

Advanced Diagnostics and Imaging Systems



Program Overview

National Energy Technology Laboratory



Advanced Diagnostic and Imaging Systems (ADIS)

- Resource potential
- Technology issues
- ADIS technology areas and approaches
- Future R&D Path
- Budget
- Project highlights



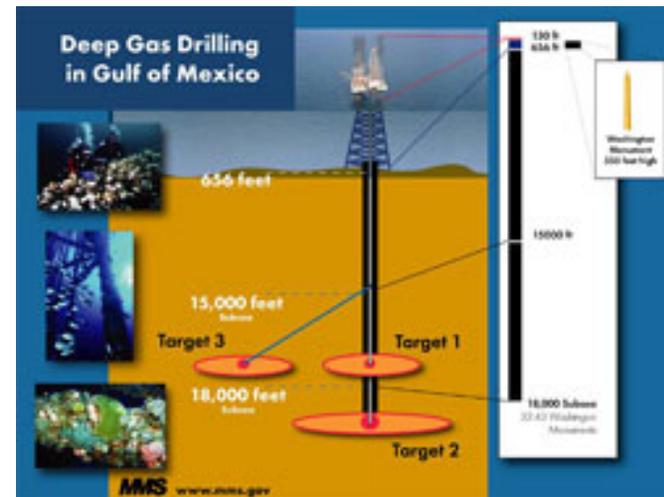
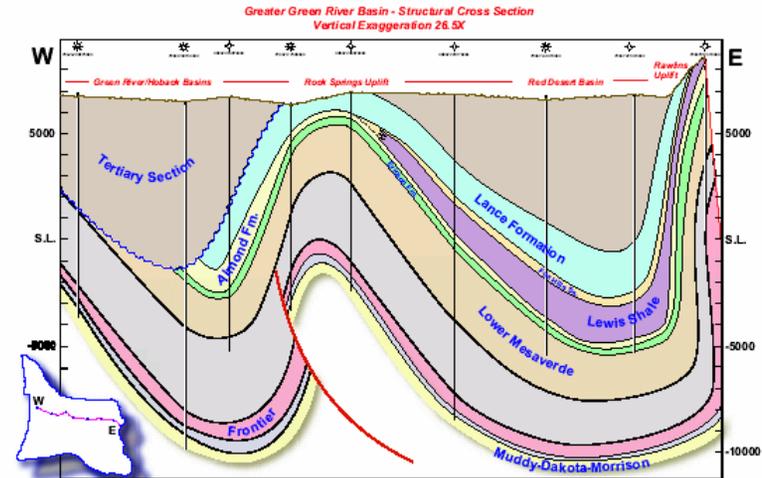
Resource Potential

- **Huge volumes of naturally-fractured tight gas and deep gas resources**

- USGS estimates (1987-1999) show over 6,800 Tcf in place (GGRB, WRB, Uinta, Bighorn, Crazy Mts.)
- New reassessments by NETL show over 4,500 Tcf in place for GGRB and WRB
- Deep gas over 1,000 Tcf

- **Deep Shelf Gas May Be More Abundant in Gulf than Earlier Forecast**

- Deep shelf lies 15,000 feet or greater below the OCS in water depths up to 656 feet
- MMS announced a 175% increase in their new resource estimate - now up to 55 Tcf from 20 Tcf
- Deep shelf is accessible to producers from existing infrastructure



Technology Issues

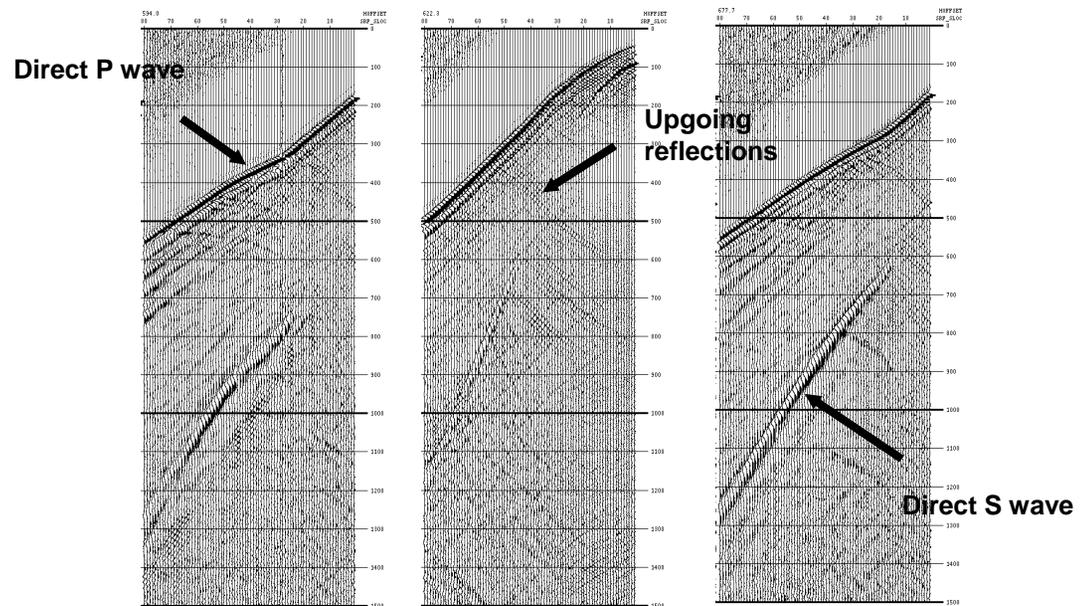
“The ability to continue to grow non-conventional production will be critical to sustaining production levels,” NPC 2003

- **What is limiting non-conventional resource recovery?**
 - Natural fracture characterization – rated #1 issue at 2002 SEG research committee meeting
 - Reservoir modeling - capability to model discrete features and heterogeneity of real fields is problematic
 - Data acquisition – the best sources and receivers require additional set up time and cost
 - Interpretation and analysis – rapid, efficient, and reliable interpretation of geophysical data beyond ability of many
 - Deep stratigraphic resolution - ability to “see” decreases with depth



ADIS Technology Areas

- Fracture Detection and Prediction
- Fracture/Fluid Property Quantification
- Deep Gas Imaging
- Reservoir Characterization
- Resource Assessment



ADIS Technology Approaches

- **Tools - seismic and borehole geophysical technologies**
 - Higher resolution seismic data acquisition
 - Advances in VSP and single well seismic sources, receivers, and data transmission systems
 - Advances in multi-component and S-Wave acquisition, technologies that combine electromagnetic and seismic data, and down hole acoustic and electrical logging and imaging tools
 - Instrumentation for direct detection of natural gas in deep reservoirs, and methodologies for improved estimation of gas saturations from geophysical data



ADIS Technology Approaches

- **Data Processing and Interpretation**
 - Innovative data processing, interpretation, and visualization technologies
 - Techniques to better utilize existing data or to improve data acquisition strategies
 - Enhanced methods of processing data during acquisition and post survey
 - Analytical advances for processed imagery to lower costs and widen technology applications to a larger resource target in the US
 - Improved basin and reservoir modeling to identify highest potential targets



ADIS Technology Approaches

- **Technology Demonstrations**
 - Apply developed ADIS technologies in the field in in conjunction with industry
- **Resource Assessments**
 - Define resources where ADIS technologies can improve resource recovery

Manuel Engineering Incorporation

Alaska Gas Hydrate Project
Gross thickness for 30-29 (TVO)



