The September edition of the Crisman Institute Newsletter contains summaries on the following projects:

1. An Investigation of Regional Variations of Barnett Shale Reservoir Properties, and Resulting Variability of Hydrocarbon Composition and Well Performance
2. Modeling and Analysis of Transient Linear Flow Regime in Shale Gas Reservoirs
3. Technical, Economic and Risk Analysis for a Multilateral Well
4. Continuous Reservoir Simulation Model Updating and Forecasting Using a Markov Chain Monte Carlo Method
5. Desalination of Brackish Water & Disposal into Waterflood Injection Wells:
   - Desalination of Oil Field Brine
   - Public Perception of Desalinated Water from Oil and Gas Field Operations: Data from Texas
6. Low Impact O&G Activity; Environmentally Friendly Drilling Systems:
   - Environmentally Friendly Modular Platform for Onshore Oil and Gas Well Sites
   - Assessments of Technologies for Environmentally Friendly Drilling Project
   - Alternative Rig Power Sources
7. Transform-Domain Regularization for History Matching of Continuous Geological Facies
8. GoM Ultra-deep Riserless Mud Recovery JIP - Feasibility Study and Planning

Go to [www.pe.tamu.edu](http://www.pe.tamu.edu) and click on the Crisman Institute icon to see menus of current, proposed, and completed projects. Theses, dissertations, technical papers, and presentations can also be downloaded from the website.
An Investigation Of Regional Variations of Barnett Shale Reservoir Properties, and Resulting Variability of Hydrocarbon Composition and Well Performance

Objectives
Although the Barnett is one of the most prolific gas plays in the U.S., fundamental controls on variable gas productivity of individual wells and different regions are poorly understood. The Barnett shale is very heterogeneous. Formation thickness and lithology (Fig. 1), thermal maturity, structural setting, reservoir fluids, etc., vary greatly throughout the basin. The objectives of this research are to:

- Clarify the regional variations of Barnett Shale reservoir and geologic properties.
- Evaluate the controls that these properties exert on Barnett Shale gas well performance.

Approach
This will be an integrated study using well log and production data to evaluate geologic and engineering controls on reservoir performance. Raster logs will be used to correlate and map Barnett Shale facies, and digital logs, if available, will be used to map petrophysical properties. Facies and petrophysical properties maps will be compared to reservoir performance maps (best monthly production, cumulative production, etc.) to assess controls on reservoir performance.

Primary tasks for this research:

1) Correlate reservoir facies to assess vertical and lateral variability of Barnett shale.
2) Determine shale lithology and clay volume, which are important factors affecting mechanical properties.
3) Evaluate shale porosity and how it affects gas storage and permeability.
4) Address shale organic geochemistry: organic richness; fluid type; and thermal maturity.
5) Petrophysical evaluations to estimate geochemical parameters from well logs, owing to the availability of limited core data and laboratory analyses.
6) Integrate the above results with production analysis to assess reservoir controls on production rates of individual wells and different regions of the Fort Worth Basin.

Significance
The study should lend insights to reservoir controls on well performance and should assist operators with optimization of development strategies and gas recovery. The results may be applicable to other developing shale gas plays, such as those in the Marcellus and Haynesville Shales.

Project Information
1,2,3 An Investigation of Regional Variations of Barnett Shale Reservoir Properties, and Resulting Variability of Hydrocarbon Composition and Well Performance

Related Publications


Contacts
Walter B. Ayers
979.574.6864
walt.ayers@pe.tamu.edu

Yao Tian
Modeling and Analysis of Transient Linear Flow Regime in Shale Gas Reservoirs

Introduction
Several shale gas wells in the Barnett shale have been observed to exhibit long-term linear behavior (Fig. 1). This long-term linear behavior is characterized by a one-half slope on a log-log plot of rate against time. Naturally fractured shale reservoirs are usually modeled by the dual porosity model and the transient linear flow regime is believed to be caused by transient drainage of low permeability matrix blocks into adjoining fractures. This transient flow regime is the only flow regime available for analysis in several wells.

