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"INCREASING WATERFLOOD RESERVES IN THE WILMINGTON OIL FIELD THROUGH IMPROVED RESERVOIR CHARACTERIZATION AND RESERVOIR MANAGEMENT"

Cooperative Agreement Number DE-FC22-95BC14934

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City of Long Beach, Department of Oil Properties
Stanford University, Stanford, CA
Magnetic Pulse, Inc. (MPI), Houston, TX

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Reporting Period July 1, 1996 to September 30, 1996

Objectives

The objectives of this quarterly report are to summarize the work conducted under each task during the reporting period July - September 1996, and to report all technical data and findings as specified in the "Federal Assistance Reporting Checklist".

The main objective of this project is the transfer of technologies, methodologies, and findings developed and applied in this project to other operators of Slope and Basin Clastic Reservoirs. This project will study methods to identify sands with high remaining oil saturation and to recompleat existing wells using advanced completion technology.

The identification of the sands with high remaining oil saturation will be accomplished by developing a deterministic three dimensional (3-D) geologic model and by using a state of the art reservoir management computer software. The wells identified by the geologic and reservoir engineering work as having the best potential will be logged with a pulsed acoustic cased-hole logging tool. The application of the logging tools will be optimized in the lab by developing a rock-log model. This rock-log model will allow us to convert shear wave velocity measured through casing into effective porosity and hydrocarbon saturation.

The wells that are shown to have the best oil production potential will be recompleated. The recompleations will be optimized by evaluating short radius and ultra-short radius lateral recompleations as well as other techniques.

Summary of Technical Progress

● Reservoir Characterization

Continued progress has been made on developing rock-log and fluid-log models needed to calibrate, interpret, and understand acoustic log data. Data from earlier tests of Wilmington cores were further analyzed to determine porosity and to refine pulse transmission velocity determinations. Additional cores of Ottawa sand were also tested to verify the source of anelasticity in the Wilmington samples.

Modelling code was developed and run to determine from the laboratory data the

velocity dispersion due to frame elasticity. A Cole-Cole distribution of relaxation times was utilized to parameterize the frequency-dependence of velocity. The transition from low to high frequency behavior predicted by this new model remains well below the frequency band excited by sonic logs. Researchers also continued to develop velocity-porosity transforms for high porosity rocks where cementation patterns vary from non-contact to contact cement. These transforms will assist in developing porosity from cased hole sonic logs.

● Reservoir Engineering

Fault Block IV production data for the Union Pacific Zone, Ford Zone, and "237" Zone have been quality controlled. All Fault Block IV Zones, except Upper Terminal, need to be converted into an official database and then exported to Production Analyst software. Quality control on injection data input is approximately 50% completed.

Fault Block V production data from the Tar Zone, Ranger Zone, Upper Terminal Zone, Lower Terminal Zone, Union Pacific Zone, and Ford Zone have been quality controlled. These data need to be converted into an official database and then exported to Production Analyst software. Quality control on injection data input is approximately 50% completed.

Fault Block VI production data from the Tar Zone, Ranger Zone, Upper Terminal Zone, Lower Terminal Zone, Union Pacific Zone, and Ford Zone have been quality controlled. These data need to be converted into an official database and then exported to Production Analyst software. Quality control on injection data input is approximately 50% completed.

● Deterministic 3-D Geologic Modeling

The deterministic 3-D geologic model continues to be updated and refined. Figures 1 and 2 represent the latest 3-D model. The model area was expanded so the horizon surfaces on the east side of the Daisy Avenue Fault could be more accurately represented. Figure 3 shows a color contour map of the top of the Hxo horizon. The grid for this map was pulled directly from the 3-D model. The structural highs were determined from the grid and are noted by the red arrows. In addition, structural

control points were added in areas of little or no data.

The geologic 3-D model uncovered a flawed interpretation to the west of the Daisy Avenue Fault. An en echelon fault is the newer interpretation and is supported by the distribution of the scattered data of the four modeled horizons. The en echelon fault interpretation is structurally consistent with other part of the Wilmington Oil Field. The fault interpretation is included in our model and provides good consistency for all the modeled layers.

The deterministic geologic 3-D model for the Upper Terminal Zone Fault Block IV prospect continues to be updated and refined. Our 3-D model suggest there is a structural trap for oil against the Harbor Entrance Fault which can be exploited by the Y-63 recompletion candidate.

