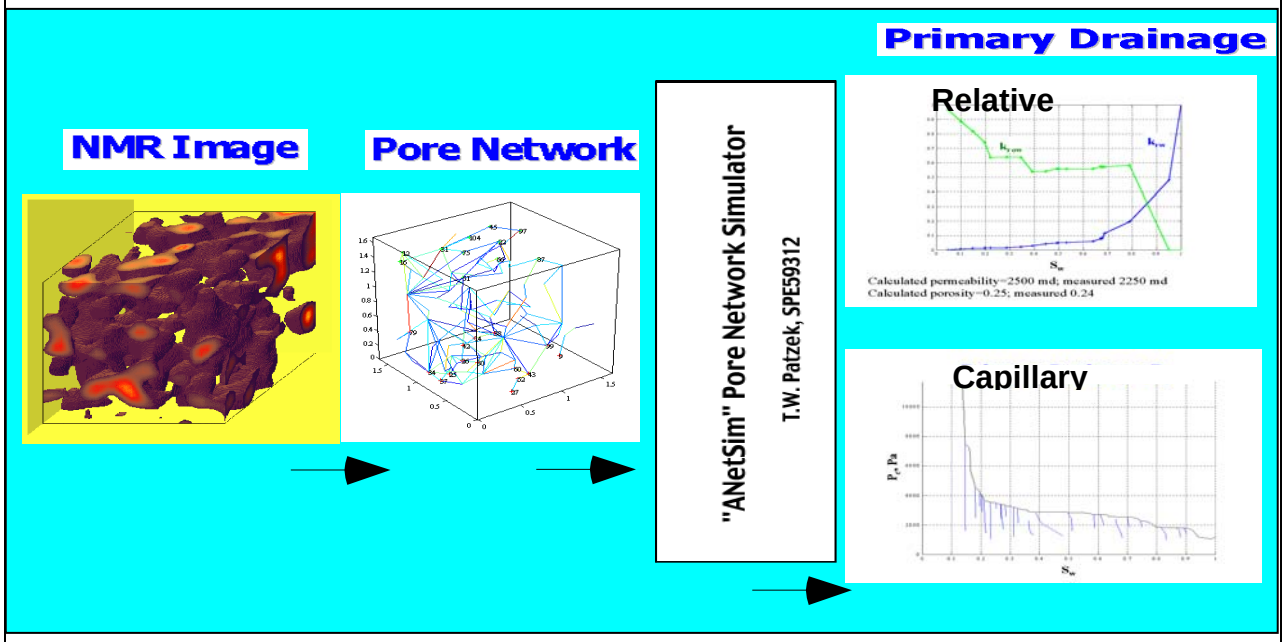
ESD99-001 Lawrence Berkeley National Laboratory

Imaging, Modeling, Measurement and Scaling of Multiphase Flow Processes

Success Story Summary

PORE NETWORK MODELING



The objective of the Imaging, Modeling, Measurement and Scaling project is to develop new and innovative logging tools or methodologies for much more rapid and accurate measurement of the petrophysical properties and fluid flow characteristics of the formations being studied. The study is basic research and is still in progress.

Multiple approaches are being used in attempts to find new and innovative ways to log, analyze, characterize and model reservoir formations on site, saving large amounts of costly rig time, shipping fees and expensive, time-consuming laboratory tests.

Lawrence Berkeley (LBL) has been successful in setting up a new, state-of-the-art imaging laboratory with an X-ray CT and linear scanner, an NMR, a centrifuge and a petrographic image analysis (PIA) device. A cooperative agreement for lab time has also been established with the Advanced Light Source and Acoustic groups at Berkeley and with Chevron.

The cancellation of plans for new equipment at one of these cooperating laboratories has slowed the program temporarily while new equipment was constructed at LBL.

It is anticipated that any new tool or process will be used in both exploration and development drilling. The goal is for the tool or process to be inexpensive enough for use in older fields to prevent the premature abandonment of mature reservoirs. A production increase of just ½ of 1% from the “discovered but unrecoverable” oil in the U S would mean gains of 1.75 billion barrels of additional domestic production. In addition, a corps of new geophysical specialists and logging engineers will be employed by the service companies using the tool or process.

Imaging, Modeling, Measurement and Scaling of Multiphase Flow Processes

Problem: Current oil and gasfield technology requires that a well be drilled and geophysically logged before promising zones within the well can be identified as potential reservoir formations. In many cases, additional data is desirable or required to confirm the economic potential or the optimal way to complete a given formation.

When additional information is needed on the petrographic properties of the reservoir or potential reservoir and the high costs can be economically justified, a rig can be brought in and a special sidewall core sample can be taken and sent to a laboratory for intense study using CT scanners and other large, expensive equipment.

This type of procedure involves considerable rig time, much of it wasted while the rig is on standby waiting for results from the lab. The sidewall coring operation is a somewhat difficult procedure and is sometimes unsuccessful. The shipping time to the lab wastes more rig and crew time and risks mishandling, damage to the core or some other accident that alters the properties of the sample to be tested. Lab testing is also expensive and is usually a slow process.

