ACTIVITY REPORT

September 2000

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**
Oil and Gas Recovery Technology Drilling, Completion, and Stimulation Technology Diagnostic and Imaging Technology	Upstream Environmental Technology Downstream Environmental Technology

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

Oil and Gas Recovery Technology

Improved Prediction of Multiphase Flow in Petroleum Reservoirs

(Mobil, Unocal, UT-Austin, and PNNL)

This project is in its final stage.

Improved Waterflooding Through Control of Brine Composition and Other Factors

(BP Amoco, U of Wyoming, and INEEL)

Highlight:

- Core from five wells selected for laboratory testing.

INEEL researchers visited the Utah Geological Society and examined core from six different wells from Utah's Greater Monument Butte region. Five wells had core of sufficient quality to extract plugs for additional laboratory testing. The cores were taken to TerraTek, Inc., where the plugs will be drilled (1.5 in. diameter by 3 in. length), cleaned using a Dean-Stark method, tested for porosity and permeability, and then sent to INEEL. We found good sections of core from the following wells:

- Well 3A-35 - 2 plugs @ 4998 ft, 4 @ 4999 ft, and 4 @ 5004 ft;
- Well 34-5 - 2 plugs @ 5025 ft;
- Well 34-8 - 2 plugs @ 4058 ft and 2 @ 4059 ft;
- Well 33-11J - 2 plugs @ 5196.5 ft;
- Well 6-35 - 2 plugs @ 5026 ft.

Inland Resources, Inc., operating fields in the Greater Monument Butte region, is working with INEEL and the University of Wyoming to determine whether waterflood oil recovery in this area can be enhanced by injecting a dilute brine. Reservoirs and crude oils from this region fit our preliminary screening criteria for applicability of the process. INEEL researchers have shown that by injecting diluted reservoir brine in laboratory corefloods, waterflood oil recovery is significantly increased under certain conditions. Fresh water is being injected along with produced brine commingled with the fresh injection water after breakthrough. This method provides a potential opportunity to test the process in the field by controlling the locations where the commingled brine is used.

University of Wyoming researchers determined that some epoxies used to coat core plugs do affect the imbibition rate of water into oil-saturated cores. However, preliminary results indicate that the epoxy used at INEEL does not affect the wettability or imbibition of oil/water systems. This epoxy appears to be nonreactive with crude oil and can be used in wettability experiments and waterfloods with confidence.

A visit to the Inland Resources, Inc., field office near Roosevelt, UT, is planned to collect field samples of water and oil and to collect field economic parameters so that an economic evaluation of the process can be undertaken.

Development of a New-Generation Petroleum Reservoir Simulator

(BP Amoco, Chevron, Conoco, Cray Research, IBM, Landmark Graphics, Mobil, Schlumberger-GeoQuest, Scientific Software-Intercomp, Texaco, Unocal, UT-Austin, and ANL)

Highlights:

- Draft of IPARS user's manual completed.
- Address given at SIAM Computational Science Symposium.
- IPARS simulator demonstrated.
- Portable, scalable interactive visualization tool for IPARS created.

A draft of a detailed user's manual for the Integrated Parallel Accurate Reservoir Simulator (IPARS) was completed. The manual documents version 3 of IPARS, which the developers intend to make as the first released version. Because several physical models have not yet been ported into version 3, the official release will not occur for several months.

Work continues on a new multigrid linear solver for IPARS, adding multiblock and multiprocessor capabilities. Preliminary results for a single fault block suggest this is the fastest solver tested to date. Robustness of the solver is questionable because of its formulation, so it may not be appropriate for highly heterogeneous reservoirs.

Mary F. Wheeler, of the University of Texas (UT)-Austin, gave an invited plenary address at the Society for Industrial and Applied Mathematics Computational Science Symposium (SIAM), September 23. She discussed the IPARS simulator and presented computational results on multinumeric and multiphysics problems. In addition, Wheeler and Wonsuck Lee, a UT postdoctoral fellow, in collaboration with Manish Parashar, of Rutgers, and Jack Dongarra and Dorian Arnold, of the University of Tennessee, presented a demonstration of interactive steering and heterogeneous computing using the IPARS simulator in Washington DC, September 21.

