IDENTIFICATION AND EVALUATION OF FLUVIAL-DOMINATED DELTAIC (CLASS 1 OIL) RESERVOIRS IN OKLAHOMA

YEARLY TECHNICAL PROGRESS REPORT for 1996

Report Type: Annual
Reporting Period: January 1 - December 31, 1996

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Report Issue Date: 11/17/1997
Cooperative Agreement No. DE-FC22-93BC14956

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ABSTRACT

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 a systematic and comprehensive collection and evaluation of information on all FDD oil reservoirs in Oklahoma and the recovery technologies that have been (or could be) applied to those reservoirs with commercial success.

During 1996, three highly successful FDD workshops involving 6 producing formations (4 plays) were completed:

	Plays	Date
1.	Layton and Osage-Layton	April 17
2.	Prue and Skinner	June 19 and 26
3.	Cleveland	October 17
4.	Peru	October 17 (combined with Cleveland play)

Each play was presented individually using the adopted protocol of stratigraphic interpretations, a regional overview, and two or more detailed field studies. The project goal was to have one field study from each play selected for waterflood simulation in order to demonstrate enhanced recovery technologies that can be used to recovery secondary oil. In this effort, software utilized for reservoir simulation included Eclipse and Boast III. In some cases, because of poor production records and inadequate geologic data, field studies completed in some plays were not suitable for modeling. All of the workshops included regional sandstone trend analysis, updated field boundary identification, a detailed bibliography and author reference map, and detailed field studies. Discussion of general FDD depositional concepts was also given. In addition to the main workshop agenda, the workshops provided computer mapping demonstrations and rock cores with lithologic and facies interpretations.

In addition to the workshops, other elements of FDD program were improved during 1996. Most significant was the refinement of *NRIS* MAPS - a user-friendly computer program designed to access *NRIS* data and interface with mapping software such as Arc View in order to produce various types of information maps. Most commonly used are well base maps for field studies, lease production maps, and regional maps showing well production codes, formation show codes, well spud dates, and well status codes. These regional maps are valuable in identifying areas of by-passed oil production, field trends, and time periods of development for the various FDD plays in Oklahoma. Besides maps, *NRIS* MAPS provides data in table format which can be used to generate production decline curves and estimates of cumulative hydrocarbon production for leases and fields. Additionally, many computer-related services were provided by support staff concerning technical training, private consultation, computer mapping, and data acquisition.

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III. EXECUTIVE SUMMARY

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 a systematic and comprehensive collection and evaluation of information on all FDD oil reservoirs in Oklahoma and the recovery technologies that have been (or could be) applied to those reservoirs successfully. 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. However, particular emphasis of this program is directed toward smaller companies and independent operators in order to help them maximize oil production from FDD reservoirs.

Specifically, this project is identifying all FDD oil reservoirs in the State; grouping those reservoirs into plays that have similar depositional and geologic histories; collecting, organizing and analyzing all available data; performing characterization and simulation studies on selected reservoirs in each play; and implementing a technology transfer program that targets operators of FDD reservoirs. These elements of the FDD program are providing the kind of assistance that will allow operators to extend the life of existing wells with the ultimate objective of recovering more oil.

The execution of this project is being approached in three phases. *Phase 1* began in January, 1993 and consisted of planning, play identification and analysis, data acquisition, database development, and computer systems design. By the middle of 1994, many of these tasks were completed or nearly finished including the identification of all FDD reservoirs in Oklahoma, data collection, and defining play boundaries. Later in 1994, a preliminary workshop schedule was developed for the implementation and technology transfer activities of *Phases 2 and 3*. In early 1995, a specific workshop agenda was formatted and folio publication requirements were identified. Later in 1995, the play workshop and publication series was initiated with the Morrow play in June and the Booch play in September. The following is a summary of <u>tasks</u> completed during 1996 as part of the implementation and technology transfer activities of this FDD project:

Task 1: Database and Applications Development: Computer support activities continued during 1996 included ongoing database maintenance, applications development, and user lab development and operation. A variety of computer applications programs are required for data analysis, for publication and workshop preparation, and to support users. Computerized mapping and report programs are necessary for reservoir analysis and regional play interpretations. These include programs to generate standard reports and tables, perform statistical analyses, generate graphical displays of the data, and produce surface and subsurface maps. During this year, work continued in the computer user laboratory. The user laboratory is one mechanism for allowing industry, especially small independents, to access the resources developed as part of this project.

Task 2: Play Analyses, Publications, and Workshops: During 1996, three FDD workshops involving 6 plays with accompanying folio publications were completed.

The Layton and Osage Layton play was presented on April 17 at the Francis Tuttle Vo-Tech Center in Oklahoma City. It was well attended by 103 people. The Layton and Osage Layton sands constitute two different zones or formations (the Layton lies 100 ft or more below the Osage-Layton). The names have been so misused by industry, that it is nearly impossible to differentiate between the two reservoirs from production records or from formation tops recorded on completion reports. This problem was addressed in the workshop but because it is so widespread, both formations were treated as one play in the regional discussion.

Detailed geologic field studies within this workshop and play publication include the East Lake Blackwell and South Coyle fields. East Lake Blackwell field is an Osage-Layton sand reservoir that also was used in the waterflood simulation study. South Coyle field is a Layton sand reservoir that lies stratigraphically below the Osage-Layton interval.

The Prue and Skinner plays were presented on June 19 and 20 in Oklahoma City, and on June 26 in Bartlesville. Because of the large number of operators and high interest in these plays, three workshops were necessary to accommodate the 201 attendees.

Similarities in depositional origin, stratigraphy, age, and environments of deposition made it convenient to group the Prue and Skinner plays into one workshop. Major topics included in the publication and workshop consisted of the regional analysis of each play along with three Skinner field studies and one Prue field study. They were selected because of their appropriate size, availability of core data and modern electric well logs, and availability of recent production information. The four fields have diverse geologic characteristics that typify many of the clastic reservoirs in the Cherokee Platform of eastern Oklahoma. Two of the fields have already been water flooded which provided a good analogy for this technology. Enhanced recovery simulation studies were completed on one Prue and one Skinner reservoir. Computer modeling utilized software demonstrated in previous workshops (Eclipse) in addition to Boast III which is more widely available to the public.

Cores from four wells were prepared for display at the workshop. These were examined and described in order to make posters that identified the important sedimentary structures and sand-body features that characterize FDD reservoirs. Core descriptions, depositional environment interpretations, scanned visual images, and well logs were incorporated into an appendix accompanying the publication.

The Cleveland and Peru workshop was completed October 17, 1996 in Bartlesville, Oklahoma with 85 attendees. Each play was presented individually using the adopted protocol of stratigraphic interpretations, a regional overview, and detailed field studies. Two field studies were completed including the Pleasant Mound Cleveland oil pool and the Hogshooter Peru oil pool. A waterflood simulation was completed for the Pleasant Mount Cleveland oil pool. The Peru field study was not considered suitable for waterflood simulation because of the lack of production data. Instead, a guest lecturer presented a talk on formation evaluation of the Peru sand in the Hogshooter oil field.

Because of delays in manuscript preparation, the Cleveland-Peru play publication was not available for the workshop but is expected to be published during 1997. Materials distributed at the workshop consisted of preliminary maps and text.

Task 3: Professional Outreach: Three levels of professional outreach have been identified as part of this overall project effort. The first, technical advising, refers to those industry contacts that take place as follow-ups to the workshop presentations. Second, the ongoing reservoir characterization and simulation studies provide opportunities for individualized efforts with operators. Third, professional activities such as conferences provide a forum for promoting the FDD program activities.

CONCLUSIONS

1996 was probably the most important period in the development of the Oklahoma FDD program. Implementation and technology transfer elements of the program predominated during the year. The computer lab facility was moved to a more accessible location in north Norman and was fully operational during the year. It is equipped with state-of-the-art hardware and software that can be utilized for a variety of tasks. Operators are utilizing this facility, and support staff are conducting training sessions for interested parties.

Three highly successful workshops and accompanying folio publications were completed on the Layton-Osage Layton, Prue-Skinner, and Cleveland-Peru plays. Additionally, significant progress was made in preparation for the upcoming Red Fork, Tonkawa, and Bartlesville workshops. With the completion of the first two workshops in 1995, the FDD team and support staff acquired a better insight regarding the magnitude of play workshops and folio publications and devised protocols to improve technology transfer elements of the program during 1996.

Numerous people provided positive feedback for the overall program, and a great deal of industry interest has been generated. Due to the nature of the Oklahoma FDD project, it is recognized as one of the most successful and respected programs to assist operators throughout the entire Mid-Continent region.

IV. 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 oil 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. However, particular emphasis of this program is directed at smaller companies and independent operators in order to help them maximize oil production from FDD reservoirs.

Project efforts include identifying all FDD oil reservoirs in the state; grouping those reservoirs into plays with similar depositional and geologic histories; collecting, organizing and analyzing all available data; conducting characterization and simulation studies on selected reservoirs; and implementing a technology transfer program that targets operators of FDD reservoirs.

The elements of the technology transfer program include developing and publishing play summaries in the form of folios, holding workshops to release play analyses and discuss opportunities in each of the plays, and establishing a public-access computer user laboratory within the OGS. The user lab will contain all the play data, as well as other oil and gas data files, together with the necessary hardware and software to analyze the information. Technical support staff will be available to assist interested operators in the evaluation of their producing properties, and professional geological and engineering outreach staff will be available to help determine appropriate recovery technologies for those properties.

The FDD project has the potential to assist thousand of operators in Oklahoma by providing them with practical ways to improve production from existing leases and/or to reduce operating costs. Currently-available technologies can improve recovery factors in these FDD reservoirs if sufficient information is available to determine the most appropriate course of action for the operator. This project will develop the needed reservoir-level information and work with interested operators in the implementation of the appropriate improved recovery technologies.

Light oil production from Class I Oil fluvial-dominated deltaic reservoirs is a major component of Oklahoma's total crude oil output. These types of reservoirs provide approximately 15 percent of the State's total oil production. Most of this production is by small companies and independent operators. This segment of Oklahoma's oil industry typically does not have ready access to the information and technology required to maximize the exploitation of these reservoirs.

Oil production from FDD reservoirs is at high risk. Individual well production is often very low (one to three barrels per day) and operating costs continue to rise. These factors, in addition to cyclic crude oil prices, resulted in oil well abandonment rates that have more than doubled in recent years. Successful implementation of appropriate recovery technologies and field development practices could help to sustain production from these reservoirs throughout much of the 21st century. Without such action, most oil production from Oklahoma FDD reservoirs will be abandoned by the beginning of the next century.

