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Quarterly Reports

DOE/BC-94/3 **Contracts for Field Projects and Supporting Research on Enhanced Oil Recovery. Progress Review No. 79. Quarter ending June 30, 1994. August 1995. 117 pp. Order No. DE94000200.** Status reports are given for various enhanced oil recovery and gas recovery projects sponsored by the Department of Energy. The field tests and supporting research on enhanced oil recovery include chemical flooding, gas displacement, thermal/heavy oil, resource assessment, geoscience technology, microbial technology, field demonstrations in high-priority reservoir classes, novel technology, and environmental technology.

DOE/BC-94/4 **Contracts for Field Projects and Supporting Research on Enhanced Oil Recovery. Progress Review No. 80. Quarter Ending September 30, 1994. November 1995. 156 pp. Order No. DE96001206.** Status reports are given for various enhanced oil recovery and gas recovery projects sponsored by the Department of Energy. The field tests and supporting research on enhanced oil recovery include chemical flooding, gas displacement, thermal/heavy oil, resource assessment, geoscience technology, microbial technology, field demonstrations in high-priority reservoir classes, novel technology, and environmental technology.

Chemical Flooding

DOE/BC/14881-12 **Improving Reservoir Conformance Using Gelled Polymer Systems. Annual Report for September 25, 1993 to September 24, 1994. The University of Kansas. July 1995. 96 pp. Order No. DE95000158.** The objectives of the research program are to identify and develop polymer systems which have potential to improve reservoir conformance of fluid displacement processes; to determine the performance of these systems in bulk and in porous media; and to develop methods to predict their performance in field applications. The research focuses on three types of aqueous gel systems - a polysaccharide (KUSP1) that gels as a function of pH, a polyacrylamide-chromium(III) system and a polyacrylamide-aluminum citrate system. This report describes work conducted during the second year of a three-year program. Progress was made in the utilization of KUSP1 as a gelling agent. It was shown that gels can be formed in situ in porous media using CO_2 or ester hydrolysis to lower pH. An ester was identified that could be used in field-scale operations. It was determined that KUSP1 will form strong gels when ortho boric acid is added to the system. It was also determined, in cooperation with Abbott Laboratories, that KUSP1 can be produced on a commercial scale. Rheological studies showed that shear rate significantly affects gelation time and gel strength. The effect of rock-fluid interactions at alkaline conditions was examined experimentally and through mathematical modeling.

DOE/BC/14884-12 **Surfactant Loss Control in Chemical Flooding Spectroscopic and Calorimetric Study of Adsorption and Precipitation on Reservoir Minerals. Annual Report for September 30, 1993 to September 30, 1994. Columbia University. June 1995. 60 pp. Order No. DE95000157.** The aim of this project is to elucidate the mechanisms underlying adsorption and surface precipitation of flooding surfactants on reservoir minerals. Effect of surfactant structure, surfactant combinations, other inorganic and polymeric species is being studied. A multi-pronged approach consisting of micro and nano spectroscopy, microcalorimetry, electrokinetics, surface tension and wettability is used to achieve the goals. The results of this study should help in controlling surfactant loss in chemical flooding and also in developing optimum structures and conditions for efficient chemical flooding processes.

DOE/BC/14885-10 **Development of Cost-Effective Surfactant Flooding Technology. Annual Report for September 30, 1993 to September 29, 1994. University of Texas. August 1995. 104 pp. Order No. DE95000180.** This research consists of the parallel development of a new chemical flooding simulator and the application of our existing UTCHEM simulation code to model surfactant flooding. The new code is based upon a completely new numerical method that combines for the first time higher-order finite-difference methods, flux limiters, and implicit algorithms. Results indicate that this approach has significant advantages in some problems and will likely enable us to simulate much larger and more realistic chemical floods once it is fully developed. Additional improvements have also been made to the UTCHEM code, and it has been applied to the study of stochastic reservoirs with and without horizontal wells to evaluate methods to reduce the cost and risk of surfactant flooding. During the second year of this contract, significant progress has already been made on both of these tasks.

DOE/BC/14886-14 **Investigation of Oil Recovery Improvement by Coupling an Interfacial Tension Agent and a Mobility Control Agent in Light Oil Reservoirs. Final Report. Surtek, Inc. December 1995. 72 pp. Order No. DE96001204.** This report studied the oil recovery potential of flooding light oil reservoirs by combining interfacial tension reducing agent(s) with a mobility control agent. The first objective was to define the mechanisms and limitations of co-injecting interfacial tension reduction agent(s) and a mobility control agent to recover incremental oil. Specifically, the study focused on the fluid-fluid and fluid-rock interactions. The fluid-fluid evaluations defined how the various alkalis and surfactants interact to develop low interfacial tension values and how physical parameters affect these interactions. The fluid-rock studies evaluated the effect of rock type on the oil recovery efficiency. The second objective was to evaluate the economics of the combination technology and investigate methods to make the process more profitable. Specific areas of study were to evaluate different chemical concentration tapers and the volume of chemical injection required to give optimal oil recovery.

NIPER/BDM-0074 **Chemical Systems for Improved Oil Recovery: Phase Behavior, Oil Recovery, and Mobility Control Studies. Topical Report. BDM-Oklahoma, Inc. September 1995. 76 pp. Order No. DE95000183.** Selected surfactant systems containing a series of ethoxylated nonionic surfactants in combination with an anionic surfactant system have been studied to evaluate phase behavior as well as oil recovery potential. These experiments were conducted to evaluate possible improved phase behavior and overall oil recovery potential of mixed surfactant systems over a broad range of conditions. The importance of maximizing the production of oil initially mobilized by surfactant chemical systems resulted in an evaluation of mobility control polymers for selected experimental conditions. Both polyacrylamide polymers and Xanthan biopolymers were evaluated. In addition, studies were initiated to use a chemical flooding simulation program, UTCHEM, to simulate oil recovery for laboratory and field applications and evaluate its use to simulate oil saturation distributions obtained in CT-monitoring of oil recovery experiments.

