Partnership Progress

Natural Gas & Oil Technology Partnership

March 1998 No. 8

U.S. Department of Energy ■ National Laboratories ■ U.S. Petroleum Industry

Farewell

From its inception, the Partnership has benefited from the dedication and support of the Director of the DOE National Petroleum Technology Office, Thomas C. Wesson. Tom retired December 31 and will be missed. The acting Director of NPTO is R. Michael Ray, with primary responsibility for Partnership activities continuing under the guidance of Alex B. Crawley, Associate Director.

Compounding this loss, David A. Northrop has announced his plans to retire in April. Dave has served as the Partnership Co-chair and Sandia representative since its formation. After 33 years of noteworthy contributions to SNL; mountain faces, trout streams, and ski slopes will be the locations of choice for Dave. Stepping in to fill this void will be David J. Borns, a SNL geologist/geophysicist.

Bob Hanold and Dave Northrop

Inside

The Partnership on the World Wide Web:
http://www.sandia.gov/ngotp/

Sand Production Examined at the Microscopic Scale

Because of its adverse effect on well productivity and equipment, one of the oldest problems facing the oil and gas industry is the production of formation sand into a well. The Near Wellbore Mechanics project (under DOE's Advanced Computational Technology Initiative [ACTI] program) was formed to gain an understanding of the mechanisms contributing to sand production occurring at the microscopic scale.

Sand production occurs when the loading on sand particles, induced by fluid flow, is greater than the strength of the formation. The formation material collapses locally, and the sand fragments are carried into the wellbore where they can block the flow, damage pumps and pipes, and contaminate the produced oil. Sand production creates cavities in the formation that continually increase in size and eventually become unstable, leading to the collapse of the wellbore. Once at the surface, the pro-

See Sand Production, Page 2

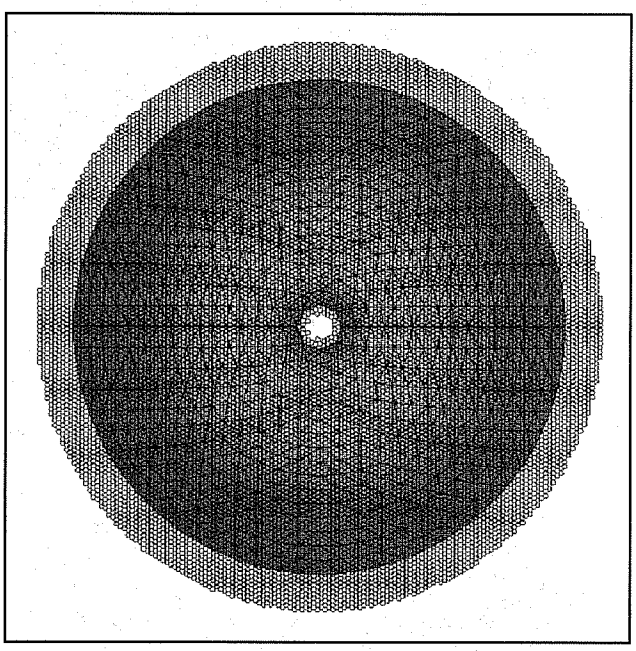


Figure 1: Assemblage of 15,000 1 mm diameter particles (circular discrete elements) overlaid by a finite-element fluid flow grid. The perforation channel is located in the middle. Fluid pressure is represented by gray shades: dark = higher pressure, light = lower pressure.

Sand Production

Continued From Page 1

duced sand also becomes an environmental issue because it contains a significant crude oil content and must be disposed of properly. These problems make it economically difficult to continue to produce the well.

In a typical recovery process, a wellbore is drilled into the oil-bearing matrix, and the fluid phase (oil, water, etc.) is pumped to the surface. Modern recovery techniques include the use of perforation channels, created by shaped charges, to enhance the production rate. The shaped charges are fired through the wellbore casing to form small conduits for fluids to flow into the wellbore. The high-pressure flow into these channels is considered the initial cause of sand production.

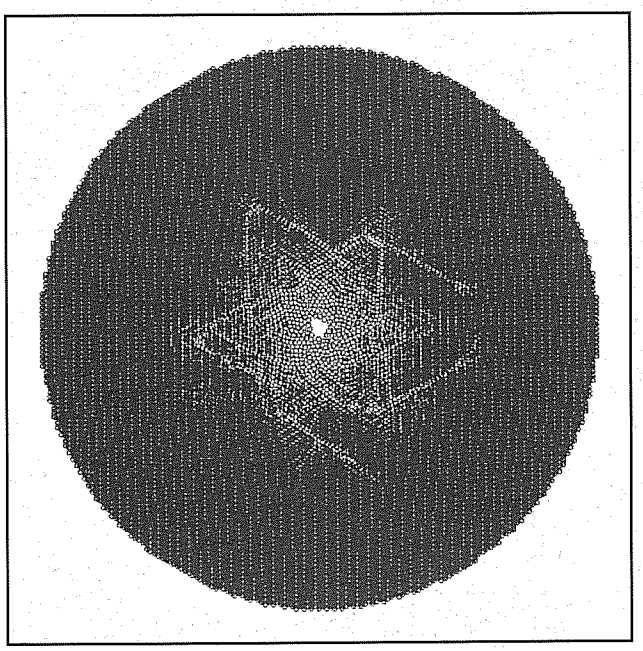


Figure 2: Perforation channel discrete element model subjected to fluid loading. Bonds (calcium carbonate cement) between particles are represented by a black dot. When the bond is broken, the dot is removed. This figure illustrates the beginning of formation breakdown as sand is pulled into the perforation channel by the fluid.

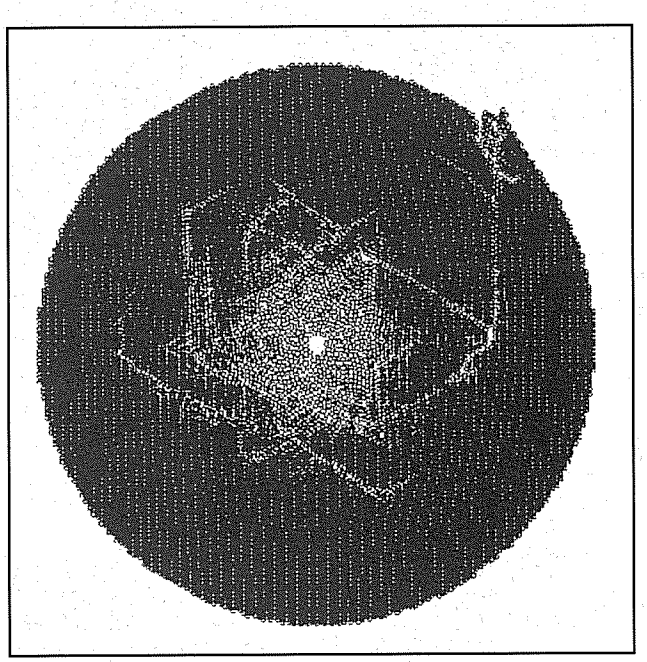


Figure 3: Later interval of formation breakdown.

Discrete Element Methods (DEM) Enhance Modeling

The Near Wellbore Mechanics project team is developing a code that will enable them to model a representative section of a single perforation channel next to a wellbore. The project is experimenting with the coupling of fluid and particle motion by combining a finite-element fluid flow model with Discrete Element Methods (DEM).

DEM is a set of numerical techniques specifically developed to model the behavior of discontinuous systems such as granular media. Each grain of material is modeled as a discrete object with a geometric representation of its surface topology and a description of its physical state (position, orientation, body forces, etc.). The simulated system evolves over time by tracing the trajectory of each particle under the influence of some physical field (Newtonian, Brownian, etc.). Particles interact through contact and bonds deteriorate between neighboring surfaces. Figure 1 shows a wellbore in its original state. Figures 2 and 3 illustrate the wellbore as sand production occurs.

Current modeling techniques utilize circular shapes to represent sand grains. DEM provides a model of granular materials that carefully depicts the motion and interaction of individual sand grains. With DEM, the project team is developing techniques to efficiently represent and process particles with irregular geometries consistent with grain shape and size, using distributions obtained from digitized micrographs and sieve testing. These will help to predict the con-

(See Algorithms, Page 3)

Algorithms

Continued From Page 2

ditions under which sand production will occur. DEM can also be used to gain an understanding of the fundamental physics involved in sand production and the relative importance of factors such as cement strength, capillary pressure, friction, fluid viscosity, and fluid flowrate.