V. DISCUSSION

The execution of this project is being approached in three phases. *Phase 1* began in January, 1993 and consisted of planning, play identification and analysis, data acquisition, database development, and systems design. By the middle of 1994, many of these tasks were completed or nearly finished including the identification of all FDD reservoirs in Oklahoma, data collection, and the definition of play boundaries. Later in 1994, a preliminary workshop schedule was developed for the implementation and technology transfer activities of *Phases 2 and 3,* respectively. In early 1995, a specific workshop agenda was developed and folio publication requirements were identified. Later that year, the Morrow and Booch workshops were completed along with the accompanying folio publications. During 1996, three more workshops were completed involving six separate plays. By this time, the workshop format evolved to include better organization of data, more information, and better allocation of time for presentations and demonstrations.

The following sections briefly describe technical activities relating to the ongoing tasks of this project.

Task 1: Database and Applications Development

Technical computer database development activities are divided into three primary tasks:

<u>1) Ongoing Database Maintenance</u>.   During 1996, this activity included efforts to develop and upgrade FDD databases and to capture the information gathered during this project. Database development also involved reformatting *NRIS* well, lease and field mainframe databases for p.c.-level access through a computer user lab.

<u>2) Applications Development.</u>   A variety of computer applications programs are required for data analysis, for publication and workshop preparation, and to support users. Many of these programs have been standardized for repeated applications in the various plays. Computerized mapping and report programs are necessary for reservoir analysis and regional play interpretations. These include programs to generate standard reports and tables, perform statistical analyses, generate graphical displays of the data, and produce surface and subsurface maps.

<u>3) User Lab Development and Operation</u>. During this year, work continued in the computer user laboratory. The user laboratory is one mechanism for allowing industry, especially small independents, to access the resources developed as part of this project.   Capabilities of the laboratory were increased during the year, largely through software donated through the Petroleum Technology Transfer Council. Housed within the offices of the Oklahoma Geological Survey, and staffed with technical advisors who can assist users in developing their own applications, the computer user laboratory is advantageous for those who have little or no experience using computerized resources for their decision-making.

Task 2: Play Analyses, Publications, and Workshops

The concept of a "play" is used to describe reservoirs that are subject to petroleum exploration or development. For the purposes of this project, the plays are characterized by a geologic formation or horizon that contains FDD reservoirs. In Oklahoma, all of the FDD oil reservoirs are Pennsylvanian in age. During 1994, a final list of FDD oil reservoirs was determined and is summarized in **Table 1**. These reservoirs were grouped into plays and delineated on regional sand trend maps that show play boundaries and regional depositional environments. In 1996, more precise delineation of these plays was a major activity, particularly for the Layton, Osage-Layton, Prue, Skinner, Cleveland, Peru, and Red Fork.

Table 1
FLUVIAL-DOMINATED DELTAIC OIL RESERVOIRS: OKLAHOMA PLAYS
Revised Listing as of December 31, 1996

PLAY	Reservoirs	Location	Class*	Leader	Comments
1. Tonkawa Play (Virgilian)	Tonkawa sd	NE Oklahoma Platform Nemaha Uplift NW Anadarko Shelf	B	Campbell	Workshop scheduled for 7/9/97
2. Layton & Osage-Layton Play (Upper Missourian)	Osage-Layton sd "True" Layton	NE Oklahoma Platform Nemaha Uplift NE Flank Anadarko Basin	B	Campbell	Workshop completed 4/17/96
3. Cleveland Play (Lower Missourian)	Cleveland sd	NE Oklahoma Platform Nemaha Uplift NE Flank Anadarko Basin	B/C	Campbell	Workshop completed 10/17/96
4. Peru Play (DesMoinesian)	Peru sd	NE Oklahoma Platform	C	Northcutt	Workshop completed 10/17/96
5. Prue & Skinner Plays (DesMoinesian)	Prue sd Skinner sd	NE Oklahoma Platform Nemaha Uplift NE Flank Anadarko Basin	A	Andrews	Workshops completed 6/19/96 and 6/26/96
6. Red Fork Play (DesMoinesian)	Red Fork sd	NE Oklahoma Platform Nemaha Uplift NW Anadarko Shelf NE Flank Anadarko Basin	A	Andrews	Workshops scheduled on 3/5/97 and 3/12/97
7. Bartlesville Play (DesMoinesian)	Bartlesville sd	NE Oklahoma Platform Nemaha Uplift	A	Northcutt and Andrews	Workshop scheduled for 10/97
8. Booch Play (DesMoinesian)	Booch sd	NE Oklahoma Platform	B	Northcutt	Workshop completed 9/95
9. Morrow Play (Morrowan)	Upper & Lower Morrow sd	NW Anadarko Shelf Hugoton Embayment	B	Andrews	Workshops completed 6/1 & 6/2/95

* "Class" is an estimate of the overall size of the play, based on geographic extent and on the number of reservoirs and operators in the play. Class "A" plays are the largest plays.

For each of the nine plays, a consistent format was developed for the presentation of materials. Presentations include both general materials regarding FDD depositional environments that are consistent for all of the plays, and specific materials that uniquely describe the characteristics of each individual play.

For each workshop and folio publication, a series of tasks is completed. These tasks include data analysis and preparation of the publication by the authors; drafting of illustrations, figures, maps, and plates by the cartographic staff; editing; and publication. The workshop agenda that was developed for the Morrow play is being used as a template for future workshops although refinements have been made. Publicity for the workshops is through press releases and by mailouts to play operators. Materials prepared for the workshops include 35mm slides, overhead transparencies, cores, field rock samples, and computer-generated production information maps. Each attendee at each workshop receives a copy of the publication, and play operators who do not attend the workshop are given an opportunity to receive a complementary copy of the play publication.

During 1996, three FDD workshops were presented with accompanying folio publications on the Layton & Osage-Layton, Prue-Skinner, and Cleveland-Peru plays. Three more workshops are planned for 1997 to complete the Oklahoma FDD project:

For 1996:	April 17	Layton and Osage-Layton
	June 19 & 26	Prue and Skinner
	October 17	Cleveland and Peru
For 1997:	March 5 & 12	Red Fork
	July 9	Tonkawa
	October	Bartlesville

During 1996, workshop sites for the various plays mentioned above were identified. Lists of operators with recent production from these and other upcoming FDD plays have been generated from the *NRIS* database. On the basis of operator addresses along with the number of operators in each FDD reservoir, potential sites are identified for each workshop presentation. Thus, the Layton, Cleveland, and Peru workshops were held in the Oklahoma City are while the Prue and Skinner workshops were held in both Oklahoma City and Bartlesville. The same criteria will be used for selecting sites for future workshops.

The following paragraphs contain a brief summaries of the workshops completed during 1996, as well as the progress on plays that are scheduled for workshops in early 1997.

THE LAYTON AND OSAGE-LAYTON PLAYS

Primary author:	Jock Campbell
Contributing authors:	Dennis Shannon, Victoria French, Roy Knapp, X. H. Yang
Workshop date:	April 17, 1996
Workshop site:	Francis Tuttle Vo-Tech Center, Oklahoma City, OK
Publication:	Oklahoma Geological Survey SP 96-1, Fluvial-Dominated Deltaic (FDD) Oil Reservoirs in Oklahoma: The Layton and Osage-Layton Play.

The FDD Osage-Layton and Layton plays occur in a relatively small area in northeastern Oklahoma. Within this area, hydrocarbon production from the Layton sands is attributed to several horizons within a stratigraphic interval of several hundred feet. Although historical production records are not available, the Layton sands in the FDD study area are generally prone to oil rather than gas production. During the last 17 years, the Layton sands have produced about 11,467,000 barrels of oil.

The Layton and Osage-Layton sands constitute two different formations, but the stratigraphic terminology is so misused by industry that it is nearly impossible to differentiate between the two reservoirs from production records or from formation tops recorded on well completion reports. This problem was addressed in the workshop and was illustrated in a stratigraphic column. Proper correlation of the lower Missourian section should reveal that the Layton sand lies 100 ft or more below the Osage-Layton sand. The Osage-Layton sand is an informal subsurface name of the Cottage Grove sandstone which is a member of the Chanute Formation. The Layton sand is an informal subsurface name of a sandstone member within either the Nellie Bly or underlying Coffeyville Formation.

Two detailed geologic field studies were prepared for this workshop. South Coyle field is a Layton sand reservoir that lies stratigraphically below the Osage-Layton interval; this study was completed by consulting geologist Dennis Shannon. East Lake Blackwell field is an Osage-Layton sand reservoir and the geological study for this field was completed by Jock Campbell and Victoria French. The geologic interpretation of East Lake Blackwell also was used in the waterflood simulation study by Roy Knapp and X. H. Yang, as briefly summarized below.

East Lake Blackwell field (ELBF) is in north central Oklahoma in western Payne County. It was discovered in 1987 as a recompletion of the Coastal #1 Arnold well in NeNw 14, 19N-1E and had initial production of 22 BOPD. It was found that the Osage-Layton interval consisted of several producing sand zones. Mapped together, the sandstone comprising the stacked channel sequence has a gross thickness of about 20-100 feet, but in the field area the cumulative sandstone thickness is only about 35-40 feet thick. Thickening occurs down-dip to the west and thinning occurs up-dip to the east. The reservoir lies at a depth of about 3300 feet and hydrocarbon trapping results from a combination of structural nosing and an up-dip reduction in net sandstone and porosity.

Total cumulative primary oil production from ELBF is estimated to be 320,000 BO which is about 12% of the original oil in place (2.6 MMBO). The field produces from four different zones and by the end of 1994, there were 10 producing oil wells completed in the Osage-Layton interval. Reservoir properties are very favorable for secondary water flooding since the sandstone generally has relatively high porosity (~15-18%) and permeability (~10-50 md). These data are summarized in **Table 2**.

TABLE 2 - Reservoir Properties, Osage-Layton Reservoir, East Lake Blackwell Field, Payne County, Oklahoma

Estimated properties	Zone A	Zone B	Zone C	Zone D
Porosity	12-22%	15.5%	17%	18%
Permeability	10-50 md	35md	40md	35md
Average Gross Pay	70 ft	50 ft	60 ft	20 ft
Average Net Pay	11 ft	6 ft	14 ft	8 ft
Initial Water Saturation	46%	46%	46%	46%
Initial Bottom-Hole Pressure	1,450 PSIA	1,440 PSIA	1,430 PSIA	1,430 PSIA
Initial Gas-Oil Ratio	400 SCF/STB	400 SCF/STB	400 SCF/STB	400 SCF/STB
Initial Formation-Volume Factor	1.22 RB/STB	1.22 RB/STB	1.22 RB/STB	1.22 RB/STB
Reservoir Temperature	110^{o} F	110^{o} F	110^{o} F	110^{o} F
Oil Gravity	43.0^{o} API	43.0^{o} API	43.0^{o} API	43.0^{o} API
Specific Gas Gravity	0.95	0.95	0.95	0.95
Initial Oil in Place	1.6 MMSTB	0.51 MMSTB	0.39 MMSTB	0.10 MMSTB

The summary of oil production is included in **Table 3** which also indicates the secondary oil recovery expected for different development cases. Waterflood modeling by Knapp and Yang indicates that unproduced mobile oil amounts to about 1.4 MMSTBO or 52% or the OOIP. Various secondary recovery scenarios were examined and they indicate that the amount of additional recoverable oil varies from 32% to 233% of primary production **(Table 3).** The various scenarios include production from existing well completions in addition to cases involving recompletions and infill development drilling.

