ACTIVITY REPORT

JANUARY 2004

Natural Gas & Oil Technology Partnership

Bringing Department of Energy national laboratories capabilities to the petroleum industry.

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Note: Natural Gas and Oil Technology Partnership projects are reported according to the following schedule:

January, March, May, July, September, November	**February, April, June, August, October, December**
Drilling, Completion, and Stimulation Technology Oil and Gas Recovery Technology Diagnostic and Imaging Technology	Upstream Environmental Technology Downstream Environmental Technology Natural Gas Technology

Natural Gas and Oil Technology Partnership on the World Wide Web: http://www.sandia.gov/ngotp/

Drilling, Completion, and Stimulation Technology

Downhole Seismic Source for Look-Ahead Pore Pressure Prediction While Drilling

(Halliburton and INEEL)

Highlights:

- Feasability Report completed
- Savoy Field Research Facility selected for prototype testing

Constructed Prototype:

The Capacitive Discharge Downhole Source (CDDS) and the Regenerative Combustion Seismic Source (RCSS) went through a second shallow well downhole source test series at the Idaho National Engineering and Environmental Laboratory (INEEL) in preparation for October 2003 testing at the Rocky Mountain Oilfield Testing Center (RMOTC) out of Casper, WY. The tests included single well and cross well seismic profiling with single and multi-channel hydrophone strings. We are currently working with RMOTC personnel to identify a suitable well to conduct the last test series of this project. The well must be uncased, have a diameter greater than six inches, have a high water table, and a known lithology. The tests will include placing seismic sources, tube wave suppression equipment, and hydrophone strings in a single well to attempt seismic profiling.

Activity: Seismic Source for Pore Pressure Prediction While Drilling

The Capacitive Discharge Downhole Source (CDDS) is scheduled to begin downhole testing at the Rocky Mountain Oilfield Testing Center (RMOTC) in Casper, WY on February 17, 2004. The original test plan had the CDDS scheduled for testing in October. The lack of existing uncased water-filled test wells at RMOTC pushed the test schedule into 2004 so that we would have the opportunity to piggy back our testing on an actual drilling operation sponsored by another organization.

A drilling rig will be moved to the well site and a 12-inch hole will be drilled to a depth of about 500 feet below the surface in a shale formation. The crew will pull out and give us 24 hours to complete our seismic test series. Following completion of our testing, the crew will return, set casing, and complete the well. The CDDS will be wire line deployed with hydrophones located in the well above the source and geophones located at the surface. The objective of our test is to detect the velocity contrasts between the shale and a sandstone unit located about 900 feet down. This test will give us an opportunity to test the technology as close as we can get to an actual drill string deployed source involved in a oilfield drilling operation.

Acoustic Telemetry (MWD) Drilling

(ABB, Electroacoustics Research Laboratory, Extreme Engineering, and SNL)

Highlight:

- Telemetry model improved

We are continuing with the improvements to the telemetry software by upgrading our graphics to IDL Version 6, which has a “virtual machine” capability. This capability allows access to the graphics package by users who do not have a license to IDL.

Effects of Well Conditions on Post-Perforation Permeability

(Halliburton, Penn State, and LLNL)

Highlights:

- Extended computational model to simulate the experiments in large cores used for completed systematic experiments conducted at JRC
- Ongoing efforts aimed at calibrating the model to the range of results provided by JRC and PSU

Parametric simulations using our computational model of perforation and post-perforation pressure surge demonstrate the influence of rock and fluid properties and core geometry on simulated estimates of core flow efficiency (CFE) under conditions representative of API RP43 section 4 flow tests. Results are consistent with experiments that suggest increased underbalance improves cleanup of charge debris and damaged rock from the perforation tunnel, especially near the tunnel entrance. However, the simulations suggest that the increasesd CFEs in laboratory flow tests may exaggerate the potential gains under downhole conditions. The axially-uniform pressure boundary conditions applied during flow tests are a good approximation of downhole conditions during the initial transient pressure surge, but once relatively steady flow is established, the three-dimensional geometry and proximity of other perforations causes alteration of the far-field pressures focusing flow near the tip of the perforation. Thus, the axial distribution of permeability enhancements is important in estimating the effectiveness of perforating schemes. Though damage removal near the tunnel entrance enhances laboratory CFE estimates, it may have a negligible effect under downhole conditions.

Automatic Flaw Detection and Identification for Coiled Tubing

(U of Tulsa, INEEL)

No report received.