Geological models are produced using the MIMES (Modeling Interacting Multibody Engineering Systems) code to represent the pressure, sandstone strength, pressure drop, type of fluids, fluid viscosity, and sand grain-size distribution of a region. A perforation channel can then be introduced into the model to see how the well will produce. The data generated from such a model can then be used to create a fluid flow "production scheme" that shows how to efficiently produce oil while minimizing the production of sand.

Currently, the MIMES code solves only 2D problems and supports multiple, arbitrarily-shaped particles. A 3D version of MIMES is now being developed.

The Near Wellbore Mechanics project is, in part, motivated by observations that sand production in oil and gas wells tends to increase when water content of produced fluids increases. DEM may be applied to investigate some of the physical processes occurring at the grain scale around cavities, such as fluid drag and capillary force effects, so that the industry can develop improved sanding prediction tools and optimum completion strategies.

Project members Ruaidhrí M. O'Connor and Dale S. Preece from Sandia National Laboratories, and John R. Williams from the Massachusetts Institute of Technology are now exercising the code on realistic problems. Terralog Technologies USA, Inc., is supporting this effort by applying its 2D discrete-element code to evaluate specific aspects of fluid flow on sanding. DOE Defense Programs funds this project, so the capabilities developed for the oil industry by this project need to have a "dual use" application for defense. Advanced discrete element capabilities can be applied to manufacturing of defense materials such as ceramics.

The techniques that are being developed in this project do not stop the production of sand, but enable the prediction of its occurrence. That prospect makes it easier to improve the efficiency of the well. The innovation will be of particular interest to oil company research departments looking for ways to predict sand production.

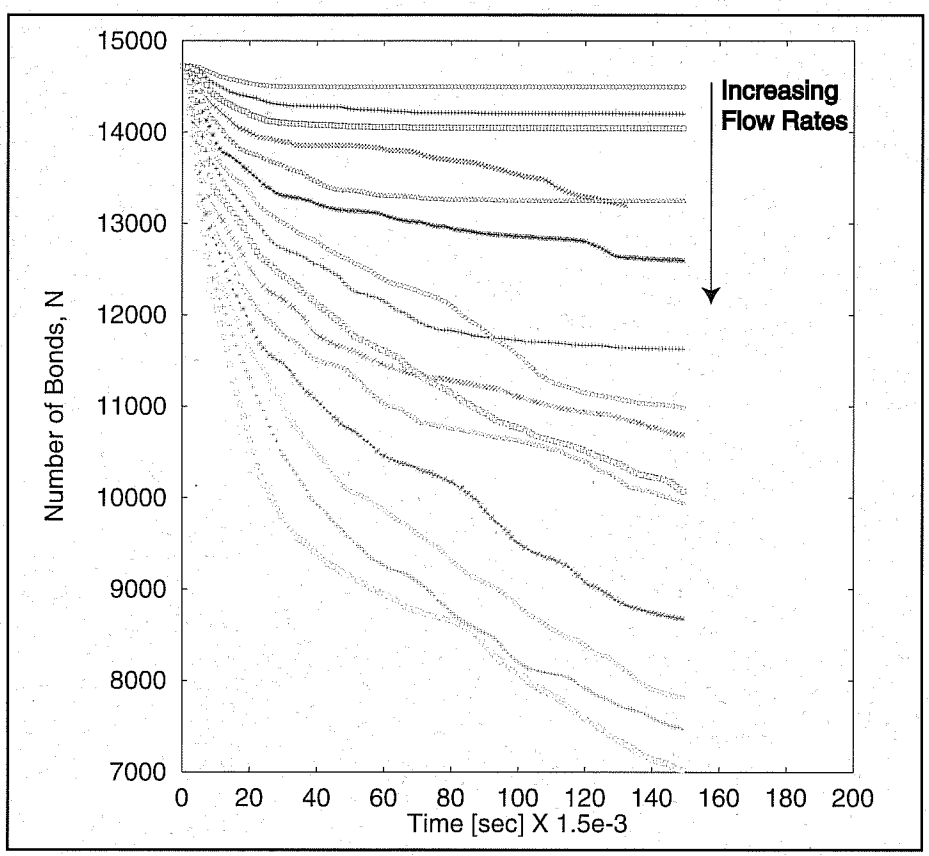


Figure 4: Numerical experiments wherein the models presented previously are subjected to increasing flow rates. The total number of bonds in the model versus time is plotted. Small flowrates break relatively few bonds, and the system comes to equilibrium with very little sand produced. Higher flow rates result in continuous production of sand as indicated by bonds being continually broken.

Contacts

D.S. Preece, SNL 505-844-6259
dspreec@sandia.gov
R.M. O'Connor, SNL 505-284-3088
rmocon@sandia.gov
J.R. Williams, MIT 617-253-7201
john@iesl.mit.edu

Publications

O'Connor, Ruaidhrí M., John R. Torczynski, Dale S. Preece, Justin T. Klosek, and John R. Williams, 1997, "Discrete Element Modeling of Sand Production," *International Journal of Rock Mechanics & Mining Science* 34:3-4, Paper No. 231.

Partnership News

ACTI and the Partnership

The computational projects previously evaluated by the Advanced Computational Technology Initiative (ACTI) Industry Review Panel and funded by Fossil Energy were integrated into the appropriate technology areas of the Partnership. This change better aligns the Partnership with the new Department of Energy (DOE) organizational structure.

FE supported Computational projects will now be reviewed and evaluated in the Oil and Gas Recovery Technology; Drilling, Completion, and Stimulation Technology; and the Diagnostics and Imaging Technology sections of the Partnership. ACTI projects receiving Defense Programs (DP) or Energy Research (ER) support in FY97 will be considered for FY98 support under the established procedures of these DOE offices.

The Partnership will report on all projects as organized in this issue of the *Partnership Progress*. The same organization will be reflected in the monthly *Activity Report* to DOE, and on the Partnership's web site. Such reporting will provide both continuity and a single national labs-petroleum industry interface for these on-going projects.

Multi-Lateral Completions

On September 18, 1997, INEEL was selected as a potential lead contractor (on behalf of the Partnership) for Global Petroleum Research Institute (GPRI) Project #10: Advanced Casing Lateral Juncture Technologies for Multilateral Wells—Phase I: Concepts Identification.

INEEL, as the lead national laboratory, will develop a scope of work for GPRI and will coordinate Phase I activities for Partnership participants. The Phase I period of performance is February 1, 1998, through July 31, 1998. This phase will identify innovative technologies and concepts that may have the potential to meet the performance requirements of a high-pressure seal at the casing-to-lateral juncture that will allow full-bore access. Upon completion, the national laboratories will submit Phase II proposals, either individually or collaboratively.

Annual Industry Reviews

The Oil and Gas Recovery Technology Review meeting was held November 12, 1997, at the National Petroleum Technology Office (NPTO) in Tulsa. Fifteen proposals (seven on-going, four on-going ACTI, and four new) were presented and reviewed and evaluated by 14 industry reviewers.

The Drilling, Completion, and Stimulation Technology Review meeting was held November 13, 1997, at the NPTO in Tulsa. Ten proposals (four on-going, two on-going ACTI, and four new) were presented and reviewed by seven industry reviewers representing the Drilling Engineering or Completion Engineering Associations.

The Diagnostics and Imaging Technology Review, formerly the Borehole Seismic Technology area, was broadened for FY98. However, the industry interface and review process will continue to be built around the participating companies of the existing Borehole Seismic Forum. The 12th Forum meeting was held December 3, 1997, at the NPTO in Tulsa, where ten proposals were reviewed.

The priorities and comments from the three reviews (Oil and Gas Recovery, Drilling Completion and Stimulation, and Diagnostics and Imaging) are being analyzed with the objective of deriving a single recommendation letter to DOE.