TABLE 3 - Oil Recovery Comparisons for Different Development Cases, Osage-Layton Reservoir, East Lake Blackwell Field, Payne County, Oklahoma

	Primary (9/30/1995)			Base (12/31/2005)			Recompletion (12/31/2005)			Infill Wells (12/31/2005)		
Formation	Cum Oil (STB)	Rec. Factor (%)	Cum Wtr (Barrels)	Cum Oil (STB)	Rec. Factor (%)	Cum Wtr (Barrels)	Cum Oil (STB)	Rec. Factor (%)	Cum Wtr (Barrels)	Cum Oil (STB)	Rec. Factor (%)	Cum Wtr (Barrels)
Zone A	227,000	14	850,000	310,000	19	1,800,000	500,000	31	1,500,000	570,000	36	1,800,000
Zone B	75,000	15	28,000	82,000	16	44,000	260,000	50	160,000	280,000	55	160,000
Zone C	6,000	1.5	240,000	7,000	1.8	470,000	165,000	42	690,000	186,000	48	580,000
Zone D	12,000	12	42,000	22,000	22	90,000	15,000	15	56,000	30,000	30	70,000
Total	320,000	12	1,200,000	421,000	16	2,400,000	940,000	36	2,400,000	1,066,000	41	2,600,000

THE SKINNER AND PRUE PLAYS

Primary author: Richard Andrews
Contributing authors: Kurt Rottmann, Roy Knapp, Z. N. Bhatti, X. H. Yang
Workshop dates: June 19 and 26, 1996
Workshop sites: Francis Tuttle Vo-Tech Center, Oklahoma City, OK and Phillips Petroleum Co. Research and Development Center, Bartlesville, OK.
Publication: Oklahoma Geological Survey SP 96-2, Fluvial-Dominated Deltaic (FDD) Oil Reservoirs in Oklahoma: The Skinner and Prue Plays.

The Prue and Skinner plays were presented individually during the same workshop on June 19 in Oklahoma City and June 26 in Bartlesville. Because of the large number of operators and high interest in these plays, two workshops were necessary to accommodate the 201 attendees.

Similarities in depositional origin, stratigraphy, age, and environments of deposition made it convenient to group the Prue and Skinner plays into one workshop. Major topics included in the publication and workshop consisted of the regional analysis of each play along with three Skinner field studies and one Prue field study. They were selected because of their appropriate size (aerial extent and cumulative oil production), availability of core data and modern electric well logs, and availability of recent production information. The four fields have diverse geologic characteristics that typify many of the clastic reservoirs in the Cherokee Platform of eastern Oklahoma. Two of the fields have already been water flooded which provided a good analogy for this technology. Enhanced recovery simulation studies were completed on one Prue and one Skinner reservoir. Computer modeling utilized software demonstrated in previous workshops (Eclipse) in addition to Boast III which is more user-friendly and widely available to the public.

The Skinner Play

In terms of stratigraphic thickness and aerial distribution, the Skinner is probably the largest single play in the Oklahoma FDD series. During the past 17 years, estimated annual Skinner oil production has been between 1.2 and 3 MMBO. The actual production rate is probably considerably higher due to the fact that much of the Skinner oil production is commingled and not always distinguished separately. These data are summarized in **Table 4.**

TABLE 4. - Annual Oil Production from the Skinner and Prue Reservoirs in Oklahoma, 1979-95

	SKINNER				PRUE			
	Skinner only		Skinner commingled with other reservoirs		Prue zones only		Prue commingled with other reservoirs	
Year	Production (MBO)	# of leases	Production (MBO)	# of leases	Production (MBO)	# of leases	Production (MBO)	# of leases
79	1,174	581	3,958	1,078	1,347	332	3,077	562
80	1,279	680	4,091	1,283	1,283	361	3,062	656
81	2,110	791	5,214	1,523	1,267	385	3,152	729
82	2,298	891	5,619	1,756	1,634	472	3,956	889
83	2,265	937	5,648	1,861	1,800	534	4,256	990
84	2,669	1,032	6,125	2,019	1,959	597	4,197	1,089
85	2,706	1,087	5,947	2,106	2,179	647	4,360	1,168
86	2,791	1,094	6,016	2,098	1,995	650	4,079	1,179
87	2,973	1,069	5,581	2,061	1,549	610	3,150	1,135
88	2,776	1,018	5,232	1,989	1,260	606	2,671	1,107
89	2,329	1,043	4,511	2,045	1,127	640	2,534	1,157
90	2,080	1,057	4,117	2,040	1,246	627	2,611	1,132
91	2,128	968	4,045	1,902	1,177	614	2,457	1,084
92	1,877	906	3,718	1,823	1,078	602	2,335	1,063
93	1,497	883	3,238	1,781	884	513	2,037	974
94	1,439	792	3,093	1,602	820	490	1,963	897
95	1,592	808	3,112	1,579	742	477	1,831	910
Cumulative (MBO)	35,982		79,264		23,346		51,726	

NOTE: Production data from NRIS. MBO = thousand barrels of oil.

The Skinner sand is a very commonly-used subsurface term that refers to a sequence consisting of up to three distinct sand zones: the upper, middle, and lower sand zones. Each sand zone is separated by a distinctive coal, limestone, and/or hot shale bed that is regionally extensive. In outcrop, the formal equivalent names of the Skinner are the Oowala and Chelsea Sandstones (upper sand and lower sand, respectively). Because of correlation problems in southeastern Oklahoma, the Skinner sands are also commonly referred to as the Senora - a reference to the formation from which they belong.

The Skinner play occurs primarily in the north half of the state exclusive of northwestern Oklahoma. This FDD system prograded to the southwest and consists of incised fluvial flood plain deposits as well as delta plain and delta front (shallow marine) deposits. A similar depositional sequence originated in the far southeastern part of Oklahoma and prograded to the northwest. The Skinner “equivalents” in this part of the state are generally referred to as Senora sands.

Production from the Skinner and Senora sands is highly gas prone, and becomes entirely gas in the deeper portions of the Anadarko and Arkoma basins. Most marine and fluvial reservoirs have good-to-excellent reservoir properties, with some problems from compartmentalization and highly variable permeability. In order to characterize these important reservoirs, three detailed geologic field studies were completed involving reservoirs of fluvial origin. Two of the Skinner fields have already undergone successful water flooding and are useful analogies to this commonly employed secondary recovery technique. These are the Perry SE field and Guthrie SW field, with basic reservoir and engineering data as shown in **Table 5**.

TABLE 5 - Reservoir Properties for the Perry S.E. and Guthrie S.W. Skinner Sand Units

	Perry S.E.	*Guthrie S.W.*
Reservoir size	610 acres	583 acres
Spacing (oil)	40 acres	40 acres
Oil/water contact	none	~-4625 feet
Gas/oil contact	none	none
Porosity (average)	15%	15%
Permeability (average)	15 md average	not determined
Water saturation (calculated)	36%	20%
Average Gas-Oil Ratio (GOR)		
Initial	492 SCF/BO	800 SCF/BO
Final	n.a.	4808 SCF/BO
Average Thickness	12.5 feet	6.8 feet
Reservoir Temperature	122^{o} F	128^{o} F
Oil Gravity	41^{o} API	42^{o} API
Initial reservoir pressure	~2000 PSI	~2367 PSI
Initial formation-volume factor	1.24 RB/STB	1.4 RB/STB
Original Oil in Place (volumetric)	4,591,000 STBO	2,467,000 STBO
Cumulative primary oil production	639,000 STBO	312,761 STBO
Cumulative primary oil recovery	84 BO/acre-ft	79 BO/acre-ft
Recovery efficiency (oil)	~13.9%	~12.6%
Cumulative primary gas production	Not determined	~1.5 BCF

The third Skinner field study included in this play analysis is Salt Fork North field, summarized below. It was selected for waterflood simulation because it is a relatively newly developed field, has good production and geologic data, and is very “average” in size - about 232MBO.

Salt Fork North Field was discovered in 1981 and developed by DEM Operating - a small Oklahoma operator. The field is located in Grant county in north central Oklahoma and consists of 15 producing wells. The field was unitized for purposes of water flooding in December 1994 and “experimental” water injection was attempted the following year.

However, because of rapid breakthrough of the water in a nearby well, the waterflood was discontinued. Total primary production is estimated at 232 MBO and 1.6 BCF.

The Skinner reservoir consists of an upper and lower sand zone. The upper sand has a net thickness of about 10-20 feet and is productive throughout the field. Within the field boundary however, the upper sand occurs in two pods that might be compartmentalized (24-25N-3W and 19-25N-3W). The upper Skinner sand is also productive in a field just to the south (sections 25 and 30) and is inferred within the western portion of section 29. The lower Skinner sand is generally thicker and has a net sand accumulation of about 10 to over 30 feet. It occurs in a narrow meandering band that is about 1/3 mile wide and at least two miles long. Hydrocarbon production from the lower Skinner is highly affected by the structural position of the sand and is best in the southeastern part of the field that is sufficiently above an inferred oil/water contact.

After spending a considerable amount of time during the initial evaluation of this field, it became apparent that oil production was not very good when considering the thickness of reservoir sand and the apparent good porosity. Then, reservoir data was acquired from cores for two wells just south of Salt Fork North that is believed to be representative of reservoir conditions within the field study. This data indicates that the Skinner reservoir is relatively tight since the average permeability is only about 4 md. With such low permeability, it is understandable why a large sand fracture was necessary to bring the wells on-line. The summary of geologic and engineering data for the Skinner sands in Salt Fork North field is shown in **Table 6**.