Laboratory Study on Borehole Stability and Sand Production in Weakly Cemented Sand

(ChevronTexaco, Shell, and LBNL)

To determine the weak and strong cementation limit of cemented sand, we measured physical and acoustic properties of uncemented silica sand and Berea sandstone (bedded). The measured properties include density, porosity, texture, and compressional and shear wave velocities using both ultrasonic wave propagation (only for Berea) and sonic resonance. We also extracted moduli of the rock using sonic wave propagation as 10kHz~20kHz. The sonic wave propagation method resulted in velocities and elastic moduli values that are consistent with the other measurement. However, attenuation of the waves (due to the viscoelastic effect) made it difficult to determine using the amplitude changes of the propagating waves.

For the sand production/borehole breakout experiment using our new triaxial cell, we are currently using synthetic sandstone samples cemented with a small quantity of calcium aluminate cement. For cement contents less than 5% of pore space, we are experiencing some problems due to the uneven cementation of the sand grains within the sample. Particularly, the edges of the samples tend to show much less strength, which affects the sample preparation and the quality of the loading test results.

Development of Smart-Proppant Technology for Hydraulic Fracturing

(U of Tulsa, Halliburton Energy Services, and INEEL)

From Project Manager Author D. Watkins: The first activity was the development of a new budget plan that was submitted to financial planning. This plan included a major replanning of researches due to the large cut in research funding received from DOE. Next, we prepared for and attended our bi-annual Industrial Partners meeting hosted at the University of Tulsa, September 18,

2003. The presentations went well and were well accepted. In addition, we have been able to restart the research efforts after the long funding lapse. Per our spring discussions with our research partner, Steve Tipton of the University of Tulsa, we were able to set up a quick experiment to collect signal integrity data with relationship to tube liftoff for CT-1 and CT-2 test tubes. This data was collected at three amperage levels 5, 6, and 7 at a speed of 700 mm/s. It is planned that this data will be reduced in October's activities. Furthermore, initial correlations for defect detection for data taken during the spring of this project were received from University of Tulsa. These correlations were based on spike height, width, etc. Nevertheless, some key correlation sets for CT-1 and CT-2 have not been received to date. An effort to reduce this data is currently under way.

From Project Manager G. A. Bala: Representative microbiological systems selected for experimentation have been augmented by a volunteer culture that exhibits the capability to liquefy guar solutions at elevated temperatures. Once liquefied by the culture at 60°C, the guar remains liquefied even when cooled to room temperature. The organism(s) responsible for the liquefaction were obtained from the nonsterile incubation of a 3% guar solution at 60°C with no nutrient amendment. The culture has not been purified to the point of individual isolates; however, it has been grown in 500 ml cultures. We continue to evaluate the culture with respect to identity, nutritional requirements for large-scale culture, and separation on nonessential community members. The liquefaction of guar associated with this culture is superior to microorganisms purchased to date.

Application of High-Powered Lasers to Drilling and Completing Deep Wells

(Parker Geosciences, Colorado School of Mines, Gas Technology Institute, Halliburton Energy Services, and PDVSA, and ANL)

Highlights:

- Data Analysis of CO2 laser multispot rock drilling test series continues
- A presentation of Laser Well Drilling Phase II (FY03) results was delivered to the DOE NGOTP Program Manager and his management team at NETL
- Proposal for FY04 work was submitted

The test series on CO_2 laser multi-spot drilling of rocks completed last November produced a great amount of laser rock interaction data, digital images, and digital movies. Rates of penetration from 10 to 25 ft/hr were estimated, based on the November results. In this reporting period, a data CD including all collected test information was created and distributed among the team members. Analysis of the test data continues. A written report on the test series is in preparation and will be issued in Q2 FY04.

The results of Laser Well Drilling Phase II (FY03) were presented to the NGOTP Program Manager and his management team at NETL, Morgantown, WV on December 16, 2003. The presentation covered multiple spot drilling technique testing, perforation testing, and discussions held with a potential new collaborator, whose proprietary technology may be useful in beam switching inside the laser drilling head. The presentation was well received and we were encouraged to include support for beam switching R&D in our FY04 funding request.

A proposal for FY04 laser well drilling work was submitted to the NGOTP. In FY04, the team proposes four major tasks:

1. Fabricate a safe vessel that allows introduction of laser energy to samples being confined under varying conditions,
2. Test new concepts of multispot hole creation in saturated and wet (covered with water) rock samples,
3. Study high power beam scanning technology, and
4. Initiate laser based drilling system conceptual design.