A portable, scalable interactive visualization tool for IPARS simulations was created. The visualization of large-scale simulations presents several problems related to (1) size of the problem, (2) irregular grids, and (3) parallel decomposition of the grid cells among processors. A typical large-scale problem has on the order of a million or more cells. For a multiphase flow model (e.g., black oil model) one may want to visualize several variables associated with the flow, and at the very least, all primary variables (three in this case). The size of the visualization dataset may easily reach 1GB or more. Unfortunately, commercial visualization tools, quite suitable for small-size problems, are inadequate for such large datasets.

The Argonne Futures Laboratory group provided IPARS developers with a tool to surmount these problems. This software tool post processes the dataset and creates a "movie" with which the user, using a 3D immersive display device (CAVE or Immersadesk), can "step inside" the 3D image to explore critical regions near wells and faults in detail. The images can simultaneously convey a range of relevant information. For example, pressure is shown using cutting planes, and saturations are shown using isosurfaces, which can be colored by other variable values. In addition, vector velocities and streamlines can be added to the overall picture. The tool is scalable and operates on distributed machines. A desktop workstation can also be used for display, although the small display area limits its usefulness.

Fluid Identification Acoustic Logging Tool

(BP Amoco, CGG, Chevron, Conoco, Landmark Graphics, Mobil, Schlumberger, Shell, Smedvig, Texaco, Unocal, Ward Petroleum, Western Atlas, and LANL)

Report delayed because of fiscal year-end transition.

High-Resolution Reservoir Characterization Using Seismic, Well, and Dynamic Data

(BP Amoco, Chevron, Exxon, Oxy, Phillips, RC2, Texaco, Western Geophysical, Texas A&M, and LBNL)

Highlights:

- General scheme developed to obtain reservoir permeability in 2D and 3D.
- Project results presented at the Joint Industry Project meeting.
- Awards presented during SPE meeting.

LBNL developed a new general scheme for obtaining reservoir permeability. In this approach, we use a very general finite-difference reservoir simulator to invert water-cut arrival times at various producing wells to obtain permeability variations between the wells. The approach has been extended from 2D to 3D. In the near future, we will apply the algorithm to a set of field data. Several discussions are under way with our industry participants to acquire additional field data, including time-lapse seismic data.

Some results from this project, in particular the transient-pressure inversion method and the generalized travel-time inversion technique, were presented at the Texas A&M-University of Tulsa, Joint Industry Project, meeting in Dallas. One member company, RC2, has implemented the water-cut history-matching algorithm. They have successfully applied the technique to water-cut data from two fields in the Middle East.

During the Society of Petroleum Engineers annual meeting, Don Vasco, of LBNL, and two of his colleagues received Cedric K. Ferguson awards for the "best peer-approved technical paper of 1999."

Vasco and Akhil Datta-Gupta, formerly of LBNL and now a professor at Texas A&M, along with Seongsik Yoon, Datta-Gupt's doctoral student now with the RC2 company of Denver, won the awards for a new method of characterizing reservoirs during secondary recovery of oil—using fast-changing data from injection and production wells.

Measuring Sucker Rod Pump Parameters Downhole

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

Highlight:

- Construction of downhole-instrumented pump began.

The mechanical design of the downhole-instrument pump is finished, and fabrication of parts has started. Laboratory testing of the "breadboard" version of the electronics was successfully completed, and fabrication of the prototype electronics has started. Prototype testing in Austin, TX, is being planned.

Formation Logging Tools for Microboreholes

(DeepLook, Texaco, and LANL)

Highlight:

- Comparative testing of commercial and microhole gamma logging tools completed.

Comparative testing of the relative performance of a 1-11/16-in.-diameter commercial logging tool and the 7/8-in. microhole gamma tool were completed. A 55-gallon drum of crushed granite and of potash served as test pits. Measurements were made of the total gamma counts over a 200–3000 KeV energy band in water-filled 7, 5-1/2, 4-1/2, and 2-3/8-in. steel casing and in 1-7/8-in. PVC tubing. Comparisons were made for the tools in both centralized and wall-contact positions. Data from these measurements are being analyzed.

Coupled Geomechanical Deformation, Fluid Flow, and Seismic Modeling

(Mobil, Schlumberger, UT-Austin, and SNL)

Highlight:

- Changes made to IPARS to include effects of a time-varying permeability.