Thermal Recovery

CONF-9502114 **Fueling for a Clean and Safe Environment. Volume 1. Proceedings for the 6th UNITAR International Conference on Heavy Crude and Tar Sands on February 12-17, 1995. 811 pp. Order No. DE95000188.** The theme for the conference was "Fueling for a Clean and Safe Environment." The program included 167 technical papers and poster presentations by authors representing 20 countries. Sessions subjects included Production, Field Projects, Processing and Refining, Environment, laboratory Studies, Upgrading, Numerical Simulation, Equipment, Reservoir Characterization, Handling and Transportation, Analytical Properties, Resource Development, and other Worldwide Activities.

CONF-9502114 **Fueling for a Clean and Safe Environment. Volume 2. Proceedings for the 6th UNITAR International Conference on Heavy Crude and Tar Sands on February 12-17, 1995. 733 pp. Order No. DE95000189.** The theme for the conference was "Fueling for a Clean and Safe Environment." The program included 167 technical papers and poster presentations by authors representing 20 countries. Sessions subjects included Production, Field Projects, Processing and Refining, Environment, laboratory Studies, Upgrading, Numerical Simulation, Equipment, Reservoir Characterization, Handling and Transportation, Analytical Properties, Resource Development, and other Worldwide Activities.

DOE/BC/14864-14 **Study of Hydrocarbon Miscible Solvent Slug Injection Process for Improved Recovery of Heavy Oil from Schrader Bluff Pool, Milne Point Unit, Alaska. Annual Report for January 1, 1994 to December 31, 1994. University of Alaska Fairbanks. July 1995. 120 pp. Order No. DE95000162.** The oil production in Alaska has started to decline in the early 1990's which is attributed to decline in the production from supergiant Prodhoe Bay field. In the 1990's, the National Energy Strategy Plan developed by U.S. Department of Energy called for 900,000 barrels/day production of heavy oil in the mid 1990's to meet the national demand. To meet this goal, it is imperative that Alaskan heavy oil fields be brought into production. Schrader Bluff reservoir, located in the Milne Point Unit, which is part of the heavy oil field known as West Sak, is estimated to contain 1.5 billion barrels of (14 to 21 degree API) oil-in-place. The field is currently under production by primary depletion. However, the primary recovery was expected to be much less than expected value of 12% because of complex reservoir structure. Hence, waterflood has been implemented earlier than anticipated. The eventual implementation of enhanced oil recovery (EOR) techniques will be vital for the recovery of additional oil from this reservoir.

DOE/BC/14899-24 **Flow and Displacement of Bingham Plastics in Porous Media. Topical Report. University of Southern California. July 1995. 32 pp. Order No. DE95000165.** Bingham plastics, which exhibit a finite yield stress at zero shear rate, have been used to model the flow behavior of certain heavy oils at reservoir conditions (Barenblatt et al., 1990). In such fluids, the onset of flow and displacement occurs only after the applied pressure gradient exceeds a minimum value. Understanding the flow behavior of such fluids has been limited to phenomenological approaches (Barenblatt et al., 1990, Wu et al. 1992). Numerical simulations and experimental visualization of flow and immiscible displacement of Bingham plastics in porous media using micromodels are presented. First, a novel pore network simulation approach to determine the onset of flow is described. The dependence of the critical yield stress on the pore-size distribution is discussed. Visualization experiments of the constant-rate immiscible displacement of Bingham plastics in glass micromodels and Hele-Shaw cells are next presented. The process is subsequently simulated in a pore network. Experiments are successfully simulated with the pore network model. The effect of the yield stress and injection rate on the displacement patterns is discussed. A classification of the displacement patterns, similar to that for Newtonian displacement is proposed (Lenormand, 1989).

DOE/BC/14899-25 **Visualization and Simulation of Immiscible Displacement in Fractured Systems Using Micromodels: Steam Injection. University of Southern California. July 1995. 36 pp. Order No. DE95000150.** A study of steam and hot water injection processes in micromodel geometries that mimic a matrix-fracture system was undertaken. The following was observed: light components existing in the crude oil generated a very high efficient gas-drive at elevated temperatures. This gas generation in conjunction with natural surfactant existing in the crude oil lead to the formation of a foam in the fracture and to improved displacement in the matrix. It was observed that the steam enters the fracture and the matrix depending on whether the steam rate exceeds or not the critical values. The resulting condensed water also moves preferentially into the matrix or the fracture depending on the corresponding capillary number. Since steam is a non-wetting phase as a vapor, but becomes a wetting phase when condensed in a water-wet system, steam injection involves both drainage and imbibition. It was found that all of the oil trapped by the condensed water can be mobilized and recovered when in contact with steam.

DOE/BC/14899-26 **Visualization and Simulation of Immiscible Displacement in Fractured Systems Using Micromodels: Imbibition. University of Southern California. July 1995. 52 pp. Order No. DE95000149.** A study of imbibition processes in micromodel geometries that mimic a matrix-fracture system was undertaken. Experiments in glass micromodels and pore network simulation were conducted. It was observed that, at low capillary number values the wetting fluid preferentially invaded the matrix. Two critical capillary numbers were identified, one for the start of penetration in the fracture when the viscosity ratio was much less than one, and another for which the rate of propagation of the front in the fracture is the same with that in the matrix, when the viscosity ratio was greater than one. These critical capillary numbers were well matched with the results of a pore network simulation. A simplified theory for both critical numbers was developed. Free imbibition in fractured system was investigated and compared favorably with pore network simulation. This process first involves the rapid invasion of the matrix, followed by the subsequent penetration of the fracture.