● Pulsed Acoustic Logging

Log data from recompletion candidates Z-223 and Z-27 were further analyzed for useable acoustic data. Shear wave logs are in satisfactory agreement with new analysis results, but compressional data is unusable. Shear velocity determined from the waveforms is stable in sections but in other sections the final results depend on how the data was filtered. This result is consistent with frequency-dependance of the shear mode velocity, but is obviously a problem for consistent estimation of physical properties.

As discussed in the previous steering committee meeting, the success of acquiring formation signals with the MPI acoustic tool has been greatly hampered by the strong presence of Stonely (tube) waves arriving at the same time as formation signals, especially where poor cement to casing bond is suspected. The acoustic tool's analog to digital converter is being upgraded from 12-bit to 16-bit. This should enhance the signal to noise ratio of the data acquired and hopefully improve the chances of obtaining formation shear and compressional data.

Researchers also found in modelling wave propagation in cased wells that good cement/casing bond can actually *degrade* low frequency waveforms in certain situations. Trapped energy is propagated more efficiently when cement/casing thickness is large and the formation is soft. This effect was exhibited in Wilmington

Field logging runs where the old logging tool yielded better results due to its lack of energy output below 1 kHz. The modified newer logging tool has a very energetic low frequency energy band around 600 Hz. This was the tool used in logging the most recent recompletion candidates.

● Recompletions

Recompletion candidate wells J-15 and J-120 have been successfully extreme overbalanced perforated and have been steam consolidated. Both wells have been shut in for soaking.

Well J-15 is the Fault Block V Tar Zone recompletion candidate which we perforated across the "F₁" and "F₀" sands. This well took 92,800 barrels cold water equivalent (bcwe) of steam injection. J-15 was shut in for soaking in late August, 1996 and will be returned to production in late October, 1996.

Well J-120 is the Fault Block V Upper Terminal Zone recompletion candidate which we perforated across the "Hx₁" sand. This well took 18,800 bcwe of steam injection. J-120 was shut in for soaking in late August, 1996 and will be returned to production in late October, 1996.

● Technology Transfer

Researchers planned the Stanford Rock and Borehole Geophysics Project Annual Meeting June 19-21, 1996. Papers written and presented included:

Chang, Zoback, Moos: "Viscoelasticity and Dispersion in Unconsolidated Reservoir Rocks from the Wilmington Field, California"

Chang, Zoback, Moos: "A Comparison of Dynamic and Static Moduli in Unconsolidated Reservoir Rocks from the Wilmington Field, California"

Moos, Hooks, Walker: "Hydrocarbon Saturation Determination from Sonic Log Data"

Dvorkin et al: "Identifying Patchy Saturation from Well Logs"

Moos, Dvorkin, Hooks: "Application of rock physics relationships to wireline log data"

Researchers revised and had accepted a paper to Geophysical Research Letters titled: "Application of Theoretically Derived Rock Physics Relationships for Clastic Rocks to Log Data from the Wilmington Field, CA", Moos, Dvorkin and Hooks.

Researchers submitted an abstract to the June, 1997 International Rock Mechanics Meeting titled: "Anelasticity and Dispersion in Unconsolidated Sands", Chang, Moos and Zoback.

Researchers submitted an abstract to the 1996 American Geophysical Union Meeting titled: "Anelasticity and Dispersion in Unconsolidated Sands", Chang, Moos and Zoback.

Researchers submitted an abstract to the 1997 American Association of Petroleum Geologists Meeting titled: "Fluid Detection and Porosity Determination using Acoustic Logs in the Wilmington Field, CA", Moos.

Discussions have been initiated with Amoco to do a joint analysis of dipole data. Amoco employees will be visiting Stanford to initiate this work.

Researchers participated in the Ocean Drilling Program Downhole Measurements Panel Meeting in Salt Lake City, Utah. DOE results were disseminated to other attendees.

Researchers made a presentation in September, 1996 on the Waterflood Project status to the Department of Energy (DOE), California Department of Oil and Gas (CDOG), California State Lands Commission, along with representatives from state and federal government in Long Beach, CA.

Researchers updated the project's World Wide Web homepage at http://pangea.stanford.edu/~moos/DOE_home.html

References and Publications

None

Y₂
X₁

Note: Model dimensions are in feet.

FIGURE 1

Deterministic 3-D Geological Model Selected Volume of Fault Blocks V and VI.

Note: Model dimensions are in feet.

FIGURE 1

Deterministic 3-D Geological Model.
The Hx1 layer is removed and the data
for the Hx0 layer is posted.

FIGURE 2

Structure Map on top of Hx0 sand.

FIGURE 3