Changes were made to the Integrated Parallel Accurate Reservoir Simulator (IPARS) to include the effects of a time-varying permeability. A significant consequence of reservoir compaction is that rock permeability will be reduced—an effect usually not considered in most geomechanics/flow codes with one-way coupling only. Dynamic permeability updates during coupled flow simulation and geomechanical deformation modeling are extremely important as they serve to damp the impact of dynamic porosity changes. The IPARS framework was modified to update the transmissibilities in all grid blocks after each JAS3D update of porosity. The well routines were also

modified so that permeability-dependent productivity/injectivity constants are updated. An evaluation of the modified framework with simple time-varying functions for permeability showed no degradation in performance compared to the static case.

The quasistatic finite-element code JAS3D is simultaneously being modified to compute and pass updated values of permeability to IPARS. An exponential relationship relating volume strain and permeability has been assumed for the reservoir rocks in this application. As JAS3D computes the volume strain in an element for a given time step, new values of both porosity and permeability are computed for that element and passed to IPARS for use in the next flow time step.

Semiautomatic System for Waterflood Surveillance

(Aera Energy LLC, Atlantis Scientific, Chevron, Electromagnetic Instruments, Integrated Micro Instruments, and LBNL)

Report delayed because of fiscal year-end transition.

Drilling, Completion, and Stimulation Technology

Evaluation of Concepts and Components for Directional Underbalanced Drilling and Microdrilling

(DeepLook, Fleet Cementers, Maurer Engineering, Mobil, Texaco, U of Tulsa, and LANL)

Project in close-out phase.

Real-Time Coiled Tubing Inspection System

(Quality Tubing and INEEL)

Highlight:

- Hall probe system completed and used to test samples.

Thin neodymium iron boron (NdFeB) flexible magnetic tapes were received from the manufacturer. The flexible magnet tape was bonded onto a short section of coiled tubing using Loctite Cold Weld compound and blue epoxy paint was applied on the surface. This bonding material has a sheer strength up to 3000 psi. The finished product was measured with the Hall probe. A Hall voltage of 0.15–0.2 V was registered at a standoff distance of 1/8 in. Following measurements with the Hall probe, the finished product was tested for hardness integrity. The coiled tubing with the magnetic marker was mounted on a vise, and a hard rod was used to scrape over the marker surface. The bonding material held together, but the magnetic tape was destroyed because the polymer composition of the flexible magnet was too soft and could not withstand the hard scraping motion.

An aluminum nickel cobalt (AlNiCo) magnet was used to fabricate markers. The AlNiCo magnet, which is very hard but brittle, has a fairly high magnetic force. Thin plates of AlNiCo with dimensions of 1 in. × 0.25 in. × 0.02 in. were cut and ground to the desirable thickness. These thin plates registered a Hall voltage of 0.02 V when measured with the Hall probe. Next, the thin plates were mounted on a long coiled tubing with Loctite Cold Weld compound and painted with blue epoxy paint. The coiled tubing was shipped to Professor Steven Tipton at the University of Tulsa on August 28 for the bending test.

Additional AlNiCO thin plates were bonded onto the remaining coiled tubing and painted over with epoxy paint.These tubes were shipped to Dr. Tipton for testing.

NdFeB magnetic thin plates will also be evaluated for marker use. NdFeB magnetic needles (0.032 in. × 1 in.) were cut with from a bulk magnet. These needles have a much stronger field than the AlNiCO magnet and will be bonded on the surface of the tubing for testing.

Perforation Dynamics in Geological Media

(Columbia Gas Transmission, Halliburton, National Fuel & Gas Supply, Panenergy, and LLNL)

No significant technical progress to report.

Drill Cuttings Injection Field Experiment

(BP Amoco, Chevron, Exxon, Gas Research Institute, Halliburton, Hughes Christensen, MSD, Pinnacle Technologies, Schlumberger, Shell, and SNL)

Highlight:

- Final report on the downhole tiltmeter monitoring completed and in review.

All field work for the Mounds Drill Cuttings Injection Field Experiment experiment was completed in 1999. Analysis of the diagnostic data continued this last period along with additional modeling and laboratory work. A final report on the downhole tiltmeter monitoring was completed and is in review. Other reports are being prepared. In addition, other contractors are working on guidelines and lessons learned from the Mounds experiment.