Environmental Technology

DOE/FE informed the Partnership that there will be sufficient funds in the Environmental Technology area to support new starts, an enlarged review panel, and a formal review meeting. Two new topics ("Tank Bottom and Sludge Treatment" and "NORM Treatment and Disposal") were added this year. "Intents to submit" proposals were due December 3, 1997, proposals on January 12, 1998, and the meeting was held January 28, 1998, in Tulsa.

Partnership Tours

Two tours of LANL were conducted at the request of two petroleum organizations which were holding meetings in Santa Fe, New Mexico. The Petroleum Technology Transfer Council and LANL hosted the first tour for the Board of Governors of the Independent Petroleum Association of America, held September 12, 1997.

The second tour, held December 7, 1997, was in conjunction with the annual meeting of the Interstate Oil and Gas Compact Commission (IOGCC). The IOGCC, the Independent Petroleum Association of New Mexico, and LANL hosted this tour for three busloads of participants.

Both tours featured the Partnership. Bob Hanold (LANL), Dave Northrop (SNL), and Earl Whitney (LANL) presented its operation and projects. A brief tour of Los Alamos and a stop at the Bradbury Science Museum rounded out the half-day tours.

Partnership Roster Change

Thomas C. Wesson, Director of the U.S. Department of Energy's National Petroleum Technology Office in Tulsa, retired on December 31, 1997. R. Michael Ray has taken over as Acting Director. Alex B. Crawley, Associate Director, is the primary DOE contact for the Partnership.

Fred Followill was named LLNL's representative to the Partnership Office, replacing Tony Chargin.

Publications

Technical Reports and Presentations

Berryman, J.G., V. Grechka, and P.A. Berge. 1997. "Analysis of Thomsen parameters for finely layered VTI media," LLNL report UCRL-JC-127249, 4 p., also in *Technical Program, Expanded Abstracts with Author's Biographies*, Society of Exploration Geophysicists International Exposition and 67th Annual Meeting, November 2–7, Dallas, TX, 941-944.

Dong, Q., and J.W. Rector. 1997. "Bi-domain modeling of borehole wave propagation," *Expanded Abstracts with Author's Biographies*, Society of Exploration Geophysicists International Exposition and 67th Annual Meeting, November 2–7, Dallas, TX, 262-265.

Glimm, J., C. Kim, D. Sharp, and T. Wallstrom. 1997. *A stochastic analysis of the scale up problem for flow in porous media*, LAUR-97-3160. Los Alamos, NM: Los Alamos National Laboratory.

Grechka, V., and I. Tsvankin. 1997. "Moveout analysis and parameter estimation for orthorhombic media," *Technical Program, Expanded Abstracts with Author's Biographies*, Society of Exploration Geophysicists International Exposition and 67th Annual Meeting, November 2–7, Dallas, TX, 1226-1229.

Hoffman, E.L. 1997. *Finite element analysis of sucker rod couplings with guidelines for improving fatigue life*, SAND97-1652. Albuquerque, NM: Sandia National Laboratories.

Mansure, A.J. 1997. "Cloud point detection using a thickness shear mode resonator," (SPE 38009) presented at the Society of Petroleum Engineers' Annual Meeting, San Antonio, October 6–8, 1997.

Ober, C.C., R.A. Oldfield, D.E. Womble, and C.C. Mosher. 1997. "Seismic imaging on massively parallel computers," *Proceedings of the 1997 Society of Exploration Geophysicists Annual Meeting*, Dallas, November 2–7, 1997.

Ober, C.C., R.A. Oldfield, D.E. Womble, L.A. Romero, and C.C. Burch. 1997. "Practical aspects of prestack depth migration with finite differences," *Proceedings of the 1997 Society of Exploration Geophysicists Annual Meeting*, Dallas, November 2–7, 1997.

Schoenberg, M. 1997. "Equivalent medium theory for fractured porous media," presented at the Third International Conference on Theoretical and Computational Acoustics, Rock Acoustics and Reservoir Geophysics Symposium, Newark, New Jersey, July 14–18, 1997.

Swift, R.P., L.A. Behrmann, P.M. Halleck, and K.E. Krogh. 1997. *Micro-Mechanical Modeling of Perforating Shock Damage*, LAUR-97-4841. Los Alamos, NM: Los Alamos National Laboratory. Also as SPE 39458, in the *Proceedings of the SPE Formation Damage Control Conference*, Lafayette, LA, February 18-19, 1998.

Tsvankin, I., V. Grechka, and J.K. Cohen. 1997. "Generalized Dix equation and modeling of normal moveout in inhomogeneous anisotropic media," *Technical Program, Expanded Abstracts with Author's Biographies*, Society of Exploration Geophysicists International Exposition and 67th Annual Meeting, November 2–7, Dallas, TX, 1246-1249.

Wallstrom, T. 1997. "Improved reservoir simulation using upscaled relative permeabilities and flexible grids," presented at the Stanford and Heriot-Watt University Forum on Reservoir Description and Modeling, South Lake Tahoe, CA, September 7–11, 1997.

Wrixon, R.C. and G.A.Cooper. 1997. "*In-situ* casing consolidation by electrokinetic and electromechanical methods," (SPE 38586) presented at the Society of Petroleum Engineers' Annual Meeting, San Antonio, October 6–8, 1997.

Journal Articles

Alkhalifah, T. 1997. "Seismic data processing in vertically inhomogeneous TI media," *Geophysics*, v. 62, 662-675.

Alkhalifah, T. 1997. "Kinematics of 3-D DMO operators in transversely isotropic media," *Geophysics*, v. 62, 1214-1219.

Anderson, J., and I. Tsvankin. 1997. "Dip-moveout processing by Fourier transform in anisotropic media," *Geophysics*, v. 62, 1260-1269.

Rueger, A. 1997. "P-wave reflection coefficients for transversely isotropic models with vertical and horizontal axis of symmetry," *Geophysics*, v. 62, 713-722.

Rueger, A., and I. Tsvankin. 1997. "Using AVO for fracture detection: Analytic basis and practical solutions," *The Leading Edge*, v. 16, 1429-1434.

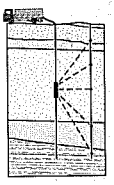
Tsvankin, I. 1997. "Reflection moveout and parameter estimation for horizontal transverse isotropy," *Geophysics*, v. 62, 614-629.

Tsvankin, I. 1997. "Anisotropic parameters and P-wave velocity for orthorhombic media," *Geophysics*, v. 62, 1292-1309.

Wilt, M.J., C. Schenkel, T. Daley, J. Peterson, E. Majer, A.S. Murer, R.M. Johnson, and L. Klonsky. 1997. "Mapping steam and water flow in petroleum reservoirs," *SPE Reservoir Engineering*, 284-287.

Zwahlen, E and T.W. Patzek. 1997. "Linear transient flow solution for primary oil recovery with infill and conversion to water injection," *In-Situ*, v. 21, 4, 297-331.

Project News



Diagnostic & Imaging Technology

Single-Well Seismic Imaging Technology

SeaCon fabricated most of the hardware pieces needed to convert the Conoco orbital seismic source to fiber optics for single-well use.

Problems with the downhole axial vibrator seismic energy source slowed data acquisition operations at the Bayou Choctaw, LA, test site. Single-well seismic data, however, were successfully recorded there by LBNL and INEEL in November.

This marks the first time that the project configured a true, single-well data acquisition system with the source and receivers deployed in a single well.

Paulsson Geophysical Services' (PGSI) axial hydraulic vibrator borehole energy source is undergoing repairs. PGSI will return to Bayou Choctaw in late January to complete data acquisitioning.

The Salt Imaging Consortium has promised their participation in the integrated national laboratory-industry-university research project in single-well seismic imaging technology.

SNL sited a seismic wave propagation algorithm, appropriate for 3D isotropic elastic media, on a UNIX workstation and initiated modeling studies of various single-well imaging scenarios.

The INEEL tube-wave suppression device was damaged during shipping and was not used during data collection. The design is being modified to prevent future shipping damage.

R. Cutler, SNL 505-844-5576 rpcutle@sandia.gov

J. Fincke, INEEL 208-526-2031 jf1@inel.gov

E. Majer, LBNL 510-486-6709 elmajer@lbl.gov

Microborehole Seismic Instrumentation

Mark Products completed the design and parts procurement for fabrication of a 0.349" horizontal geophone. One challenge is the termination of the fine wire within the geophone. Mark Products is developing a vertical geophone which is slightly larger, but produces significantly more signal.