DOE/BC/14899-27 **Scaling of Bubble Growth in a Porous Medium. Topical Report. University of Southern California. July 1995. 16 pp. Order No. DE95000166.** Processes involving liquid-to-gas phase change in porous media are routinely encountered, for example in the recovery of oil, geothermal processes, nuclear waste disposal or enhanced heat transfer. They involve diffusion (and convection) in the pore space, driven by an imposed supersaturation in pressure or temperature. Phase change proceeds by nucleation and phase growth. Depending on pore surface roughness, a number of nucleation centers exist, thus phase growth occurs from a multitude of clusters. Contrary to growth in the bulk or in a Hele-Shaw cell, however, growth patterns in porous media are disordered and not compact. As in immiscible displacements, they reflect the underlying pore microstructure. The competition between multiple clusters is also different from the bulk. For example, cluster growth may be controlled by a combination of diffusion with percolation. Novel growth patterns are expected from this competition.

DOE/BC/14899-28 **SUPRI Heavy Oil Research Program. Annual Report for February 8, 1994 to February 7, 1995. Stanford University. July 1995. 184 pp. Order No. DE95000167.** The goals of this project are to 1) assess the influence of different reservoir conditions (temperature and pressure) on the absolute and relative permeability to oil and water and on capillary pressure; 2) evaluate the effect of different reservoir parameters on the in-situ combustion process. This project includes the study of the kinetics of the reactions; 3) develop and understand the mechanisms of the process using commercially available surfactants for reduction of gravity override and channeling of steam; 4) develop and improve techniques of formation evaluation such as tracer tests and pressure transient tests; and 5) provide technical support for design and monitoring of DOE-sponsored or industry-initiated field projects.

DOE/BC/95000151 **Multifrequency Crosshole EM Imaging for Reservoir Characterization. FY 1994 Annual Report. Lawrence Berkeley Laboratory. June 1995. 12 pp. Order No. DE95000151.** Electrical conductivity of sedimentary rock is controlled by the porosity, hydraulic permeability, temperature, saturation, and the pore fluid conductivity. These rock parameters play important roles in the development and production of hydrocarbon (petroleum and natural gas) resources. For these reasons, resistivity well logs have long been used by geologists and reservoir engineers in petroleum industries to map variations in pore fluid, to distinguish between rock types, and to determine completion intervals in wells. It is therefore a natural extension to use the electrical conductivity structure to provide additional information about the reservoir. Reservoir simulation and process monitoring rely heavily on the physical characteristics of the reservoir model. At present, numerical codes use point measurements of porosity, permeability, and fluid saturation and extrapolate these data throughout a three-dimensional (3-D) grid. The knowledge of a high-resolution geophysical parameter such as electrical conductivity would aid this extrapolation and improve the reservoir simulation effort. In addition, since conductivity is sensitive to changes in the composition and state of fluids in pores and fractures it becomes an ideal method for monitoring a reservoir process.

DOE/BC/95000152 **Electrical and Electromagnetic Methods for Reservoir Description and Process Monitoring. Annual Report for October 1, 1992 to September 30, 1993. Lawrence Berkeley Laboratory. July 1995. 20 pp. Order No. DE95000152.** At the beginning of FY 91 a coordinated electrical and electromagnetic (EM) geophysical research program for petroleum reservoir characterization and process monitoring was initiated. The overall objectives of the program were to: integrate research funded by DOE for hydrocarbon recovery into a focused effort to demonstrate the technology in the shortest time with the least cost; assure industry acceptance of the technology developed by having industry involvement in the planning, implementation, and funding of the research; and focus the research on real world problems that have the potential for solution in the near term with significant energy payoff. Specific research activities conducted through this integrated effort have been in the following five general areas: EM modeling development, data interpretation methods development, hardware and instrumentation development, EOR and reservoir characterization, and controlled field experiments.

DOE/BC/95000153 **Electrical and Electromagnetic Methods for Reservoir Description and Process Monitoring. Annual Report for October 1, 1991 to September 30, 1992. Lawrence Berkeley Laboratory. July 1995. 28 pp. Order No. DE95000153.** One of the important geophysical parameters that can be used to help monitor and characterize a petroleum reservoir is the electrical conductivity. The electrical conductivity of rock is dominantly a function of fluid type, its saturation, the porosity, and hydraulic permeability of the rock. For these reasons, resistivity well logs have long been used by geologists and reservoir engineers in petroleum industries to map variations in pore fluid, to distinguish between rock types, and to determine completion intervals in wells. It is therefore a natural extension to use the electrical conductivity structure to provide additional information about the reservoir. Reservoir simulation and process monitoring rely heavily on the physical characteristics of the reservoir model. At present, numerical codes use point measurements of porosity, permeability, and fluid saturation and extrapolate these data throughout a three-dimensional (3-D) grid. The knowledge of a high-resolution geophysical parameter such as electrical conductivity would aid this extrapolation and improve the reservoir simulation effort. In addition, since conductivity is sensitive to changes in the composition and state of fluids in pores and fractures it becomes an ideal method for monitoring a reservoir process.

DOE/BC/95000168 **Foam Flow Through a Transparent Rough-Walled Rock Fracture. Lawrence Berkeley Laboratory. July 1995. 36 pp. Order No. DE95000168.** This paper presents an experimental study of nitrogen, water, and aqueous foam flow through a transparent replica of a natural rough-walled rock fracture with a hydraulic aperture of roughly 30μm. It is established that single-phase flow of both nitrogen and water is well described by analogy to flow between parallel plates. Inertial effects caused by fracture roughness become important in single-phase flow as the Reynolds number approaches 1. Foam exhibits effective control of gas mobility. Foam flow resistances are approximately 10 to 20 times

greater than those of nitrogen over foam qualities spanning from 0.60 to 0.99, indicating effective gas-mobility control. Because previous studies of foam flow have focused mainly upon unfractured porous media, little information is available about foam flow mechanisms in fractured media. The transparency of the fracture allowed flow visualization and demonstrated that foam rheology in fractured media depends upon bubble shape and size. Changes in flow behavior are directly tied to transitions in bubble morphology.