POSTED WELL DATA

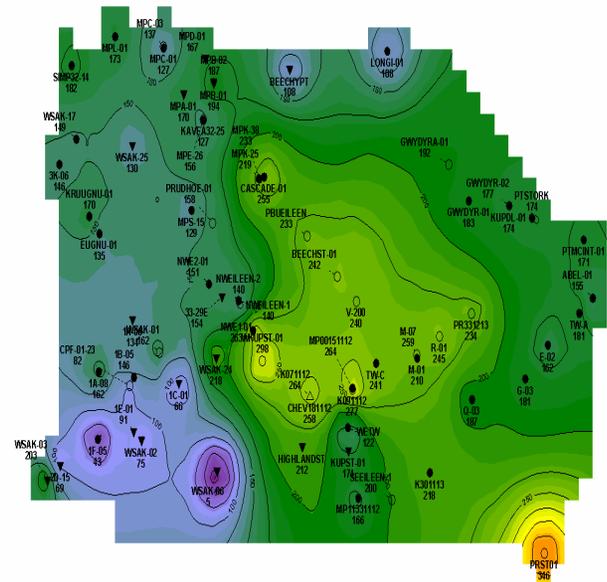
Well Name
WELL - GROSS(29) (FEET)

CONTOURS
Gross thickness for 30-29 (TVO)
GROSS(29) (FEET)
Contour Interval = 25



WELL SYMBOLS
● G-normalized w/ hydrate
○ G-normalized w/ hydrate
△ G-normalized w/ hydrate
○ G-normalized w/ hydrate

By Justin Manuel
November 1, 2008



400 Level Downhole Seismic Receiver Array

Paulsson Geophysical Services, Inc.

Objective: Design, build, & test 400-level receiver array and companion software for high-resolution borehole seismic imaging; pods and cables designed to operate up to 400 degrees F and 25,000-30,000 psi; Improved resolution of reservoir details; Potential for rapid, cost effective imaging.

Schedule/Status:

Began Oct., 2001

Ends Sept., 2006

Funding:

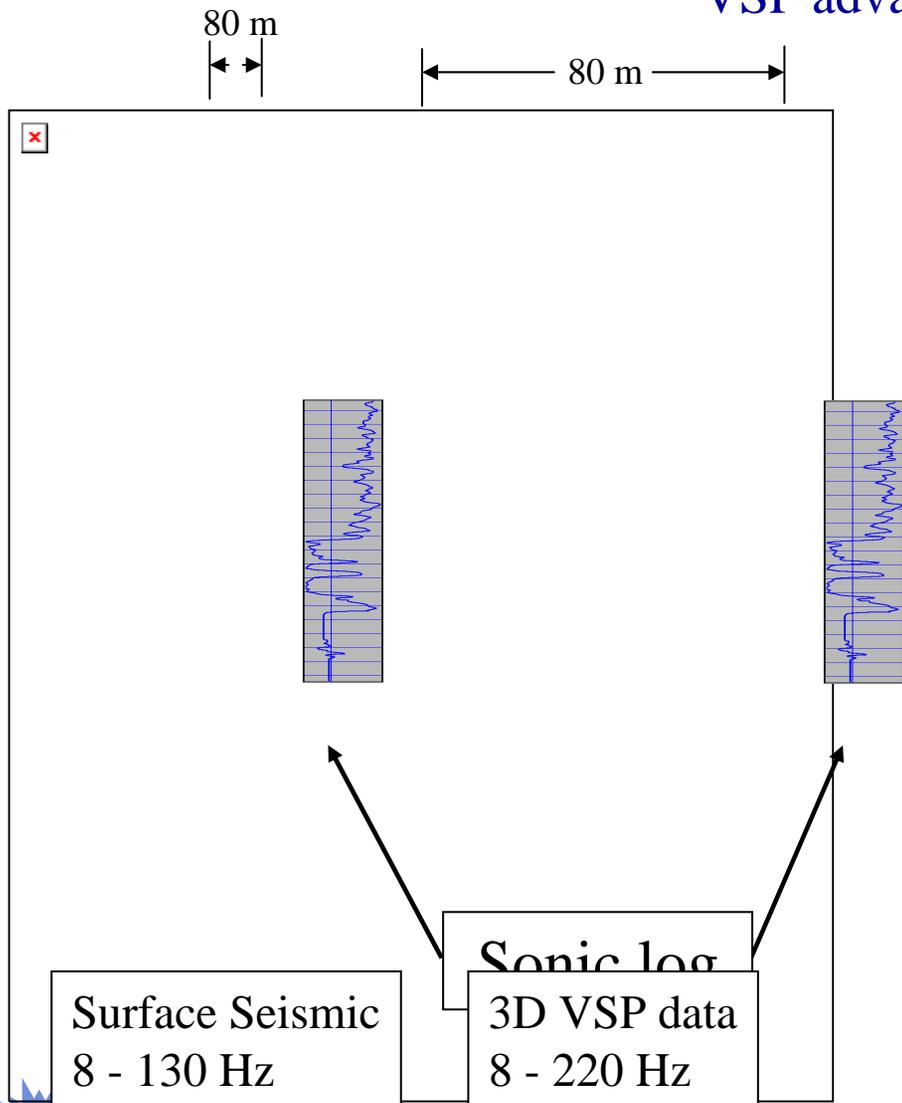
DOE \$1,815,201;

Performer \$1,815,201



400-Level Downhole Seismic Receiver Array

VSP advantage



Conventional surface seismic image (far left) and borehole seismic image (near left) of the same geologic interval.

VSP image provides:

- improved frequency content
- ability to resolve individual beds within the reservoir interval

Reduce the risk of missing the target!

400 Level Downhole Seismic Receiver Array

Accomplishments

Accomplishments

- 2002- Manufacture completed, five 80-level receiver cables built.
- Long Beach, California survey completed by Occidental Petroleum, resulting in 120-150 Hz vs. 30 Hz for previous OBS coverage of the Wilmington field.
- Milne Point, Alaska survey completed by BP resulting in 3 million seismic traces and a three- to four-fold increase in image resolution over pre-existing data. The images from this survey aided in successful new wells and elimination of 20 side track wells.
- San Juan Basin, New Mexico survey completed by ConocoPhillips, recorded 140-160 Hz data and resulted in successful imaging of internal reservoir structure.
- 2003- Hemphill Field, Texas survey completed by ChevronTexaco, resulting in successful imaging of Morrow sand channel.
- 2004- Hot Ice #1, North Slope, Alaska hi-res survey completed
- Time-lapse survey completed at Frio well, Texas, for monitoring CO2 injection.
- 2005- SAFOD well, cable deployed down to 9000 feet to image the San Andreas Fault and monitor microseismic activity at depth.
- 2006- continued upgrades to this downhole seismic receiver array contribute to an increase in VSP surveys in the oil and gas industry.
- 2002-2006 Numerous papers and presentations given at national and international meetings promoting this technology.

Status

- Currently compiling survey results and completing Final Report



Integrated Seismic, Log and Production Analysis, San Juan Basin, NM

Geospectrum, Inc

Objective: To locate fracture sweet spots in the Dakota sandstone reservoirs of the San Juan basin, New Mexico, by mapping and integrating seismic lineaments, seismic velocities, clay content, and a gas-sensitive AVO attribute.