An experiment at Humble Field was initiated with the installation of 1" microtool tubing access strapped to 2-3/8" tubing in a production well provided by Texaco E&P. The well produced 180 bbl/day immediately following a recent stimulation, and subsequently declined to about 4 bbl/day. All data were collected with borehole packages deployed at a 1300' depth. Signals fired from neighboring wells compared favorably for geophones in casing alone, in 2-3/8" and 1.0" tubing, and with geophones cemented in another well.

D. Dressen, LANL 505-667-1913 dreesen@lanl.gov

P. Harben, LLNL 510-422-3571 harben1@llnl.gov

Seismic Imaging Behind Production Tubing

The bi-domain wave equation-based modeling method was developed to model VSP and crosshole seismic surveys with a complex tool inside the receiver borehole. The method was accurate in both travel time and amplitude in open or cased boreholes. A typical hard formation velocity model was used to generate bi-domain modeling borehole pressure data for cased and non-cased boreholes, and showed excellent agreement with quasi-static modeling data at frequencies of 10-1000 Hz.

This method uses local time steps and a one-way absorbing boundary condition that help reduce computation time and memory requirements.

J. Rector, LBNL 510-486-5247 jwrector@lbl.gov

F. Followill, LLNL 510-422-3920 followill1@llnl.gov

Large Downhole Sensor Array

Dave Weinberg and Jim Fincke (INEEL), met with OYO personnel at the Society of Exploration Geophysicists' annual meeting, held November 2–7 in Dallas, to discuss the status of the CRADA and technical details of the overall project. The CRADA was signed December 18.

OYO has tentatively established the size requirement for the downhole electronics and picked a geophone sensor. This allows project researchers to develop clamping concepts and hardware designs.

J. Fincke, INEEL 208-526-2031 jf1@inel.gov

Gulf of Mexico Subsalt Seismic Imaging

Researchers ported the project's migration algorithm to run in a message-passing interface environment and did some testing on both an Origin 2000 and a Sun multiple processor workstation. Results are encouraging, with a migrated field dataset working quite well on the Sun system. Testing continues with differing aperture and taper functions in an attempt to improve the image obtained.

Continued on Page 7

Project News (Continued from Page 6)

Project participants developed a travel-time and ray-amplitude calculation approach to calculate the maximum amplitude travel time between source and image point, and between receiver and image point to be used in migration. Researchers hope to obtain improved images by using maximum amplitudes, over what is obtained when using earliest arrival time, which is the common method for doing Kirchhoff migration. The travel-time solver was successfully tested.

M. Fehler, LANL 505-667-1925
fehler@lanl.gov

Locating Geopressured Hydrocarbon Reservoirs

A report that details 1D geomechanics was prepared. It describes the nature of a relative permeability/capillary pressure seal in 1D heterogeneous media and 2D pressure/saturation fields. The project subcontractor submitted the report and made it available for initial geomechanical modeling.

Work scope was expanded to include pore pressure prediction as related to well planning. Personnel from the Conoco Research Center in Ponca City, Oklahoma, visited INEEL to offer technical support and confirm their commitment to the project.

G.M. Shook, INEEL 208-526-6945
ook@inel.gov

3D Seismic Analysis using SEG/EAGE Dataset

A parallel code for carrying out 3D focusing velocity analysis using common-azimuth downward continuation was developed. This will be part of a 3D prestack depth migration sequence that will use azimuth move-out (AMO) to speed up the migration by as much as a factor of 10 or more, compared to existing migration approaches.

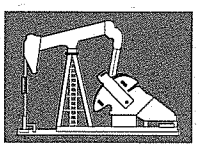
An attenuation algorithm was developed for the 3D elastic modeling code, "E3D." The algorithm uses a relaxation mechanism approach, which will allow attenuation to vary as a function of frequency. E3D is also being modified to use a common message-passing interface (Parallel Virtual Machine) so that it can be run on a network of workstations as well as massively parallel processors.

Elastic modeling and imaging experiments were carried out in 2D using the SEG/EAGE salt model. Two-dimensional pseudospectral elastic and acoustic codes were used to generate multishot, multichannel synthetic seismic data sets. Those datasets were used for 2D prestack depth migration experimentation. Elastic modeling was also done in support of interpretation of a field dataset from the Gulf of Mexico. Strong mode conversions from salt interfaces were identified in the field data.

L. House, LANL 505-667-1912
house@lanl.gov

S. Larsen, LLNL 510-423-9617
larsen8@llnl.gov

J. Barhen, ORNL 423-574-7131
barhenj@ornl.gov



Oil & Gas Recovery Technology

Applied Production Technology (APT)

Sucker Rod Failures

The Downhole Dynamometer Database was completed and distributed. A report by E.L. Hoffman was published (see "Publications" P. 5) and placed on the APT web site at **http://132.175.127.176/apt/rodfailu/rodfailu.htm**. The analysis examines the stresses induced in sucker rod couplings for a number of combinations, including three sizes of sucker rods, slimhole couplings, standard couplings, Flexbar modified pin geometry, Spiralock threads, and varying amounts of make-up. The analysis also describes the relative effects of these combinations on predicted fatigue life and makes recommendations to reduce fatigue failures.

During pump fluid modeling, a sample case with typical pump and well properties was run using new equations for flow rate, Reynolds number, friction factor, and pressure drop. Uphole tests are planned to validate and refine the model

Field Measurement of Oil Properties

The response of thickness shear mode quartz crystal resonators to pressure was tested as the first step in designing crystal mountings for an *in situ* Cloud Point Detector and/or Deposition Detector. The effect of pressure on crystal response can be controlled to equal or be less than the effect of the cloud point, allowing cloud point or deposition detection, even when pressure is not constant.

A US Patent was issued for the cloud point detector. Also, "Cloud point detection using a thickness shear mode resonator," was presented at the SPE Annual Meeting (see "Publications" P. 5).

Continued on Page 8

Project News (Continued from Page 7)

Artificial Lift Using Foam Pigs

During wear-testing of foam materials, T.D. Williamson's Red Skin Pig displayed an abrasion resistance more than ten times better than other materials tested. The material evaluation phase of the project is now complete, allowing the design phase to proceed with the Red Skin foam as the preferred material.

Methods are being developed to measure elastic modulus of foam rubber materials. Significant creep was measured and identified as a complicating factor in specifying foam rubber elastic modulus.

Production Control Services has supplied a number of commercial plungers that are being tested to establish a baseline for evaluating plungers fitted with foam rubber seals.

Pump Hydraulics

University of Tulsa was visited to become familiar with the sucker rod pump test facilities.

This project is developing a fluid model of downhole sucker rod pumps to quantify the pump effects which lead to buckling of the sucker rod string, learn how pump geometry and pumping rate affect pump fillage and contribute to gas interference and gas locking, and indicate areas for improvement in the internal design of sucker rod pumps.

Tech Transfer

The Cloud Point Detector was loaned to Nalco/Exxon for testing. A presentation about the Downhole Dynamometer Database was made to the Artificial Lift Forum, and more than 50 copies of the database were distributed. Technical advice was provided for an Oklahoma automatic casing swab field trial, the first such trial west of the Mississippi.

C. Mansure, SNL 505-844-9315
ajmansu@sandia.gov

Optimizing Reservoir Production

The performance of the LANL-BP-Chevron (LBC) scale-up code for 2D waterfloods was extensively analyzed during two sets of tests. The first set compared fine-grid simulations of a line drive waterflood through a 2D cross-section with scaled-up methodologies. During these tests, the LBC scale-up consistently gave superior results. These results were presented at the Stanford and Heriot-Watt University Forum on Reservoir Description and Modeling and in a LANL report (See "Publications" P. 5)

The second set of tests compared the LBC scale-up code and uniform scale-up using the BP scale-up code "renorm." This comparison showed that LBC gave better results on very coarse grids. The LBC scale-up gives consistently small, unsystematic errors, whereas renorm always gives early breakthrough time relative to the fine grids. The success of LBC facilitates the installation of enhanced capabilities, for which a C++ integrated code is being written.