DOE/BC/95000169 **Population Balance Model for Transient and Steady-State Foam Flow in Boise Sandstone. Lawrence Berkeley Laboratory. July 1995. 60 pp. Order No. DE95000169.** An experimental and mechanistic-modeling study is reported for the transient flow of aqueous foam through 1.3-μm2 (1.3-D) Boise sandstone at backpressures in excess of 5 Mpa (700 psi) over a quality range from 0.80 to 0.99. Total superficial velocities range from as little as 0.42 to 2.20 m/day (1.4 ft/day to 7 ft/day). Sequential pressure taps and gamma-ray densitometry measure flow resistance and in-situ liquid saturations, respectively. Experimental pressure and saturation profiles in both the transient and steady states are garnered. Adoption of a mean-size foam-bubble conservation equation along with the traditional reservoir simulation equations allows mechanistic foam simulation.

Geoscience

DOE/BC/14477-18 **An Experimental and Theoretical Study to Relate Uncommon Rock/Fluid Properties to Oil Recovery. Final Report. Pennsylvania State University. July 1995. 340 pp. Order No.DE95000164.** The most commonly used secondary oil recovery technique is waterflooding. Macroscopic (or common) rock-pore characteristics such as porosity, permeability, and irreducible water saturation and fluid properties such as viscosity have been shown by previous investigators to influence the results of waterflooding and consequently ultimate oil recovery. The objectives of this study are to consider the influence of microscopic (or uncommon) rock-pore characteristics such as wettability, tortuosity, mercury intrusion volume, pore surface area, specific surface area, average pore diameter, median pore-throat diameter, pore length, apparent (skeletal) density and mercury recovery efficiency on residual oil saturation and oil recovery realized in linear-core waterfloods. The results were statistically analyzed to determine the quantitative relations between the various properties, and empirical equations were developed for predicting waterflood performance. The characteristics were analyzed and modeled at both breakthrough and floodout.

Resource Assessment Technology

DOE/BC/14831-14 **Assist in the Recovery of Bypassed Oil from Reservoirs in the Gulf of Mexico. Annual Report for February 18, 1994 to February 18, 1995. Louisiana State University. September 1995. 244 pp. Order No. DE95000185.** During the past year, a report on the simulation work performed on the U-8 reservoir was completed. Also, modifications to handle steeply dipping reservoirs have been successfully implemented in the MASTER simulator and critical process parameter laboratory experiments and computer simulations of the experiments have been completed. In addition, development of predictive models for undeveloped oil and immiscible/miscible processes began. The methodology for determination of undeveloped potential has been completed. The design of the miscible and updip displacement models as well as the design of the economic and timing models is under way. The coding and calibration of the models began. Data validation, map measurements, model development and supporting cost data collection was in progress.

Gas Displacement

DOE/BC/14862-10 **Productivity and Injectivity of Horizontal Wells. Annual Report for March 10, 1994 to March 9, 1995. Stanford University. July 1995. 172 pp. Order No. DE95000163.** This project has eight principal goals to be studied and developed over a five-year period. These goals are as follows: Task 1 is to develop special gridding techniques and associated averaging algorithms for accurate simulation of HW-performance. Task 2 is to study impacts of various types of heterogeneity and develop methods for incorporating their effects in both fine-grid and coarse-grid models. Task 3 is to plan, execute, and interpret two-phase flow experiments at an oil company research facility, and use results to analyze/validate a new two-phase model. Task 4 is to define improved methods for computing two-phase pseudo-functions for effective relative permeabilities for coarse grid blocks near an HW - determine sensitivities to heterogeneities, flow conditions, skin factors, etc. Task 5 is to develop numerical techniques and software in a parallel computing architecture capable of interactively coupling multiple detailed HW - models to a large scale reservoir simulator. Task 6 is to work with affiliate's member companies to establish HW-modeling capabilities from field measurements, particularly for pathological problem cases. Task 7 is to provide and implement practical HW aspects into modeling of EOR processes - miscible gas, steam displacement, in-situ combustion. Task 8 is to seek field opportunities for HW's and study their best implementation in various reservoir scenarios e.g., multiple laterals, hydraulic fracture variants, etc.

DOE/BC/14977-6 **Improved Efficiency of Miscible CO_2 Floods and Enhanced Prospects for CO_2 Flooding Heterogeneous Reservoirs. Annual Report for April 14, 1994 to April 13, 1995. New Mexico Institute of Mining and Technology. September 1995. 80 pp. Order No. DE95000187.** The overall goal of this project is to improve the efficiency of miscible CO_2 floods and enhance the prospects for flooding heterogeneous reservoirs. This objective is being accomplished by extending experimental research in three task areas: 1) foams for selective mobility control in heterogeneous reservoirs, 2) reduction of the amount of CO_2 required in CO_2 floods, and 3) miscible CO_2 flooding in fractured reservoirs. In the first task, a desirable characteristic of CO_2-foam called Selective Mobility Reduction (SMR) that promises an improvement in displacement efficiency by reducing the effects of reservoir heterogeneity is investigated. In the second task, preliminary results on the phase behavior tests of a West Texas crude with CO_2 are reported. In the third task, the results of prediction of multicomponent, reservoir condition interfacial tension (IFT) are reported.

Reservoir Characterization

DOE/BC/14894-5 **Application of Artificial Intelligence to Reservoir Characterization. Annual Report for October 1993 to October 1994. The University of Tulsa. July 1995. 72 pp. Order No. DE95000145.** The basis of this research is to apply novel techniques from Artificial Intelligence and Expert Systems in capturing, integrating and articulating key knowledge from geology, geostatistics, and petroleum engineering to develop accurate descriptions of petroleum reservoirs. The ultimate goal is to design and implement a single powerful expert system for use by small producers and independents to efficiently exploit reservoirs.