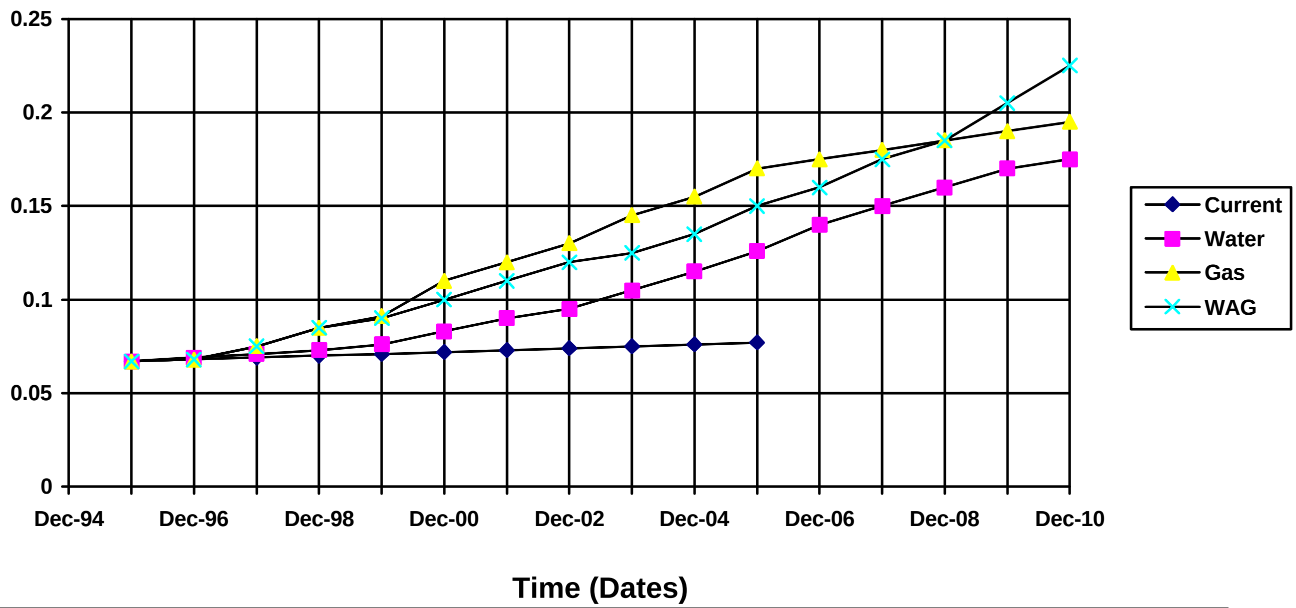
TABLE 6 - Reservoir Properties for the Skinner Sandstones in Salt Fork North Field, Grant County, Oklahoma

	Lower Skinner Sand	*Upper Skinner Sand*
Reservoir size	~375 acres	~645 acres
Spacing (oil)	40 acres	40 acres
Oil/water contact	~ -3950	above ~ -3950
Gas/oil contact	undetermined	undetermined
Porosity	10-18% (avg 12%)	10 - 19% (avg 13%)
Permeability[1]	0.25-8 md (avg 4 md)	0.25-8 md (avg 4 md)
Water saturation (calculated)	26-60% (avg 41%)	33-50% (avg 43%)
Thickness[2] (net sand $\phi \geq 10\%$)	10-20 ft (avg 16 ft)	10-35 ft (avg 12 ft)
Reservoir Temperature	125° F	125° F
Oil Gravity	40-42° API	40-42° API
Initial reservoir pressure	1,826 PSI	1,826 PSI
Initial formation-volume factor	1.3 RB/STB	1.3 RB/STB
Original Oil in Place (volumetric)	2,376,000 STBO	3,137,000 STBO
Cumulative primary oil production	73,337 STBO (est)	159,313 STBO (est)
Recovery efficiency (oil)	3.1%	5.1%
Cumulative gas[3] production	336,044 MCF	1,286,000 MCF

1 Based on permeabilities measured in cores from two Skinner wells located a few miles south of the study area.
2 Entire sand bed thickness. In places, adjacent to the oil-water contact, the thickness of net sand above the oil-water contact is somewhat lower than the entire sand bed thickness.
3 Not including produced gas used for on-site power generation.

Primary oil production in Salt Fork North was essentially complete by early-1996 when modeling for this project was initiated. Because the low permeability of the Skinner reservoir meant that simple water flooding had a very long response time, alternative recovery techniques were modeled by Knapp and Bhatti. Immiscible gas injection and alternating gas/water injection (WAG) scenarios were tried which significantly reduced the oil production response time. The predicted outcome of exploitation schemes are compiled in **Fig. 1**. Based upon this modeling effort, it was learned that in a relatively tight sand reservoir, an alternating gas/water injection program (WAG) was optimal (without regard to economics). In the Salt Fork North study, using the WAG model, recovery of more than 500 MSTBO (15% OOIP) was predicted over a 15 year period, which is over 2.1 times the primary recovery. This assumed injection of 4.2 MMMCFG and 2.2MMSTBW. The simulation projected that most of the injected fluids and gas were ultimately recovered by the end of the 15 year enhanced recovery period.

Figure 1: Predicted outcome of exploitation schemes from 1996 to 2010
% Recovery of Original Oil in Place based on Simulation Results



The Prue Play

In terms of stratigraphic thickness and aerial distribution, the Prue is a medium-sized play - much larger than the Peru and Booch but smaller than the Red Fork. During the past 17 years, estimated annual Prue oil production was between 0.7 and 2.2 MMBO. The actual production rate is somewhat higher owing to the fact that much of the Prue oil production is commingled and not always distinguished separately. These data were summarized in **Table 4.**

The Prue is a very commonly-used subsurface term that refers to a sand interval consisting of usually one or two individual sand zones. When more than one distinct sand zone is present, they are not always separated by a distinctive marker bed such as coal, limestone, and/or hot shale beds as are the Skinner zones. At outcrop, the formal equivalent name of the Prue sand is the Lagonda Sandstone, although this terminology is seldom used by the oil industry.

Because of correlation problems in southeastern Oklahoma, the Prue sands are commonly referred to as the Calvin Sandstone - a formal surface name.

The Prue play is located primarily in the eastern half of the state in the Cherokee Platform Province. Progradation of the Prue FDD system to the southwest took place in a manner similar to the Skinner but deposition was not as extensive or intensive. As a result, Prue deposition was redirected southward away from structurally positive areas arising along the Nemaha Uplift, thereby inhibiting the transport of coarser grained sediments into the Anadarko basin. The stagnation of the Prue FDD system resulted in very dirty reservoirs containing abnormally high amounts of clay and mica. Subsurface evidence marking the maximum westward extent of Prue FDD occurs along the southern extent of the Nemaha fault zone just west of Oklahoma City. The southern limit of the Prue FDD system adjoins a marine seaway.

In approximately the same stratigraphic position, a similar depositional sequence originated in far southeastern Oklahoma (Arkoma Basin) and prograded to the northwest. The Prue "equivalents" in this part of the state are referred to as the Calvin sands, and are much thicker than the Prue interval of the Cherokee Platform Province farther to the north.

Hydrocarbon production from the Prue and Calvin sands is highly oil prone although a significant proportion of well completions are classified as gas wells. Since this play does not extend into the deeper part of the Anadarko basin, there are no large areas of production that are entirely gas. Most of the reservoirs, whether marine or fluvial, are second-rate and do not produce as well as the cleaner reservoirs found in the Bartlesville, Red Fork, and some Skinner zones. Another problem with Prue reservoirs is formation evaluation because the sands often calculate wet. This is due to errors in the interpretation of true (deep) resistivity which is suppressed by the high interstitial clay content. Clean sands in the Prue interval are sometimes difficult to interpret from gamma-ray logs because of the unusually high mica content in the reservoir. Other drawbacks that are inherent to this class of reservoirs include compartmentalization and highly variable permeability. These problems were addressed in the evaluation of the Prue oil pool in Long Branch field.

Long Branch Field, Prue oil pool is located in eastern Payne county in north central Oklahoma. Prue production was discovered and commercially produced early in 1993 despite several earlier Prue penetrations in the center of the field. These earlier wells were drilled to deeper targets and often had live oil shows in the Prue although the electric logs calculated wet. Completion of the discovery well was pursued by an alert consulting geologist who recognized the oil potential of the zone in spite of high water saturation calculations. The field opener tested at least 15 BOPD and subsequent drilling or recompletions led to 15 Prue oil wells with primary reserves of at least 200-300 MSTBO. The exact amount of oil production will never be known because it is commingled with production from several other pay zones. The basic reservoir and engineering data for this field are shown in **Table 7**.

TABLE 7 - Reservoir Properties for the Prue Sandstone in Long Branch Field, Payne County, Oklahoma

Reservoir size	~800 acres
Spacing (oil)	20-40 acres
Oil/water contact	~ - 2475 feet
Gas/oil contact	none
Porosity	10-22% (avg. ~ 16%)

Permeability[1]	10-63 md (avg. ~ 23md)
Water saturation (calculated)	44-60%
Average Gas-Oil Ratio (GOR)	probably < 1000 SCF/BO
Thickness (net sand $\phi \geq 10\%$)	15-42 ft (avg ~27 ft)
Reservoir Temperature	108^o F
Oil Gravity	40-41^o API
Initial reservoir pressure	NA
Initial formation-volume factor	1.25 (est from GOR, BHT, oil gravity)
Original Oil in Place (volumetric)	10,725,000 STBO
Cumulative primary oil production	undetermined, commingled with Peru
Estimated cumulative primary oil per well	15,000 - 30,000 BO
Recovery efficiency (oil)	undetermined, probably < 10%
Cumulative gas production	undetermined, commingled with Peru

1 All wells have been fracture treated, possibly resulting in preferentially oriented enhanced permeability.

The Prue reservoir sand in Long Branch field has a net thickness of 20-40 feet. The sandstone pinches out rapidly along the edges of the channel and is discontinuous up-dip to the northeast. The down-dip limit of the field is defined by an oil/water contact. The field is about 1½ miles long and about 2/3 mile wide. Despite the large volume of oil in-place (~10 MMSTBO), only about 15-30MSTBO are expected to be recovered on a per-well basis. This very low recovery is due to the relatively high water saturation calculated to be 50-60%. The porosity (~16%) and permeability (~23 md) is relatively high (see **Table 7**) but without massive stimulation, the Prue reservoir probably would not be productive.

Waterflood simulations by Knapp and Yang indicate that the estimated volume of unproduced mobile oil is about 5.6 MMSTBO which is about 52% of the OOIP. Results of a 10-year model simulation show that this oil pool would be a very attractive secondary recovery operation using any alternative considered in this study. These include water flooding using existing wells versus water flooding with infill wells. The performance of these two scenarios is compared to a base case whereby current operations are maintained **(Table 8)**. The incremental oil recovery due to water flooding is estimated to be as much as about 1,700 MSTBO or 20% OOIP. This is 4.7 times the amount that would be recovered by continuing the current operation conditions for 10 years.

TABLE 8 - Ten-Year Production Forecast Based on Reservoir Simulations

	Current operations	Waterflood with existing wells	Waterflood with infill wells
Cumulative oil production (mstb), 1/01/96	210	210	210
Expected cumulative oil production (mstb), 1/01/06	460	1,800	2,150
Incremental recovery from waterflood (mstb), 1/01/06	*	1,340	1,700
Cumulative water production (mstb), 1/01/06	1,700	12,000	15,250
Cumulative water injected (mstb), 1/01/06		14,350	18,100
Cumulative gas production (mmscf), 1/01/06	1,660	6,900	8,400
Maximum field oil production rate (stb/d)	70	700	900
Time at maximum oil rate (date)	1/01/06	2/01/00	5/01/00
Oil production rate (stb/d), 1/01/06	70	250	275

THE CLEVELAND AND PERU PLAYS

Primary authors:	Jock Campbell - Cleveland Robert Northcutt - Peru
Contributing authors:	Bruce Carpenter, Roy Knapp, X. H. Yang
Workshop date:	October 17, 1996
Workshop site:	Phillips Petroleum Co. Research and Development Center, Bartlesville, OK.
Publication:	Anticipated publication later in 1997

The Peru and Cleveland sands are important oil-producing FDD plays in Oklahoma. They were combined for a dual workshop because of the relatively small number of operators attributed to each play in addition to the relatively small amount of oil production recorded during the past 17 years. The Peru sand is the informal subsurface name of the Englevale Sandstone and lies at least 100 feet beneath the Cleveland sand interval. The Cleveland sand is also an informal subsurface name and the sand interval is often comprised of an upper and lower sand horizon. The formal surface equivalents are the Tulsa and Jenks Sandstones, respectively.

