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QUARTERLY REPORT

MICHIGAN TECHNOLOGICAL UNIVERSITY

JANUARY, 1994

Visual Display of Reservoir Parameters Affecting Enhanced Oil Reservoirs

Contract Number: DE-AC22-93BC14892

University: Michigan Technological University

Contract Date: 29 September 1993

Completion Date: 30 September 1996

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Reporting Period: 1st Quarter, FY 1994

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EXECUTIVE SUMMARY

Two organizational meetings were held during the month of October and a data gathering and decision-making session was held in late November and early December.

Between October 14 and October 20, J. R. Allan and A. Nigrini visited the Michigan Technological University (MTU) campus to meet the faculty and students who are involved in the project and to discuss project goals, facilities, and lines of communication.

On October 27, the first formal meeting and planning session for project members was held in Bakersfield, CA. J. R. Wood, C. A. Salotti, J. R. Allan, and A. Nigrini, and graduate student C. McKissock represented MTU, while W. R. Berry and D. M. Olson represented Digital Petrophysics Inc. (DPI). The purpose of the meeting was to assemble the project team, review the Statement of Work, and assure that all project members were aware of their responsibilities.

During the week of November 29 to December 3, A. Nigrini, J. R. Allan, and J. R. Wood met the DPI offices to organize and collect data and to coordinate the next several months' efforts with Berry and Olson.

The technical progress for the quarter is summarized below by Task and Subtask.

OBJECTIVES

The principal objective of this project is to provide the small-to-medium-sized oil-field operator with the tools necessary to undertake an EOR reservoir characterization and evaluation of similar quality and sophistication to those performed by large international oil companies. The techniques will be demonstrated in a field trial on Pioneer Anticline in the southern San Joaquin Valley. The study will include collection, visualization, and manipulation of well-log and borehole -sample data. Physical and chemical property data gathered from laboratory measurements of conventional core and cuttings will be used to develop algorithms relating geological and engineering parameters to log responses. Digitized logs calibrated in this fashion will be used to characterize the reservoirs in fields on the Pioneer Anticline. Core, well-log, and production data will be assembled in a commercial PC-based database manager. The database manager will be used to provide data input to commercial visualization software to produce 2D and 3D representations of reservoir geometry, facies and subfacies stratigraphy, and distribution of remaining oil in place, as well as spatial displays of measured and calculated reservoir parameters. These database and visualization tools will be used to evaluate the reservoirs for enhanced oil recovery. In addition, rock alteration due to interaction with hot fluids will be quantitatively modeled and used to predict reservoir response to thermal EOR. Many of the above tasks are currently being performed on expensive computer workstations by major oil companies. A primary goal of this project is to transfer this workstation technology to personal computers, where programs can be run for a tenth of the cost by small independent operators.

Professors J. R. (Jim) Wood, J. Y. (Jim) Hwang, and C. A. (Charlie) Salotti and Research Scientists J. R. (Jack) Allan and A. (Andy) Nigrini form the MTU team, which will be responsible for reservoir characterization, database construction, and rock/water modeling. Drs.

Allan and Nigrini will be located in southern California for the duration of the project. An MTU graduate student will work on the project as part of his or her dissertation. Dr. Wood will be the student's thesis advisor.

Mr. W. R. (Rick) Berry and Ms. D. M. (Deborah) Olson of DPI head the industrial arm of the group. DPI, which specializes in formation evaluation and development geology, with special expertise in the San Joaquin Basin, will be responsible for well-log acquisition, calibration, and interpretation.

SUMMARY OF TECHNICAL PROGRESS BY TASK

TASK 1. PROJECT ADMINISTRATION AND MANAGEMENT

1.1 THE SPATIAL DATABASE MANAGER

A. Nigrini is testing and evaluating commercial PC-based database management systems to choose one that is best for the project and for the small-to-medium-sized producers that will ultimately utilize the results of the project. Database managers fall into two general categories: those that are simple and user friendly (e.g., Access, Approach), but may lack some features desirable for dealing with geological data sets, and those that are more flexible, but also more complex (e.g., Fox PRO, Paradox), and may therefore be more difficult for the uninitiated to operate. The advantages of ease of operation Vs flexibility will be carefully weighed before reaching a final decision. In the interim, all data are being collected in Quattro PRO spreadsheets, from which they can easily be transferred to the database management system of choice.

Nigrini will test and evaluate 2D and 3D visualization software packages available for PC systems. Many 3D geological/geophysical visualization programs are designed to run on workstations. Simplified versions of some are available for the PC. These programs are specifically designed to receive and manipulate geologic data, but the amount of flexibility sacrificed in adapting workstation programs to the PC is unknown to us at present. Visualization software packages, including Autocad and Geographic Information Systems (GIS), will be tested on sample data sets in order to choose the package that will best fit the needs of the smaller independent producer.

On December 9, A. Nigrini and J. R. Allan met with Dr. W. Kowalik and members of the Computer Visualization Working Group at Chevron Petroleum Technology Company to discuss the advantages of different commercial hardware and software configurations. The CPTC staff was very receptive to interaction with our project and should prove to be a valuable resource.