DOE/BC/14896-6 **Geological and Petrophysical Characterization of the Ferron Sandstone for 3-D Simulation of a Fluvial-Deltaic Reservoir. Annual Report for September 29, 1993 to September 29, 1994. Utah Geological**

Survey. July 1995. 52 pp. Order No. DE95000172. The objective of the Ferron Sandstone project is to develop a comprehensive, interdisciplinary, quantitative characterization of a fluvial-deltaic reservoir to allow realistic inter-well and reservoir-scale models to be developed for improved oil-field development in similar reservoirs worldwide. Quantitative geological and petrophysical information on the Cretaceous Ferron Sandstone in east-central Utah will be collected. Both new and existing data will be integrated into a three-dimensional model of spatial variations in porosity, storativity, and tensorial rock permeability at a scale appropriate for inter-well to regional-scale reservoir simulation. Simulation results could improve reservoir management through proper infill and extension drilling strategies, reduction of economic risks, increased recovery from existing oil fields, and more reliable reserve calculations. Transfer of the project results to the petroleum industry is an integral component of the project. This report covers research activities for fiscal year 1993-94, the first year of the project. Most work consisted of developing field methods and collecting large quantities of existing and new data.

DOE/BC/14897-6 **Anisotropy and Spatial Variation of Relative Permeability and Lithologic Character of Tensleep Sandstone Reservoirs in the Bighorn and Wind River Basins, Wyoming. Annual Report for September 15, 1993 to September 30, 1994. University of Wyoming. July 1995. 80 pp. Order No. DE95000156.** This research will associate spatial distributions and anisotropy of relative permeability with the depositional subfacies and zones of diagenetic alteration found within the Tensleep Sandstone. The associations between depositional lithofacies diagenetic alteration, and pore geometry will link relative permeability with the distinct and measurable dimensions of lithofacies, and authigenic mineral facies. Effects of the depositional processes and burial diagenesis will be investigated. The primary goal of this task is to establish the regional trends and variations in lithologic character of the eolian and marine subfacies of the upper Tensleep Sandstone in the Bighorn and Wind River basins.

Field Demonstrations

DOE/BC/14953-10 **Increased Oil Production and Reserves from Improved Completion Techniques in the Bluebell Field, Uinta Basin, Utah. Annual Report for September 30, 1993 to September 30, 1994. Utah Geological Survey. July 1995. 132 pp. Order No. DE95000171.** The Bluebell field produces from the Tertiary lower Green River and Wasatch Formations of the Uinta Basin, Utah. The productive interval consists of thousands of feet of interbedded fractured clastic and carbonate beds deposited in a fluvial-dominated deltaic lacustrine environment. Although some wells have produced over 1 million barrels (159,000 m3) of oil, many have produced only 100,000 to 250,000 barrels (15,000-31,000 m3), or less, of oil. The lower portion of the productive interval is overpressured, requiring that approximately 10,000 feet (3,050 m) of intermediate casing be set. The final 2,000 to 4,000 feet (610-1,220 m) of drilling is slow and difficult requiring weighted mud. Wells are typically completed by perforating 40 or more beds over 1,000 to 3,000 vertical feet (305-915 m), then applying an acid-frac treatment to the entire interval. This completion technique is believed to leave many potentially productive beds damaged and/or untreated, while opening up some water and thief zones.

DOE/BC/14954-5 **Advanced Secondary Recovery Demonstration for the Sooner Unit. Annual Report for October 1992 to May 1993. Diversified Operating Corporation. July 1995. 160 pp. Order No. DE95000170.** The objective of this project is to demonstrate the effectiveness of a multi-disciplinary approach to targeted infill drilling and improved reservoir management. The first phase of the project involves geophysical, geological and engineering data acquisition and analysis to identify optimum well sites and to develop a reservoir operations plan, maximizing secondary recovery using water injection and gas recycling. The second phase will involve drilling of up to three geologically targeted infill wells and establishing production/injection schedules. Reservoir simulation, transient well tests and careful production monitoring will be used to evaluate the results. The third phase will involve technology transfer through a series of technical papers and presentations of a short course. Emphasis will be on the economics of the project and the implemented technologies. This report summarizes the activities, results and conclusions from Phase I activities of the Sooner Unit Project. The Sooner Unit is located in Weld County, Colorado and produces from the "d" sandstone member of the Upper Cretaceous Graneros formation at a depth of about 6,300 ft.

DOE/BC/14955-8 **Applications of Advanced Petroleum Production Technology and Water Alternating Gas Injection for Enhanced Oil Recovery - Mattoon Oil Field, Illinois. Final Report. American Oil Recovery, Inc. September 1995. 80 pp. Order No. DE95000184.** Phase I results of a CO_2-assisted oil recovery demonstration project in selected Cypress Sandstone reservoirs at Mattoon Field, Illinois are reported. The design and scope of this project included CO_2 injectivity testing in the Pinnell and Sawyer units, well stimulation treatments with CO_2 in the Strong unit, and infill well drilling, completion and oil production. The field activities were supported by extensive CO_2-oil-water coreflood experiments, CO_2-oil phase interaction experiments, and integrated geologic modeling and reservoir simulations. Five Cypress Sandstone layers ("A", "B", "C", "D", "E") were identified within the study area in Mattoon Field. Three-dimensional geologic models, created from well data, were used to interpret the location, size and continuity of the productive intervals. The CO_2 injectivity tests were performed in the "A" interval in the Pinnell unit, "E" interval in the Sawyer unit and "D" interval in the Strong unit.

DOE/BC/14957-7 **Improved Oil Recovery in Fluvial Dominated Deltaic Reservoirs of Kansas - Near-Term. Annual Report for June 18, 1993 to June 18, 1994. The University of Kansas. October 1995. 204 pp. Order No. DE95000161.** Common oil field problems exist in fluvial dominated deltaic reservoirs in Kansas. The problems are poor waterflood sweep and lack of reservoir management. The poor waterflood sweep efficiency is the result of 1) reservoir heterogeneity, 2) channeling of injected water through high permeability zones or fractures, and 3) clogging of water injection wells with solids as a result of poor water quality. In many instances the lack of reservoir management results from failure to 1) collect and organize data, 2) integrate analyses of existing data by geological and engineering personnel, and 3) identify optimum recovery techniques.

