IDENTIFICATION AND EVALUATION OF FLUVIAL-DOMINATED DELTAIC (CLASS I
OIL) RESERVOIRS IN OKLAHOMA

Quarterly Technical Report

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ABSTRACT

This document is provided as a Quarterly Technical Progress Report for the program entitled "Identification and Evaluation of Fluvial-Dominated Deltaic (Class I Oil) Reservoirs in Oklahoma", covering the reporting period of January 1 - March 31, 1997.

Work is progressing as expected for the project. The FDD computer facility is fully operational. During this quarter, there were 28 industry "visits" to use the facility. The Red Fork Play workshop was completed on March 5 in Norman, and on March 12, 1997 in Bartlesville, with a total of 195 attendees. The Tonkawa Play workshop is scheduled for July 9, 1997 in Norman. The Tonkawa text, figures, maps, and plates are in preparation. The Bartlesville workshop is scheduled for October, 1997, although the exact time and place have yet to be determined. Regional work and field studies for that play are in progress.

This project is serving an extremely valuable role in the technology transfer activities for the Oklahoma petroleum industry, with very positive industry feedback.

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EXECUTIVE SUMMARY

This document is provided as a Quarterly Technical Progress Report for the program entitled "Identification and Evaluation of Fluvial-Dominated Deltaic (Class I Oil) Reservoirs in Oklahoma", covering the report period of January 1 - March 31, 1997.

The FDD computer facility is fully operational following a recent move from the OU Energy Center to a more accessible location just north of Norman, Oklahoma. During the first quarter, 26 industry individuals utilized the FDD computer facility. Several of these users had repeat visits, resulting in 28 total "visits" to the facility. The facility primarily was used for computer mapping, NRIS data retrieval, and plotter applications.

The Red Fork Play workshop was held on March 5, 1997 at the Norman Postal Service Technical Training Center, and again on March 12, 1997 at the Phillips Petroleum Company Research Center in Bartlesville, Oklahoma. There were a total of 195 attendees at these two workshops, 69 of whom were from companies that operate in the Red Fork. Overall, attendee evaluations of the workshop were very positive, with ninety-eight percent of the attendees rating the overall workshop as "above average" or "outstanding".

The Tonkawa workshop is scheduled for July 9, 1997 in Norman. Efforts are underway to generate the text and illustrations for that play. Regional analyses and field studies are underway for the Bartlesville Play workshop, to be held late in the year.

This project is serving an extremely valuable role in the technology transfer activities for the Oklahoma petroleum industry, with very positive industry feedback. The popularity of the program is spreading with each workshop. It is fully expected that the remaining play presentations for 1997 - the Tonkawa and the Bartlesville - will see a continued growth in industry responses.

INTRODUCTION

The Oklahoma Geological Survey (OGS), the Geo Information Systems department, and the School of Petroleum and Geological Engineering at the University of Oklahoma are engaged in a five-year program to identify and address Oklahoma's oil recovery opportunities in fluvial-dominated deltaic (FDD) reservoirs. This program includes the systematic and comprehensive collection and evaluation of information on all of Oklahoma's FDD reservoirs and the recovery technologies that have been (or could be) applied to those reservoirs with commercial success. This data collection and evaluation effort is the foundation for an aggressive, multifaceted technology transfer program that is designed to support all of Oklahoma's oil industry, with particular emphasis on smaller companies and independent operators in their attempts to maximize the economic producibility of FDD reservoirs.

Specifically, this project is identifying all FDD oil reservoirs in the State; grouping those reservoirs into plays that have similar depositional origins; collecting, organizing and analyzing all available data; conducting characterization and simulation studies on selected reservoirs in each play; and implementing a technology transfer program targeted to the operators of FDD reservoirs. By fulfilling these objectives, the FDD project is expected to help sustain the life expectancy of existing wells and provide incentive for development and exploratory drilling with the ultimate objective of increasing oil recovery.

Elements of the technology transfer program include developing and publishing play portfolios, holding workshops to release play analyses and identify primary and secondary oil recovery opportunities in each of the plays, and establishing a computer laboratory that is available for industry users. The laboratory contains the play data files, as well as other oil and gas data files, together with the necessary hardware and software to analyze the information. Technical support staff are available to assist interested operators in the evaluation of their producing properties, and professional geological and engineering outreach staff are available to assist operators in determining appropriate recovery technologies for those properties.