Seismic Stimulation for Enhanced Production of Oil Reservoirs

(AERA Energy LLC, Applied Seismic Research, Chevron, Conoco, Fluidic Technologies, Halliburton, Marathon, Oil and Gas Consultants Int'l., PerfClean, Phillips, Piezo Sona-Tool, Texaco, Wave Energy Resources, Wellington Operating, UC-Berkeley, LANL, and LBNL)

Highlights:

- Lost Hills stimulation monitoring plans finalized.
- Equation obtained for two-phase fluid mass change in a porous medium.
- Laboratory experimental data collection and analysis continue.

Field plans were made to monitor the Chevron stimulation project being conducted at the Lost Hills diatomite reservoir in central California. Applied Research Corporation, of Plano, TX, is providing the stimulation source. LBNL wirelines and receivers were taken to Lost Hills to monitor seismic signals within 200 ft of the source, as well the pressure in the monitor well. Stimulation started in late July and will continue for several months.

Initial results show an increase in oil cut for more than 60 wells. A homogeneous diffusion equation whose dependent variable is a linear combination of fluid pressure and dilatational stress has been derived previously by Chandler and Johnson for an elastic porous medium containing one fluid. The project team has been able to generalize this important result. First, it verified that, in a porous medium containing two fluids, a change in porosity can be described as a linear combination of fluid pressure and dilatational stress. Secondly, the team showed that the change in mean fluid density is proportional to fluid pressure. Because a linearized change in fluid mass results from a combination of the changes in porosity and in mean fluid density, it follows that the linearized change in fluid mass is also a linear combination of fluid pressure and dilatation stress. This change in fluid mass then can be shown to satisfy the homogeneous diffusion equation obtained previously for a single fluid in an elastic porous medium. Thus, the "porosity diffusion" hypothesized to be the phenomenon underlying permeability enhancement by a compressional wave traveling through a reservoir has been demonstrated for the first time in an elastic porous medium containing two fluids.

Laboratory two-phase flow experiments are providing new data on stimulated enhancement of oil and brine flow for different flow-rate ratios. These data, and previously collected flooding data, will be analyzed to determine dynamic stress effects on relative permeability behavior of sandstone.

In-Well Imaging and Heating: Multiple-Use Well Design

(Aera Energy LLC, Chevron, SteamTech Environmental Services, and LLNL)

No significant technical progress to report.

3D Analysis for Induction Logging in Horizontal Wells

(BP Amoco, Chevron, Conoco, Electromagnetic Instruments, Exxon, Halliburton, Mobil, Phillips, Schlumberger-Doll, Shell, Texaco, Unocal, Western Atlas, and SNL)

Highlight:

- Presented results at the SEG meeting.

SNL presented new results at the 2000 International Exposition and 70th Annual Meeting of the Society of Exploration Geophysicists in Calgary, Alberta, Canada. Topics included (1) simulated induction logs in fully 3D anisotropic media, and (2) induction tool sensitivity analysis in layered anisotropic media.

A special issue of *Petrophysics*, a journal of the Society of Professional Well Log Analysts, has solicited contributions from presenters who attended their workshop in Corpus Christi, TX, last spring. In response, we have submitted a manuscript titled "Electromagnetic induction by a tilted magnetic dipole in an electrically anisotropic formation." A second manuscript, which describes how anisotropy affects standard induction log tool sensitivity, is in the last stages of preparation for submission to the same journal. A formal report being written describes the effects of anisotropy on all possible combinations of induction tool sensors.

In response to industry's need for "fast" solutions to the electromagnetic induction problem, efforts continue in the area of code optimization for the fully 3D finite-difference software. This work includes benchmarking analysis, as well as investigation into efficient preconditioners and a matrix-free implementation of the forward problem.

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

(Chevron, INEEL, and LBNL)

Highlights:

- Feasibility report completed.
- Savoy Field Research Facility selected for prototype testing.

Evaluation of test sites for testing of the two prototype sources was completed and resulted in the selection of the Savoy Field Research Facility (University of Arkansas). The decision was based primarily on the available infrastructure that includes a three-component geophone system, recording system, surface seismic source, and field support equipment. Negotiations were initiated with the University of Arkansas for use of the facility.