DOE/BC/14958-11 **Green River Formation Water Flood Demonstration Project. Annual Report for April 1, 1994 to March 31, 1995. Lomax Exploration Company. September 1995. 72 pp. Order No. DE95000182.** The successful water flood of the Green River Formation in the Monument Butte unit was analyzed in detail in the last yearly report. It was shown that primary recovery and the water flood in the unit were typical of oil production from an undersaturated oil reservoir close to its bubble point. The reservoir performance of the smaller Travis unit was also analyzed. The Monument Butte unit is currently producing at around 300 barrels per day of oil. Two of the new wells drilled in the unit had zones pressurized by the water flood. The third well produced from pressurized as well as from zones which were unaffected by the water flood. The water flood response of the Travis unit is slow, possibly because of problems

with reservoir continuity. Water injection continues in the unit and the reservoir pressure is increasing steadily. The new well that was drilled in Travis did not intersect the Lower Douglas Creek Sand into which most of the water has been injected. Plans for water flooding the Boundary unit were drawn.

DOE/BC/14959-13 **Revitalizing a Mature Oil Play: Strategies for Finding and Producing Unrecovered Oil in Frio Fluvial-Deltaic Sandstone Reservoirs of South Texas. Annual Report for October 1993 to October 1994. The University of Texas at Austin. July 1995. 168 pp. Order No. DE95000160.** The objectives of this project are to develop interwell-scale geological facies models of Frio fluvial-deltaic reservoirs from selected fields in South Texas and combine them with engineering assessments to characterize reservoir architecture and flow-unit boundaries and to try to determine the controls that these characteristics exert on the location and volume of unrecovered mobile and residual oil. Results of these studies should lead directly to the identification of specific near-term opportunities to exploit these heterogeneous reservoirs for incremental recovery by recompletion and strategic infill drilling.

DOE/BC/14959-15 **Strategies for Reservoir Characterization and Identification of Incremental Recovery Opportunities in Mature Reservoirs in Frio Fluvial-Deltaic Sandstones, South Texas: An Example from Rincon Field, Starr County. Topical Report. The University of Texas at Austin. November 1995. 120 pp. Order No. DE95000190.** Fluvial-deltaic sandstone reservoirs in the United States are being abandoned at high rates, yet they still contain more than 34 billion barrels of unrecovered oil. The mature Oligocene-age fluvial-deltaic reservoirs of the Frio Formation along the Vicksburg Fault Zone in South Texas are typical of this class in that, after more than three decades of production, they still contain 61 percent of the original mobile oil in place, or 1.6 billion barrels. This resource represents a tremendous target for advanced reservoir characterization studies that integrate geological and engineering analysis to locate untapped and incompletely drained reservoir compartments isolated by stratigraphic heterogeneities.

DOE/BC/14960-8 **Post Waterflood CO_2 Miscible Flood in Light Oil, Fluvial-Dominated Deltaic Reservoir. Annual Report for October 1, 1993 to September 30, 1994. Texaco Exploration and Production. July 1995. 52 pp. Order No. DE95000173.** Texaco Exploration and Production Inc. (TEPI) and the U. S. Department of Energy (DOE) entered into a cost sharing cooperative agreement to conduct an Enhanced Oil Recovery demonstration project at Port Neches. The field is located in Orange County near Beaumont, Texas. The project will demonstrate the effectiveness of the CO_2 miscible process in Fluvial Dominated Deltaic reservoirs. It will also evaluate the use of horizontal CO_2 injection wells to improve the overall sweep efficiency. A database of FDD reservoirs for the gulf coast region will be developed by Louisiana State University, using a screening model developed by Texaco Research Center in Houston. Finally, the results and the information gained from this project will be disseminated throughout the oil industry via a series of Society of Petroleum Engineers papers and industry open forums.

DOE/BC/14962-7 **The Utilization of the Microflora Indigenous to and Present in Oil-Bearing Formations to Selectively Plug the More Porous Zones Thereby Increasing Oil Recovery During Waterflooding. Annual Report for January 1, 1994 to December 31, 1994. Hughes Eastern Corporation. August 1995. 60 pp. Order No. DE95000177.** This project is a field demonstration of the ability of in-situ indigenous microorganisms in the North Blowhorn Creek Oil Field to reduce the flow of injection water in the more permeable zones thereby diverting flow to other areas of the reservoir and thus increasing the efficiency of the waterflooding operation. This effect is to be accomplished by adding inorganic nutrients in the form of potassium nitrate and orthophosphate to the injection water. Work on the project is divided into three phases, Planning and Analysis (9 months), Implementation (45 months), and Technology Transfer (12 months).

DOE/BC/14983-5 **Recovery of Bypassed Oil in the Dundee Formation Using Horizontal Drains. Annual Report for April 1994 to June 1995. Michigan Technological University. August 1995. 260 pp. Order No. DE95000181.** Devonian rocks have been the most prolific hydrocarbon producers in the Michigan Basin. The Traverse, Dundee, and Lucas Formations have produced more than half of Michigan's oil since the late 1920's. The Dundee Formation is Michigan's all-time leader with 352 million barrels of oil and 42 billion cubic feet of gas. About 30% of the original oil in place and 80% of the original gas in place is usually recovered from hydrocarbon reservoirs during the initial production phase. This project will demonstrate through a field trial that horizontal wells can substantially increase oil production in older reservoirs that are at or near their economic limit. To maximize the potential of the horizontal well and to ensure that a comprehensive evaluation can be made, extensive reservoir characterization will be performed. In addition to the proposed field trial at Crystal Field, 29 additional Dundee fields in a seven-county area have been selected for study in the reservoir characterization portion of this project.

DOE/BC/14984-5 **Improved Recovery Demonstration for Williston Basin Carbonates. Annual Report for June 10, 1994 to June 9, 1995. Luff Exploration Company. September 1995. 88 pp. Order No. DE95000186.** The purpose of this project is to demonstrate targeted infill and extension drilling opportunities, better determinations of oil-in-place, methods for improved completion efficiency and the suitability of waterflooding in Red River and Ratcliffe shallow-shelf carbonate reservoirs in the Williston Basin, Montana, North Dakota and South Dakota. Improved reservoir characterization utilizing three-dimensional and multi-component seismic are being investigated for identification of structural and stratigraphic reservoir compartments. These seismic characterization tools are integrated with geological and engineering studies. Improved completion efficiency is being tested with extended-reach jetting lance and other ultra-short-radius lateral technologies. Improved completion efficiency, additional wells at closer spacing and better estimates of oil in place will result in additional oil recovery by primary and enhanced recovery processes.

