BR-14 Drill new directional well through San Andres, open all zones. Conduct RFT, Core, full log suite. Date on production is October 1, 1996. Cumulative production in twenty year is 106 MSTB.
7. FS-11 Drill straight hole through San Andres, RFT, Core, logs. Date on production is July 1, 1996. Cumulative production in zone is 105 MSTB
8. Clean-out injection wells as needed to get injection below the A zone. Historically, 70% of the injected water has gone into the A zone. Priority one should be the FP-3X (set a bridge plug below the Lower Grayburg to stop the loss of injection water into the San Andres. Remaining injectors to clean out include: FS-6, FS-5, FS-1, BR-9, FP-1, WH-8.
9. Additional workovers, new wells and waterflood pattern optimization as guided by results of above work.

FIGURE 4

FIGURE 5

FIGURE 6

FIGURE 7

FIGURE 8

FIGURE 9

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