W. Soll, LANL 505-665-6930
weasel@lanl.gov

Reduction of Well Failure in Diatomite

Two independent Work-For-Others agreements between SNL and the primary industry partners for this task (Chevron USA Production Company and Aera Energy LLC) were negotiated and approved by the DOE.

Data were reviewed in preparation for development of numerical models for Lost Hills geomechanical simulations.

L. Myer, LBNL 510-486-6456
lrmeyer@lbl.gov

J. Fredrich, SNL 505-844-2096
fredrich@sandia.gov

Fluid Injection into Tight Rocks

Research showed that the wellbore and associated hydraulic fractures can be modeled adequately by their lossy transmission line analog. In most cases, the well geometry will be known *a priori*. Therefore, the system identification through transient analysis reduces to identifying the fracture dimensions. Different inversion strategies are currently being tested for their suitability for the system identification problem. The accuracy of these methods is being tested using synthetic data.

T. Patzęk, LBNL 510-643-5834
patzek@patzek.berkeley.edu

C. Bruton, LLNL 510-423-1936
bruton1@llnl.gov

Extending Borehole EM Imaging

It is necessary, in order to properly evaluate measurements through steel-cased boreholes, to separate the magnetic fields inside the cased borehole attributable to the changes in formation resistivity, from those due to the casing and changes in casing parameters. Using the wavefield approach, which transforms diffusive EM fields to wavefields, researchers were able to determine the casing properties in terms of the casing's lumped parameter. The lumped parameter is defined by the thickness of the casing, times the square root of the conductivity-permeability product. Preliminary numerical results show that resolution of the casing parameter is within a few percent.

K. Lee, LBNL 510-486-7468
khlee@lbl.gov

P. Harben, LLNL 510-422-3571
harben1@llnl.gov

(Continued on Page 9)

Project News

(Continued from Page 8

Improved Prediction of Multiphase Flow

Improved routines were developed to compute residual oil saturation in mixed-wet porous media, and then implemented into the UTCHEM code. The code will be tested against recently obtained laboratory pressure and saturation data from detailed waterflood experiments in 1-m-long columns. If UTCHEM tests successfully as compared to laboratory data, the code is complete.

Future efforts include implementation of the extended three-phase model. R.J. Lenhard and M. Oostrom (PNNL) presented this theoretical model to Mobil Oil E&P in Dallas.

M. Oostrom, PNNL 509-372-6044
m_oostrom@pnl.gov

Improved Waterflooding

Data were collected from the West Semlek waterflood (reinjected produced water exclusively) and from the Moran waterflood (injected low-salinity water exclusively). Both of these floods are in the Powder River Basin of Wyoming and produce from the Minnelusa Formation. The low-salinity flood has a better recovery, which supports laboratory experimental results.

E. Robertson, INEEL 208-526-7456
epr@inel.gov

Development of a New Generation Petroleum Reservoir Simulator

The fully implicit EOS compositional model was successfully tested in parallel on a 16-processor IBM SP2. In this test, the IPARS framework was used to handle domain decomposition across processor memories, and PETSc was used to solve the linear system generated from the model in parallel. A fully detailed efficiency evaluation of parallel runs of the model is under way.

A waterflood model was completed under the IPARS framework and is running on both single and multiprocessor platforms. The black oil model was debugged in IPARS. Multiblock data structures were incorporated into IPARS and are currently being tested with the hydrology model.

A new, fast, accurate method for multiphase flow (an enhanced IMPEC) was formulated and a 2D model implemented for two-phase flow. This model has advantages over fast streamtube models in that the method is locally conservative and can treat gravity, capillary pressure, and general boundary conditions. Preliminary results indicate that it is efficient and accurate.

Multiblock irregular geometries were implemented and tested in the two-phase prototype simulator UTMB. A time splitting procedure of IMPES type for the hydrology model is currently being incorporated into IPARS.

T. Morgan, ANL 630-252-5218
tmorgan@anl.gov

Innovative Gridding and Solution Techniques

Conversion of the LANL unstructured multi-phase simulator to Fortran 90 was completed, and the code was ported to the LANL parallel computing environment.

Studies are near completion for the structured phase of the grid resolution study which used a typical geologic setting. A series of unstructured grids representing the same geologic setting is now being generated and will be compared to the structured case.

The octree-type adaptive mesh refinement capability is an alternative to unstructured tetrahedral grids. This methodology has the capability of adaptive mesh refinement (AMR) based on model geometry. With this approach, a regular orthogonal grid is superimposed on the model geometry. The AMR increases resolution to resolve model geometry. This method should be useful, except in the boundary region between high- and low-resolution gridding, because of the structured-like grids.

G. Zyvoloski, LANL 505-667-1581
gaz@lanl.gov

Fracture Mapping and Slimhole Geophone Array

The project identified a broadband noise source in an isolation amplifier of the 1-11/16" geophone tool uphole electronics. Design changes were implemented. The Cotton Valley Stage 2 hydraulic-fracture microseismic data were translated from SEGY to Seismic Analysis Code format. Nine, 3-component stations were selected for use in a decimation study evaluating the feasibility of mapping with retrievable geophone arrays in various spacing and deployment depth configurations. After arrival times were picked, data were analyzed for reliability of first-arrival particle motions used in locating events from a single-well array.

A joint hypocenter-velocity inversion was conducted using 26 primacord shot records with shot-break origin times and 72 of the highest quality microearthquake events. The starting model was derived from sonic logs, and fracture geometry was reliably mapped. A cluster of microearthquakes was repicked and mapped to examine the detailed structure of the fractures affected. The relative locations delineate linear, horizontal features. Examination of temporal-spatial-energy distributions in the clusters show repeated patterns of event migration toward the injector well.

J. Rutledge, LANL 505-667-8938
jrutledge@lanl.gov

(Continued on Page 10)

Project News

(Continued from Page 9

Wireless Telemetry Tool

The prototype was deployed in a 11,500' well in Mississippi with measured attenuation levels ranging between 6 and 8 dB/1000'. The Prototype operated to 6000' before excessively high temperatures damaged the tank-circuit coil. The string, with the prototype tool in place, was then used to drill out 70' of debris in the bottom of the hole. The tool survived drilling with 7000 lbs of weight on the bit and operated normally after the damaged portion of the coil was bypassed.

A meeting was held at Baker Oil Tools to discuss a marketing point-of-entry for the wireless telemetry tool. Baker has established a project group and schedule to commercialize the tool. SNL will continue to act in the capacity of technical advisor and provide support for future field testing.

D. Drumheller, SNL 505-844-8920
dsdrumh@sandia.gov

Drilling, Completion, & Stimulation Technology

Tiltmeter Hydraulic Fracture Imaging

LLNL and Pinnacle Technologies designed an improved data-logger circuit board with a simplified analog circuit for the tilt signals. The circuit board will no longer need plus and minus 12V power supplies.

Steven Hunter (LLNL) and Chris Wright (Pinnacle Technologies) presented the tiltmeter to the Venezuela Ministry of Energy and Mines as a tool to monitor subsidence caused by oil production in coastal regions of Lake Maracaibo. Wright showed data from the Bakersfield area demonstrating oil-production-caused subsidence and its effect on local stress, as evidenced by changes in hydrofracture orientation.

S. Hunter, LLNL 510-423-2219
hunter5@llnl.gov

N. Warpinski, SNL 505-844-3640
nrwarpi@sandia.gov

Reduction of Bit Balling Using Electro-Osmosis

Constant voltage electrokinetic experiments were conducted on samples of San Francisco Bay silty clay with water content of 75%, 62.5%, and 50%. As expected, the higher water content samples showed the largest percentage increase in bearing capacity. When salinities of samples were increased to reflect salinities found in marine mud, similar shear strength increases were observed when the applied voltage during the experiments was the same as that used with the fresh water samples. These saline samples require significantly higher current levels to consolidate.

Water content of samples in subsequent tests was 62.5%; the mixtures were prepared in saline and fresh water environments to investigate the effect on the consolidation process of using different metals as the anode material. Copper anodes yielded an increased unconsolidated shear strength by 100% to 800%. The steel anodes showed increases of between 100% and 500%. Aluminum anodes produced a maximum increase of 150%. In many cases the consolidated shear strength was lower than that achieved with no electrokinetic consolidation.