The surface seismic source will be used to compare its known source function to the prototypes. Project researchers are in discussion with the Office of Naval Research to obtain a capacitive discharge source (sparker) that was developed for other applications. This source is very similar in terms of design and functionality to the INEEL prototype, and using it will provide a cost benefit to the project. The identification of this source was accomplished during preparation of the feasibility study. If the Navy's system cannot be obtained, a similar system will be constructed at INEEL. Development procedures for testing the prototype were initiated. A three-component geophone was received from OYO and arrangements made to obtain "Shotgun" surface seismic source and geophones.

Work proceeded on construction of the prototype regenerative combustion source and development of the field test protocol.

Acoustic Telemetry (MWD)

(ABB, Passband Downhole Communications, Electroacoustics Research Laboratory, and SNL)

Highlights:

- New participants joined project.
- Design of logic software/hardware completed.

Two new participants have joined the project. Passband Downhole Communications (PDC) is a new company devoted solely to commercialization of SNL's measurement-while-drilling (MWD) technology. Initially PDC plans to invest more than $5.5 million in this effort. In two years they expect to initiate an MWD service for the oilfield. We have also joined with the Electroacoustics Research Laboratory at the University of Texas-Austin (UT-Austin).

UT-Austin has a continuing research effort using stress waves to communicate through steel drill pipe. Our first participant, ABB, is still interested in using this technology for smart deployment of sea floor systems.

Based on the results of recent successful surface tests, we have completed the system software development and finalized the logic circuit designs. Battery packs have been ordered and are scheduled to arrive soon. Integration of these components into the tool will begin this month. We still plan to deploy the tool in its first field test before the end of this calendar year.

Development of Chemically Bonded Ceramic Borehole Sealants (GPRI, ANL, and LANL)

Highlights:

- CBPC slurries that provided mixing times of 1.75–4.5 hours were developed, but setting time was always 10 min.
- Fracture toughness enhanced by incorporating 0–3 wt.% glass fibers.
- CRADA completed and submitted to the DOE for approval.

Preparation of a cooperative research and development agreement (CRADA) between ANL and the Global Petroleum Research Institute (GPRI, a consortium of Exxon-Mobil, Chevron, BP Amoco, and Shell) was completed and submitted to the DOE for approval. This CRADA will bring $120K in cash and in-kind for the supplemental work related to this project.

The newly installed consistometer was operated at atmospheric pressure and room temperature. Clearwater, Inc., provided initial training at the Pittsburgh laboratories, where some testing of the borehole sealant consistency was also done. Using that experience, we operated the consistometer at ANL, and the earlier results were reproduced. Additional compositions were also tested at ANL, and slurry compositions that provided mixing times of 1.75–4.5 hours were developed. To vary the mixing time, boric acid was used as a retardant of the setting reaction. When the consistency was 50 Bearden units of consistency, the slurry was removed from the slurry cup to prevent its setting. Boric acid concentration in the powder blend ranged from 1–1.4 wt.%. One interesting result of these tests was that the setting time was only 10 minutes in each case. This short setting time helps to form dense borehole by preventing gas migration in the downhole environment.

Previously, the project team reported fabrication of glass fiber-reinforced ceramics to enhance the flexural properties and toughness of the sealants. Samples with 0, 1, 2, and 3 wt.% fibers of 0.25- and 0.5-in. lengths were incorporated into the ceramics, and fracture toughness of these composites was then measured. By incorporating the fibers, we enhanced the fracture toughness ranging from 0.22–0.66 MPa $m^{1/2}$, which was three times the value without the fibers. Typical fracture toughness for cement is the same as the phosphate ceramic without fibers.

Testing slurry consistency of the slurry will be extended to higher temperatures and pressures. ANL researchers will also measure the strength characteristics of the samples as a function of the amount of boric acid they contain. Once the CRADA is in place, additional tests will be done in Chevron Laboratories in Houston.

Coiled-Tubing Deployed Microdrilling with Real-Time, Downhole Monitoring (DeepLook, Fleet Cementers, Phillips, Texaco, and LANL)

Highlight:

- The upgraded coiled-tubing drilling unit is almost ready to attempt an 850-ft drilling demonstration at the San Ysidro drilling site.

Coiled-Tubing Microdrill Rig

During the demonstration of the new mud pumps a number of minor deficiencies were identified and corrected. A 1,000-ft string of 1-in. OD, 0.087-in. wall thickness, 70,000-psi yield tubing was installed on the coiled tubing unit. The revamped hydraulic system was demonstrated and no significant deficiencies were identified during yard testing and a brief drilling demonstration. Testing of all of the upgraded systems was completed. A field drilling demonstration was initiated at the end of September.

