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**APPLICATION OF INTEGRATED RESERVOIR MANAGEMENT
AND RESERVOIR CHARACTERIZATION
TO OPTIMIZE INFILL DRILLING**

Cooperative Agreement Number: DE-FC22-94BC14989

FINA OIL AND CHEMICAL COMPANY

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Reporting Period: December 13, 1994 - March 12, 1995

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QUARTERLY TECHNICAL PROGRESS REPORT

"APPLICATION OF INTEGRATED RESERVOIR MANAGEMENT AND RESERVOIR CHARACTERIZATION TO OPTIMIZE INFILL DRILLING"

INSTRUMENT NO. DE-FC22-94BC14989

**NORTH ROBERTSON UNIT DEPARTMENT OF ENERGY
CLASS II OIL PROGRAM PROJECT**

REPORTING PERIOD: 12/13/94 TO 3/12/95

This Quarterly Progress Report summarizes the technical progress of the project from 12/13/94 to 3/12/95. Project work planned for the next Quarter is also summarized.

ACTIVITY I.1 - MANAGEMENT AND ADMINISTRATION

PROJECT MANAGEMENT AND ADMINISTRATION - TASK I.1.1

The project is on track for accomplishing objectives, goals, and milestones. Work assignments have been progressing smoothly for all team members.

The third project Technical Committee Meeting is scheduled for March 30, 1995.

ACTIVITY I.2 - RESERVOIR CHARACTERIZATION AND ANALYSIS

GEOLOGICAL ANALYSIS - TASK I.2.1

The core/log rock typing algorithm is complete for all wells with the required modern well logs unitwide. The algorithm is used to identify pay and non-pay rock types over the entire Unit.

Correlative flow units (21 units) have been extended to include the Glorieta interval in all wells unitwide. Structural and isopach maps for flow units and crossflow barriers have been constructed to assist in the deterministic and geostatistical reservoir description. Predictive facies maps of primary pay, secondary pay, and non-pay rock types have been constructed to show the distribution of rock types for each of the flow units.

The results of the geological analysis are being used as input parameters for the deterministic and geostatistical reservoir description and reservoir simulation studies. During the next Quarter, a final report on the geological work will be prepared.

CROSS-BOREHOLE TOMOGRAPHY - TASK I.2.2

Fina recommended to the DOE that no additional surveys be conducted. DOE approved this change in scope to the Statement of Work. The change was recommended due to operational difficulties and poor cost/benefit of the technology.

In addition, the effective application of this technology relies on being able to obtain multiple surveys in a given area in order to provide a sufficient degree of confidence in the data. At present, it is economically and operationally difficult to support several surveys.

Data processing on the first crosswell survey on NRU 403 (Source) and NRU 207 (Receiver Array) has been completed by Reservoirs Imaging Inc. and Tomoseis. At this time, Schlumberger has not been able to provide any results.

During the next Quarter, Fina will be completing a final report on the cross-borehole tomography. The knowledge gained from the tomography will be passed on to industry through the project's technology transfer mechanisms.

FLUID PROPERTIES VALIDATION - TASK I.2.3

Fluid properties for the Upper and Lower Clearfork reservoir fluids were revised using PVT-x by considering residual volume B_o and R_s in the differential liberation experiment (DLE).

These properties have been provided to the University of Tulsa for the reservoir simulation initialization. No additional work in this area is planned.

RESERVOIR PERFORMANCE ANALYSIS - TASK I.2.4

Production data for the North Robertson Unit has been analyzed using Material Balance Decline Type Curve Analysis. All primary (40-acre) and secondary (20-acre) producing wells have been analyzed to determine total/movable volumes and formation flow characteristics (permeability and skin factor) based on individual well performance. Maps of OOIP, kh, and estimated ultimate recovery (EUR) using primary production data, and maps of kh and EUR using secondary production data have been generated for comparison with the geological interpretation.