Oil and Gas Recovery Technology

Measuring Sucker Rod Pump Parameters Downhole

(Harbison-Fischer, UT-Austin, and SNL)

Highlight:

- Instrumented pump for Texas Tech fabricated

The pump fabricated by Harbison-Fischer for Texas Tech has been checked out and minor changes are being made. Miscellaneous parts are being acquired. The unit will be ready by April when Texas Tech plans field testing.

Direct Simulation of Near-Wellbore Mechanics

(ChevronTexaco, Halliburton, Schlumberger, Shell, MIT, NM Tech, and SNL)

No report received.

Well Integrity Assurance for Sub-Salt and Near-Salt Deepwater GoM Reservoirs

(BHP, BP Amoco, ChevronTexaco, ConocoPhillips, ExxonMobil,Halliburton, Kerr-McGee, Shell, and SNL)

Highlight:

- Partners meeting held January 27, 2004

A Partners Meeting was held in Houston on January 27, 2004 and included 18 participants representing the 7 industry partners. The project met multiple milestones at the end of calendar year 2003, and several deliverables were formally released at the meeting.

One of the completed milestones related to the main work task of reservoir-scale finite element modeling to constrain in situ stress perturbation adjacent to and within massive salt bodies. *Microsoft Excel* spreadsheets containing numerical stress results, and related graphs, derived from non-linear finite element simulations performed for 15 different idealized deepwater GoM reservoir settings were distributed. The spreadsheets include all of the pertinent stress data extracted from multiple transects through the three dimensional finite element models and overall conclusions derived from the modeling were also presented. The 15 models for which results were formally released (many of which include multiple analyses) are variants of the following four basic geometries: spherical salt body, salt sheet, salt diaper, and salt diaper with tongue. Numerical results and implications were also presented for a fifth geometry that includes two separate salt bodies. Additional results were presented showing the effect of the far field material model. With the completion of this milestone, much of the future effort in this area will now be directed towards establishing behavior during depletion.

A second major milestone was completed in the second main task of wellbore scale modeling. A software program was released that predicts closure time for circular through-salt boreholes and for the four most common GoM hole/casing configurations for elliptical through-salt boreholes. The circular borehole program predicts closure time as a function of temperature, the difference between the salt stress and borehole pressure, and closure amount (borehole strain). The elliptical borehole program predicts time-to-contact and time-to-yield for specific hole/casing configurations for two different hole ellipticities. The programs are written in the JavaScript language and can be run with any of the common PC- or UNIX-based web browsers. The programs were well received by the partners and they expressed strong desire for continued work in this area.

A database was also distributed at the meeting that contains the results to

date of the extensive salt cuttings analysis program conducted during the last half of 2003. The database is organized according to geographic area as defined by the the Bureau of Land Management (BLM) Minerals Management Service (MMS) and presently includes over 70 analyses. Implications and future directions were also discussed at the meeting.

Finally, a series of analyses were conducted to analyze stress relaxation around through-salt and Leak Off Pressure (LOP) in salt. Input was received from the partners to define further work that will ultimately lead to development of geomechanical guidelines for LOP while drilling massive salt sections.

A proposal for fourth-year DOE/NGOTP funding was submitted to the Partnership Office in December 2003.

An Integrated Approach to Assessing Seismic Stimulation

(Aera Energy, ASR, BP Amoco, ChevronTexaco, ConocoPhillips, Halliburton, Marathon, OGCI, Piezo Sona-Tool, Schlumberger, Shell, UC-Berkeley, LBNL, and LANL)

During the last two months the data from the Lost Hills experiment has been further processed and analyzed. The data recorded on the hydrophone and the geophone have been determined to be reliable. The implication is that from the theoretical and modeling work it appears that we may have recorded the second wave type, i.e., a coupled fluid matrix wave, at a 1000-foot distance from the stimulation well.. The stimulation effects are on the order of 6 percent to 10 percent increased oil production to date. Plans were also made to perform another round of field experiments in the intermediate distance from the stimulation well to complement the near offset (43 feet) and the far offset (1000 feet).

Direct Quantification of Uncertainties Associated with Reservoir Performance

(ChevronTexaco and LANL)

No work scheduled this reporting period. Project awaiting further funding.