Schedule/Status:

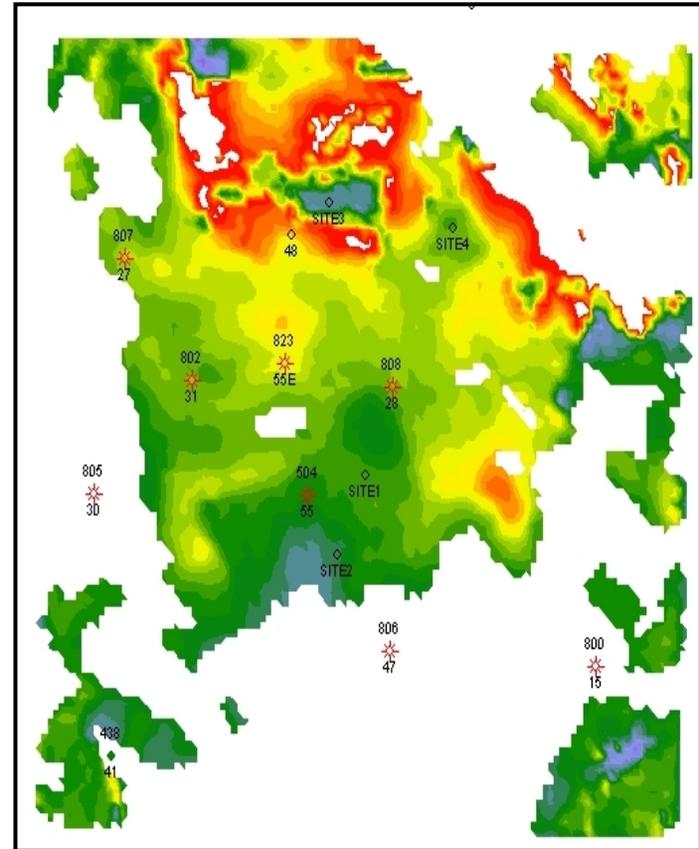
Began Oct, 2000

Completed Jan, 2006

Partners: Burlington Resources,
Huntington Energy

Funding:

DOE \$1,318,451; Performer \$329,612



Integrated Seismic, Log, and Production Analysis, San Juan Basin, NM

Accomplishments

Accomplishments

- 2003-2004, 4 wells drilled in FY04 with excellent results.
- 3 wells on AVO attributes are some of the best producers in the Canyon Largo unit.
- Drilling results validate a methodology for locating fracture sweet spots.
- 2002-2006 Numerous publications and presentations at national meetings.

Status

- 2006, Final Report awaiting approval from Burlington Resources.



Quantification of Naturally-Fractured Gas Reservoirs

Lawrence Berkeley National Lab

Objective: To develop the next generation capability in fracture imaging, by testing new tools, including VSP and single well; and by seismic attribute analysis of existing multicomponent seismic data.

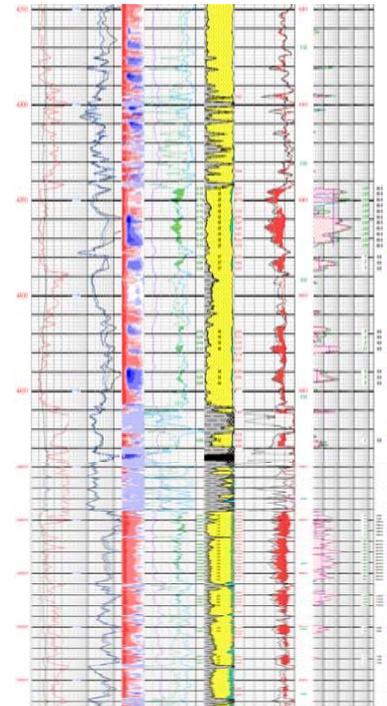
Schedule/Status:

Began Feb, 1995

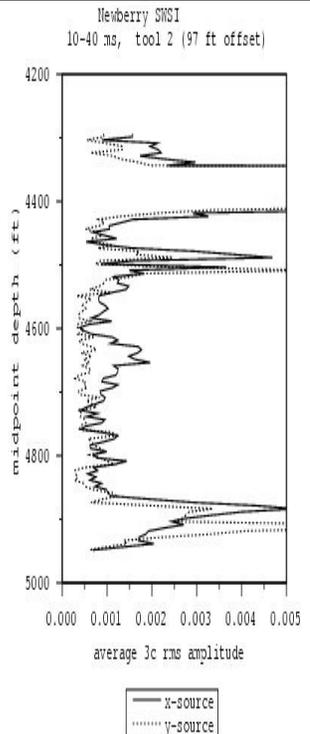
Completed Sept, 2004

Partners: ConocoPhillips, Schlumberger, Stanford, Virginia Tech

Funding: DOE \$4,191,000; Performer \$4,150,000



gas content imaged with single well tool



Quantification of Naturally-Fractured Gas Reservoirs

Accomplishments

- 2000, Surface seismic attribute analysis completed.
- 2001, Moore and Newberry wells drilled on seismic attributes.
- Massive VSP survey completed with Paulsson tool in 2002.
- Single Well Seismic surveys completed with Schlumberger tool in 2002.
- Numerous publications and presentations
- Best Practices Manual available on CD and on NETL web site.



Advanced Fracturing Technology for Tight Gas: An East Texas Field Demonstration

University of Texas at Austin

Description: Develop and improve performance as well as reduce cost of fracture treatments.

Industry Partner:

Anadarko Petroleum Corporation

- Dowdy Ranch Field: 6 wells - Bossier Sand

- Carthage Gas Unit (CGU):

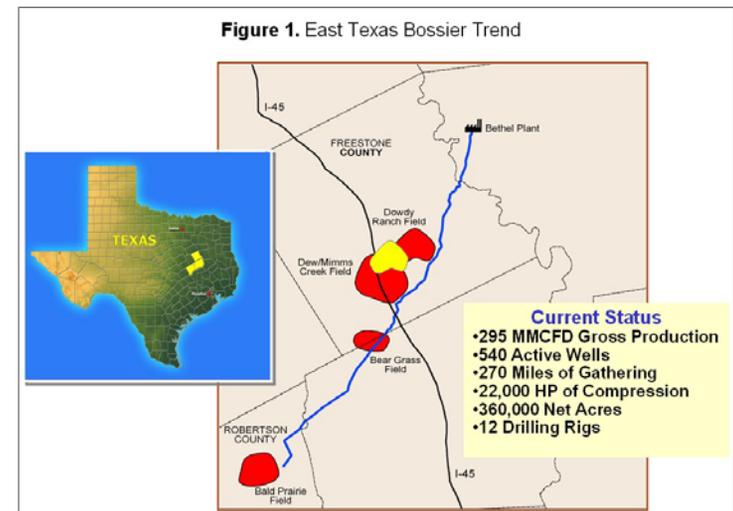
2 wells – Cotton Valley Sand

Schedule:

– Oct. '01 to Dec. '04

Funding:

DOE \$884,000; Performer \$420,000



Advanced Fracturing Technology for Tight Gas: An East Texas Field Demonstration

University of Texas at Austin

- **Project Goals:**

- initial focus on Bossier Sands, later Cotton Valley Sands
- analysis & interpretation of current fracture treatments
- petrophysical analysis of new well data
- fracturing and fracture diagnostics program
- enhance current models to properly model water-fracs
- core flow & simulation studies for fracture cleanup
- validation of field results
- Dowdy Ranch Field: 6 wells in the Bossier Sands
- Carthage Gas Unit (CGU): 2 wells in the Cotton Valley Sands



Advanced Fracturing Technology for Tight Gas: An East Texas Field Demonstration

University of Texas at Austin

- **Accomplishments**

- Analysis and modeling of six wells in Dowdy Ranch Field completed
- Extensive petrophysical analysis of Bossier Sand section in Anderson #2
 - Core data/analysis posted on Omni Laboratories, Inc. web site (www.omnilabs.com; click on 'Log-in'; user ID = DOE , password = UT)
- Technique and model successfully applied to two Cotton Valley Sand wells in Carthage Field using UTFRAC-3D.
- Two technical workshop presentations and five papers presented at two conferences