These results were similar in the freshwater and saline silty clay mixtures, however a far higher current was drawn in the saline mixtures to employ the same consolidation voltage.

G. Cooper, LBNL 510-642-2996
gcooper@socrates.berkeley.edu

D. Glowka, SNL 505-844-3601
daglowk@sandia.gov

Air/Mist/Foam and Underbalanced Drilling

MUDLITE 2 is ready for distribution. MUDLITE 2 handles hydraulics for air, mist, foam, and aerated fluid drilling/completion/workover operations. The original MUDLITE is reported to match field measurements very well.

NITRO, a nitrogen cost model, was delivered recently. This program compares costs and sensitivities for operations with liquid N_2 and membrane-generated N_2.

UBCOST 1.1, the underbalanced drilling cost model, was upgraded with a sensitivity analysis feature for comparing costs and optimizing operations for various underbalanced drilling systems.

The Underbalanced Drilling and completion Manual, the three DEA-101 programs, and the three users manuals are being placed on a single CD, easing its distribution within companies by DEA-101 participants.

D. Dreesen, LANL 505-667-1913
dreesen@lanl.gov

Coiled Tubing Fatigue

Results of this DEA joint industry project are "Proprietary." As results are

Continued on Page 11

Project News (Continued from Page 10

made available to the public, they can be accessed at **http://www.utulsa.edu/collegeofengr%26as/coil/announce.htm**.

A. Watkins, INEEL 208-529-1217
adw4@inel.gov

S. Tipton, University of Tulsa
Tulsa, OK 74104

Perforation Dynamics in Geological Media

Project participants performed extensive simulations of Halliburton's OMNI conical-shaped-charge penetrator into 6061-T6 aluminum alloy targets to validate the constitutive model developed for the composite liner. Researchers performed simulations of this perforator against standard API Section 1 (RP43 concrete) targets, which replicated the penetration measured in these targets by Halliburton.

All concrete simulations exhibited the formation of a residual stress cage, hypothesized to be mainly responsible for decreased permeability associated with the perforation process. The stress cage might be destabilized by an asymmetric penetrator, with 3D simulations being set up to explore this possibility. Experiments are under way on non-axisymmetric-shaped-charge jets.

L. Glenn, LLNL 510-422-7239
glenn5@llnl.gov

Increased Effectiveness of Hydraulic Fracturing

TerraTek improved performance of the TerraFrac code, specifically in terms of convergence and minimizing volume balance errors. This should allow for easier porting to the PC environment and improved accuracy. Some problems with thin layers were resolved, particularly those dealing with elastic modulus.

Work on the updated graphical user interface (GUI) is also progressing well. The improved GUI is the key to simplifying the customer's interface to the program.

Revised proppant routines using SNL-supplied relations are being integrated into the code to improve slurry transport modeling. SNL continues to examine the transport phenomenon under fracture-related conditions.

N. Warpinski, SNL 505-844-3640
nrwarpi@sandia.gov

A. Graham, LANL 505-665-5259
graham@lanl.gov

Mapping Steam and Water Flow in Diatomite

Data from the Chevron Lost Hills experiment were processed in conjunction with Western Atlas. These data were recorded with Tomoseis as part of a prototype experiment to test the feasibility of using microseismicity to map hydrofractures in diatomite. The analysis indicates that there were multiple events that could be used to map hydrofractures.

Plans were made with Chevron to complete data analysis and to explore mechanisms for technology transfer.

E. Majer, LBNL 510-486-6709
elmajer@lbl.gov

P. Harben, LLNL 510-422-3571
harben1@llnl.gov

Evaluation of Concepts and Components for Directional Underbalanced Drilling

Robello Samuel (University of Tulsa) presented his recent work on modeling of positive displacement motors (PDMs) to the LANL and Maurer Engineering project team. A review of the modeling work continued, and an exact calculation of the PDM cross-section areas for typical rotor and stator profiles, hypocycloid envelopes, and epi/hypocycloids was derived. The model includes algorithms that predict flow leakage and torque loss and thus simulate a real motor as opposed to an ideal motor. First attempts to reproduce the derivation of algorithms were unsuccessful. Additional data from the University of Tulsa were received and are being reviewed.

Modification of the Maurer Engineering drilling test stand is 75% complete. A demonstration of a high-data-rate acquisition system is planned, using water as the PDM power fluid. Air, mist, and foam powered PDM testing will be scheduled based on compressor availability following a successful demonstration with water. LANL procured geophones for the vibration measurements and found surplus pressure transducers and accelerometers to support the pressure measurements. A high-frequency data acquisition system is being assembled using equipment that previously had supported the borehole acoustic programs.

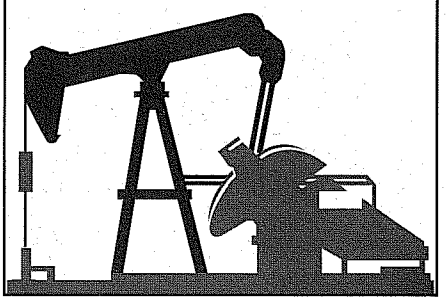
This project will be combined with the Drilling, Completion & Stimulation project, Underbalanced Directional Drilling.

D. Dreesen, LANL 505-667-1913
dreesen@lanl.gov

Industry Participants

The Partnership's World Wide Web site includes a complete list of industry participants and their project affiliations. See:

http://www.sandia.gov/ngotp/



Project News (Continued from Page 11

Environmental Technology

Monitoring of Particulate Emissions

Field trials began of laser-induced breakdown spectroscopy as a continuous monitor for inorganic particulate matter in the combustion products from stationary sources used in natural gas and oil production.

Six days of testing were conducted in the stack of Unit B at Chevron's Kern River Cogeneration Facility near Bakersfield. The unit uses a gas turbine and a duct burner to generate steam and electricity for field operations. The measurement technique generates a plasma by focussing a pulsed Nd:YAG laser into a small volume of combustion products, ionizing the atoms. The wavelengths of light emitted and their intensities are used to determine the elements present and their concentrations. When only one particle is present in the spark, intensity is used to estimate its size. Single particles of most metal oxides can be detected at sizes well below 2.5 micrometers.

As some data analysis for the tests was conducted off line, results are not yet available. Particle concentrations were low; therefore, measurements were taken of the ambient air entering the combustion air intake to compare with stack concentrations.

The next tests will measure particulate matter in the exhaust of a natural gas-fueled spark ignition engine that drives a natural gas compressor.

P.M. Walsh, SNL 510-294-3726
pwalsh@sandia.gov

Development of an In-well Oil/Water Separator

Costner Industries Nevada, Inc., Oak Ridge Tool and Engineering, Inc., and REDA Pump agreed to collaborate on the development of the Centrifugal Down Hole Separator. Chevron, Halliburton, Phillips, Texaco, and Unocal will also support its development.

A bench scale mixer/settler system was constructed, and tests with the tributyl phosphate in dilute nitric acid solutions are complete. Test results indicate that the system and procedures are suitable for testing motor and crude oils. Such tests continue.

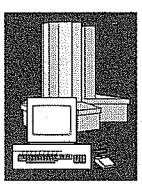
A bench scale, liquid-liquid centrifugal separator, which will be used in initial laboratory tests, was purchased and installed. Initial testing will be with tributyl phosphate in dilute nitric acid solutions to confirm operation and design parameters, prior to processing motor oils and crude oils.

J.F. Walker Jr., ORNL 423-241-4858
wfj@ornl.gov

Stationary Source Emission Control

The electrical power consumption and gas-phase chemistry were characterized during tests of a laboratory prototype of the plasma-assisted catalyst device using the exhaust from a Cummins diesel engine generator set. Results showed that plasma processing efficiency and electrical energy consumption in real exhaust gas were consistent with those taken with model gas. This suggests that the plasma can perform well in a realistic environment.

B. Penetrante, LLNL 510-423-9745
penetrante1@llnl.gov



Defense Programs Supported Computational Projects

Geologic Structure and Reservoir Mechanics

A model problem that exhibits softening behavior was developed for use with both dynamic-relaxation (DR) and conjugate-gradient (CG) iterative methods, with the DR implementation adapted to incorporate the variable arc-length algorithm. The combined technique was robust and rapidly convergent. It will be incorporated into SANTOS, the 2D, finite-element code.