Objectives
The objectives of this study are:

- To develop mathematical models for multi-stage hydraulically fractured horizontal shale gas well performance
- To develop a method of analyzing field production data to determine required reservoir parameters, characterize fracture network, characterize completion methods and determine drainage volume or OGIP.

Approach
This study utilizes a linear dual porosity model.

Accomplishments
- Development of asymptotic equations for analysis of the linear transient linear regime
- Development of preliminary field analysis procedure (can determine fracture spacing, matrix drainage area with assumptions and known parameters).

Future Work
- Refine field analysis procedure – present assumptions
- Present sample cases to test field analysis procedure
- Write and defend dissertation

Significance
An industry tool to conduct rate transient analysis in this type of reservoirs

Fig. 1 - Log-log plot of field production rate as a function of time. Line drawn on plot indicates half slope.

Project Information
1.2.8 Modeling and Analysis of Transient Linear Flow Regime in Shale Gas Reservoirs

Related Publications

Contacts
R.A. Wattenbarger
979.845.0173
bob.wattenbarger@pe.tamu.edu

Rasheed Bello
Technical, Economic and Risk Analysis for a Multilateral Well

Objectives
The objective of this study is to develop a methodology to assist engineers in their decision making process of maximizing access to reserves. The process encompasses technical, economic and risk analysis of various alternatives in the completion of a well (vertical, horizontal or multilateral) by using a well performance model for technical evaluation and a deterministic analysis for economic and risk assessment.

Approach
In the technical analysis of the decision making process, the flow rate for a defined reservoir is estimated by using a “pseudo-steady state” flow regime assumption and decline curve analysis. The economic analysis departs from the utilization of the flow rate data which assumes a certain pressure decline. The Financial Cash Flow is generated for the purpose of measuring the economic worth of investment proposals. A deterministic decision tree is then used to represent the risks inherent in geological uncertainty, reservoir engineering, drilling, and completion for a particular well.

The geological features include structural complexity of faulting and folding, compartmentalization, natural fracture network, lateral extent of the reservoir, and lithology of target formation. The reservoir engineering considerations refer to horizontal and vertical permeability, porosity, reservoir pressure, decline rate, and fluid properties. The drilling feature consists of junction stability, debris management, re-entry feasibility, laterals isolation, tubular capacity, and wellbore stability. Furthermore, mechanical integrity, control of sand production, stimulation, and ability to implement the lifting mechanism are included in the completion aspect.

The Net Present Value is utilized as the base economic indicator. By selecting a type of well that maximizes the expected monetary value in a decision tree (Fig. 1), one can make the best decision based on a thorough understanding of the prospect.

Significance
As the Oil and Gas industry is moving away from conventional reservoirs towards unconventional reservoirs, traditional vertical completions may not be the most effective techniques to maximize hydrocarbon recovery. However, we can not assume that horizontal or multilateral technologies are always the best alternative for any well to be drilled since reservoir conditions are always unique and are not necessarily ideal to effectively drain the reservoir. The method introduced in this study emphasizes the importance of a multi-discipline concept in drilling, completion and production technology.

The significance of this study resides in the process that engineers could adopt prior to making a decision whether to drill and complete a well by conventional or more sophisticated methods. One needs to take into account that not only the technical considerations but also the economic and risk aspects have equally important roles when evaluating options.

Project Information

Related Publications


Contacts
Ding Zhu
979.458.4522
ding.zhu@pe.tamu.edu

Dulce Arcos
In this project we apply Markov Chain Monte Carlo (MCMC) methods in a real-time reservoir modeling application. The system operates in a continuous process of data acquisition, model calibration, forecasting, and uncertainty quantification, providing continuously updated probabilistic forecasts of well and reservoir performance, accessible at any time.