Project Objective: The objective of the Imaging, Modeling, Measurement and Scaling project is to develop new and innovative methodologies for much more rapid and accurate determination of the petrophysical properties of the formations being studied.

The goal is to move the ability to accurately image and model the flow characteristics of the reservoir from a distant laboratory to the drillpad. In the case of new drilling, the objective is to save expensive rig time by allowing much more-accurate well-completion decisions to be made during the initial well-logging phase, rather than having to cut a series of side-wall cores and standby while samples are shipped to distant laboratories. Improved modeling and understanding of formation flow processes will allow overall drilling and completion costs to be cut, while, at the same time, improving the overall field recovery rates and prolonging well life.

In the case of older fields, the objective is to ensure that the tool or process is sufficiently inexpensive that it can be economically applied to older wells in mature fields to better understand the conditions in nearly-depleted reservoirs and to identify zones that still hold potential for advanced treatments and enhanced recovery operations. If this goal is met, it will allow the extension of the productive life of older wells.

Project Costs: This project began in 1999 as a $780,000 program with all of the funding coming from the DOE.

The work at Lawrence Berkley National Lab (LBL) was to be coordinated with additional research being conducted by Chevron and the National Institute for Standards and Testing (NIST). The programs were to share equipment and work synergistically. The Chevron/NIST program was terminated at an early stage, meaning that the equipment that they were supposed to develop did not become available for use by LBL.

With the loss of the expected equipment, the work by LBL had to be redesigned and new arrangements had to be made. LBL has submitted a request to extend the project for an additional year and for additional funding of $250,000 for the program. The request was only recently submitted and is still pending. If the request is not approved, the project will presumably be terminated with no output.

Technology change: The project is still in progress and has not yet produced a product or new technology.

The project began in 1999 with an initial goal of setting up a new Rock – Fluid Imaging Laboratory at LBL with an X-ray CT and linear scanner, an NMR, a centrifuge and a petrographic image analysis (PIA) facility. The objective was to coordinate and integrate work on this DOE project with work on other earth sciences projects at LBL and other US institutions. It was anticipated that similar advanced laboratories would be set up at some of these other sites, including Chevron's research lab and the Advanced Light Source group at Berkeley, with all the new facilities contributing and sharing access to the new equipment and labs on DOE and other basic research projects for government and industry work.

The research projects grew out of earlier research programs, each of which had experienced problems for lack of good equipment or other lab capabilities, and the goal was, in part, to update and advance the state-of-the-art for American basic research in the field of rock mechanics, fluid flow and similar areas important to the petroleum industry.

LBL was successful in moving, installing and bringing its rock – fluid imaging facilities on line. At the same time, a separate, innovative laboratory of a different type was planned for the Chevron research facilities. Their work, concerning research on the properties of foamy oil, was being done, as mentioned above, in cooperation with the NIST. Some important aspects of the work for the LBL DOE research were planned for the new Chevron facilities. Revised plans by the Chevron – NIST team caused the work on the new facilities at Chevron to be cancelled. This was a distinct problem for the LBL team in terms of reaching their ultimate goal within the original timeline.

The goal of the LBL team is to develop a new methodology or methodologies for the rapid extraction of pore parameters at the well site for pore network and fluid flow modeling. This will require innovative methods to measure the petrophysical values from small samples of the rock, possibly from the drill cuttings that are produced as the well is drilled.

One approach uses the modeling of synthetic sedimentary sections based on grain size distribution analysis extracted from samples as small as the previously-mentioned well cuttings. A second technique involves work with thin sections and PIA. 3-D investigation and imaging of the actual pore spaces in small samples using X-ray microtomography is also being tried. Flow measurements are also being taken using low field NMR. Measurement of relaxation times on small samples is also providing vital data.

Significant progress has been made toward this goal, but the loss of access to the expected new Chevron lab facilities cut off some of the avenues of investigation that had been planned and budgeted for. Without access to the planned new Chevron lab equipment, some of the LBL work was not completed within the original budget and schedule, and the team is now in the process of applying for an extension to the current work and some additional money to replace money spent to compensate for the missing equipment.

The LBL team has developed good cooperation with the Advanced Light Source and Acoustic teams at Berkeley and with Chevron, despite the cancellation of the new Chevron facilities and has succeeded in incorporating innovative new imaging technologies in projects being run by those groups.

The Advanced Light Source team now has a new sub-micron pore imaging facility that is helping with the LBL work.

Notable progress has been made toward the rapid measurement of petrophysical parameters from cores. This work should allow upscaling for improved accuracy in the measurement of permeability and relative permeability in heterogeneous cores. In addition to work in conventional reservoirs, efforts are being made to extend the work for application in heavy oil reservoirs and with buried deposits of gas hydrates. Input from the Acoustic Group should allow improved logging techniques based on commonly-available data obtained from acoustic logs.