The utility of the variable arc-length method with both DR and CG must be demonstrated prior to its implementation into JAS3D.

Development and implementation of the element-free Galerkin (EFG) quasi-static technology into JAS3D began. EFG technology will allow development of discrete fractures in geomechanical analyses.

Continued on Page 13

Project News

(Continued from Page 12)

A theory for strain hardening/softening using the cap model is in development. The main research areas are in the hardening/softening, and the numerical integration.

M. Stone, SNL 505-844-5113
cmstone@sandia.gov

Models for Deep Water Oil and Gas Production

All software modules were completed and integrated into a single code, but validation against known analytical solutions and experimental data is incomplete. Preliminary calculations of a circular cylinder moving through a fluid for a distance of one body diameter show that the wall layer model reduces the number of vortices shed, which significantly reduces computer time for longer simulations.

A portion of the funding required to complete the pseudo-3D, deep ocean riser vortex-induced vibrations code was received. Remaining funding is forthcoming. Progress on the current project and the FY98 proposal were presented to the DeepStar Vessel and Riser Committee.

C. Peterson, SNL 505-844-6775
cwpeter@sandia.gov

3D Imaging of Complex Geologies:

The I/O routines in the imaging code were rewritten to support phase encoding as a background operation. Tests of the modified code indicate that using the I/O partition in the code can reduce the overall migration run time by up to 40%.

Salvo was modified to allow phase encoding as a standard option. Phase encoding is regularly being used to produce images of comparable quality to standard prestack, finite-difference migration, with less work.

Porting of Salvo to the new Digital Equipment Company (DEC) Central Site Computer began in preparation for the decommissioning of the Intel Paragon in March. There are plans to port Salvo to SNL's Computational Plant, which is expected to be the next generation supercomputer paradigm. Work has begun on parallel fast Fourier transforms algorithms to extend the capabilities of Salvo.

Two papers were presented during the Society of Exploration Geophysicists' (SEG) Annual Meeting, held November 2–7 in Dallas (See "Publications" P. 5). Project representatives also participated in a workshop on the SEG/EAEG salt model during the SEG meeting. Results from Salvo's processing of the SEG/EAEG salt model were well received.

SNL staff visited GX Technology to learn how to use their model-building software.

Oryx Energy hosted a partnership meeting on December 4, 1997 where. participants looked at 3D datasets for processing by Salvo and established a working group for the commercialization of Salvo.

D. Womble, SNL 505-845-7471
dewombl@cs.sandia.gov

C.C. Ober, SNL 505-844-1846
ccober@cs.sandia.gov

Advanced Reservoir Management (ARM)

Equitable Resources is near completion of a compilation of marker picks for seams in the Middle Lee Formation and other well information in the Nora Coalbed Methane Field. Data are catalogued in a database that supports a 3D geological modeling effort at LANL.

Wold Oil and Gas has made progress in building the dynamic simulation model of the Big Sand Draw Field near Casper, Wyoming. The model is used to study the cause of high water cuts and to examine the sensitivity of water cuts to various production parameters. The history matching phase began.

Flying J Oil and Gas constructed a porosity model of the Ordovician Red River Formation in the Brorson Field, Montana. An interpretation of subzones within the Red River is currently being formed. Maps defining the subzones add conductivity constraints to the reservoir model and guide the distribution of other reservoir rock properties. Flying J is also describing geological pinch-out mechanisms and locations to improve definition of reservoir volumetrics.

Midland Resources completed the history-matching of a dynamic multiphase flow model of the Cope Unit. The history-matched model will allow Midland to evaluate various development scenarios. Engineering personnel will use the simulator to make production forecasts for a waterflood design.

Farrar Oil and Gas constructed a conceptual field model for the West City Unit, Mt. Vernon, Illinois, to be used to determine whether injected water is bypassing oil in the unit.

E. Whitney, LANL 505-667-3595
whitney@lanl.gov

Computer Simulation in Support of Nuclear-Well Logging Devices

Theoretical developments were made in time-dependent neutron diffusion. Previous methodology required 50,000,000 neutrons to be sampled in a Monte Carlo calculation to yield statistically significant neutron capture photon spectra. Now, the same results can be achieved with 5,000 particles! This work will be verified with generic and industrial pulsed-neutron tools and then validated on industrial field data.

P. Soran, LANL 505-667-8103
soran@lanl.gov

J. Ferguson, LLNL 510-424-4768
ferguson@viper.llnl.gov

Continued on Page 14

Project News (Continued from Page 13)

Near Wellbore Mechanics

MIT's Intelligent Engineering Systems Laboratory is researching 3D discrete element modeling. Research includes extension/improvement of the discrete-element contact search algorithm as well as an investigation of methods to display the results from 3D simulations.

A display technique stores the simulation results in VRML format. The simulation can then be animated. Three-dimensional model manipulation tools, such as rotation and translation, are enabled while the animation is running on the browser, allowing the user to look at details of the simulation as they occur. Current development of the 3D discrete-element capability includes file output in VRML format.

For more information, see the feature story on Page 1.

D. Preece, SNL 505-844-6259
dspreec@sandia.gov

Coupled Rock/ Fluid Mechanics:

Work proceeded toward creating a 3D reconstruction of grain-pore structure from x-ray synchrotron computed microtomography data. These data will form the basis of 3D code calculations to model rock grain damage from perforation shaped-charge jets. Algorithms for processing the synchrotron data into a format that will allow the use of edge detection schemes are under way. Bonds between particles are being implemented in the Smooth Particle Hydrodynamics (SPH) approach to permit fracture between pairs of particles when a threshold is reached. This allows damage-involved particles to maintain integrity with particles in directions where tensile failure has not occurred and to have no communication with particles that intersect across the fracture plane. A normalization technique for determining gradients is being implemented to improve stability for tension states and also help provide boundary condition integrity.

A paper entitled "Micro-Mechanical Modeling of Perforating Shock Damage," SPE 39458, was completed (See "Publications" P. 5).

R. Swift, LANL 505-665-7871
bswift@lanl.gov

B. Nellis, LLNL 510-422-7200
nellis1@llnl.gov

L. Mondy, SNL 505-844-1755
lamondy@sandia.gov

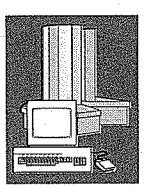
Oil and Gas Data Infrastructure (OGDIP)

The original Oil and Gas Data Infrastructure project (OGDIP) production-data prototype Web site is still used for real work by oil and gas professionals throughout California. Feedback, however, noted deficiencies in the query and report mechanisms. The second prototype provided advanced queries, but the underlying technology is unstable and resulted in poor performance and system crashes.

The current prototype is built with advanced Java™ tools. This prototype, combined with a newly designed database scheme, provides rapid access to data through a new tab-based Web interface. The prototype downloads a Java™ applet to the user's browser and the applet implements the interface on the client's desktop machine and accesses the OGDIP database directly. This increases performance and flexibility and provides new functionality.

A demonstration version of this prototype can be found at: **http://wildcat.llnl.gov/**. Subsequent versions will include the reporting functions necessary for a production system.

J. Wagoner, LLNL 510-422-1374
wagoner1@llnl.gov



Energy Research Supported Computational Projects

Velocity Analysis, Parameter Estimation, and Constraints on Lithology

Vladimir Grechka, Colorado School of Mines (CSM) researcher working on this project, received the prestigious Karcher Award for Young Scientists during the Society of Exploration Geophysicists (SEG) meeting, held November 2–7 in Dallas. LLNL and CSM researchers presented talks at the SEG meeting on normal moveout in inhomogeneous anisotropic media, parameter estimation for orthorhombic media, and analysis of Thomsen parameters for layered anisotropic media.

Recent project publications include: "Analysis of Thomsen parameters for finely layered VTI media," "Moveout analysis and parameter estimation for orthorhombic media," "Generalized Dix equation and modeling of normal moveout in inhomogeneous anisotropic media," and "Using AVO for fracture detection: Analytic basis and practical solutions," (See "Publications" P. 5).