The Peru play

This play is confined primarily to Osage and adjacent Washington counties in northeast Oklahoma. In terms of aerial extent and oil production, the Peru play is the smallest in the FDD series. During the past 17 years, estimated cumulative oil production is between 1 to 2 million barrels. The higher reserve estimate includes commingled oil production whereas the lower reserve estimate includes only Peru oil production. Typically, annual Peru oil production accounts for about 40-50 MBO. The play was developed primarily during the early 1900's and producing reservoirs are generally very shallow - less than 3000 feet.

Hogshooter field, Peru producing area: Most fields having Peru production were developed in the early 1900's which inhibits any kind of detailed geologic field study. Log records are generally poor, and production records of individual wells are often incomplete or lost to history. Because of these problems, a suitable field study for waterflood modeling was not identified. Instead, an area of recent Peru production was identified and studied in as much as the data permitted. This area occurs within the Hogshooter field in central Washington county. The area of interest is confined to about 160 acres. Production was established during the early 1980's from a very thick channel sand (~80'). Most wells produced only a few barrels of oil per day and upwards to 275 barrels of water. The initial oil/water ratio varied from about 2-5% and because of this high water cut, the reservoir was essentially being produced under waterflood conditions during primary production. The reservoir lies at a depth of about 700 feet and hydrocarbon trapping results from structural nosing. Only the very upper part of the channel is perforated since the sand is mostly wet.

Total cumulative primary oil production from the Peru sand in the Hogshooter field is estimated to be about 42,000 barrels of oil. The original oil in place was not determined. Peru oil production was established in up to 8 wells. Reservoir properties **(Table 9)** are very good as the sandstone generally has relatively high porosity (~20%) and permeability (~28 md).

TABLE 9 - Reservoir Properties for the Peru Oil Reservoir

in Hogshooter Field, Washington County, Oklahoma

Reservoir size	~230 acres
Spacing (oil)	10 acres
Oil/water contact	~ 40 ft above mean sea level
Gas/oil contact	none
Porosity	20%
Permeability	28 md
Initial water saturation	<56%
Thickness (net sand in reservoir)	48 feet average
Reservoir temperature	85° F
Oil gravity	35° API
Initial reservoir pressure	unknown
Initial formation-volume factor	unknown
Original Oil in Place (volumetric)	unknown
Cumulative primary production (Peru-only)	42,040 BO (13 wells)
Recovery efficiency	unknown
Cumulative primary gas production	no data

However, because of the strong water drive and high water cut during production, this reservoir is not suitable for secondary water flooding since the reservoir is being water-flushed concurrent with primary production (an induced water flood).

The Cleveland Play

This play occurs throughout much of north central Oklahoma. It consists largely of fluvial and delta front (marine) sediments that prograded in a westerly direction. This is very unlike many of the Cherokee plays that advanced in a southerly direction. Although FDD components constitute a large part of the Cleveland interval, there are scattered areas of sandstone deposition that are probably entirely of marine origin rather than deltaic. These areas are primarily located in western Oklahoma.

Over the past 17 years, Cleveland production was reported from 158 fields and the total estimated oil production is about 12,500,000 barrels **(Table 10)**. During the past six years, annual production was typically about 500 MBO. The play was developed primarily during the early 1900's but is now more often regarded as a secondary objective. Field mapping and regional production data indicate that there are still local areas containing significant oil potential in this play. Cleveland reservoirs are generally shallow - less than 6000 feet.

Table 10. Crude Oil Production from Cleveland Sand Reservoirs, 1979-1995

Reservoir	Leases reporting[1]	Cumulative oil	Average bbl/lease	Other leases[1,2]
Cleveland sand	326	11,445,443	35,109	264
"Jones"[3] sand	56	999,696[4]	17,852	34

1 Average number of leases during the time frame, 1979-95.
2 Commingled production with that from other formations.

[3] "Jones " sand is a local equivalent of the Cleveland.
[4] "Jones" sand reservoirs include production from Cleveland sand and other formations.
SOURCE: Natural Resources Information System (NRIS) oil and gas production data base

Pleasant Mound field study is located in north central Oklahoma in western Payne County. The Cleveland oil pool in Pleasant Mound field was discovered in 1956 and was fully developed four years later with a total of 35 producing wells. The Cleveland reservoir consists of several producing sand zones. Sandstone reservoir facies occur locally within layers B, C, and D although most of the production is from layer B. Isopach mapping of this layer shows a net sandstone thickness of ~10-15 feet. The reservoir lies at a depth of about 2200 feet and hydrocarbon trapping results from an up-dip stratigraphic pinch-out of net sandstone. Reservoir properties are very favorable for secondary water flooding since the sandstone generally has relatively high porosity (~20-23%) and permeability (~50-130 md). These data are summarized in **Table 11**.

TABLE 11 - Reservoir Properties, Cleveland Sand Reservoir, Pleasant Mound Oil Field, Lincoln County, Oklahoma

Estimated properties	Zone B	Zone C	Zone D
Porosity	23%	20%	20%
Permeability	130 md	50 md	50 md
Average Gross Pay	20 ft	20 ft	25 ft
Average Net Pay	10 ft	15 ft	13 ft
Initial Water Saturation	32%	32%	32%
Initial Bottom-Hole Pressure	950 PSIA	950 PSIA	950 PSIA
Initial Gas-Oil Ratio	385 SCF/STB	385 SCF/STB	385 SCF/STB
Initial Formation-Volume Factor	1.20 RB/STB	1.20 RB/STB	1.20 RB/STB
Reservoir Temperature	106^{o} F	106^{o} F	106^{o} F
Oil Gravity	48^{o} API	48^{o} API	48^{o} API
Specific Gas Gravity	0.8	0.8	0.8
Initial Oil in Place	7.5 MMSTB	5.6 MMSTB	0.6 MMSTB
Initial Gas in Place	3,800 MMSCF	3,000 MMSCF	220 MMSCF

Total cumulative oil production from the Cleveland sand prior to water flooding in Pleasant Mound field is estimated to be 400,000 BO which is about 3% of the original oil in place (13.6 MMSTBO). In 1960, because of a steep decline in oil production, the Pleasant Mound Cleveland sand unit was formed. Initially, there were six injectors and up to 18 producing wells although not all of the producing wells were completed in the zone being water flooded. Water was injected at a rate of about 100-400 BWPD per well. However, response to water injection did not occur for nine years until 1970 at which time four more injectors were added. The biggest response in oil production occurred the following year when it more than tripled to about 2000 BO/month in 1971. By the end of 1995, primary plus secondary oil production totaled about 860,000 BO or about 6% of the OOIP. The summary of oil production is included in **Table 12** which also indicates the secondary oil recovery expected for different development cases.

TABLE 12 - Oil Recovery Comparisons for Different Development Cases,

Cleveland Sand Reservoir, Pleasant Mound Oil Field, Lincoln County, Oklahoma

	Primary & Water-flooding (12/1995)			Base (12/2005)			Recompletion -Option 1 (12/2005)			Recompletion -Option 2 (12/2005)		
Formation	Cum Oil (STB)	Rec. Factor (%)	Cum Wtr (MSTB)	Cum Oil (STB)	Rec. Factor (%)	Cum Wtr ((MSTB)	Cum Oil (STB)	Rec. Factor (%)	Cum Wtr (MSTB)	Cum Oil (STB)	Rec. Factor (%)	Cum Wtr (MSTB)
Zone B	835,000	11.1	2,700	940,000	12.5	2,900	1,550,000	21	11,000	2,000,000	26.7	40,000
Zone C	25,000	0.4	400	30,000	0.5	500	470,000	8.4	380	650,000	11.6	2,000
Zone D	0	0	0	0	0	0	80,000	13	20	150,000	25	1,000
Total	860,000	6.3	3,100	970,000	7.2	3,400	2,100,000	15.5	11,400	2,800,000	0.6	43,000

Waterflood modeling by Knapp and Yang indicates that unproduced mobile oil amounts to about 6.8 MMSTBO or 50% or the OOIP. Various secondary recovery scenarios were examined and they indicate that up to 2,800,000 STBO could be recovered in 10 years which is about 3.3 times the recovery during the past 40 years. The various enhanced recovery scenarios include the recompletion of several wells for injection (for a total of 14 injectors) and varying water injection rates and bottom-hole pressures (300 vs. 1800 psi - Options 1 and 2, respectively). The base case assumed that there were no changes in field development and well operating conditions.

THE RED FORK PLAY

Primary author:	Richard Andrews
Contributing authors:	Kurt Rottmann, Roy Knapp, X. H. Yang
Scheduled workshop dates:	March 5 and 12, 1997
Scheduled workshop sites:	Postal Service Technical Training Center, Norman, OK. and the Phillips Petroleum 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.

This workshop is scheduled for March 5, 1997 at the Norman Postal Service Technical Training Center and March 12, 1997 at the Phillips Petroleum Company Auditorium in Bartlesville, Oklahoma. Considerable effort has been made to upgrade the introduction to FDD concepts because of its repetitiveness in previous workshops. In this respect, the organization of this part of the program will include 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 form previous SP publications.

The Red Fork workshop will include three detailed field studies, two by Richard Andrews, and one by consulting geologist Kurt Rottmann. One field has a good secondary recovery history, another is currently in the early phases of water flooding, and a third field is identified as an excellent waterflood candidate.

The Red Fork text was completed and submitted for technical and grammatical editing in early November, 1996. Prior to this, all figures, maps, and plates were submitting to cartography for drafting. Red Fork cores from three wells were slabbed and prepared for workshop display. A brief description of the cored intervals as well as visual images will be incorporated in the publication appendix. This material is of great demand by geologists and has been very useful in their interpretations of FDD systems.

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 play has been of continued interest for many operators and geologists for a long time, but recently has become very active in western Oklahoma. The renewed interest in the Tonkawa centers in the Anadarko Shelf and Basin areas where production is prone to 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 play in two parts: FDD oil and non-FDD gas. The funding will therefore be divided between FDD (fluvial oil reservoirs) and the Petroleum Technology Transfer Council project (marine gas reservoirs).

Relatively little has been published about the Tonkawa play, and the interpretation supporting FDD deposition is documented in only a few thesis and by well log evaluations by the 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 primarily 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 geologic 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. The Oklahoma Geological Survey SP publication however, will include only information and maps relevant to Tonkawa FDD (oil) play. Information concerning the Tonkawa gas play in the predominantly marine facies of the Anadarko Basin will be available as an OGS open file report.