Decline type curve and waterflood performance analyses indicate that the NRU is not performing as well as expected under secondary recovery operations. This indicates the need for a complete review of the fluid flow behavior in the reservoir (required for reservoir simulation), and the completion/stimulation procedures used in the past. This work is critical for determining the placement of the 10-acre infill wells, and for

RESERVOIR PERFORMANCE ANALYSIS (Con't) - TASK I.2.4

optimization of future completion and stimulation practices. In addition, a new waterflood performance type curve is being formulated to more accurately monitor the performance of individual wells and patterns. These studies will be performed during the next Quarter.

Pressure transient (buildup and falloff) data are being used to estimate reservoir pressure and formation flow characteristics. The estimated bottomhole pressures from buildup surveys conducted during 1987-1991 and the present pressure falloff tests have been tabulated for use in the geostatistics and reservoir simulation. The analyses of the buildup tests indicate that the hydraulic fracture treatments were ineffective (short fracture half-lengths) in creating good pressure sinks at the wellbore due to the presence of large, discontinuous gross pay intervals containing many individual layers, and possessing no effective barriers to vertical fracture propagation.

INTEGRATED RESERVOIR DESCRIPTION - TASK I.2.5

The stratigraphic and flow unit zonation of the Unit has been completed and is being used for the deterministic and geostatistical reservoir description. A work meeting was held with the University of Tulsa in late February to ensure that all qualitative and quantitative aspects of the geological and engineering data are used for the reservoir description.

GEOSTATISTICAL ANALYSIS - TASK I.2.6

A geostatistical reservoir description for the first modelling area is being generated by the University of Tulsa. A stepwise approach will be used to first complete spatial modelling of rock types by reservoir layer (variograms), and then to generate rock type distributions. This is followed by estimation of the petrophysical properties (porosity and permeability) consistent with the underlying rock type. The petrophysical parameters will be matched with the reservoir-scale well test data. A method of upscaling the foot-by-foot rock type data to the grid block level will also be used. During the next Quarter, these geostatistical reservoir descriptions will be used for reservoir simulation.

RESERVOIR SIMULATION - TASK I.2.7

The four areas for detailed reservoir simulation have been "fine-tuned" by considering reservoir performance attributes to define desirable features for infill drilling and poor candidate areas for infill drilling. Three of the four areas selected for detailed reservoir simulation have performance attributes indicating high productivity and poor connectivity.

The first simulation area is in Section 329 and encompasses approximately 320 acres. Two PVT regions are being used, one for the Glorieta and Upper and Lower Clearfork; and the

RESERVOIR SIMULATION (Con't) - TASK I.2.7

second region for the Lower Clearfork. Available steady-state and unsteady state relative permeability data are being used primarily to define displacement endpoints. Historical oil and water production data will also serve as relative permeability data for the history match. Initial water saturations will be obtained using well log data from the 20-acre infill wells (which were drilled after unitization, 1987). As these wells were drilled in "virgin" areas of the reservoir, they may be a reasonable reflection of initial water saturation. Performing water saturation calculations on the original 40-acre producers would be difficult due to the lack of complete or accurate log suites for many wells drilled during the field's initial development. In addition, there are uncertainties as to the original R_w measurements.

Initially, a deterministic approach to reservoir description and history match will be used, and then a geostatistical reservoir description will be performed. We will be able to determine if the geostatistical reservoir description provides a better history match.

All of the simulation areas have injectors as boundary wells, which is more practical for allocation. It will be assumed that there is no flux across the modelling areas since they are located in multi-patterned waterflood areas. The number of wells in the modelling areas range from 18 to 32 wells.

History match criteria have been developed and will primarily be production data, as only limited reservoir pressure data are available.

During the next Quarter, the simulation will be extended to several of the modelling areas.

ACTIVITY I.3 - INTEGRATED RESERVOIR MANAGEMENT

INTEGRATED RESERVOIR MANAGEMENT - TASK I.3.1

Nine pressure falloff tests have been completed and one test is in progress using surface pressure data acquisition. Initial results show that the current reservoir pressure in areas around the injection wells is between 3000 and 4000 psia. All of the injection wells analyzed appear to be well stimulated, however, this is most likely the result of extensive fracture propagation due to continuous injection at or near the fracture pressure of the formation. A few tests indicate that offset injection wells may be in contact with each other via hydraulic fractures.