Diagnostic and Imaging Technology

Next-Generation Seismic Modeling and Imaging

(Advanced Data Solutions, Anadarko, BHP Petroleum, BP Amoco, ChevronTexaco, Conoco, Core Laboratories/Tomoseis, ExxonMobil, Fairfield Industries, Fugro Geoservices, GeoCenter, Geophysical Development, GX Technology, Marathon, Mitchell Energy, Paradigm Geophysical, PGS, Phillips, Shell, Unocal, Veritas DGC, WesternGeco, Society of Exploration Geophysicists, Stanford University, University of Houston, LANL, and LLNL)

Highlights:

- Progress made on wave-equation migration in the offset/azimuth domain

Synthetic elastic seismic data have been computed in the challenging 2-D Marmousi II (elastic) model. Synthetic traces have now been computed for two cases: (1) a reflecting boundary at the sea surface (a normal free-surface boundary), and (2) an absorbing boundary at the sea surface. In case 1, sea column multiples are expected to be strong, and in case 2, they will be suppressed. Comparison of the two data sets will help test the effectiveness of multiple suppression during seismic processing. The Marmousi II model was described in a paper presented at the Society of Exploration Geophysicists 2002 annual meeting (Martin, G.S., K.J. Marfurt, and S. Larsen, 2002, "Marmousi-2: An updated model for the investigation of AVO in structurally complex

areas," Soc. Expl. Geophys. 72nd Ann. Meeting, Exp. Abstr., pp. 1979-1982). A brief description of the model follows. It was created by modifying the original acoustic model (termed "Marmousi I") by: (1) assigning elastic properties, (2) extending the horizontal extent to 17 km, (3) adding 500 m of water at the top, and (4) adding multi-component receivers along the sea floor and in a well embedded in the model. Synthetic elastic seismic data were being computed with a shot grid of 25 m spacing. The computations were done on two different computing systems. The model estimated that the equivalent of about 12,800 cpu hours of an HP/Compaq Alpha cluster was required. Plans are being made to get the data converted to a standard format and make it generally available. The total volume of synthetic trace data (from computations with the reflecting and the absorbing top boundary) is about 50 GBytes. No work is scheduled during the reporting period.

Results of research that used synthetic data produced by the project were presented in two talks at the annual meeting of the Society of Exploration Geophysicists. Full citations for the talks follow:

"Elastic modeling and steep dips: unraveling the reflected wavefield," (2003), by Cory Hoelting, Mariana Gherasim, Leigh House, and Kurt Marfurt, presented at 73rd Annual Meeting, Society of Exploration Geophysicists, (Oct 26-31, 2003), Expanded Abstracts pp. 1833-1836.

"Multi-mode wavepath depth imaging for the SEG/EAGE salt model", (2003), by Alexander Druzhinin, Leigh House, and Jan Pajchel, presented at 73rd Annual Meeting, Society of Exploration Geophysicists, (October 26-31, 2003), Expanded Abstracts pp. 1106-1109.

Rapid Imaging of Interwell Fluid Saturations Using Seismic and Multiphase Production Data

(BP Amoco, ChevronTexaco, ConocoPhillips, ExxonMobil, JNOC, Landmark, RC2, Statoil, Tomoseis, Total-Fina-Elf, Texas A&M, and LBNL)

No report received.

Offshore Oil Field Characterization with EM Methods

(Scripps, Texas A&M, and SNL)

No report received.

Innovative Wave-Equation Migration

(Advanced Data Solutions, Amerada-Hess, Applied Geophysics Services, Baker Atlas, BHP, ConocoPhillips, ExxonMobil, FairfieldIndustries, GX Technology, Petroleum GeoServices, Screen Imaging, Shell, TomoSeis, Unocal, Veritas DGC, and LANL)

Highlight:

- Progress reported at Society of Exploration Geophysicists Meeting

LANL researchers continued research on wave-equation migration in the offset/azimuth domain. They generalized one of their wave-equation migration algorithms for migration of 3D common-azimuth dataset. They tested the new algorithm using a synthetic common-azimuth dataset for the SEG/EAGE salt model, and obtained better images compared to those published. They will compare the common-azimuth migration results with those to be obtained from the newly developed 3D stationary-phase wave-equation migration. One way to improve efficiency of wave-equation migration is to perform migration after plane-wave decomposition. Such plane-wave wave-equation migration would make wave-equation migration feasible for large 3D imaging problems while maintaining its accuracy the same as migration in the shot-domain. LANL researchers are conducting research on developing new plane-wave wave-equation migration methods.

Testing and Validation of High-Resolution Fluid Imaging in Real Time

(DeepLook, KMS Technologies, KJT Enterprises, U of Wisconsin, LBNL, and SNL)

No report received.