1.1.1 DATABASE INITIALIZATION

Log and core data from all 13 wells that penetrate the Monterey Formation in Pioneer Field and immediately adjacent areas were recovered and inventoried. DPI technical staff is currently performing a database search to identify additional wells that penetrate the Monterey on the

Pioneer Anticline west and north of Pioneer Field. About one hundred twenty additional wells have been identified to date.

DPI technical staff set up a Quattro PRO spreadsheet in which to collect well location and depth, well-log, and sample data in the interim period until a database management program has been chosen. The information collected during this initial search is being compiled in a Quattro PRO spreadsheet and will be transferred to the project database as soon as possible.

1.1.2 DATABASE MANAGEMENT

Every manager and site will need a high-end PC (e.g., a 486-based computer or better) in order to access the database and use the visualization applications programs. These computers will be networked and linked to a common server at MTU. It is anticipated that A. Nigrini will be responsible for setting up the network and S. Milligan will be responsible for database access, updates, and backup at MTU.

1.2.1 PROJECT COORDINATION

J. R. Wood will ultimately be responsible for assigning tasks to project teams. J. R. Allan will coordinate communication among project members. Because the study team is widely dispersed, travel will be an essential element in communication. J. R. Allan and A. Nigrini will make at least one trip per month to DPI in Bakersfield, and one trip per quarter to MTU. J. R. Wood will visit Bakersfield at least once per quarter and DPI personnel will try to visit MTU once or twice per year. An annual schedule which lists all projected travel for the coming year will be prepared at MTU and distributed to all participants.

1.2 ORGANIZATION AND MANAGEMENT

Organization and management were discussed in detail at the October 27 meeting in Bakersfield. The organizational structure agreed upon is attached as Fig. 1.

1.2.2 BUDGET MANAGEMENT AND QUARTERLY REPORTS

S. Milligan, in cooperation with other MTU staff, will prepare quarterly budget reports and distribute them to DOE, project members, and industrial participants involved in cost-sharing.

TASK 2. DATA COLLECTION

2.1 WELL LOGS AND WELL DATA

The following strategic decisions were made during the November 29 - December 3 working session in Bakersfield:

Structural data on the entire Pioneer Anticline will be input to the database management and visualization software programs, so that Pioneer Field can be viewed within a broader structural context and data from outside of the immediate vicinity of Pioneer Field can easily be included

in the study at a later date if so desired. The Pioneer Field covers a small area relative to the structure. Numerous small fields are spread across the structure. Surface geology of the area to the immediate south and west of Pioneer Field will be recovered from existing maps and included on the basemap.

The reservoir interval to be characterized in detail will be confined to a zone of principal interest which extends from about 300 ft above the top of the Miocene to the base of the Monterey reservoir facies. Although reservoir characterization studies will focus on the Monterey reservoir, this interval includes the Etchegoin sandstone reservoir as well. There is evidence that most of the Pioneer Anticline structure outside of the Pioneer Field limits contains heavy oil in the Monterey.

2.1.1 LOG DATABASE MANAGEMENT

DPI staff constructed a Quattro PRO spreadsheet in which to collect well location and depth, well-log, and sample data during the interim period until a database management system has been chosen. Data can be easily exported from this Quattro PRO inventory file to the database manager of choice. Once the well logs are digitized, well-log data will be input, managed, and analyzed at DPI using the PC-based version of Crocker Data Processing's Petrolog program. The petrophysical parameters calculated by this program will be input to the database management system and used in visualization applications.

2.1.2 LOG DIGITIZATION

DPI technical staff have begun to digitize the basemap and the zone of principal interest on well logs from the initial 13 wells. Digitization of these first 13 wells should be completed in the second quarter of FY94, at which time they will be ready for analysis using the Crocker Petrolog program.

As more logs are collected from elsewhere on the Pioneer Anticline, tops and bases of the formations of interest will be picked to improve control on the structure of the anticline for use in the visualization package, and additional wells will be chosen for digitization and input to the Crocker Petrolog program.

2.2 CORE AND SAMPLE ACQUISITION

2.2.1A CORE AND CUTTINGS

Sidewall core and cuttings samples recovered from one of the initial 13 wells and were shipped to MTU in December by J. R. Wood for petrographic, petrophysical, and geochemical analysis. It is anticipated that core and cuttings samples will be recovered from many of the other wells on Pioneer Anticline that are now being inventoried.

2.2.1B ARCO CORE

Project members will approach ARCO and attempt to acquire additional core and cuttings samples from several ARCO wells in the vicinity of Pioneer Field. As wells elsewhere on the Pioneer Anticline are inventoried, other operators will be contacted as well.

DPI will approach ARCO and/or Western Geophysical to request access to several seismic lines shot over the Pioneer Anticline. If access can be arranged, picks on the top of the Miocene and on other stratigraphic markers will be used to further improve control on the structure of the anticline for the visualization package.

2.2.2 FLUIDS

Fluid sampling has not yet begun.