Findings
Since the system operates continuously, over time many more realizations can be run than with traditional approaches. This allows more thorough investigation of the parameter space and more complete quantification of forecast uncertainty. The system was validated on the PUNQ synthetic reservoir in a years-long, simulated continuous modeling scenario, and yielded probabilistic forecasts that narrow with time (Fig. 1).

Significance
Most reservoir simulation studies are conducted in a static context – at a single point in time using a fixed set of historical data for history matching. MCMC methods have been used in static studies for rigorous exploration of the parameter space for quantification of forecast uncertainty, but these methods suffer from long burn-in times, low acceptance rates, and many required runs for chain stabilization. In our new continuous approach, once the chain is established, subsequent data assimilations require much less burn-in time, making MCMC practical for reservoir simulation history matching. In addition, each element in the chain consists of a match of the entire production history, ensuring consistency between all static and dynamic variables, unlike EnKF methods also proposed for real-time modeling applications. Finally, since the method is applied over time, it can be used to calibrate uncertainty estimations.

Fig. 1–Forecast of 16.5-year recovery for PUNQ reservoir generated over time.
Desalination of Oil Field Brine

Objectives
In late 1999, researchers at Texas A&M took a new look at traditional oil field operations in mature reservoirs. They found that the disposal of large amounts of oil field produced water in reinjection or pressure maintenance operations represented a major expense, one that often shortened the economic lifetime of low producing fields. It also became evident that available, affordable water resources would be a key to cost effective drilling operations in unconventional reservoirs. An oil field brine desalination program was established with the goal of demonstrating that treatment of oil field waste water for re-use will reduce water handling costs by 50% or greater.

Approach
A research project was established to study membrane technology to remove contaminants from water produced from oil and gas operations. Work included (1) integrating advanced materials into existing prototype units and (2) operating short and long-term field testing with full size process trains. The project identified improved pre-treatment oil removal techniques and new oil tolerant RO membranes, and employed them in extended testing in “field laboratories” to gather extended run time data on filter salt rejection efficiency and plugging characteristics of the process trains.

Accomplishments
Process trains designed by the desalination team were able to treat produced water with hydrocarbon concentrations of 110 ppm and total dissolved solids concentration of 45,000 ppm. A mobile desalination unit (Fig. 1) was used to collect long term test data. The field results showed that membrane separation efficiency and flux across the filters could be maintained at acceptable levels by using periodic washes of the membrane surfaces with special cleaning agents. The study proved that these new membrane filtration processes could treat and purify oilfield brine and create a beneficial freshwater resource.

Significance
The results of our work show that from 20 to 50% of oil field brine (depending on the nature of the produced water) can be treated and recovered as fresh water. The benefit to the oil and gas industry will be the economic savings on produced water disposal, which equates to reduced operating costs for operators. The treated water can be used in other oil field operations or for different ecological applications such as habitat and rangeland restoration, agricultural, horticulture, livestock or

Project Information
4.2.8 Desalination of Brackish Water & Disposal into Waterflood Injection Wells

Related Publications


Oluwaseun, O., Burnett, D., Hann, R., and Haut, R. Application of Membrane Filtration Technologies to Drilling Wastes. SPE 115587.


Contacts
David Burnett
979.845.2274
david.burnett@pe.tamu.edu

Fig. 1–The A&M mobile desalination unit in McFaddin, Texas.
Desalination of Oil Field Brine (continued)

industrial use. With additional pre-treatment the technology can be adapted to recovering flowback brine from fracturing operations in such field developments as the Barnett Shale.

Lower Footprint Desalination System, GPRI Designs™ Technology

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Analytical Data from Commercial Field Test of GPRI Designs™ desalination technology.
Public Perception of Desalinated Water from Oil and Gas Field Operations: Data from Texas

Objectives
In 2004, a study of over 10,000 Texas residents to identify critical issues confronting their communities found that issues associated with water quantity and quality ranked among the top five priorities in 213 counties of the state’s 254 counties. It is evident that solutions to the pressing water quantity and quality issues in Texas and other places throughout the world will require novel approaches and technologies.