Environmental

DOE/MT/92006-9 **The Cost of Wetland Creation and Restoration. Final Report. University of Maryland. August 1995. 120 pp. Order No. DE95000174.** This report examines the economics of wetland creation, restoration, and enhancement projects, especially as they are used within the context of mitigation for unavoidable wetland losses. Complete engineering-cost-accounting profiles of over 90 wetland projects were developed in collaboration with leading wetland restoration and creation practitioners around the country to develop a primary source database. Data on the costs of over 1,000 wetland projects were gathered from published sources and other available databases to develop a secondary source database. Cases in both databases were carefully analyzed and a set of baseline cost per acre estimates were developed for wetland creation, restoration, and enhancement.

DOE/MT/92007-9 **Characterization of Oil and Gas Waste Disposal Practices and Assessment of Treatment Costs. Final Report. Rice University. August 1995. 220 pp. Order No. DE95000175.** This study examines wastes associated with the onshore exploration and production of crude oil and natural gas in the United States. The objective of this study was to update and enhance the current state of knowledge with regard to oil and gas waste quantities, the potential environmental impact of these wastes, potential methods of treatment, and the costs associated with meeting various degrees of treatment. To meet this objective, the study consisted of three tasks: 1) the development of a Production Environmental Database (PED) for the purpose of assessing current oil and gas waste volumes by state and for investigating the potential environmental impacts associated with current waste disposal practices on a local scale; 2) the evaluation of available and developing technologies for treating produced water waste streams and the identification of unit process configurations; and 3) the evaluation of the costs associated with various degrees of treatment achievable by different treatment configurations.

DOE/MT/92008-10 **Oil Production Enhancement Through a Standardized Brine Treatment. Final Report. Pennsylvania State University. August 1995. 272 pp. Order No. DE95000179.** The Pennsylvania Oil and Gas Association (POGA) approached the Pennsylvania State University to develop a program designed to demonstrate that a treatment process to meet acceptable discharge conditions and effluent limitations can be standardized for all potential stripper well brine discharge. This project has been under way since 1987. A bench-scale prototype model was developed for conducting experiments in laboratory conditions. The experiments in the laboratory conditions were focused on the removal of ferrous iron from synthetically made brine. The results of a number of experiments in the lab were indicative of the capability of the proposed brine treatment process in the removal of iron. In the second phase of this project, a field-based prototype was developed to evaluate and demonstrate the treatment process effectiveness. These experiments were conducted under various conditions and included the testing on five brines from different locations with dissolved constituents.

DOE/MT/92010-10 **Wetland Treatment of Oil and Gas Well Waste Waters. Final Report. University of Michigan. August 1995. 64 pp. Order No. DE95000176.** Constructed wetlands are small, on-site systems that possess three of the most desirable components of an industrial waste water treatment scheme: low cost, low maintenance and upset resistance. The main objectives of the present study is to extend the knowledge base of wetland treatment systems to include processes and substances of particular importance to small, on-site systems receiving oil and gas well wastewaters. A list of the most relevant and comprehensive publications on the design of wetlands for water quality improvement was compiled and critically reviewed. Based on our literature search and conversations with researchers in the private sector, toxic organics such as phenolics and b-naphthoic acid, (NA), and metals such as Cu(II) and Cr(VI) were selected as target adsorbates. A total of 90 lysimeteres equivalent to a laboratory-scale wetland were designed and built to monitor the uptake and transformation of toxic organics and the immobilization of metal ions.

DOE/MT/92011-12 **Geologic, Geochemical, and Geographic Controls on NORM in Produced Water from Texas Oil, Gas, and Geothermal Reservoirs. Final Report. The University of Texas at Austin. August 1995. 76 pp. Order No. DE95000178.** Water from Texas oil, gas, and geothermal wells contains natural radioactivity that ranges from several hundred to several thousand picocuries per liter (pCi/L). This natural radioactivity in produced fluids and the scale that forms in producing and processing equipment can lead to increased concerns for worker safety and additional costs for handling and disposing of water and scale. Naturally occurring radioactive materials (NORM) in oil and gas operations are mainly caused by concentrations of radium-226 and radium-228, daughter products of uranium-238 and thorium-232, respectively, in barite scale. The following areas are examined (1) the geographic distribution of high NORM levels in oil-producing and gas-processing equipment, (2) geologic controls on uranium, thorium, and radium in sedimentary basins and reservoirs, (3) mineralogy of NORM scale, (4) chemical variability and potential to form barite scale in Texas formation waters, (5) radium activity in Texas formation waters, and (6) geochemical controls on radium isotopes in formation water and barite scale to explore natural controls on radioactivity. The approach combined extensive compilations of published data, collection and analyses of new water samples and scale material, and geochemical modeling of scale precipitation and radium incorporation in barite.

Microbial Technology

BNL 60119 **Effects of Selected Thermophilic Microorganisms on Crude Oils at Elevated Temperatures and Pressures. Final Report. Brookhaven National Laboratory. July 1995. 184 pp. Order No. DE95000159.** During the past several years, a considerable amount of work has been carried out showing that microbially enhanced oil recovery (MEOR) is promising and the resulting biotechnology may be deliverable. At the Brookhaven National Laboratory (BNL), systematic studies have been conducted which dealt with the effects of thermophilic and thermoadapted bacteria on the chemical and physical properties of selected types of crude oils at elevated temperatures and pressures. Current studies indicate that during the biotreatment several chemical and physical properties of crude oils are affected.