RESULTS AND DISCUSSION (SUMMARY OF TECHNICAL PROGRESS)

Computer Applications, Database, and User Lab Developments

In cooperation with the Petroleum Technology Transfer Council (PTTC) program, the computer facility has acquired several new software packages. This software will be useful for a variety of oil industry projects such as log analysis, reservoir and waterflood modeling, digitizing, and mapping. Software acquired during the first three months of 1997 includes:

- Pfeffer (log analysis and interpretation program)
- Boast III (reservoir simulation and waterflood modeling to upgrade Boast II)
- RIS-View (well log display functions)
- RIS-Intro (well data information functions)
- Neuralog NDS-Log (log analysis and digitizing)
- Neuralog NDS-Map (mapping functions, digitizing)
- Rockware utilities (multi-purpose).

These programs are in the process of being installed and tested. The basic hardware has not changed and includes four Pentium 5-150 computers, one HP Designjet 755CM inkjet plotter, laser printer, and Neuralog scanner. The computer facility is coordinated by Jane Weber of the OGS.

Many maps, tables, and specialty illustrations used in the Red Fork publication and in poster displays were made using *NRIS MAPS* - a user-friendly computer program designed to access *NRIS* data. These include maps for detailed field studies such as well base maps and lease production maps. Tables with individual lease production records were generated by *NRIS MAPS* for use in decline curves and in determining cumulative field production. Large display posters were made showing well production codes, formation show codes, well spud dates, and well status codes. These regional maps were used to illustrate areas of development and exploration potential, production trends, and drilling periods of well completed in the Red Fork. Registrations for the Red Fork workshop were completed utilizing the mail-out program that identifies operators having production from the targeted plays.

During the first quarter, 26 industry individuals utilized the FDD computer facility. Several of these users had repeat visits, resulting in 28 "visits" to the facility. Thirteen of the 26 users during this quarter were first-time users. The facility primarily was used for computer mapping, *NRIS* data retrieval, and plotter applications. Six persons took GeoGraphix seminars, and about 34 hours of computer time were logged by users.

Play Analyses, Publications, & Workshops

Table 1 summarizes the level of activity and industry responsiveness to the FDD workshop and publication series. From this table, it is apparent that about 100-200 participants attend each workshop regardless the number of operators. Although we see many “repeat” attendees, many of the participants at each workshop are first-timer’s. This may indicate that the program is reaching out to a broad spectrum of operators and geologists in addition to attracting professionals interested in learning more about FDD in Oklahoma. Verbal comments by many attendees indicate they are extremely interested in these types of workshops and have benefited greatly. Following Table 1 is a brief summary of plays completed or in progress during the quarter.

**Table 1: Summary of Technology Transfer Activities for FDD Plays
as of March 31, 1997**

<u>Play</u>	<u>Workshop Dates & Locations</u>	<u># Regis- tered</u>	<u># of play opers.</u>	<u>Play operators</u>		<u>Oper- ators not in play</u>	<u>Total Wrkshp Operator s</u>
				<u>@ reduce d rate</u>	<u>@ regular rate</u>		
1. Morrow	June 1 & 2, 1995 Norman	215	604	90	5	5	100
2. Booch	September 11, 1995 Muskogee	128	432	31	0	20	51
3. Layton & Osage- Layton	April 17, 1996 OKC	103	342	15	6	25	46
4. Prue & Skinner	June 19 & 26, 1996 OKC & Bartlesville	201	1599	36	36	23	129
5. Cleveland & Peru (2 plays combined)	October 17, 1996 Bartlesville	85	516	11	13	14	38
6. Red Fork	March 5 & 12, 1997 Norman & Bartlesville	195	1478	29	40	29	98
7. Tonkawa	July 9, 1997 Norman		347				
8. Bartlesville	October, 1997		1420				
TOTALS:		927	6,738	212	100	116	462

The 927 total registrations reflect 514 individuals, many of whom have registered for multiple workshops. Of the 514 individuals:

- 307 (60%) are from active operating companies, based on a comparison of company names to gross production tax records
- 129 (25%) are from other industry interests such as service companies, or are “consultants” (26) or “independents” (22), that could not be linked to the gross production tax records.
- 40 (8%) are OGS, University, and program staff members

- 38 (7%) are from other State and Federal agencies, and from “data suppliers” such as the Oklahoma City Geological Society and PI/Dwights.

Excluding the OGS, University, and program staff members from consideration, of the remaining 474 individuals,

- 131 (28%) have attended at least two of the workshops
- 60 (13%) have attended three or more workshops
- 22 (5%) have attended four or more workshops
- 3 (1%) have attended five workshops.