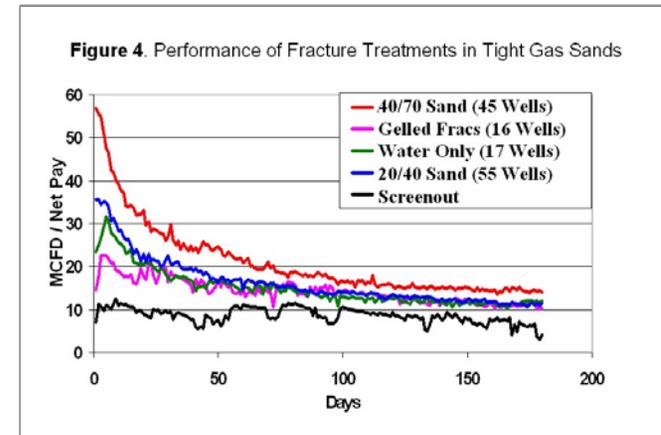
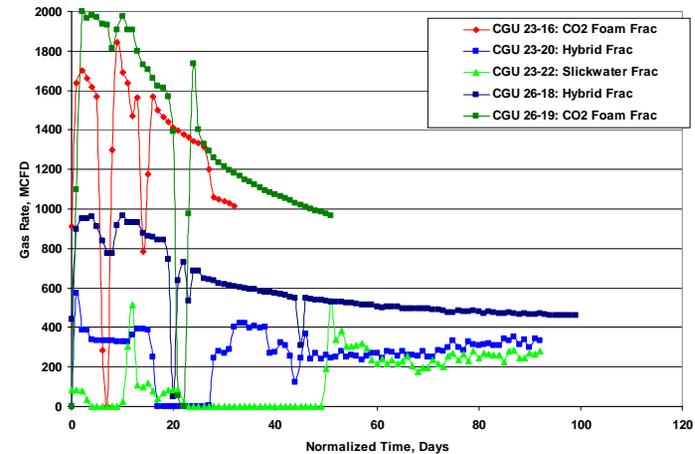
Advanced Fracturing Technology for Tight Gas: An East Texas Field Demonstration

University of Texas at Austin

Accomplishments:

- UTFRAC-3D model and research from Dowdy Ranch Field used to design fracs for CGU 26-18 and 26-19, summer 2004.
- Wells are on 20 acre spacing - reduced from 320 acres for discovery well.
- Current reservoir pressure is 2,100 psi, original pressure was 4,800 psi when Cotton Valley production established in 1970.
- CGU 26-18: Hybrid Frac with 20/40 proppant, flowed 950 MCFD
- CGU 26-19: CO2 Foam Frac with 20/40 proppant, flowed 2,000 MCFD

Anadarko CGU 2004 Well Normalized Prod (20 acre spacing)



Geomechanical Modeling of Fault-Related Fractures

Advanced Resources International

- Developing next generation fracture detection and prediction technology:
 - Phase III
Demonstration/Validation in a complex field setting.

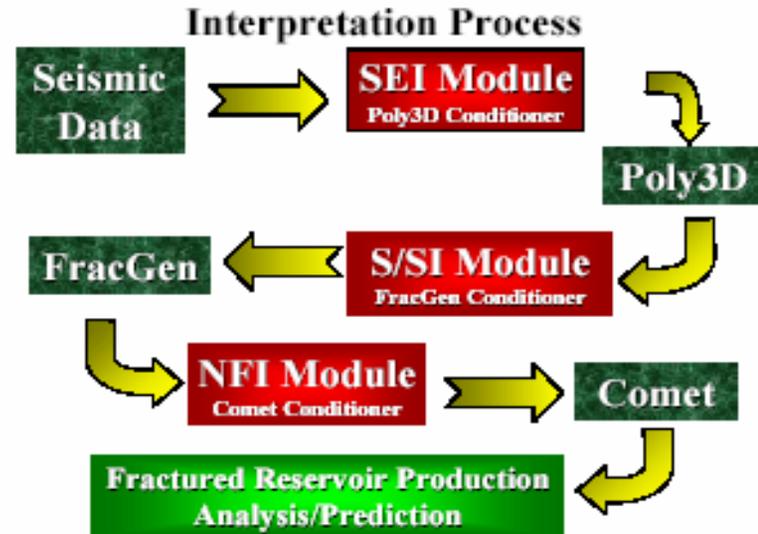


Figure 1. The GMI program is an integrated analysis tool for natural fracture prediction.

	Phase I FY 99/02	Phase II FY 02/03	Phase III FY 03/06	Totals
DOE Share	\$275k	\$320k	\$300k	\$895k
Cost Share	\$0k	\$1,632k	\$2,358k	\$3,990k



Geomechanical Modeling of Fault-Related Fractures

Status/Accomplishments:

- **Successful completion of Phase I Development of Theoretical Code**
 - Core module selection for the Geomechanical Integration (GMI) program has been completed.
 - Application interface has been developed for the GMI program to apply the following software:
 - Seismic Integrator (SEI) using Stanford/Poly3D
 - Stress/Strain Integrator (S/SI) using EG&G/FRACTGEN
 - Natural Fracture Integrator (NFI) using ARI/COMET 2
- **Successful completion of Phase II Validation using existing geologic and production data.**
 - Greater Green River Basin (GGRB) field data collected
 - Calibration and Validation of the GMI approach completed
- **Phase III Completed**
 - Considerable difficulty in finding industry partner(s) for field demonstration in the Rocky Mountain Region (potential partner in GGRB backed out).
 - Decision was made to terminate project early and final report was completed and delivered to DOE/NETL.



Multi-Site Application of the Geomechanical Approach for Natural Fracture Exploration

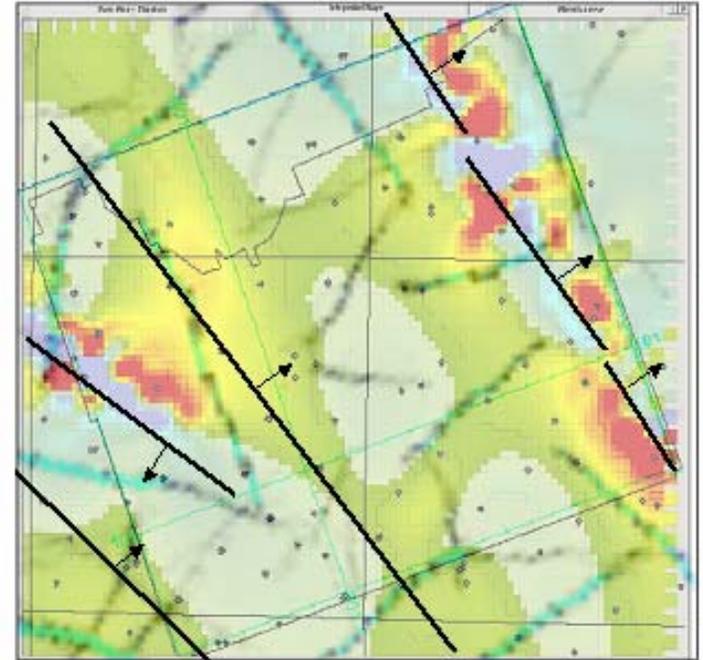
Advanced Resources International

Objective:

Provide successful demonstrations of natural fracture detection and predictions in an exploration setting using the geomechanical approach in 3 geologic/basin settings

Schedule/Status:

- Began Sept '99 and Ends Winter '05
- Wind River Basin Model Complete
- Anadarko Basin Model Complete May '03
- Burlington drills well in Anadarko Basin Aug '03
- Powder Mountain Unit Model Complete April '04
- Powder Mountain well drilled Aug '04
- Joined the CSM/RCP Consortium Fall '04
- Study completed Spring '06



Partners: CSM/RCP, Burlington, Stone Energy, Barrett Resources/Williams

Funding: DOE \$1,220,729; Performer \$9,857,210



Innovative Methodology for Detection of Fractured Controlled Sweet Spots in the Appalachian Basin

State University of New York, Buffalo and Quest Energy

Description: The effort integrates a number of exploration tools to define fractured, dolomitized fairways in the Trenton-Black River formations of New York. Seismic, satellite imagery, aeromagnetics, geochemistry and geological mapping were done over known gas production and well sites located for Phase 2 of the study.