Conformance control workovers will be considered to address this and other communication problems. These phenomena are typical of waterfloods in low permeability carbonate formations, and result in early water breakthrough and poor sweep efficiency.

INTEGRATED RESERVOIR MANAGEMENT (Con't) - TASK I.3.1

Falloff data acquisition will continue in order to get as much usable data as possible for simulation history matching and subsequent infill drilling.

Additional bottomhole pressure buildup surveys are presently being recorded throughout the Unit to confirm the results of the pressure falloff program (which utilizes surface pressure data acquisition) to provide further data for pressure matching during reservoir simulation, and to locate areas of the reservoir (if any) which have not been effectively repressured. A new pressure data acquisition technique will be utilized for several of the tests in which data is sent uphole real-time using radio signals via the casing string. It is felt that the use of this emerging technology is in keeping with the goals of this project for the identification of such techniques. The cost of the survey is only slightly more than the usual pressure buildup test.

Available step-rate data have been tabulated to determine the net increase in the required injection pressure/rate over time and to help identify workover candidates. It has been determined that additional tests cannot be accurately performed using surface (instead of bottomhole) gauges. It has also been determined that after the reservoir fill-up stage of the waterflood, the utilization of step-rate data to set individual well surface injection pressure limits should be discouraged since results no longer show the true fracture pressure of the reservoir due to pore pressure increases.

The evaluation of the current water saturation profile throughout the unit will be done using Thermal Decay Time (TDT) logs. The new data can be compared with original water saturation data for reservoir surveillance purposes, and can be used as an additional history match parameter for reservoir simulation. Two surveys have been completed to date, and several more will be completed during the next Quarter.

Additional analyses will be performed to identify the optimum completion and stimulation practices for the North Robertson Unit wells. Existing completion intervals are being cross-checked using the results of the rock typing. A stimulation database will be set up to determine which stimulation methods, fluids, and volumes produce the best completions. Conformance workovers, used to ensure that the injected fluids (water) are being placed in the correct zones for optimum sweep efficiency, will also be studied and introduced.

ACTIVITY I.5 - TECHNOLOGY TRANSFER

NEWSLETTERS - TASK I.5.2

A Project Newsletter is being developed.

PUBLICATIONS AND PRESENTATIONS - TASK I.5.3

Technology transfer activities for the project this Quarter are:

- **Published Papers and Professional Meeting Presentations:**

- **AAPG Annual Convention, March 5-8, 1995**

- *"Flow Unit Modelling of a Heterogeneous Shallow Shelf Carbonate Reservoir (Clear Fork/Glorieta), North Robertson Unit, Gaines County, Texas"*

- **Presentations Scheduled For Next Quarter:**

- **SPE Rocky Mountain Regional Meeting and Low Permeability Reservoirs Symposium, March 20-22, 1995, Denver, CO.**

- *SPE 29594, "An Integrated Geologic and Engineering Reservoir Characterization of the North Robertson (Clearfork Unit), Permian Basin, West Texas - A Case Study."*

- **Southwestern Petroleum Short Course, April 19-20, 1995, Lubbock, TX.**

- *"An Integrated Geologic and Engineering Reservoir Characterization of the North Robertson (Clearfork Unit), Permian Basin, West Texas - A Case Study."*

- **Conference Program and Technical Committee Contributions:**

- **1995-96 SPE/SEG Forum on Application of Geophysics to Reservoir Development and Production:** Tom Blasingame, Mohan Kelkar, and P.K. Pande are serving on a joint SPE/SEG Forum Committee (Forum to be held during Summer, 1996). The Committee is also providing input to the 1995 SEG/SPE Development and Production Forum.

- **1996 Permian Basin Oil and Gas Recovery Conference:** P.K. Pande is serving as Conference Co-chairman for this technical meeting. Mike Clark is serving as Speaker Chairman.