Instrumentation

Control System. The new hydraulics system was successfully interfaced with the PC (LabVIEW data acquisition and control software) control system to facilitate a gradual transition from manual to automatic control of various drilling functions and processes, as it becomes feasible. A magnetic pick-up was installed to measure the pump speed and provide flow measurement and/or pumping performance monitoring when a turbine flow meter is installed to measure the "actual" mud flow rate.

Downhole Sensor Sub. No activity to report.

Drilling Site

Permits needed to conduct a series of microdrilling demonstration at a new site near San Ysidro, NM, were obtained. The microdrilling system was mobilized on the site, and a brief drilling demonstration is in progress to complete the evaluation of the rig and pump modifications and modified well completion methods. It is anticipated that this site will provide near-surface sediments much closer to "typical petroleum drilling" sediments. This should provide a more realistic evaluation of the drilling and mud cleaning systems than can be obtained while drilling volcanic tuff at the LANL, Fenton Hills drilling site. The attempt to drill to a depth of 850 ft will be initiated when the coiled-tubing drilling unit subsystems are checked out.

Diagnostic and Imaging Technology

Advanced Sensor Technology for Microborehole and Other Seismic Instrumentation

(Input/Output, Texaco, and LANL)

Highlight:

- Arrays assembled and tested in preparation for field testing.

Two, four-level, three-component micromachine arrays were fabricated from electronic subassemblies designed and fabricated over the past eight months. Planning for the incorporation of the microhole arrays into a commercial seismic reflection survey was deferred until land issues have been resolved. In preparation for the commercial survey, an 850-ft, 2-3/8-in. microhole will be drilled in October and an abbreviated characterization of the improved microhole system will be conducted in the microhole.

Development of Single-Well Seismic Imaging Technology

(BP Amoco, Chevron, Conoco, Exxon, OYO Geospace, P/GSI, Phillips, Schlumberger, Shell, Texaco, TomoSeis, Unocal, Western Atlas, Stanford, LBNL, SNL, and INEEL)

Highlights:

- Series of test conducted to observe tube-wave response using various sources.
- Three presentations given at SEG meeting.
- Single-well test run at Lost Hills site to perform a base-line survey next to a hydrofracture.

INEEL conducted a series of tests to observe tube-wave response using, among other sources, the explosive cap source. Receivers used consisted of hydrophones, fixed geophones, and bellows-clamped geophones (with surface supplied air pressure). The attenuator used (when used) was the small diaphragm (completely filled). Depths and water levels were not necessarily consistent because that was not the focus of the tests running at the time. The results follow:

1. The fixed geophones, while sensitive to a weight drop, are completely unstimulated by wellbore disturbances.
2. Hydrophones record explosive cap wellbore disturbance attenuations from about 25% to about 60% reduction in signal amplitude (SA) depending on geometry. (Piezo disturbance attenuations were many decades reduced.)
3. Unclamped geophones were greatly stimulated by the cap's signal.
4. Tightly clamping the geophones only created a 50% reduction in SA.

5. Unclamped geophones with attenuator demonstrated a 70% reduction in SA vs. unclamped and unattenuated.
6. Tightly clamped geophones with an attenuator demonstrated about a 90% reduction in SA.

SNL continues to conduct computational simulations of crosswell and reflection responses recorded at the Bayou Choctaw Salt Dome field test site in Louisiana. Synthetic seismic data are calculated with a parallel version of a 3D finite-difference elastic wave propagation algorithm sited on a Linux cluster. An improved match to the field-recorded data is obtained by (1) incorporating horizontal reflecting horizons into the model of the sedimentary sequence adjacent to the near-vertical salt flank and (2) increasing the spectral bandwidth of the seismic source wavelet. However, limited computational hardware resources still restrict the frequency content of the synthetic data to a bandwidth well below that of the field-recorded data. Work has been initiated on a 3D finite-difference viscoelastic wave propagation algorithm, based on the standard linear solid formalism. This approach should allow more realistic modeling of seismic responses in geologic media characterized by low Q values, such as the Gulf Coast sedimentary environment.