Schedule/Status:

- Phase 1 began June, 2000, to December, 2003.
- Phase 2: No cost extension to June, 2006 due to new well of opportunity. Obtain a core in a horizontal well in a gas producing trend in New York State

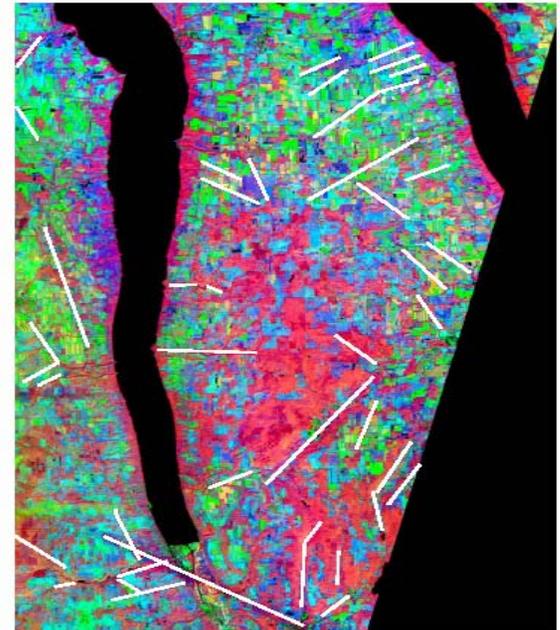


FIGURE 3.3-2

Innovative Methodology for Detection of Fractured Controlled Sweet Spots in the Appalachian Basin

State University of New York, Buffalo and Quest Energy

- **Funding**

- DOE - \$827,505
- SUNY - \$396,447
- Total – \$1,223,952

- **Accomplishments**

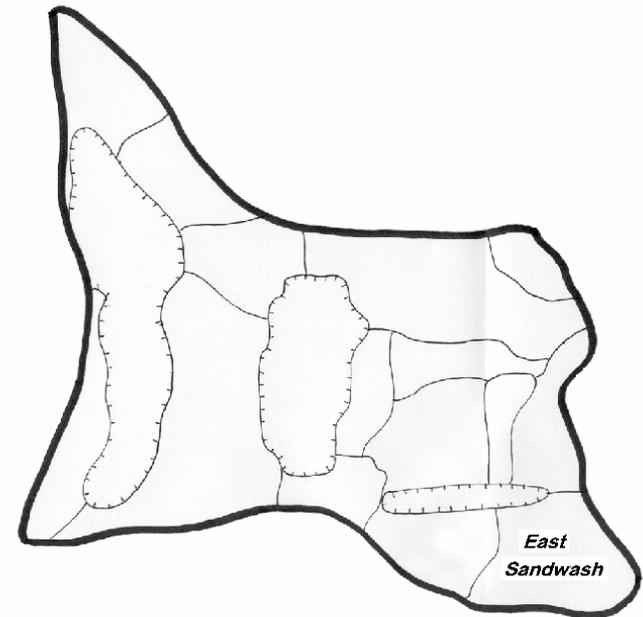
- AAPG Posters and Papers on Phase 1 Results of Field E&P Tool Evaluation to Select a Well Site.
- Current Phase 2 Plan to Drill a Horizontal Well, Core and Log Section Through Dolomite Faults at a Prime Location in West-Central New York State.



Identify and Remediate Water Production Problems

Advanced Resources International

- Develop a conceptual water distribution model for western tight gas reservoirs to better understand water production problems
- Partners: BP Wild Rose Field
- Schedule/Status:
 - Began April 2002 and Ends September 2005
 - Conceptual model developed
 - Presented at AAPG
 - BP joined project to study Wamsutter arch area
 - Database completed and put on SCNGO website, 9/05



Funding and Accomplishments

- **Funding:**

- DOE - \$548K
- ARI - \$178K

- **Accomplishments:**

- Created a database of water chemistry for the GGRB
- Established an industry partner to look at detailed water distribution in the Wild Rose Field on the Wamsutter Arch of western Wyoming.



Imaging Super-Deep Gas Plays Across the Gulf of Mexico Shelf

The University of Texas at Austin, Bureau of Economic Geology

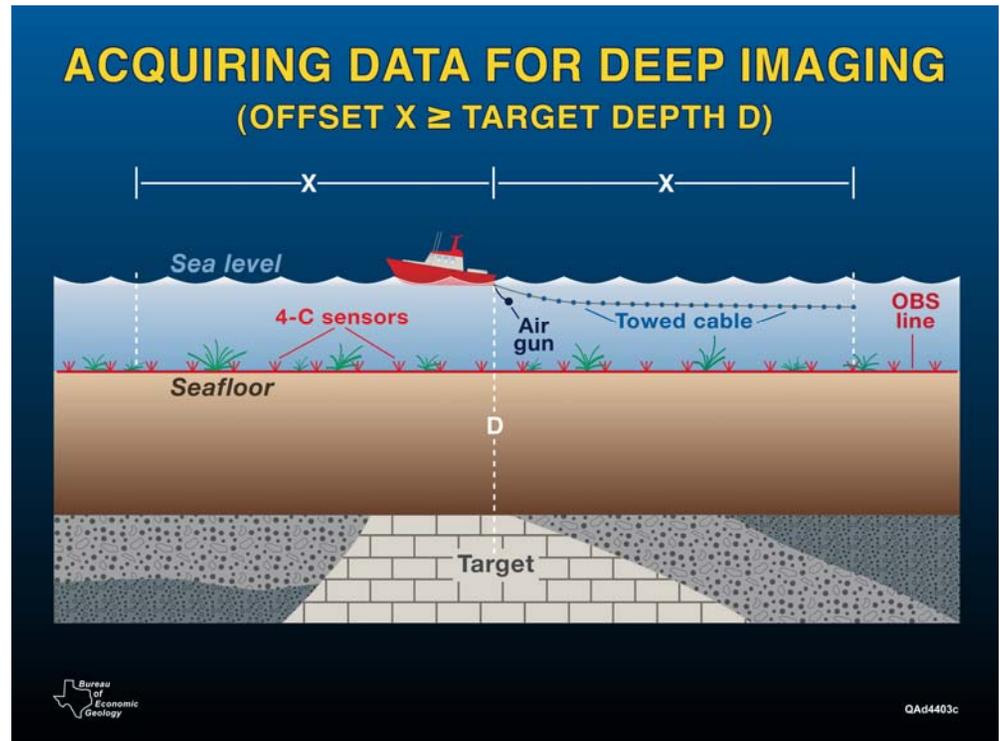
Description: Document the value of P-SV seismic data relative to P-P data and demonstrate the maximum depths to which good-quality P-P and P-SV imaging can be extended using available ocean-bottom-cable multi-component data. Develop improved processing algorithms for deep geologic imaging.