OPERATOR RESPONSES

At each of the workshops given during 1996, attendees were asked to complete evaluation forms reflecting their assessments of the materials and presentations. For all three of the plays, attendee evaluations were overwhelmingly positive, with average scores ranging from "very good" to "great" on nearly every item in the evaluation form. A summary of the compiled evaluations for each of the three plays is provided in Appendix A.

Additionally, participants at the workshops have verbally expressed their interest in the Oklahoma FDD project. Some of the comments or areas of interest that were extremely beneficial to these people include:

1. Better map interpretations can be accomplished through the recognition of generalized facies from well logs and mapping them separately. This has resulted in the extension of several play concepts originating from detailed field studies and regional play analysis.
2. Acquisition of basic reservoir properties as presented in detailed field studies was extremely useful.
3. Identification of the regional play outlines and principal depositional trends was very important. Many operators used this concept in conjunction with facies recognition to re-examine exploration and development strategies. Several small operators consulted with FDD project geologists for assistance in this area of expertise to help them plan new exploration or development programs that would otherwise not be attempted. Several new trends in the Prue and Skinner were identified because of the FDD initiative and these will contribute new oil and gas reserves to the state.
4. Most people were left with a better understanding of fluvial processes and how they might affect reservoir performance during primary and secondary recovery efforts.
5. Areas of by-passed production were clearly identified using recently developed *NRIS* MAPS software. Regional computer mapping showed areas of production and development trends that were not fully exploited. This was clearly shown for some of the younger FDD plays such as the Cleveland. In the vicinity of Pleasant Mound field, the Cleveland zone was often over-looked because many wells were drilled to deeper targets. Large areas having reported oil shows in the Cleveland were identified and many operators were interested in pursuing such opportunities as a result of the workshop.
6. Waterflood analogies were useful and interesting because it was shown exactly what can be expected, good and bad, during secondary recovery. These types of field studies were compared to the waterflood modeling studies and some operators who participated in the simulation studies planned to adjust their programs for better recovery. This was evident in Salt Fork N. field (on-going Skinner waterflood), Long Branch (Planned Prue water flood), and Pleasant Mound field (on-going Cleveland waterflood).

Task 3: Professional Outreach

Three levels of professional outreach have been identified as part of this overall project effort. The first, technical advising, refers to those industry contacts that take place as follow-ups to the workshop presentations. Second, the ongoing reservoir characterization and simulation studies provide opportunities for individualized efforts with operators. Third, professional activities such as conferences provide a forum for promoting the FDD program activities.

Technical Advising: Following each of the workshops that were held in 1996, the workshop participants (particularly the play leaders and the engineering staff) were called on to serve in an advisory role to respond to various industry inquiries. Operators call with specific questions about how to best manage a property they may have in the play. In this role, the project staff typically cannot fully research the property to recommend a course of action, but generally are able to direct people towards the kinds of information and issues they should address. These contacts have been fruitful not only for industry, but also for the project staff as they obtain feedback on the value of the publications and workshop materials.

Reservoir Characterization and Simulation Studies: These studies are being conducted in cooperation with the operators of the selected reservoirs, with the goal of identifying opportunities for increasing recovery from those reservoirs. Operators are selected for these studies based on the quality of data they have for the reservoir, their willingness to participate and contribute resources to the study, their willingness to make investments that will realize the recovery opportunities that are identified, and their willingness to allow the project results to be published and otherwise made available to industry.

A primary goal for these reservoir characterization studies is to develop methodologies that are affordable, understandable, and usable for the small independent oil operator. While the data collection for these selected reservoirs is in far greater detail than for other reservoirs in the plays, it may still be at a "minimized" level of detail relative to comprehensive reservoir studies that are performed in research facilities or by major companies in industry. The typical reservoir for these studies has about 15 to 40 wells, and fields with current production data and modern well logs are preferred. No seismic or other geophysical data are expected to be available for these studies. Lithology, estimates of the original hydrocarbons-in-place, and production profiles (oil, gas and water) for the reservoir are important components for the reservoir characterization. When necessary, algorithms are developed to estimate water and gas production from the reservoir, and to describe the geologic framework. The level of precision resulting from these studies is necessarily limited, but should accomplish the basic goals of helping operators target the remaining resource.

Professional Activities: Information on the FDD project activities is distributed through a number of professional outlets. During 1996, an OGS display and representative provided information about the FDD program at events such as the annual meetings of the American Association of Petroleum Geologists and the Geological Society of America, and at various regional and local meetings and events. Additionally, the play leaders from each of the work shops were periodically called upon to present short summaries of their work in area professional gatherings, such as the monthly meetings of the Oklahoma City Geological Society.

VI. CONCLUSIONS

1996 provided the highest level of technology transfer activities in the development of the Oklahoma FDD program. Three highly successful workshops and accompanying publications were completed on six FDD horizons including the Layton, Osage-Layton, Prue, Skinner, Cleveland, and Peru. Additionally, significant progress was made in preparation for upcoming workshops for the Red Fork, Tonkawa, and Bartlesville. Experience with these workshops and public comments have enabled the project staff to establish a much better workshop agenda than envisioned during the inception of this program.

Technology transfer elements of the program continued during the year as an outgrowth of *Phase 1* activities. Systems design, database expansion, and computer lab development permitted many users to perform diversified geological and engineering functions related to all aspects of the oil and gas industry. Development of *NRIS* MAPS provided the necessary link to access *NRIS* data and enabled people to make a variety of oil & gas field maps and retrieve critical production data. The computer lab facility was moved to a more accessible location north of Norman and was the focal point for many instructional classes by industry personnel. This facility continues to provide state-of-the-art hardware and software that can be utilized for a variety of tasks. Support staff are fully versed in all aspects of computer lab usage and are knowledgeable in software applications.

Numerous operators and industry people provided positive feedback for the overall program. They indicated that the workshops were extremely valuable and provided important reservoir, geologic, and engineering information. Participants also said they gained a better insight regarding depositional environments and reservoir characteristics which would help them in exploration and development strategies. The regional trend analysis and detailed field study protocol combined with waterflood simulation exercises were directly applicable for most people. Due to the nature of the Oklahoma FDD project, it is recognized as one of the most successful and respected programs to assist operators throughout the entire Mid-Continent region. Nearly everyone wants this program continued or expanded.

ATTENDEE EVALUATION SUMMARY REPORT
FDD WORKSHOP: LAYTON & OSAGE-LAYTON PLAY

April 17, 1996 **Oklahoma City, OK**

DEMOGRAPHIC INFORMATION

Type of Company	Small Independent	Major Producer	Service Co.	Govern-ment	Mid/Large Independent	Acad-emia	Con-sultant	Other	# of responses
TOTALS	16	1	1	1	1	0	8	0	28
Technical Background	Geol/Geoph	Engr	Both	Other					
TOTALS	21	3	0	2					26

How did you learn about this workshop?
- mailing 13
- conversation with OGS staff 2
- attending other workshops 2
- word of mouth 2
- OGS 2
- OGS ads 1
- Tulsa Geol Soc Newsletter 1
- SPE newsletter 1

OVERALL WORKSHOP EVALUATION

	1 (Poor)	2	3 (Avg.)	4	5 (Great)	# of responses	Average
Was this workshop useful?	0	0	2	14	13	29	4.38
Was this workshop worth your time and money?	0	1	1	7	19	28	4.57

WORKSHOP AUXILIARY COMPONENTS

	1 (Poor)	2	3 (Avg.)	4	5 (Great)	# of responses	Average
Preconference materials	0	0	4	13	11	28	4.25
Registration process	0	0	1	8	20	29	4.66
Presentation facilities	0	0	1	7	21	29	4.69
Supplemental Materials	0	0	3	7	19	29	4.55
Breaks and lunch arrangements	0	0	0	4	25	29	4.86
Overall location	0	0	1	7	21	29	4.69

Please provide any suggestions or comments that you believe would help to improve these workshops.
- more, more, more
- Basically an excellent job...everyone did an excellent job
- Have presenters refer to page #'s and/or figure #'s in their discussions to minimize page flipping
- I would like to attend a seminar on the Bartlesville sand.
- Would like to see a repeat of the Morrow workshop sometime in the future.
- Closer relationship between sample descriptions, core analysis and thin sections with available electric logs.
- Computer demo useful but hard to follow
- Motel/Hotel number on registration form to correlate to map.
- More info on lithology - thin sections, clay minerals, etc.
- Keep up this high quality!
- Great job, keep it up.
- Very well done.

Do you see an opportunity to apply the information and/or technologies discussed in today's workshop?

YES: 21 NO: 1

If so, what information and/or technologies?

- We have recompletions in both the True Layton and the Corrage Grove that have been proposed and approved. This information will prove very useful in recompletion choices.
- This type of study emphasizes the work that is yet to be done in order to maximize OK production, both in terms of production enhancement and exploration. You have uncovered a lot of potential areas for further study.
- Geologic info & review of things I have not used lately. Reservoir simulation was interesting and possibly useful.
- The fact that it is not at all unusual for low resistivity changes to be the difference between production and water makes our observations more important and encourages me to map sands for recompletion that at first glance appear wet.
- Being employed by an independent operator, I no longer have the opportunity to increase skills & knowledge by attending in-house schools. This workshop is a fantastic substitute. I predict this idea will be a great help to the independent petroleum operator.
- Reservoir simulation & care that must be given low resistivity reservoirs.
- Regional data as well as specific prospect areas.
- Logs & x-sections for correlation purposes;nomenclature;production analogs;reservoir simulation study;sequence stratigraphy
- In mapping & prospecting
- Investigation of passed-over potential
- Knowledge gained from regional perspectives