In late 1999, researchers at Texas A&M began a project to use membrane desalination technology to remove contaminants from water produced from oil and gas operations, treats and purifies the produced water, and ultimately creates a beneficial freshwater resource. It was not clear, however, that the public would embrace such new technology and would be willing to utilize fresh water from desalination.

Approach
A sociological study was undertaken to assess the public’s acceptance of the new technology. Data collected in two counties in north central Texas were used to empirically explore issues associated with public perception of desalinated water from oil and gas field operations. Specific topics investigated included: level of familiarity with the process of desalination; level of agreement that desalinated water from gas and oil field operations could safely be used for selected purposes; and, level of confidence that desalinated water could meet human drinking water quality and purity standards.

Accomplishments
The data revealed that small percentages of respondents are extremely familiar with the process of desalination and extremely confident that desalinated water could meet human drinking water quality and purity standards. The data also indicate that respondents are more favorably disposed toward the use of desalinated water for purposes where the probability of human or animal ingestion is lessened.

Significance
The development of new technology to address fresh water scarcity in Texas is a necessary but not sufficient step in getting that technology developed into a commercial process. Knowing that the best opportunity for the use of fresh water recovered from oil field brine would not be the municipal market, research was redirected toward re-use in the oil field, and for use in industrial operations.
Environmentally Friendly Modular Platform for Onshore Oil and Gas Well Sites

Objectives
The goal of the low impact drilling systems project is to reduce the environmental impact of rig operations through integration of low-impact site access and site operations. One of the critical areas where the impact of drilling operations could be reduced is the size of the well site location and its impact on the surrounding environment.

Approach
Conventional onshore drilling for oil and gas consists of placing a gravel pad for leveling and carrying capacity purposes. The use of an elevated platform as an alternative to the gravel pad is less intrusive and leads to a more environmentally friendly approach to oil and gas drilling.

Elevated drilling platforms will require the use of piles. Piles are used to transfer the load from the structures to the underlying soil mass. An engineering study was undertaken to get a basic idea regarding pile designs of a platform for various platform weights and soil conditions in environmentally sensitive areas (e.g., desert environments and wetland applications). By design the pile should meet not only the axial capacity criterion but also the lateral capacity criterion.

A model to determine the estimated capacities of piles was created using the Load and Resistance Factor Design (LRFD) and the Working Stress Design (WSD) methodology. Approximately one thousand different cases of pile capacity calculations were conducted, varying soil types, pile types, and design methods. The results of these calculations were organized into a series of tables for the engineer to choose an appropriate pile size for a given condition without performing an extensive pile design analysis.

Accomplishments
Based on the engineering study, a modular platform for a light weight drilling rig was designed (Fig. 1). A set of Tables were developed to provide a simple way to choose an appropriate pile size for various soil conditions according to the LRFD method. Using the model would allow an engineer to make quick, but accurate estimates of the expense of modular platform construction for well operations as an alternative to traditional gravel well pads.

Significance
The optimization scheme for the installation of modular platforms can be extended to the construction of modular platform bridges and roadways in marsh areas. Such modular roads would allow temporary access to environmentally sensitive well sites and provide a facile way of removing the roads when drilling operations are completed.

Fig. 1—Three dimensional (3-D) layout of light weight drilling rig on a platform consisting of 40 modules, each 12.5 ft by 52 ft.