Schedule/Status:

- Oct. 1, 2004 – Sept 30, 2007
- Project in budget period 2 of 3

Partners: WesternGeco, Devon Energy

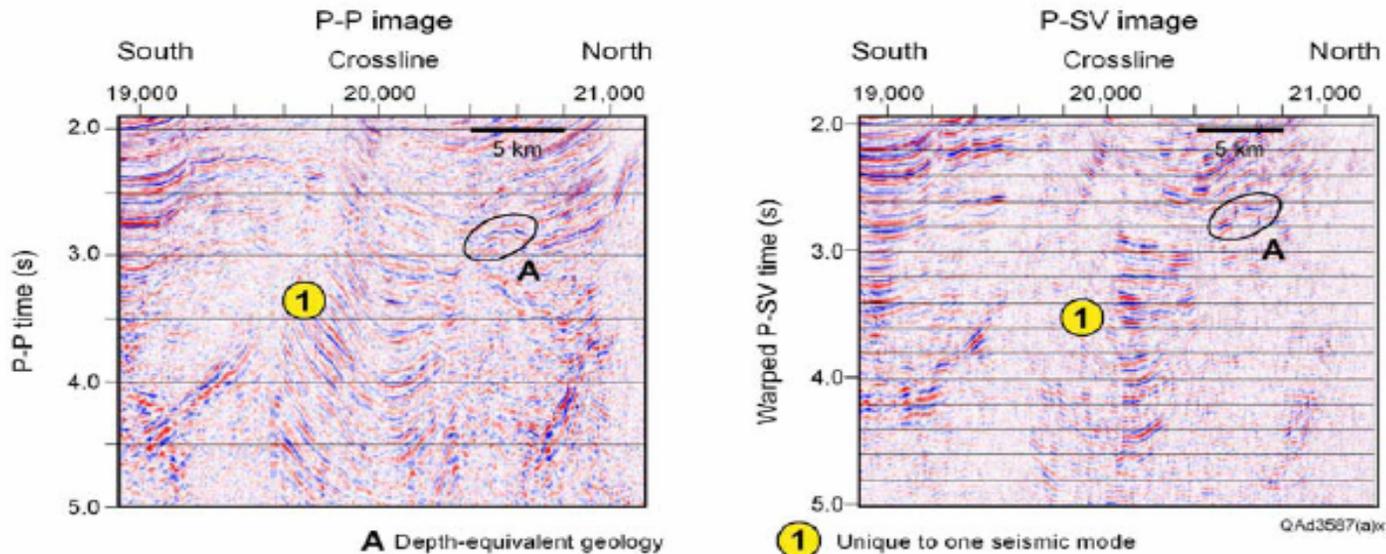
Funding: DOE \$985,870;
Performer: \$2,000,000



Imaging Super-Deep Gas Plays Across the Gulf of Mexico Shelf

- **Accomplishments:**

- 4-C OBC data available to the project have been selected that can best demonstrate technologic capability with good-quality data
- Selected data segregated into compressional (P-P) and converted-shear (P-SV) wavefields
- P-SV data provide excellent images of geology underneath the northern GOM shelf to depths of approximately 30,000 ft

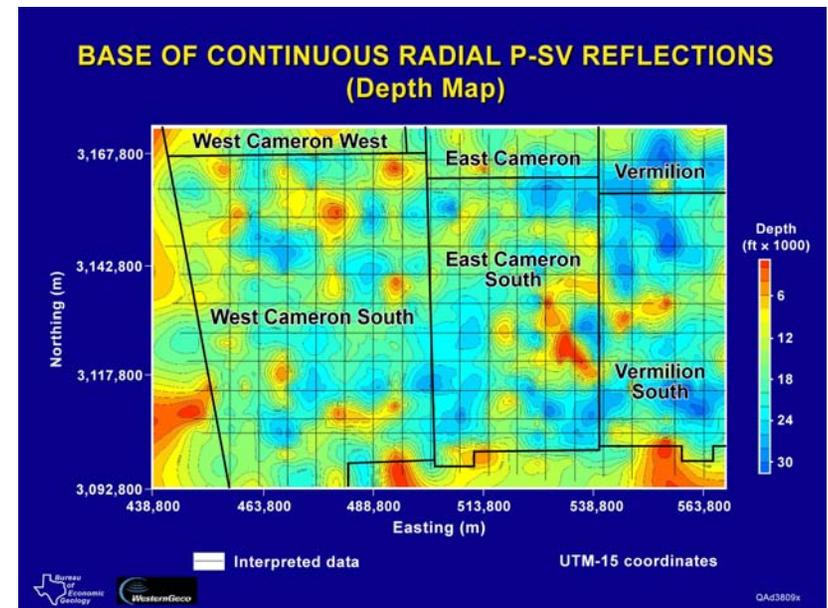
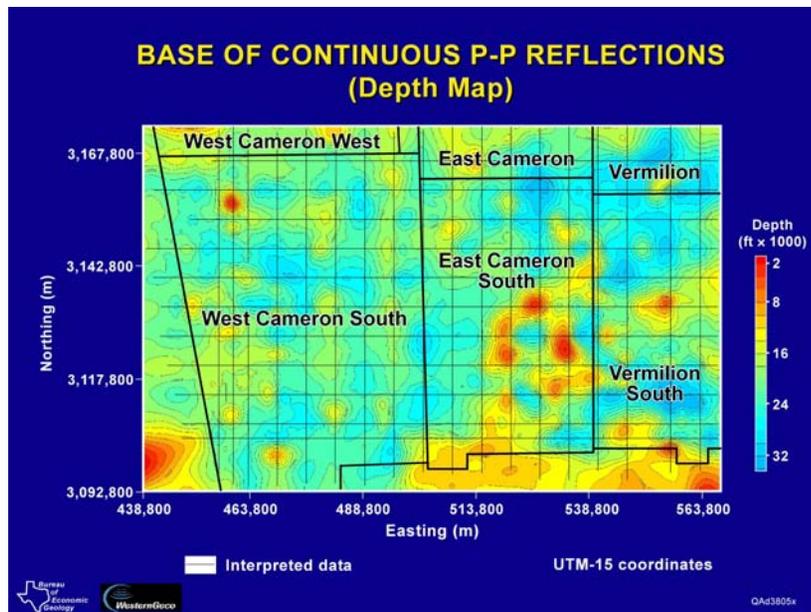


Comparison of deep, depth-equivalent, P-P and P-SV data windows

Imaging Super-Deep Gas Plays Across the Gulf of Mexico Shelf

- **Accomplishments:**

- Sediment beneath the study survey is potentially 50,000 to 65,000 feet thick
- Good-quality continuous reflections extend 30,000 feet for both P-P and P-SV modes



Analysis of Critical Petrophysical Properties for Western Tight Gas Sandstones

University of Kansas, Kansas Geologic Survey

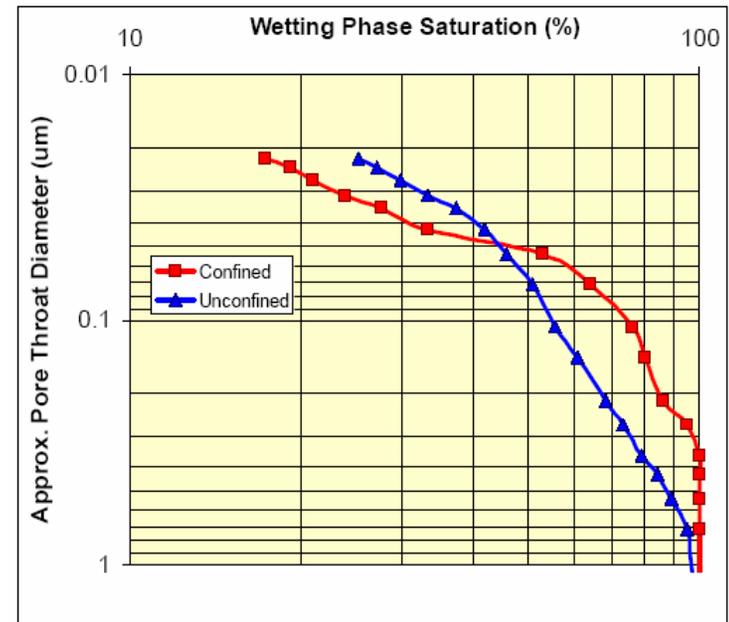
Objective: Provide petrophysical formation evaluation tools related to relative permeability, capillary pressure, electrical properties and algorithm tools for wireline log analysis for tight gas sandstones of the Mesaverde Group in major Tight Gas Sandstone basins (Washakie, Uinta, Piceance, Upper Greater Green River, Wind River)

Schedule/Status:

- October 1, 2005 - September 30, 2007
- Compiling published data on physical properties, collecting Mesaverde sandstone samples from gas wells, acquiring and digitizing logs from sample wells.