If the project is extended and gets its requested additional funding, it should lead to major reductions in the time and cost required to accurately measure relative permeability in a reservoir and to generate the type of capillary pressure curves needed for proper reservoir modeling. Better modeling will improve the ability of oil companies to characterize and intelligently complete their target zones. Improved characterization and upscaling will lead to improved productivity and extended reservoir life spans.

The techniques are also being studied for application in unconventional reservoirs like heavy oils and in gas hydrate deposits.

Technology Transfer Methods: The LBL team has made four presentations at national and international meetings. These are listed in Appendix A.

The two presentations listed that were made to the Society of Petroleum Engineers (SPE) have also been published as SPE papers: SPE 71498 and SPE 75533. The presentation given at the U.S. Rock Mechanics Symposium has been published in the proceedings volume for that conference.

A web page is currently under development.

Students have worked on the project, although none of them were totally supported by this work.

Cooperation with Chevron and the Advanced Light Source and Acoustic groups at Berkeley has been extensive, with benefits flowing to all participants. The project has been slowed by the loss of some of the expected cooperation with Chevron and the non-development of new equipment expected to come from that team's work.

Tech transfer efforts are expected to increase as the project progresses and generates additional results.

Technology Implementation: The new tool or process is still under development and has not yet been implemented.

End Users: The end users of this technology will be the well-logging and sidewall-coring service companies and super-majors who may perform such operations in-house.

The exact nature of the final product of this research has not yet been identified, but this work may lead to a new type of rock-properties measurement. Whatever logging or rock measurement tool is developed will presumably need a support staff of new geophysical and well-logging specialists.

Impacts:

Overall Value of Technology: While the nature of the new tool or procedure that may be developed has not yet been determined, it will presumably be used in both exploratory well drilling and in development drilling. Although the economics of the tool or procedure are currently unknown, the goal is for it to be inexpensive enough to use in old fields to evaluate near-depleted formations to prevent premature abandonment of marginally-economic formations.

Increased Oil Production: The goal of this project is to develop a new tool or procedure that will allow reservoir engineers to better identify the properties of the reservoir or potential reservoir to optimize the well completion techniques or the formation treatment to be used in older fields. The goal will be to maximize production or to prevent early abandonment of older fields with remaining economic viability.

Since the nature of the new tool or technique is still unknown, it is not possible to quantify the amount of oil that may be recovered in the future.

The Fossil Energy Division of the DOE has estimated that there are 351 billion barrels of oil in the US that are currently "discovered but unrecoverable," based on current technology. If the LBL succeeds in developing a new logging tool or methodology that can prevent the premature abandonment of just ½ of 1% of this total, this will represent a total of 1.75 billion barrels of additional domestic production.

Increased Gas Production: It is anticipated that the new tool or procedure will also be of great value to the natural gas industry.

New Products/Technologies: The goal of this project is to develop a new procedure or tool, although its exact nature remains to be determined.

Cost Savings: The goal of this project is to develop a new well logging tool or procedure that could greatly cut rig time costs on new wells due to a significantly faster decision time as to whether to complete or abandon a new hole. There should also be big savings in laboratory costs and improved oilfield management costs in the long run due to significantly improved reservoir characterization, understanding and management.

Additional Research Investment: The project was originally budgeted at $780,000.

Chevron and the NIST withdrew from a related project that was supposed to provide vital equipment to the LBL program. With the loss of that equipment, the LBL project is being redesigned. An additional $250,000 has been requested and a one-year extension has been requested. If the money and time are granted, this will be $250,000 in additional research funding.

New Markets/Jobs: If the new technique or tool is developed, a new branch of geophysicists and logging engineers will need to be trained and employed to use the new equipment. This will provide new employment within the service companies or the super-majors that are large enough to have their own well-logging operations.

Appendix A

Presentations made by the Lawrence Berkley Laboratory team

Tomutsa, L., SPE, B. M. Freifeld, T. J. Kneafsey, L. A. Stern, X-ray Computed Tomography Observation of Methane Hydrate Dissociation, SPE 75533, SPE Gas Technology Symposium held in Calgary, Alberta, Canada, 30 April2 May 2002.

N. Sahni, A, F. Gaddelle, M. Kumar, A.R. Kovscek and L. Tomutsa, Experiments and Analysis of Heavy Oil Solution Gas Drive, SPE 71498, SPE Annual Technical Conference and Exhibition, New Orleans, Louisiana, 30 September-3 October 2001

Z. Liu, J.W. Rector, K.T.Nihei, L. Tomutsa, L.R.Myer, and S. Nakagawa, "Extensional wave attenuation and velocity in partially saturated sand in the sonic frequency range" presented at the 38th U.S. Rock Mechanics Symposium" Rock Mechanics in the National Interest", July 7-10, 2001, Washington, D.C.

Nihei, Kurt, L. Tomutsa, L.R.Myer, J.T.Geller, "Sonic Frequency Attenuation in Partially Saturated, Unconsolidated Sand" by Z. Liu, presented at AGU Fall Meeting, December 15-19, 2000, San Francisco, CA.