TASK 3. DATA ANALYSIS AND MEASUREMENT

3.1 PETROPHYSICS

This subtask is not scheduled to begin until the second half of FY94.

3.1.1 KPF MEASUREMENTS

This subtask is not scheduled to begin until the second half of FY94.

3.1.2 FTIR SPECTRA

This subtask is not scheduled to begin until the second half of FY94. However, IMP (Institute of Mineral Processing) has purchased a condenser lens for the FTIR.

SUBTASK 3.2 PETROLOGY

This subtask is not scheduled to begin until the second half of FY94.

3.2.1 XRD

This subtask is not scheduled to begin until the second half of FY94.

3.2.2 SEM/IMAGE ANALYSIS

This subtask is not scheduled to begin until the second half of FY94. However, it is part of Ruth Kramer's Ph.D. thesis and she has begun image analysis work on cuttings from one of the Pioneer wells. Also, IMP has paid \$1000 toward this years maintenance contract on the SEM from project funds.

3.2.3 PETROLOGY

This subtask is not scheduled to begin until the second half of FY94.

3.3 LOG CALIBRATION

W. R. Berry is completing acquisition of the modern log suite and conventional core data from a well through the Monterey in nearby Cymric Field which has been promised to the project by UNOCAL. This information will be used to calibrate well-log data to rock properties in Pioneer Field. The core is currently stored in the UNOCAL Research Center in Brea, CA, and will be sampled by J. R. Allan and A. Nigrini when final permission is granted.

3.3.1 DATA PREPARATION

During the second and third quarters of FY94, D. M. Olson will supervise entry of well-log data for the 13 initial wells in the Crocker Petrolog program, correct all depths for well deviation, print out all logs at the same scale, and correlate the reservoir intervals between wells.

3.3.2 MODEL SELECTION

After calibration of these logs to the Cymric core, W. R. Berry and D. M. Olson will use the Crocker Petrolog program to calculate additional parameters, such as porosity, S_o , % clays, and matrix properties, from the Pioneer well-log suite. These parameters are critical to a reservoir evaluation. This work will continue through the third and fourth quarters of FY94, and will result in logs of calculated parameters that will be adjusted to the same scale and used to zone the reservoir. This information will be primary input to the reservoir visualization program.

TASK 4. MODELING

4.1 GEOCHEMICAL MODELING

The geochemical modeling program CHILLER will be used to model fluid-rock interaction. This has very practical significance because of active steamflooding of the Monterey and Etchegoin Formation elsewhere in the southern San Joaquin Valley. Geochemical modeling is scheduled to begin in late FY95.

4.1.1 GEOCHEMICAL MASS TRANSFER

This subtask is not scheduled to begin until the last quarter of FY95.

4.1.2 THERMODYNAMIC DATABASE

This subtask is not scheduled to begin until the last quarter of FY95.

SUBTASK 4.2 BASIN MODELING

This subtask is not scheduled to begin until the last quarter of FY95.

4.2.2 2D AND 3D BASIN MODELS

This subtask is not scheduled to begin until the last quarter of FY95.

4.2.1 GEOHISTORY

This subtask is not scheduled to begin until the last quarter of FY95.

TASK 5. TECHNOLOGY TRANSFER

Since the goal of this project is to provide smaller operators with the tools necessary to do sophisticated EOR evaluation, the first act of technology transfer was to announce our program to operators in the southern San Joaquin Valley through a press release submitted to the Bakersfield Californian (the local newspaper). The article described the project and encouraged interested parties to contact project members to obtain further information.

5.1 REPORTS

J. R. Allan is responsible for preparation of technical reports to DOE, for coordination of communication between project members, and for technology transfer. It was decided at the October 27 meeting that each task manager will prepare a quarterly summary of his individual efforts, all relevant activity by subordinates, and all trips, and will submit this summary to Allan 30 days in advance of the quarterly deadline to facilitate preparation of DOE Quarterly and Annual reports. Financial reports will be prepared by MTU staff and will be transmitted directly from MTU to DOE.

The American Association of Petroleum Geologists (AAPG) and The Society of Petroleum Engineers (SPE) regional and national meetings are the preferred venues for presentation of project results. Professional papers will be submitted to the AAPG Bulletin, to SPE journals (e.g., Formation Evaluation), and to other publications deemed appropriate for communicating results to the petroleum industry. Ad hoc subgroups will be formed, as required, to put together papers on specific subjects.

5.2 WORKSHOPS

Short courses and workshops will be run through AAPG, since SPE has no mechanism for this type of communication. The possibility of running additional workshops in the Bakersfield area was discussed at the October 27 meeting. These may be run in conjunction with a local geological or engineering society meeting or may be run independent of either. A list of "customers" will be prepared and publicity will be generated to make these customers aware of workshops that are run independently of professional organizations. DPI offered to lead the effort and will coordinate local workshops with J. R. Allan. Suggested format is four hours of

prepared discussions followed by an informal examination of the database, maps, logs and other materials. A. Nigrini will coordinate the database aspects of the workshops.

Arrangements have been made to present preliminary results of the project at an academic booth in the exhibition hall at the 1994 AAPG National Meeting in June.

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