Partners: Discovery Group

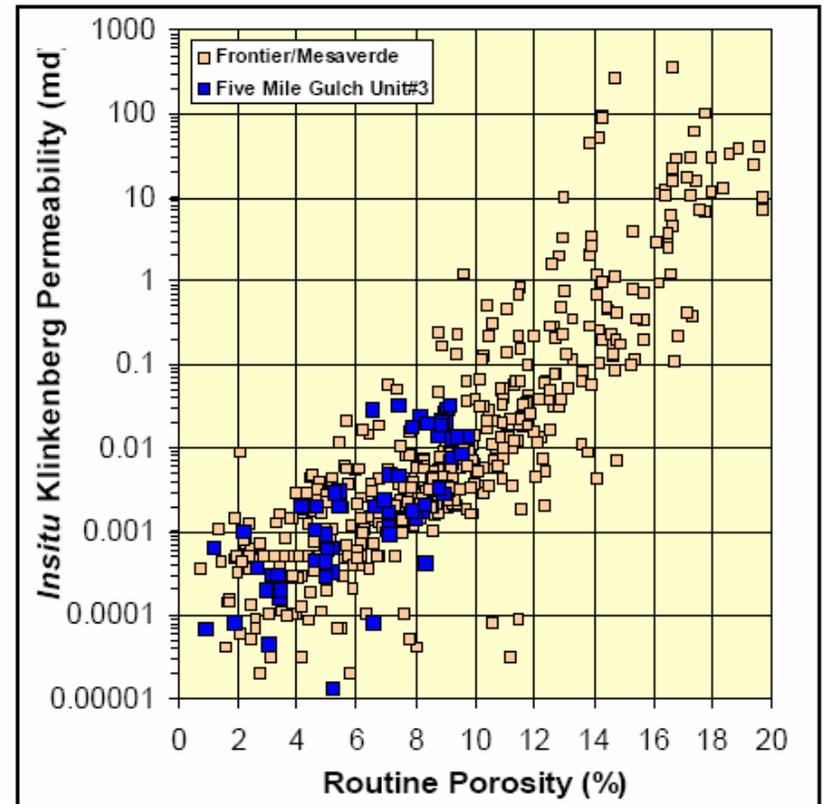
Funding: DOE \$411,030; Performer \$102,804



Analysis of Critical Petrophysical Properties for Western Tight Gas Sandstones

- **Current Activities**

- Advanced rock properties data for tight gas sandstone is being compiled and petrophysical data extracted
- Mesaverde core being obtained for study. Companies participating in the study include Endurance Resources, Bill Barrett Corp., Encana Corp., Questar Corp., ExxonMobile
- Core plugs from Green River Core taken from well cores at the USGS Core Research Center
- Initial core analysis of porosity and permeability trends



Fiber Optic MEMS Sensors

Paulsson Geophysical Services, Inc.

Objective: To design, prototype, and test a multi-component seismic sensor based on Fiber Optic and MEMS technologies. The FOMEMS sensor has the potential to dramatically increase the number of receivers deployed simultaneously in a borehole seismic array.

Schedule:

- Project began Oct. 1, 2004
- Phase I design ends Sept. 30, 2006
- Phase II testing ends Sept 30, 2007

Partners: Optiphase for FO telemetry, Micralyne and Davidsson Instruments for MEMS sensors

Funding:

DOE \$1,204,538; Performer: \$1,204,538



FOMEMS Pressure Sensor



Fiber Optic MEMS Sensors

Accomplishments

Accomplishments

- Sept, 2005 Initial design completed for the first all fiber optic downhole seismic receiver system; unlike all other receiver strings it will operate with no electronics in the borehole, which eliminates the need to send power downhole.
- Agreement reached with Optiphase to design and build the telemetry for the system.
- Paulsson visited NETL to report on the Project's Year 1 accomplishments
- Agreement reached with Davidsson and Micralyne Instruments to design and build the sensor prototype.
- October, 2005 Paulsson, Optiphase agreed to a multicomponent sensor equipped with 3 orthogonal MEMS accelerometers on a 1 x 1 x 1 cm cube. Each accelerometer is a micromachined quartz wafer with a hinged flap that accelerates in response to ground motions and is equipped with an optical interrogation system that measures the magnitude of the acceleration.
- November, 2005 Paulsson and Optiphase completed initial design concepts for the optical interrogation system to measure the magnitude of ground acceleration
- Prototype sensor design is near completion, with targeted maximum operating temperatures of 350-400 deg F, and maximum operating pressure of 25,000 psi.

Status

- Awaiting completion of prototype sensor design specifications and manufacturing sequence.



Deep Wave-Equation Imaging

3DGeo Development, Inc.

Objective: To develop and test a new seismic data processing methodology that applies wave equation depth migration and wave-equation velocity model building to datasets acquired at extended offset and extended record length.

Schedule:

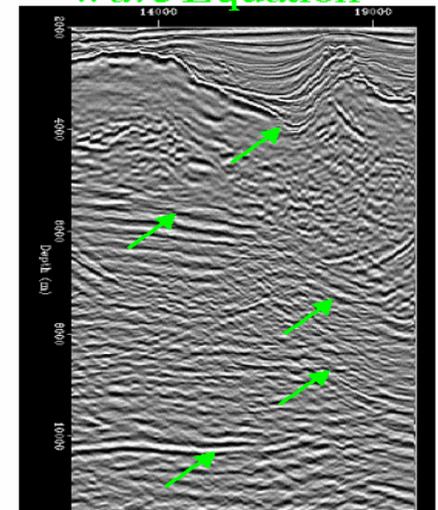
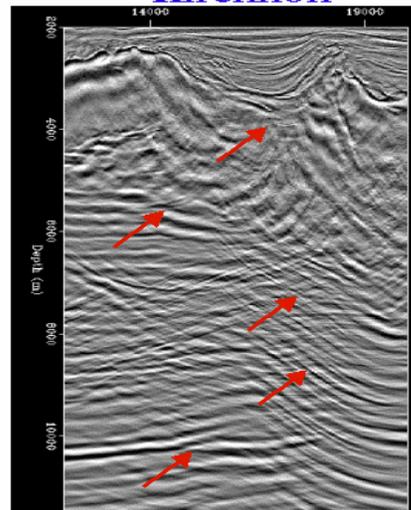
- Began Oct. 01, 2004
- Ends Sept. 30, 2006

Partners: British Petroleum, Total, & PGS

Funding:

DOE \$504,944; Performer \$120,236

Deep-water GOM (zoom)
Kirchhoff
Wave Equation



Deep Wave-Equation Imaging

Accomplishments

Accomplishments

- Sept, 2005 3DGeo completed a set of algorithms to optimize pre-stack time migration and wave-equation velocity model building
- Oct, 2005 3DGeo took delivery of PGS Onshore's ultra-deep POC2 line that spans the onshore and offshore portion of the Texas gulf coast.
- Nov, 2005 Processing team is running iterations of algorithms developed during the first year of the project, using the POC2 vibroseis/airgun dataset.
- Jan, 2006 3DGeo also testing a true-amplitude imaging algorithm that improves the clarity of deep and steeply dipping events. conducting a series of tests to validate algorithms developed during the first year of the project.