Project Information
4.2.9 Low Impact O&G Activity: Environmentally Friendly Drilling Systems

Contacts
David Burnett
979.845.2274
david.burnett@pe.tamu.edu
Assessments of Technologies for Environmentally Friendly Drilling Project

Objectives
The U.S. Department of Energy awarded GPRI (Global Petroleum Research Institute) at Texas A&M University, the Houston Advanced Research Center (HARC) and industry sponsors a financial assistance partnership to create an engineering and environmental research program to integrate current and new technology into a field demonstrable drilling system for compatibility with ecologically sensitive, restricted access, off-limits areas (e.g., Otero Basins of New Mexico, Wetlands of Louisiana, East Texas and Mississippi Coasts, and Rocky Mountain areas etc.). The goal:

1) Define the Best Available Technology for sustainable drilling in specific areas
2) Demonstrate that technology is sufficiently available to economically develop oil & gas resources while protecting the environment (Sustainable E&P development can be achieved)

Approach
As part of the Environmentally Friendly Drilling (EFD) project, a technology Assessment Study was undertaken to define the state of the art of the O&G industry, identifying currently available technologies, and documenting the trends of technology development. While technology has allowed the industry to contact almost 60 times the volume of subsurface rock material that could be accessed in 1970 while occupying only one third the surface area (Fig. 1), newer practices promise to reduce that footprint ever further. The drilling and production process can be unobtrusive and more efficient if the state of the art technologies are used concurrently on the same well. The Technology Assessment Report reviews the current state of the art of drilling technology and how the current surface rig technology modern drilling methods can lower the surface impact safely and economically.

Accomplishments
The Study has been compiled into a comprehensive review of drilling systems and includes 14 chapters of information on key developments in drilling technology, waste management, access, and other low impact technology.

Significance
Findings from this study have become the basis of the Environmentally Friendly Drilling Program’s “Five Key Areas”. Currently the compilation of technologies includes more than 100 practices designed to reduce the impact of O&G operations. The EFD program is currently funding a Systems Engineering Model to be used to identify the best combination of techniques for given well design and specified environmental goals.


Project Information
Environmentally Friendly Drilling Project

Related Publications

Contacts
David Burnett
979.845.2274
david.burnett@pe.tamu.edu
Alternative Rig Power Sources

Objectives
As one of the GPRI funded Environmentally Friendly Drilling projects, this preliminary study aimed to (a) develop an energy inventory of the drilling process and (b) investigate alternative sources of power to see if energy efficiency improvements are possible that result in lower fuel consumption, reduce subsequent emissions, and reduce the overall rig footprint.

Approach
Since most modern era drilling rigs are utilizing Silicon Controlled Rectifier (SCR) units with power from diesel generator packages, the shift to electric power could enable other more environmentally-friendly sources for the rig power generation, either as a supplement to a smaller set of diesel generators or by replacing the entire diesel generation system. However, any alternative rig power source must satisfy several criteria concerning portability, continuous power operation, weight, height, footprint, and atmospheric emissions.

There are a number of current technologies that can be used to partially provide power to a rig and reduce fuel consumption and emissions. These technologies were evaluated technically and economically to determine the feasibility of application to a drilling rig, e.g., diesel additives, types of fuels (gas, dual fuel system, synthetic fuels etc.) wind energy, solar cells, fuel cells, power management, and gas turbine generators. Together with these technologies, new energy storage technology (specifically energy storage compatible with drilling operations) will be required.

Accomplishments
The study considered the feasibility of using wind turbines, solar cells, fuel cells, or power from the electrical grid for rig power generation. Power requirements sufficient for National Oilwell Varco’s Rapid Rig™, a fully manufactured drilling rig, were the basis for this study (Fig. 1). Three of the four alternative energy systems have been ruled out for rig power generation for the foreseeable future. Although wind, solar, and fuel cells operate with essentially no atmospheric emissions and little or no noise, both wind and solar provide only intermittent power and cannot operate as a sole power source. On the other hand, rig power from the grid has clear potential for replacing part or all of the rig’s diesel generator packages.

Significance
A recent design study has indicated that a modular system to link grid power to a rig could save an average of $15,000 per well per month. Environmental benefits would be substantial. A new study is being commissioned to develop an actual engineering design for a modular link from a rig to a power grid. The study would include the design of energy storage devices, either kinetic or electrical.