Autonomous Monitoring of Production

(Aera Energy, ChevronTexaco, SteamTech Environmental Services, TomoSeis, and LLNL)

We are completing the processing and interpretation of results to date at the Vacuum Field. One set of results has been incorporated in a paper prepared for publication in a technical journal. Our objective is to make the technology accessible to those companies that can benefit from it and can use it. Representatives from four oil companies have expressed an interest in using the technology. We have chosen The Leading Edge as a forum for communicating to the community. A draft of the paper has been prepared.

The field acquisition equipment has been moved to a new site about to undergo CO_2 flood. The field design and acquisition strategy implements concepts developed through working with ChevronTexaco at Vacuum, including protection of the equipment from lightning damage during long-term operation and avoiding magnetotelluric noise.

Anisotropic Properties of Compacted Clay-Rich Rocks

(BP Amoco, ChevronTexaco, ConocoPhillips, and LBNL)

Laboratory tests are currently under way on pure clays (kaolinite and montmorillonite) formed from powders. A scoping test on compacted kaolinite indicated favorable shear wave transmission at relatively low confining stresses (~2 MPa). Compacted clay samples are also being made with heavy water (deuterium) for neutron scattering texture measurements to be performed at the Los Alamos Neutron Science Center (LANSCE). In the next reporting period, we will report the results of ultrasonic anisotropy measurements on these pure clays performed using our phased array compaction cell, as well as efforts to characterize the texture of these compacted clays via neutron scattering. During this period, we plan on collecting a set of core samples from our industry partners for anisotropy measurements (ChevronTexaco and BP).

Realistic Anisotropic Velocity Estimation in Complex 3D Environments

(BP Amoco, ChevronTexaco, ConocoPhillips, Kerr-McGee, Shell, TomoSeis, and LBNL)

In finite difference modeling, a free-surface topography (nonplanar free surface) is more difficult to simulate than a planar free surface, however, even the planar free surface is not easy to simulate with sufficient accuracy. Kristek et al (2002) found that both the stress-imaging technique and vacuum formulation approach are not efficient and accurate. They proposed the adjusted finite difference approximations for updating the stresses and displacements near the planar free surface. They showed that their methods improved efficiency and accuracy significantly in a planar free surface in isotropic media.

We have extended one of Kristek's methods to anisotropic media in a planar free surface. The advantage of this method is that no virtual grids are needed near free surface and accurate results can be obtained with this method.

Joint Geophysical Imaging

(ChevronTexaco, Core Laboratories, Electromagnetic Instruments, ExxonMobil, and LBNL)

The objectives of this research are two-fold. The first is to investigate the feasibility of simultaneously inverting different types of geophysical data (electromagnetic and seismic) linked through a rock physics model to produce a single self-consistent reservoir model of hydrologic parameters (porosity, fluid and gas saturations, etc.) rather than geophysical parameters. Second, if such inversion is feasible, develop specific algorithms to use surface (land or marine) data and assess these algorithms in terms of parameter resolution and computational requirements.

The last two months have focused on improving the computational performance of the 3D electromagnetic (EM) modeling and inversion codes that will be coupled with amplitude versus offset (AVO) seismic codes for the Joint Inversion Project. Work on the EM inversion software includes a better restart capability for the 3D inversion runs, whereby previous information on the search direction vectors used in the minimization process is now saved to disk. Whenever the inversion codes require a restart due to a system crash or queue time limits, the saved information is utilized to avoid a poorer rate of convergence in the inversion algorithms; previously the restarts used steepest descent direction at the current model. We have also implemented an approximate adjoint preconditioner to further accelerate convergence of the inversion iteration. Initial testing is encouraging, showing nearly a factor of three reduction in the inversion iterations (also correspondingly in time), but more testing is required to fully exploit the advantages of the preconditioner. These efforts have focused on improving 3D electromagnetic imaging codes for inverting long-offset marine data, with offset measured from the EM transmitter.

Partnership Office

FY04 Partnership Review Process set for Diagnostics and Imaging Technology, Oil and Gas Recovery Technology, and Drilling Completion and Stimulation Techology.

This year's process is similar to the preproposal review process used in the past for new proposals. Reviews of projects will be done by their respective industry panels (e.g., a DIT project will be reviewed by the DIT panel). All continuing projects from FY 03 are eligible to submit a continuation proposal. The partnership confirms funding the three selected new starts at $250K (minus their pro rata taxes). The Gas Issues Forum Project will be funded at FY03 levels as directed by DOE (minus their pro rata taxes).

Calendar

February 25, 2004 - “Upstream Environmental Forum” Project Review Meeting, Sheraton North Houston Hotel.