In August, SNL researchers delivered three presentations about issues in seismic wave propagation modeling at the 2000 International Exposition and 70th Annual Meeting of the Society of Exploration Geophysicists in Calgary, Alberta, Canada. These presentations involved seismic Q modeling, air/earth interfaces in finite-difference algorithms, and 3D elastic simulations of salt flank reflections.

In August, LBNL ran a single-well test with Chevron at their Lost Hills, CA, site as part of their CO_2 injection to perform a base-line survey next to a hydrofracture. The Conoco orbital and piezoelectric source were both run with three-component locking geophones and hydrophones as receivers. The objective was to collect data prior to the CO_2 injection into the hydrofracture. A crosswell dataset was also collected as part of the CO_2 sequestration effort, which will be used to validate the single-well data.

Large Downhole Seismic Sensor Array

(Chevron, Conoco, Exxon, OYO Geospace, Shell, Texaco, U of Arkansas, and INEEL)

Highlight:

- Construction of demonstration prototype begun.

The totally passive design details were adjusted according to discussions with Jack Cole, of the University of Arkansas, to make the prototype readily adaptable to other well logging applications. Construction of the demonstration prototype has begun. The electronics package was removed from the demonstration coiled-tubing segment to be used in the new prototype.

Detailed drawings are nearly complete. These drawings will provide documentation of the more capable of the module configurations developed and tested by INEEL. They will be provided as part of the output documentation from the project. Also the design of a compact, three-component housing will be included in the detailed documentation. This housing was a by-product of the large downhole seismic sensor array model development.

The final report draft is out for continuing review.

Improved Prestack Kirchhoff Migration for Complex Structures

(Conoco, Cray/SGI, Golden Geophysical, Kerr-McGee, Mobil, Shell, and LANL)

Report delayed because of fiscal year-end transition.

Locating Geopressured Hydrocarbon Reservoirs in Soft, Clastic Sediments Through Identifying Associated Pressure Seals (Conoco and INEEL)

Highlights:

- Reservoir modeling completed.
- Synthetic modeling completed.

Report detailing results of the synthetic seismic modeling of pressure profiles was completed. The results of the modeling suggest several potential applications of the algorithm that was developed. These applications include:

- detection of geopressure transition zones in processing of surface-acquired seismic data using low-frequency sources,
- detection of geopressure transition zones in "ahead-of-bit" downhole seismic methods using low-frequency sources,
- improved control of spectral whitening for seismic data processing in the presence of gradational acoustic contacts,
- estimation of gradient thickness and total acoustic contrast across gradational boundaries, and
- "ahead-of-bit" detection of entrained sediments and fluid-rich zones within salt-layers for subsalt petroleum drilling.

Testing Advanced Computational Tools for 3D Seismic Analysis Using the SEG/EAGE Model Dataset (Advanced Data Solutions, Anadarko, BHP Petroleum, BP Amoco, Burlington Resources, Chevron, Conoco, Edison Chouest Offshore, Exxon, GECO-Prakla, Golden Geophysical, Kerr-McGee, Marathon, Mitchell Energy, Mobil, Paradigm Geophysical, PGS-Tensor, Phillips, Shell, Society of Exploration Geophysicists [SEG], Texaco, Union Pacific Resources, Unocal, Western Geophysical, Houston Advanced Research Center/Rice, Stanford, UC-Davis, U of Houston, LANL, LLNL, and ORNL)

Highlights:

- 3D elastic modeling results presented at SEG meeting.
- Project meeting held.

Results of 3D elastic modeling of selected shots over the SEG/EAGE numerical model were presented at the annual meeting of the Society of Exploration Geophysicists, August 6-11.

A project meeting was held at the University of Houston on September 19 to discuss technical progress and future work. More than 30 project participants from industry, universities, and national laboratories attended. Discussions included plans for finishing up the two remaining tasks, which are funded for the final close-out year of this project.

Integrated Reservoir Monitoring Using Seismic and Crosswell Electromagnetics (Chevron, Electromagnetic Instruments, TomoSeis, LBNL, and SNL)

Report delayed because of fiscal year-end transition.

Frequency-Dependent Seismic Attributes of Fluids in Poorly Consolidated Sands (Baker-Atlas, Chevron, TomoSeis, Vastar, and LBNL)

Report delayed because of fiscal year-end transition..