![Varco Rapid™ Rig.](image)

Project Information
Environmentally Friendly Drilling Project
(final report available upon request)

Contacts
Christine Ehlig-Economides
979.458.0797
c.economides@pe.tamu.edu

David Burnett
979.845.2274
david.burnett@pe.tamu.edu

Juan Fernandez
Objectives
Estimating spatially-continuous reservoir properties from scattered production measurements while respecting their natural structural continuity is a challenging inverse problem. Reconstructing a pixel-based spatial description of geological facies from production measurements is often an ill-posed problem and results in non-unique solutions that may fail to respect the expected geological continuity. In this project, an efficient feature-based estimation framework will be developed to honor the structural continuity of geological formations during data integration and history matching by recognizing that spatial features can have sparse representations in an appropriate transform domain such as Fourier.

Approach
Reconstruction of continuous geological facies is facilitated by estimating their sparse description in an appropriate transform domain. Our approach in this project consists of:

1) Designing an effective transformation basis that provides sparse descriptions for subsurface formations that characterize specific depositional environments; and
2) Estimating the transformed properties by promoting sparsity in the transform domain and using different sources of observations. The sparse reconstruction framework is inspired by recent advances in statistical signal processing, known as compressed sensing.

Significance
Fig. 1 summarizes preliminary findings in this project. A simple example to reconstruct facies distribution in the discrete cosines transform (DCT) domain from production observations is illustrated. A comparison of the reconstruction results on the second row reveals that a more accurate solution is obtained by promoting sparsity of the solution in the DCT domain. Different implementation of this framework as well as its application to large-scale three dimensional problems is currently being investigated.

Project Information
Transform-Domain Regularization for History Matching of Continuous Geological Facies

Related Publications


Contacts
Behnam Jafarpour
979.845.0666
behnam@pe.tamu.edu
GoM Ultra-deep Riserless Mud Recovery JIP - Feasibility Study and Planning

Riserless Mud Recovery (RMR) is one of the MPD techniques developed for offshore drilling. This system recovers the drilling fluid from the seafloor to the floating vessel. Therefore, this system minimizes drilling fluid discharge to the seafloor and allows use of tailored fluid for drilling operation. Moreover, recovering the drilling fluid reduces the cost of the drilling operation. The main goal of this project is to study the feasibility of current technologies to drill top holes in ultra-deep waters, between 6,000 ft and 12,000 ft, for industry and research purposes. After the feasibility analysis, field trial will be conducted in the Gulf of Mexico. Fig. 1 illustrates the principal concept of this technique.

Approach
This technique is new and different technologies are available separately. The approach is to integrate proven technologies and improve their capabilities to meet the technical requirements for drilling in ultra-deep waters. A drillship is being modified to accommodate new equipments and be capable of performing new procedures required in this project. A New Drilling fluid system is being designed to match the limitation of the system. Other requirements for this project are predictions of drilling windows, drilling fluid design, solid handling at the surface, and safety and operational procedures.

Significance
The result of this work would be very beneficial to the oil industry. This project assesses the current technological capabilities of drilling in ultra-deep waters and provides geological information for scientific applications. More importantly this project introduces an environmentally friendly drilling operation for top hole drilling, which allows using designed drilling fluid to reduce problems, reduce the cost of drilling fluid, increase the safety of the operation, and reach the target at lower cost.

Future Work
The ultimate goal of this project is to integrate different technologies safely and economically for commercial applications. Future work will focus on the safety of operations and the integration of equipments. This work will be done while consulting with experts and MMS.

Fig. 1—Principal concept of RMR™ is pump the mud from the return line at the seabed to the vessel.

Project Information
GoM Ultra-deep Riserless Mud Recovery JIP - Feasibility Study and Planning

Related Publications


Contacts
Jerome Schubert
979.862.1195
jerome.schubert@pe.tamu.edu

Arash Haghshenas