P. Berge, LLNL 510-423-4829
berge1@llnl.gov

Continued on Page 15

Project News

(Continued from Page 14)

Modeling and Processing Seismic Data

Researchers formulated a wavefield propagator that works for the acoustic (variable density) wave equation. This approach improves previous work with the acoustic wave equation, in that it is exact for vertical wave propagation. The method was tested for forward propagation through a random medium characterized by a Gaussian autocorrelation function. The new results compared favorably to other methods of wavefield calculations.

P. Roberts, LANL 505-667-1199
proberts@lanl.gov

Subsalt Imaging with Marine Magnetotellurics

Marine MT is moving into commercial application, with sponsors planning multiple surveys in 1998. The bottom of the salt can be resolved to within about 10% of its depth using the LBNL-developed Sharp-Boundary MT inversion algorithm. Plans for FY98 are to extend the Sharp-Boundary inversion to a joint gravity MT inversion to obtain a common model for the salt structure.

H.F. Morrison, LBNL 510-642-3157
hfmorrison@lbl.gov

Optimal Fluid Injection Policy and Producibility

The lossy transmission line model for the wellbore and the fracture is adequate for the simulation of the transient response of the diatomite wells.

Seventeen waterflood injectors in Section 12 of the Middle Belridge diatomite and three steam injectors in Section 29 of the South Belridge diatomite were analyzed to study the growth of hydrofractures that are attributable to transient linear flow in a low-permeability, soft rock.

Carter's simple theory of hydrofracture growth was extended to the case of variable injection pressure and simplified. The growth of fracture area at constant injection rate was expressed in terms of two, easily measured field parameters: the early "injection slope" in linear transient flow, and the average injection rate. Carter's fracture growth rate was further halved to account for the reservoir layer homogeneity, parallel and perpendicular to the hydrofracture plane.

An optimal injection control strategy was designed, based on minimization of a quadratic performance criterion under linear constraints.

T. Patzek, LBNL 510-643-5834
patzek@patzek.berkeley.edu

Synchrotron Computed Microtomography

Microtomographs of reservoir and seal rock samples analyzed down to 3 micrometers of resolution were produced at the Brookhaven National Synchrotron Light Source. This facility includes a stereo display viewing room where 3D renderings of the samples are stereographically projected.

This work extended the capabilities of the facility by improving instrumentation, applying Fourier reconstruction and parallel processing techniques, and developing algorithms for subvolume sampling. A number of "dual-use" investigations also took place, with two of the most promising being in the areas of medical imaging and visualization of protein structures.

The Visualization Facility and its applications were presented as a Research Exhibit at the Supercomputer '97 conference. The facility will continue to be used to process core samples from Mobil, and the staff continues to make improvements to increase image resolution and reduce computation time.

A. Peskin, BNL 516-344-4161
peskin@bnl.gov

Advanced Computational Analysis of Drill Cuttings

A new version of the graph theory-based network model was completed, with the tubes of circular cross-section connecting pores being replaced by tubes of triangular cross-section. This permits coexistence of both wetting and nonwetting phases in the tubes, with the corners representing the roughness of the surfaces defining the pore space.

A 3D image of the pore space in Fountainbleau sandstone was obtained from BDM Petroleum Technology. The image was generated using a microfocus nuclear magnetic resonance at a resolution of about 11.5 microns.

An extensive benchmarking effort began in which a comprehensive set of laboratory measurements is being conducted on samples of two different sandstone reservoir rocks with various permeabilities. Simulations from the graph-theory-based network code will be compared to experimental observations. Porosity, intrinsic permeability, and mercury porosymmetry measurements are complete. Additional work includes thin sectioning, from which pore images will be obtained, and measurement of relative permeabilities. Simulations were performed using pore throat-size data from the mercury injection experiments. Based on this data, the intrinsic permeability could be well-matched for most, but not all samples.

Wood's metal and mercury injection was also carried out on the samples to produce Wood's metal casts of the pore space. Qualitative and quantitative correlations are sought between properties of these casts and measured permeabilities.

L. Myer, LBNL 510-486-6456
lrmyer@lbl.gov

Partnership Contacts

R. Michael Ray DOE/NPTO
DOE National Petroleum Technology Office
P.O. Box 3628
Tulsa, OK 74101
Phone: 918-699-2010 Fax: 918-699-2005
E-mail: mray@npto.doe.gov

Alex Crawley DOE/NPTO
DOE National Petroleum Technology Office
P.O. Box 3628
Tulsa, OK 74101
Phone: 918-699-2055 Fax: 918-699-2005
E-mail: acrawley@bpo.gov

Chuck Komar DOE/FETC
DOE Federal Energy Technology Center
P.O. Box 888
Morgantown, WV 26507-0880
Phone: 304-285-4107 Fax: 304-285-4403
E-mail: ckomar@fetc.doe.gov

Dave Schmalzer ANL
Argonne National Laboratory
955 L' Enfant Plaza SW, Suite 6000
Washington, DC 20024
Phone: 202-488-2415 Fax: 202-488-2413
E-mail: schmalzer@anl.gov

Allen Goland BNL
Brookhaven National Laboratory
P.O. Box 5000, Bldg. 815
Upton, NY 11973-5000
Phone: 516-344-3819 Fax: 516-344-7905
E-mail: goland@bnl.gov

Dick Rice INEEL
Idaho National Environmental and
Engineering Laboratory
P.O. Box 1625, MS 3710
Idaho Falls, ID 83415
Phone: 208-526-1992 Fax: 208-526-9822
E-mail: rrr@inel.gov

Bob Hanold (Co-chair) LANL
Los Alamos National Laboratory
P.O. Box 1663, MS D446
Los Alamos, NM 87545
Phone: 505-667-1698 Fax: 505-667-3494
E-mail: rjhanold@lanl.gov

Norman Goldstein LBNL
Lawrence Berkeley National Laboratory
1 Cyclotron Road, 90-1116
Berkeley, CA 94720
Phone: 510-486-5961 Fax: 510-486-5686
E-mail: negoldstein@lbl.gov

Fred Followill LLNL
Lawrence Livermore National Laboratory
P.O. Box 808, MS L-644
Livermore, CA 94551
Phone: 510-423-8785 Fax: 510-423-7914
E-mail: followill1@llnl.gov

Tom Schmidt ORNL
Oak Ridge National Laboratory
P.O. Box 2008, MS 6273
Oak Ridge, TN 37831-6273
Phone: 423-574-4977 Fax: 423-574-7229
schmidttw@ornl.gov

Bernie Saffell, Jr. PNNL
Pacific Northwest National Laboratory
P.O. Box 999, MS-P7-41
Richland, WA 99352
Phone: 509-372-4565 Fax: 509-375-3778
E-mail: bf_saffell@pnl.gov

Dave Northrop (Co-chair) SNL
Sandia National Laboratories
P.O. Box 5800, MS-0706
Albuquerque, NM 87185-0706
Phone: 505-844-2302 Fax: 505-844-0240
E-mail: danorth@sandia.gov

DOE HQ Contacts

Sandra L. Waisley DOE
FE-30, Fossil Energy-Office of Oil and Gas
Exploration and Production
Rm. 3E-028
Phone: 202-586-3087Fax: 202-586-3119
E-mail: Sandra.Waisley@hq.doe.gov

Diane E. Bird DOE
DP-17, Defense Programs-
Technology Transfer
Phone: 202-586-0499 Fax: 202-586-1057
E-mail: Diane.Bird@dp.doe.gov

Nick Woodward DOE
ER-15, Energy Research-Engineering
and Geosciences
Rm. 8439
Phone: 301-903-4061 Fax: 301-903-0271
E-mail: Nick.Woodward@oer.doe.gov

Walter Polansky DOE
ER-32, Laboratory Technology Research
Technology Applications
Rm. G-347/GTN
Phone: 301-903-5945 Fax: 301-903-7500
E-mail: Walt.Polansky@oer.doe.gov

All of the above available at:

U.S. Department of Energy
1000 Independence Ave., SW
Washington, DC 20585

Natural
Gas &
Oil
Technology
Partnership

Bulk Rate
U.S. Postage
PAID
Albuquerque, NM
Permit No. 232