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1. DOE/BC-88/1/SP. ***EOR Predictive Models***: Handbook for Personal Computer Versions of Enhanced Oil Recovery Predictive Models. BPO Staff. February 1988. 76 pp. NTIS Order No. DE89001204. FORTRAN source code and executable programs for five EOR Predictive Models shown below are available. The five recovery processes modeled are Steamflood, In-Situ Combustion, Polymer, Chemical, and CO_2 Miscible Flooding. The models are available individually. Min Req.: IBM PC/XT, PS-2, or compatible computer with 640 Kbytes of memory.

   a- DOE/BC-86/6/SP. ***Steamflood Predictive Model***, Supporting Technology for Enhanced Oil Recovery, Fossil Energy Report III-2. December 1986. 594 pp. NTIS Order No. DE87001219.

   b- DOE/BC-86/7/SP. ***In-Situ Combustion Predictive Model***, Supporting Technology for Enhanced Oil Recovery, Fossil Energy Report III-3. December 1986. 263 pp. NTIS Order No. DE86000264.

   c- DOE/BC-86/10/SP. ***Polymer Predictive Model***, Supporting Technology for Enhanced Oil Recovery, Fossil Energy Report III-4. December 1986. 394 pp. NTIS Order No. DE87001207.

   d- DOE/BC-86/11/SP. ***Chemical Flood Predictive Model***, Supporting Technology for Enhanced Oil Recovery, Fossil Energy Report III-5. December 1986. 360 pp. NTIS Order No. DE87001208.

   e- DOE/BC-86/12/SP. ***CO_2 Miscible Flood Predictive Model***, Supporting Technology for Enhanced Oil Recovery, Fossil Energy Report III-6. December 1986. 469 pp. NTIS Order No. DE87001209.

2. DOE/BC-95/2/SP. ***Infill Drilling Predictive Model:*** User's Guide and Documentation Manual - Release 1.2.0, 1995 for the PC. FORTRAN source code and executable program. Min Req.: 80386/80387, DOS v3.1, and 2 Mbytes extended memory.

3. DOE/BC-86/10/SP. ***Polymer/Waterflood Predictive Model: Windows Version 1.1*** June 1995. This is an update to the Polymer Flood Predictive Model (PFPM) released in 1986. An addendum is available describing the updated economic cost and tax functions included in this release. This serves as a supplement to the original PFPM user's manual. This version runs out of the Microsoft Windows environment and supports post-processing graphics. Min Req.: 80386, 4 Mbytes extended memory, and Windows v3.1.

4. ***CO_2 Prophet:*** Water and CO_2 Flood Prediction Software. CO_2 Prophet, conceived by Texaco Exploration and Production Technology Department (EPTD), was partially developed as part of the DOE Class I cost share program *"Post Waterflood, CO2 Flood in a Light Oil, Fluvial Dominated Deltaic Reservoir"* under DOE Contract No. DE-FC22-93BC14960. Min Req.: 80386/80387 and 4 Mbytes extended memory and will run under the Microsoft Windows environment. The DOE does not provide technical support for this application.

5. DOE/BC-89/3/SP. Handbook for Personal Computer Version of ***BOAST II***: A Three-Dimensional, Three-Phase Black Oil Applied Simulation Tool. Bartlesville Project Office. January 1989. 82 pp. NTIS Order No. DE89000725. FORTRAN source code and executable program. Min. Req.: IBM PC/AT, PS-2, or compatible computer with 640 Kbytes of memory.

6. NIPER-542. User's Guide and Documentation Manual for ***BOAST-VHS***. National Institute for Petroleum and Energy Research (NIPER). January 1992. 92 pp. NTIS Order No. DE92001021. FORTRAN source code and executable program. Min. Req.: IBM PC/AT, PS-2, or compatible computer with 640 Kbytes of memory. Math coprocessor optional

7. DOE/BC-91/2/SP. ***MASTER***: Miscible Applied Simulation Techniques for Energy Recovery - Version 2.0. User's Guide and Technical Manual. Morgantown Energy Technology Center (METC). February 1991. 192 pp. NTIS Order No. DE91002222. FORTRAN source code and executable program. Min. Req.: See Users Guide.

8. NIPER-705. ***PC-GEL:*** A Three-Dimensional, Three-Phase, Permeability Modification Simulator. IIT Research Institute, National Institute for Petroleum and Energy Research (NIPER). October 1993. 190 pp. NTIS Order No. DE94000104. FORTRAN source code and executable program. Min. Req.: IBM PC/AT, PS-2, or compatible computer with 640 Kbytes of memory. Math coprocessor optional

9. DOE/BC/20006-18. ***TRACRL-Single-Well Chemical Tracer Test Simulator***. A deliverable as part of *"The Single-Well Chemical Tracer Method for Measuring Residual Oil Saturation-Final Report."* Bartlesville Energy Technical Center (BETC), predecessor to National Institute for Petroleum and Energy Research (NIPER). October 1980. 190 pp. FORTRAN source code and sample input datasets for both PC and Apple environments. Executable program for the PC.

10. ***UTCHEM:*** A Three-Dimensional Chemical Flood Simulator, version 5.1, May 1992. Developed under the Enhanced Oil and Gas Recovery Research Program at the Center for Petroleum and Geosystems Engineering, The University of Texas at Austin. This software is not distributed or supported by the DOE. Contact Dr. Gary Pope at (512) 471-7234 for details.

11. ***NPC Public Database:*** (NPCPUBDB.GEO) Database developed for the National Petroleum Council (NPC) for its 1984 assessment of the nation's enhanced oil recovery (EOR) potential. The technical data description is at the reservoir level. Included with the database are the Appendices from the *"TORIS Data Preparation Guidelines"* (NIPER/BDM-0042) defining the data elements in the database.

12. ***CLEVER:*** Class Evaluation Executive Report, Version 2.0, 1995. Database application describing information from the DOE's Geologic/Reservoir Class Program. Developed at National Institute for Petroleum and Energy Research (NIPER) by BDM-Oklahoma, Inc. This includes administrative and general technical data. Classes 1 - 3 are included to date. PC and Apple versions are available. Distributed as an executable program, FoxPro application not required. Min Req.: Windows v3.1 and/or Apple System 7.1, and an 80386 or 68030, respectively.

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