PRESENTATION DETAILS	1 (Poor)	2	3 (Avg.)	4	5 (Great)	# of responses	Average
Mankin: Opening Remarks: Technical content	0	0	9	13	9	31	4.00
Mankin: Opening Remarks: Value of the info	0	0	6	16	9	31	4.10
Mankin: Opening Remarks: Applicability to you	0	1	8	11	10	30	4.00
Campbell: Intro to FDD: Technical content	0	0	6	13	12	31	4.19
Campbell: Intro to FDD: Value of the info	1	0	4	12	14	31	4.23
Campbell: Intro to FDD: Applicability to you	0	1	5	12	13	31	4.19
Campbell: Lower Missourian Strat: Technical content	0	0	4	15	12	31	4.26
Campbell: Lower Missourian Strat: Value of the info	0	0	3	15	13	31	4.32
Campbell: Lower Missourian Strat: Applicability to	0	0	6	13	12	31	4.19
Campbell: Regional Overview: Technical content	0	0	2	17	11	30	4.30
Campbell: Regional Overview: Value of the info	0	0	4	12	14	30	4.33
Campbell: Regional Overview: Applicability to you	0	0	4	12	14	30	4.33
Shannon: South Coyle Field: Technical content	0	1	8	14	7	30	3.90
Shannon: South Coyle Field: Value of the info	0	1	10	10	9	30	3.90
Shannon: South Coyle Field: Applicability to you	0	4	8	11	7	30	3.70
Campbell: East Lake Blackwell: Technical content	0	0	6	15	9	30	4.10
Campbell: East Lake Blackwell: Value of the info	0	1	7	10	12	30	4.10
Campbell: East Lake Blackwell: Applicability to you	0	3	6	11	10	30	3.93
Knapp & Yang: Res. Simulation: Technical content	0	1	5	11	13	30	4.20
Knapp & Yang: Res. Simulation: Value of the info	0	4	6	11	9	30	3.83
Knapp & Yang: Res. Simulation: Applicability to you	1	4	9	7	9	30	3.63
Core Exhibits Technical content	0	1	7	11	9	28	4.00
Core Exhibits Value of the info	0	1	7	9	11	28	4.07
Core Exhibits Applicability to you	0	2	7	9	10	28	3.96
Computer Demonstrations Technical content	0	0	6	13	8	27	4.07
Computer Demonstrations Value of the info	0	3	6	11	7	27	3.81
Computer Demonstrations Applicability to you	0	2	7	11	7	27	3.85

FDD WORKSHOP: SKINNER AND PRUE PLAYS

June 19 & 20, 1996 — **Oklahoma City, OK**
June 26, 1996 — **Bartlesville, OK**

DEMOGRAPHIC INFORMATION

Type of Company	Small Independent	Major Producer	Service Co.	Govern-ment	Mid/Large Independent	Acad-emia	Con-sultant	Other	# of responses
TOTALS	47	2	2	0	6	0	19	2	78
June 19	20	0	1	0	3	0	9	0	33
June 20	10	1	0	0	2	0	3	0	16
June 26	17	1	1	0	1	0	7	2	29
Technical Background	Geol/Geoph	Engr	Both	Other					
TOTALS	54	9	5	6					74
June 19	26	1	3	2					32
June 20	11	4	1	0					16
June 26	17	4	1	4					26

How did you learn about this workshop?

	June 19	June 20	June 26	TOTAL
mailing	17	9	15	41
company announcement			1	1
other workshops	4	1	3	8
OGS	3	1	1	5
TGS Newsletter			2	2
Newsletter		1	2	3
OGS Advertisement			1	1
OKC Geol Library	2	1		3
Friends/word of mouth	4	3		7
FDD literature	1		1	2
OGS/OIPA		1		1
Shale Shaker		1		1
Tulsa World News		1		1

OVERALL WORKSHOP EVALUATION

	1 (Poor)	2	3 (Avg.)	4	5 (Great)	# of responses	Average
Was this workshop useful?	0	0	7	40	29	76	4.29
June 19	0	0	2	17	13	32	4.34
June 20	0	0	3	7	5	15	4.13
June 26	0	0	2	16	11	29	4.31
Was this workshop worth your time and money?	0	0	5	27	42	74	4.50
June 19	0	0	1	10	21	32	4.63
June 20	0	0	3	7	5	15	4.13
June 26	0	0	1	10	16	27	4.56

WORKSHOP AUXILIARY COMPONENTS

	1 (Poor)	2	3 (Avg.)	4	5 (Great)	# of responses	Average
Preconference materials	0	1	20	27	26	74	4.05
June 19	0	1	6	11	12	30	4.13
June 20	0	0	6	5	4	15	3.87
June 26	0	0	8	11	10	29	4.07
Registration process	0	0	6	29	41	76	4.46
June 19	0	0	3	11	18	32	4.47
June 20	0	0	1	6	8	15	4.47
June 26	0	0	2	12	15	29	4.45
Presentation facilities	0	0	1	28	47	76	4.61
June 19	0	0	0	13	19	32	4.59
June 20	0	0	0	4	11	15	4.73
June 26	0	0	1	11	17	29	4.55
Supplemental Materials	0	0	5	34	37	76	4.42
June 19	0	0	3	12	17	32	4.44
June 20	0	0	1	7	7	15	4.40
June 26	0	0	1	15	13	29	4.41
Breaks and lunch arrangements	0	0	5	17	53	75	4.64
June 19	0	0	2	5	25	32	4.72
June 20	0	0	0	2	12	14	4.86
June 26	0	0	3	10	16	29	4.45
Overall location	1	0	3	20	50	74	4.59
June 19	1	0	1	7	23	32	4.59
June 20	0	0	0	1	12	13	4.92
June 26	0	0	2	12	15	29	4.45

Please provide any suggestions or comments that you believe would help to improve these workshops.

June 19:

- This is a first class workshop in all respects. Very professional. I'm impressed.
- You must come to Tulsa, half of industry excluded when you don't. All previous presentations (Morrow, etc.) should be done in Tulsa.
- Great workshop & lecture data
- Continue the good work. Geologists need the education & networking.
- A+!
- Show slides of cores or have us look @ photos in book @ 9:10 a.m.: (1) explain main features (2) encourage us to see the features on our own during break (3) rotate core expert between core tables during break to answer questions we may have.
- Waterflood segments too short, hard to understand. Please let us know when Boast 3 is available.
- Best location yet.

June 20:

- Allow more time for engineering discussion.
- Keep lights up a little more (too dark during some of the presentations for note taking.)
- Great place to have these workshops.
- I got a flyer about the workshop but not any registration material. I had to ask around to get the registration form. I missed the earlier workshops for the same reason.
- Limited access of telephone at breaks for the use of attendees. Noticed some staff held the phone for many minutes.
- I feel these workshops are great, I wish our survey (Kansas) would contribute half of what the OGS has been doing!
- Try to present the materials in a manner that can be easily understood by company personnel that may not have a strong geology background, such as workover and completion engineers.
- Leave lights on (dim at least) during slide presentations. It was too dark for me to see to take notes during the first couple of talks.
- Would appreciate including data regarding stimulation procedures, injection rates & volumes

June 26:

- Good workshop.

- Phillips has uncomfortable chairs!
- Excellent overheads - these really help the presentation
- Scales on logs!
- Have producers do these vs. school teachers.
- Since the bulk of the data that is available to an independent geologist is electric logs, it would really be helpful to see what log signatures correspond to the cores. A small display of the electric log showing the cored intervals and a short description of all or just noteworthy lithologies would just be great.
- Maybe supply economic discussion - Feasibility of each study field; or even separate study of mature floods and their economic impact - failure or success although no one would comment on their failures.
- Workshop presentations and cost is excellent. Can't think of any suggestions. Very helpful!
- More information regarding initial treatment of wells.
- Great format. Excellent materials provided for follow-up research.
- Have E-logs laid out along cores.
- Come to Tulsa. I am surprised no one studied the fracture pattern in the field study areas.
- How about Tulsa U or TJC?

Do you see an opportunity to apply the information and/or technologies discussed in today's workshop?

June 19: YES: 22 NO: 0
June 20: YES: 10 NO: 1
June 26: YES: 17 NO: 2

If so, what information and/or technologies?

June 19:

- Fine regional studies.
- I made a list of prospect and further investigation ideas.
- Reservoir simulations
- Secondary Recoveries
- Computer Mapping
- Injection patterns & waterflood evaluation criteria. Regional Skinner correlations will help understanding of local terminology.
- The general approach to sand reservoirs and how to plan secondary recoveries from those reservoirs.
- All of it!
- Software USA

June 20:

- Clearer understanding of regional framework of both reservoir systems.
- Study and development of Skinner wells. Will use study for mapping & sales.
- It always helps seeing field interpretations to help give ideas of how to make environment interpretations.
- There was no new information or technology introduced. Admitted that not all available data was used to make the interpretations.
- Continuation of log curve analysis as exploration tool.
- Field studies, regional overview.
- I will use this information for modeling
- NRIS; exposure to reservoir simulators and mapping software.
- Found out what is really happening (geologically) in my L. Skinner field.

June 26:

- Boast 3 - Excel links
- Regional geology very helpful; interpretation of log characteristics as relating to specific environments.
- Interesting demonstration of Boast
- information of the regional Skinner & Prue in Oklahoma plus examples of existing fields
- computer simulation
- Greater understanding of Fluvial environments will aid our exploration process.
- Uphole potential
- Geological interpretations/evaluations for Analogy. Geographic localvalued if applicable (??)
- All except computer
- Geological mapping & interpretation

PRESENTATION DETAILS	1 (Poor)	2	3 (Avg.)	4	5 (Great)	# of responses	Average
Mankin: Opening Remarks: Technical content	0	3	25	29	19	76	3.84
June 19	0	2	8	16	9	35	3.91
June 20	0	0	6	5	3	14	3.79
June 26	0	1	11	8	7	27	3.78
Mankin: Opening Remarks: Value of the info	0	0	23	34	20	77	3.96
June 19	0	0	9	18	8	35	3.97
June 20	0	0	5	5	5	15	4.00
June 26	0	0	9	11	7	27	3.93
Mankin: Opening Remarks: Applicability to you	1	1	24	30	19	75	3.87
June 19	1	1	7	17	9	35	3.91
June 20	0	0	7	3	4	14	3.79
June 26	0	0	10	10	6	26	3.85
Andrews: Intro to FDD: Technical content	1	1	12	40	30	84	4.15
June 19	0	0	5	21	13	39	4.21
June 20	1	0	3	6	5	15	3.93
June 26	0	1	4	13	12	30	4.20
Andrews: Intro to FDD: Value of the info	1	1	18	36	27	83	4.11
June 19	0	0	7	18	13	38	4.16
June 20	1	0	4	6	4	15	3.80
June 26	0	1	4	13	12	30	4.20
Andrews: Intro to FDD: Applicability to you	1	2	17	37	26	83	4.02
June 19	0	0	7	19	12	38	4.13
June 20	1	1	3	6	4	15	3.73
June 26	0	1	7	12	10	30	4.03
Andrews: Skinner/Senora Regional: Technical content	0	0	6	47	35	88	4.33
June19	0	0	2	21	16	39	4.36
June 20	0	0	2	10	4	16	4.13
June 26	0	0	2	16	15	33	4.39
Andrews: Skinner/Senora Regional: Value of the info	0	0	9	44	35	88	4.30
June 19	0	0	3	19	17	39	4.36
June 20	0	0	3	9	4	16	4.06
June 26	0	0	3	16	14	33	4.33
Andrews: Skinner/Senora Regional: Applicability to	0	2	13	46	27	88	4.11
June 19	0	1	5	20	13	39	4.15
June 20	0	1	4	8	3	16	3.81
June 26	0	0	4	18	11	33	4.21
Rottmann: Guthrie SW Technical content	0	4	22	40	19	85	3.87
June 19	0	2	6	20	10	38	4.00
June 20	0	1	3	6	4	14	3.93
June 26	0	1	13	14	5	33	3.70
Rottmann: Guthrie SW Value of the info	0	3	17	47	18	85	3.94
June 19	0	0	5	22	11	38	4.16
June 20	0	1	4	6	3	14	3.79
June 26	0	2	8	19	4	33	3.76
Rottmann: Guthrie SW Applicability to you	0	3	28	37	17	85	3.80
June 19	0	0	11	17	10	38	3.97
June 20	0	2	5	4	3	14	3.57
June 26	0	1	12	16	4	33	3.70
Andrews: Salt Fork North Technical content	0	1	12	53	19	85	4.06
June 19	0	0	5	25	8	38	4.08
June 20	0	1	2	8	3	14	3.93
June 26	0	0	5	20	8	33	4.09
Andrews: Salt Fork North Value of the info	0	3	12	45	25	85	4.08
June 19	0	0	5	22	11	38	4.16