Inversion of Full Waveform Seismic Data for 3D Elastic Parameters (Amerada Hess, Conoco, Fairfield Industries, GX Technology, Marathon, Texaco, Unocal, and SNL)

Highlight:

- Organizational meeting held.

An organizational meeting was held May 23 at Amerada Hess in Houston, TX. Three target deliverables were agreed upon by SNL and the industry collaborators:

1. The existing 3D elastic forward modeling code will undergo further verification tests.
2. A prototype inversion code will be developed using simplified assumptions.
3. Algorithms developed in the course of the project will have a 3D character, but modeling runs may be conducted in 2D to reduce the computational burden.

Further vetting of the forward modeling code has been conducted. The theoretical basis of the inversion algorithm is being studied, and some preliminary coding was initiated.

High-Speed 3D Hybrid Elastic Seismic Modeling

(Burlington Resources, GX Technology, and LBNL)

Highlight:

- Local boundary condition method tested for elimination of artifacts from grid discretization.

One of the critical goals of the project is to demonstrate that local boundary-condition matching can be used at high-contrast interfaces to eliminate artifacts from grid discretization. The effect is especially strong for interfaces with high impedance contrasts; although, if weak reflections are of an interest, its presence also can be important.

A local boundary condition method was tested for such elimination. The method requires introducing additional grid nodes for a grid mesh in the points of intersection of the high-contrast interface with grid lines and local rotation of field components with respect to local orientation of the interface. All derivatives for adjacent points are calculated using these additional grid nodes. When the approach was tested for 2D computations it showed good performance, decreasing artificial reflection amplitudes eight-fold on average. The downside of the approach is its computational cost. A more straightforward less computationally expensive solution to the problem was found, which has about the same degree of artifact elimination effect as the local boundary conditions method. This solution, which should be applied at the pre-computational stage, consists of specially organized spatial model grid filtering. Therefore, it does not require any extra changes of computational algorithm and does not affect computational speed. The best results can be obtained when the width of the smoothing zone depends on the local slope of the interface.

Next-Generation Seismic Modeling and Imaging

(Advanced Data Solutions, Anadarko, BHP Petroleum, BP Amoco, Burlington Resources, Chevron, Conoco, Exxon, GECO-Prakla, Marathon, Mobil, Paradigm Geophysical, PGS-Tensor, Phillips, Shell, Society of Exploration Geophysicists [SEG], Texaco, Union Pacific Resources, Unocal, Western Geophysical, Stanford, U of Houston, LANL, and LLNL)

Highlights:

- New-start efforts began on wave-equation imaging and 3D elastic modeling.
- Project meeting held.

As a new-start follow-up effort to a previous project, initial work has begun on improved wave-equation migration methods. Also, an existing elastic modeling code will be used to generate synthetic data for a suite of next-generation 2D and 3D numerical models.

A project meeting was held at the University of Houston on September 19 to discuss technical progress and future work. More than 30 project participants from industry, universities, and national laboratories attended the meeting. Discussions included plans for continuing the imaging and modeling efforts begun under the previous project. It was agreed that the project will work closely with a new Society of Exploration Geophysicists committee that will be formed to select appropriate new numerical models.

Partnership Office

Proposal Reviews

As this report goes to press, the Partnership will have completed annual project and new proposal reviews for the Ultra-Clean Fuels, Downstream Processing and Environmental, and Upstream Environmental technology areas. These reviews were held in Houston, TX, October 10–11. The Partnership thanks Tom Schmidt and Linda Puckett, of ORNL, and Dexter Sutterfield, of NPTO, for their efforts in organizing and driving these reviews.

The Partnership also completed the review of preproposals in the Drilling, Completion, and Stimulation; Oil and Gas Recovery; and Diagnostics and Imaging technology areas. We thank the three sets of industry reviewers who helped with the reviews. The successful projects and associated principal investigators have been notified. Full proposals will be reviewed in Houston, TX, mid-November.

Ultra-Deepwater Research

DOE Fossil Energy recently has been focusing on an "Offshore Technology Roadmap for Ultra-Deepwater Gulf of Mexico." The Partnership has great interest in using its research portfolio to answer needs for ultra-deepwater technology and in enabling technology transfer to the domestic industry. This will a discussion item in upcoming Partnership meetings as we brainstorm approaches to address these areas of growing technology needs. As always, we solicit suggestions from industry and other interested parties.