The 307 individuals from active operating companies actually represent 209 different companies. Of these 209 companies,

- 71 (34%) had a representative in attendance for at least two workshops
- 54 (26%) had a representative in attendance for at least three workshops
- 11 (5%) had a representative in attendance for at least four workshops
- 3 (1%) had a representative in attendance for at least five workshops
- 1 (0%) had a representative in attendance for all six workshops

All of these statistics are based on registration records and a post-hoc linking to the gross production records. Because of this, it is possible that some company identifications and operator designations have been missed. Therefore, these should be considered “conservative” estimates of the operator contacts through the FDD program.

The Cleveland and Peru Plays:

This workshop was completed October 17, 1996. Because of delays in manuscript preparation, the Cleveland-Peru play publication was not available for the workshop, but is scheduled to be published during 1997. However, that publication could not be completed during the first quarter due to the priority of the Red Fork publication.

The Red Fork Play:

Primary author: Richard Andrews

Contributing authors: Kurt Rottmann, Roy Knapp, X. H. Yang

Workshop dates: March 5 and 12, 1997

Workshop sites: Postal Service Technical Training Center, Norman, OK.
Phillips Petroleum Co. Research and Development Center,
Bartlesville, OK.

Publication: Oklahoma Geological Survey SP 97-1, *Fluvial-Dominated Deltaic (FDD)
Oil Reservoirs in Oklahoma: The Red Fork Play.*

Because of the high interest and large number of operators in this play, the workshop was presented twice, once in the Oklahoma City area (Norman) and once in the Tulsa area (Bartlesville). A combined total of 195 people (69 Red Fork operators) attended the workshop.

Considerable effort was made to upgrade the main workshop agenda by including more interesting and representative field studies that show a variety of geologic and production characteristics. Also, to avoid repetitiveness with previous workshops, the introduction to FDD concepts was completely reformatted. Emphasis was placed on awareness of fluvial bar morphologies and sedimentary structures as found in contemporaneous and ancient deposits. In this respect, the organization of that first part of the program included low-level air photography of present-day fluvial systems and related bar morphologies, channel bar trenching to show bedding characteristics of point bars versus longitudinal bars, slides of Red Fork outcrops showing reservoir geometry, and a brief conceptual summary using selected figures from previous publications.

The Red Fork workshop included three detailed field studies, two by Richard Andrews, and one by consulting geologist Kurt Rottmann. Rottmann's study of Otoe City South field characterized a relatively tight Red Fork reservoir that was successfully water flooded. Primary oil recovery for this field was about 586 MSTBO whereas secondary recovery was about 336 MSTBO resulting in a secondary to primary recovery ratio of 57%. The relatively good ultimate recovery efficiency of 24% may be due to natural fracturing or induced fractures as the result of well stimulation.

Other field studies completed by Andrews included N. Carmen field which is in the early phases of water flooding, and Long Branch field which produces from both fluvial and marine sandstone facies. North Carmen field was selected for waterflood simulation and appears to be a compartmentalized reservoir. The sandstone was deposited in an incised valley and is flood plain in origin. Total primary oil production is estimated to be 412 MSTBO which is about 10% of the OOIP. North Carmen was recently unitized for purposes of water flooding in 1995 and the initial response occurred 2-3 months after water injection began. Production has steadily increase from about 1 BOPD/well (late 1995) to 12-20 BOPD/well by December 1996. Modeling indicates that unproduced mobile oil amounts to about 1,260 MSTBO and that up to 720 MSTBO could be recovered by water flooding over the next five years. This is 1.6 times the amount of oil recovered during primary production over the past 12 years.

The Red Fork oil pool in Long Branch field is one of the most interesting field studies of the FDD series. The oil pool occurs in two totally isolated compartments that are adjacent to one another. The depositional history involves a marine bar incised by a fluvial channel. The marine facies in Long Branch produces black oil with an API gravity of 36° whereas the fluvial facies (point bar) produces green 41° oil. These oils were exhibited at the workshop to dramatically show the effectiveness of compartmentalization.

Other exhibits presented at the Red Fork workshop included Red Fork cores from three wells that were slabbbed and prepared for display. Brief descriptions of the cored intervals as well as visual images were incorporated into the publication appendix. Computer mapping demonstrations utilizing *NRIS MAPS* were also provided by GIS staff. Sample plots showing production codes and regional production trends of the Red Fork were displayed. These types of maps highlighted areas of Red Fork production and are useful in identifying potential areas for Red Fork development.