June 20	0	1	2	8	3	14	3.93
June 26	0	2	5	15	11	33	4.06
Andrews: Salt Fork North Applicability to you	0	5	16	39	25	85	3.99
June 19	0	0	6	21	11	38	4.13
June 20	0	2	4	5	3	14	3.64
June 26	0	3	6	13	11	33	3.97
Knapp & Bhatti: Salt Fork North: Technical content	3	4	23	36	20	86	3.77
June 19	2	3	13	14	7	39	3.54
June 20	1	0	1	9	4	15	4.00
June 26	0	1	9	13	9	32	3.94
Knapp & Bhatti: Salt Fork North: Value of the info	2	5	35	31	13	86	3.56
June 19	1	4	15	13	6	39	3.49
June 20	1	0	5	6	3	15	3.67
June 26	0	1	15	12	4	32	3.59
Knapp & Bhatti: Salt Fork North: Applicability to you	1	8	37	26	14	86	3.51
June 19	0	4	19	10	6	39	3.46
June 20	1	2	5	4	3	15	3.40
June 26	0	2	13	12	5	32	3.63
Rottmann: Perry SE Technical content	0	1	16	42	26	85	4.09
June 19	0	0	6	18	14	38	4.21
June 20	0	0	4	7	4	15	4.00
June 26	0	1	6	17	8	32	4.00
Rottmann: Perry SE Value of the info	0	3	16	39	27	85	4.06
June 19	0	1	4	18	15	38	4.24
June 20	0	0	5	6	4	15	3.93
June 26	0	2	7	15	8	32	3.91
Rottmann: Perry SE Applicability to you	0	2	18	40	24	84	4.02
June 19	0	1	6	18	13	38	4.13
June 20	0	0	5	7	3	15	3.87
June 26	0	1	7	15	8	31	3.97
Andrews: Prue/Calvin Regional Technical content	0	1	11	42	29	83	4.19
June 19	0	1	5	17	13	36	4.17
June 20	0	0	3	8	4	15	4.07
June 26	0	0	3	17	12	32	4.28
Andrews: Prue/Calvin Regional Value of the info	0	3	12	34	34	83	4.19
June 19	0	2	5	14	15	36	4.17
June 20	0	0	3	7	5	15	4.13
June 26	0	1	4	13	14	32	4.25
Andrews: Prue/Calvin Regional Applicability to you	1	3	15	35	28	82	4.05
June 19	0	3	7	15	11	36	3.94
June 20	0	0	4	6	4	14	4.00
June 26	1	0	4	14	13	32	4.19
Andrews: Long Branch Technical content	1	1	10	38	32	82	4.21
June 19	0	1	3	17	14	35	4.26
June 20	1	0	2	7	5	15	4.00
June 26	0	0	5	14	13	32	4.25
Andrews: Long Branch Value of the info	1	1	11	37	32	82	4.20
June 19	0	1	3	17	14	35	4.26
June 20	1	0	1	8	5	15	4.07
June 26	0	0	7	12	13	32	4.19
Andrews: Long Branch Applicability to you	3	0	16	34	28	81	4.04
June 19	1	0	7	15	12	35	4.06
June 20	1	0	2	7	4	14	3.93
June 26	1	0	7	12	12	32	4.06
Knapp & Yang: Long Branch Technical content	0	4	17	30	17	68	3.88
June 19	0	2	7	14	6	29	3.83

June 20	0	0	5	2	5	12	4.00
June 26	0	2	5	14	6	27	3.89
Knapp & Yang: Long Branch Value of the info	0	4	25	25	14	68	3.72
June 19	0	1	10	12	6	29	3.79
June 20	0	0	5	4	3	12	3.83
June 26	0	3	10	9	5	27	3.59
Knapp & Yang: Long Branch Applicability to you	4	7	21	23	13	68	3.50
June 19	2	1	11	10	5	29	3.52
June 20	0	1	4	4	3	12	3.75
June 26	2	5	6	9	5	27	3.37
Core Exhibits Technical content	0	1	7	32	30	70	4.30
June 19	0	0	3	16	11	30	4.27
June 20	0	0	1	3	7	11	4.55
June 26	0	1	3	13	12	29	4.24
Core Exhibits Value of the info	0	2	6	37	25	70	4.21
June 19	0	0	4	17	9	30	4.17
June 20	0	0	1	3	7	11	4.55
June 26	0	2	1	17	9	29	4.14
Core Exhibits Applicability to you	1	0	9	33	26	69	4.20
June 19	0	0	6	15	9	30	4.10
June 20	0	0	1	3	6	10	4.50
June 26	1	0	2	15	11	29	4.21
Computer Demonstrations Technical content	0	1	11	23	16	51	4.06
June 19	0	1	5	8	7	21	4.00
June 20	0	0	1	2	4	7	4.43
June 26	0	0	5	13	5	23	4.00
Computer Demonstrations Value of the info	1	1	10	26	13	51	3.96
June 19	0	0	6	10	5	21	3.95
June 20	0	0	1	3	3	7	4.43
June 26	1	1	3	13	5	23	3.87
Computer Demonstrations Applicability to you	2	2	9	24	14	51	3.90
June 19	0	1	5	9	6	21	3.95
June 20	0	0	2	2	3	7	4.14
June 26	2	1	2	13	5	23	3.78

FDD WORKSHOP: CLEVELAND AND PERU PLAYS

October 17, 1996 **Bartlesville, OK**

DEMOGRAPHIC INFORMATION

Type of Company	Small Independent	Major Producer	Service Co.	Govern-ment	Mid/Large Independent	Academia	Con-sultant	Other	# of responses
TOTALS	13	0	0	1	1	0	2	2	19
Technical Background	Geol/Geoph	Engr	Both	Other					
TOTALS	15	1	0	3					19

How did you learn about this workshop?

	TOTAL
mailing	8
other workshops	3
OGS	2
Friends/word of mouth	3

OVERALL WORKSHOP EVALUATION

	1 (Poor)	2	3 (Avg.)	4	5 (Great)	# of responses	Average
Was this workshop useful?	0	2	4	8	5	19	3.84
Was this workshop worth your time and money?	0	2	2	6	9	19	4.16

WORKSHOP AUXILIARY COMPONENTS

	1 (Poor)	2	3 (Avg.)	4	5 (Great)	# of responses	Average
Preconference materials	0	2	6	6	4	18	3.67
Registration process	0	0	4	1	14	19	4.53
Presentation facilities	0	0	0	5	14	19	4.74
Supplemental Materials	0	0	4	10	5	19	4.05
Breaks and lunch arrangements	0	0	3	3	13	19	4.53
Overall location	0	0	2	7	10	19	4.42

Please provide any suggestions or comments that you believe would help to improve these workshops.

- A great job as usual.
- I have rated all presentations as average. All presenters did an excellent job but presented very little that could be considered new. I found the Pleasant Mound Reservoir simulation to be most interesting from a content point of view.
- Field studies of more general interest, even though e. logs, cores, etc. may not be available. Computer simulations are not helpful to average attendee.
- All of the presenters did a really good job, however I was left with the feeling that there is not a lot of future to these two reservoirs. Neither of the field studies were very economic, or was that the point?
- The seminar proved valuable by showing a zone which we always wondered about but never had time to map.
- Why Bartlesville location? It would seem that more might avail themselves to the workshop if in OKC & Tulsa primarily....I have been to several workshops, but never in Tulsa...Are there facilities here? Also, I felt the Peru portion was practically a waste of time due to the lack of economic significance of this reservoir. Based on the presentation, I don’t know many operators that would re-complete this zone, much less drill for it.
- Could have found some better Peru wells in Osage - Even made workovers behind pipe not feasible for Peru. Should have spent one day per zone study - Some old geologists never change.
- The “plays” presented were not commercially feasible.
- This was the poorest of the series. Previous workshops were better prepared & discussed in more detail. Overall the series has been great. Please keep the program expanding even into other geologic areas.
- Provide core analysis of cores on display and full log suite.

- I would like to see upcoming workshops held in Bartlesville again.
- Great facility - good for folks operating in central & NE Oklahoma.
- Wish all day on Cleveland!
- Core was very good - Could have used core analysis data & correlative core/log relationship quantification. Discussion of secondary projects needs more than 1 project, and info on what works, what are problems to be aware of, etc.

Do you see an opportunity to apply the information and/or technologies discussed in today's workshop?

YES: 17 NO: 0

If so, what information and/or technologies?

- Log analysis by Bruce Carpenter contained a great deal of universal information that I have found useful.
- This workshop provided me with review of Cleveland and Peru sand information that I need for my present job.
- Waterflood technology
- Overview of formations studied
- Bruce Carpenter's talk was very helpful in evaluating logs.
- The history matching at Pleasant Mound is deemed worthy of further investigation. Excellent program!!
- Extent of Cleveland production.
- Infield drilling on Cleveland sand leases - most studies say won't flood? I believe it will & has in some compartmental instances. As usual you guys & gals do an excellent job!
- Fluvial vs. marine
- Geological info will help in future prospecting.
- Engineering reservoir simulations give insight into secondary recovery operations.
- Location of Clev. fields w/in whole depositional setting...as explanation for some probs. w/ low Rt, grain size (pore size) vs. perm. distribution -- & need for core!

PRESENTATION DETAILS	1 (Poor)	2	3 (Avg.)	4	5 (Great)	# of responses	Average
1. Mankin: Opening Remarks	0	0	5	7	6	18	4.06
2. Jock Campbell: Introduction to FDD Concepts	0	0	6	9	3	18	3.83
3. Jock Campbell: Cleveland Regional Overview	0	0	5	11	2	18	3.83
4. Kurt Rottmann: Pleasant Mound Field Study	0	1	6	9	2	18	3.67
5. Knapp & Yang: Pleasant Mound Reservoir Simulation	0	5	4	6	3	18	3.39
6. Robert Northcutt: Peru Regional Overview	1	4	7	4	1	17	3.11
7. Robert Northcutt: Hogshooter Field Study	1	4	5	6	0	16	3.11
8. Bruce Carpenter: Hogshooter Log Analysis	0	1	3	10	2	16	3.81
9. Core Exhibits	0	0	3	11	3	17	4.00
10. Computer Demonstrations	0	0	3	10	3	16	4.00