Overall, attendee evaluations of the workshop were very positive, with the highest average evaluation scores of any workshop so far. Ninety-eight percent of the attendees rated the overall workshop as “above average” or “outstanding”. Selected comments from attendees include:

- Keep up the good work!
- The Red Fork play is the best yet: Excellent slides, excellent food, excellent speakers.
- The organization - management - & conduct of the workshop was outstanding.
- This entire series of FDD sessions has been superlative - keep them coming!
- All of you have done incredible jobs in gathering and presenting data. I am amazed at how much work you have done.
- We are presently putting in 2 Red Fork water floods in Grant & Alfalfa Co. Wish it (the workshop) had been 18 months earlier.
- This presentation provides me the incentive to revisit many of my Red Fork plays. By using the more subtle log variations, I should be able to extract more prospects.

The Tonkawa Play:

Primary authors: Jock Campbell, Carlyle Hinshaw

Contributing authors: Kurt Rottmann, Roy Knapp, X. H. Yang

Scheduled workshop date: July 9, 1997

Scheduled workshop site: Postal Service Technical Training Center, Norman, OK.

A one day workshop for the Tonkawa play is scheduled for July 9, 1997. The Tonkawa has been of continued interest for many operators and geologists for a long time, but recently has become the focus of greater activity in western Oklahoma. The renewed interest in the Tonkawa centers in the Anadarko Shelf and Basin areas where the production primarily is natural gas from marine sands. Although portions of north central Oklahoma have significant areas containing FDD deposits, only scattered areas within the FDD portion of the play produce oil. Because of the nature of hydrocarbon distribution patterns within the Tonkawa play and the high interest in the predominantly gas prone areas of the state, it was decided to complete the Tonkawa workshop in two parts: an FDD oil presentation, and non-FDD natural gas presentation. (The Tonkawa

publication will only address the FDD oil information.) The natural gas portion of the Tonkawa workshop will be funded through the Petroleum Technology Transfer Council program.

Relatively little has been published about the Tonkawa play. The interpretation supporting FDD deposition is documented in only a few thesis, and through well log evaluations by this project's primary author. The basic patterns of deposition appear to be primarily FDD along the outcrop belt and into the shallow subsurface. In western Oklahoma, the Tonkawa is interpreted to be primarily of marine origin although some investigations indicate that lower delta-plain and/or deep marine deposition took place. These contradictory interpretations have provided an incentive to more accurately evaluate the regional deposition environment of the Tonkawa play and better identify the principal sandstone trends.

Regional evaluation of the Tonkawa FDD play is being completed by Jock Campbell. This involves the organization of stratigraphic nomenclature, regional sand trend mapping and interpretation of general depositional environments, and regional cross sections. This work is supported by two detailed field studies by consulting geologist Kurt Rottmann - one of an FDD oil reservoir and a second of a marine facies gas reservoir. The FDD oil field study will be used for waterflood simulation by Knapp and Yang.

Segments of the regional Tonkawa play that extend into the gas-prone portion of the Anadarko Basin are being interpreted and mapped by Carlyle Hinshaw, Geo Information Systems staff geologist. This work will be of the same nature as that of Campbell's and will extend mapping and reservoir evaluations of the Tonkawa play into the Texas panhandle and southern Kansas. Information concerning the Tonkawa gas play in the predominantly marine facies of the Anadarko Basin will not be formally published, but will be available as an OGS open file report.

The Bartlesville Play:

<i>Primary author:</i>	<i>Robert Northcutt</i>
<i>Contributing authors:</i>	<i>Richard Andrews, Roy Knapp</i>
<i>Planned workshop date:</i>	<i>October, 1997</i>
<i>Planned workshop site:</i>	<i>to be determined</i>

During this quarter, efforts on the Bartlesville play included regional mapping of sand trends, production, fields, and selected references, as well as the development of regional cross sections. The first Bartlesville field study was completed by Richard Andrews, on the Paradise Field in Payne County. That field probably will serve as the site for the reservoir simulation study for this play.

CONCLUSION

This project is serving an extremely valuable role in the technology transfer activities for the Oklahoma petroleum industry. Industry feedback to the program is very positive, with numerous comments stating that this is the most valuable program that has been sponsored by the Oklahoma Geological Survey. The popularity of the program is spreading with each workshop. It is fully expected that the remaining play presentations for 1997 - the Tonkawa and the Bartlesville - will see a continued growth in industry responses.