Status

- April 2006 All tasks appear to be on-schedule



Advanced Seismic While Drilling

Technology International Inc. (TII)

Objective: Develop an acoustically augmented hybrid (*Seismic Drill Bit*) SDB with a controllable Sparker Pulsating Nozzle and demonstrate the adequacy of the SDB source with measurement using low noise *Micro Electro-Mechanical Systems (MEMS)* seismic monitoring.

Schedule/Status:

- Began Oct. 01, 2004
- Ends Sep. 30, 2006

Partners: GE, I/O, Axis, & KSI

Funding:

DOE \$799,985; Performer \$200,000 (in kind)

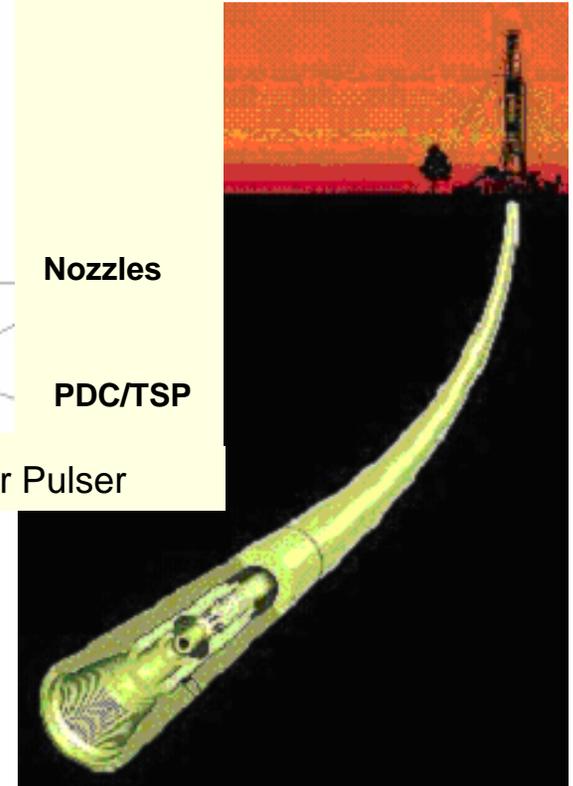
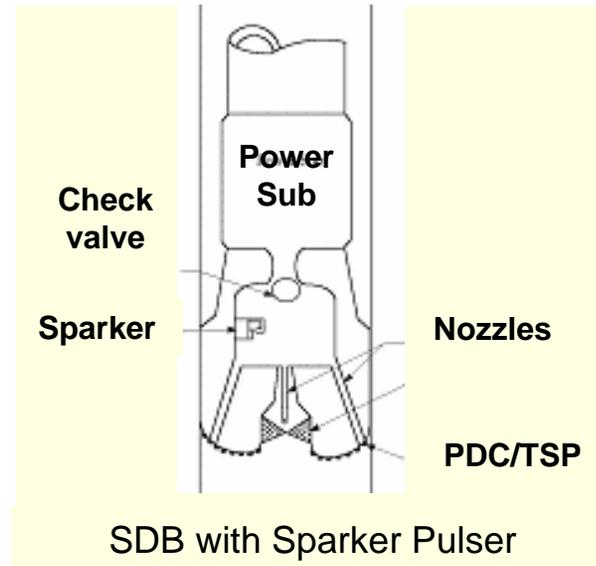


Illustration of Power/Control Sub



Advanced Seismic While Drilling

Technology International Inc. (TII)

- **Status / Accomplishments:**
 - Successful lab tests of Seismic Drill Bit Source (Sparker-Coupler) Designs.
 - Successful Field Test of Source at the U. of Texas Devine Field Test Site. (From 1800 ft. well depth to surface MEMS detectors). Cross-Well tests experienced hydrophone problems (still being evaluated).
 - Hybrid PDC/Roller Cone drill bit design requirements are being developed with RBI (formerly RBI-Gearhardt). Impact resistant PDC cutters fabricated and tested (with mixed results).
 - Draft Power Generation & Control Subsystem Specifications are developed.



Advanced Seismic While Drilling

Technology International Inc. (TII)

- **Activities in the Planning Stage:**
 - Flow Loop Tests at the U. of Tulsa to further test the sparker-coupler design.
 - Test Requirements for GTI Catoosa Site Field Test.



Novel Use of P-wave Seismic Attenuation for Deep Natural Gas Exploration and Development

Rock Solid Images (RSI)

Objective: Develop a simple and effective methodology for estimating reservoir properties (gas saturation, lithology & porosity) from P-wave and S-wave seismic attenuation attributes.

Schedule/Status:

- Began Oct. 01, 2004
- Ends Sep. 30, 2006

Partners: Stanford University, Seitel

Funding:

DOE \$776,321; Performer \$332,709 (in kind)

Summary Economic Results		
Porosity	NPV	NPV _n - NPV _{base}
15%	\$64,365,067	
16%	\$65,368,890	\$1,003,823
17%	\$66,323,985	\$1,958,918
18%	\$67,235,572	\$2,870,505
19%	\$68,020,227	\$3,655,160
20%	\$68,736,479	\$4,371,412
Δ high case - low case		\$4,371,412

Increase in Net Present Value of a gas field in response to improved reservoir characterization.



Novel Use of P-wave Seismic Attenuation for Deep Natural Gas Exploration and Development

Accomplishments

Accomplishments

- Sept 2005 RSI completed the project's first milestone, development of equations for computing seismic wave attenuation from digital well log data. This represents a significant accomplishment, as there is currently no commercial tool to measure attenuation in the borehole, and it is known to contain useful information about critical reservoir properties, including gas charge.
- Dec 2005 RSI has loaded the Seitel Eugene Island GOM ocean-bottom-cable seismic data along with the accompanying velocity data. These data will be used to test the validity of equations they developed during the first year of the project for relating p- and s-wave attenuation attributes to gas saturation, porosity, and lithology.
- Jan 2006 RSI has developed a qualitative method for registering multicomponent seismic data, based on the nature and similarity of particular PS and PP reflections. Richard Uden is also consulting with UT BEG on their methodologies for co-registering PP and PS seismic displays. The co-registration is one step in interpreting the Seitel Eugene Island, Gulf of Mexico dataset.

Status

RSI is working to validate the reliability of their equations with Eugene Island ocean-bottom-cable seismic data. The ultimate goal of the project is to develop a new tool for estimating gas saturation, porosity, and reservoir lithology from seismic attenuation attributes.



Production of Natural Gas and Fluid Flow in Tight Gas Reservoirs

Florida International University

- **Goal:** The project will look at the influence of microscopic physical parameters of fluid flow in tight gas reservoirs and determine the effect of these on macroscopic flow. The results will be applied to improving flow simulation models for the petroleum industry.
- **Project Schedule:**
 - Began 7-1-04 to 6-30-06
- **Funding:**
 - DOE - \$111,000.00
- **Participants:**
 - NETL and Florida International University, Center for Energy and Technology of the Americas.



Resource Assessments

- **Assessments “re-initiated” upon 1999 NPC Study recommendation**
 - Focused on gas-in-place
 - Allows for technology, policy and price modeling
- **GGRB and WRB completed October 2002**
 - 400 copies handed out at 2003 AAPG meeting
- **Anadarko and Uinta Basins – Summer 2004**
- **Two new starts October 1 under BBFA**
 - Black River/Trenton - Appalachian basin (WV, OH, PA, NY & KY Geologic Surveys)
 - Deep gas – onshore interior salt basins (U. Alabama)
 - Coalbed methane – Illinois basin (KY, IL, & IN Geologic Surveys)



SCNGO Technology Needs Assessments

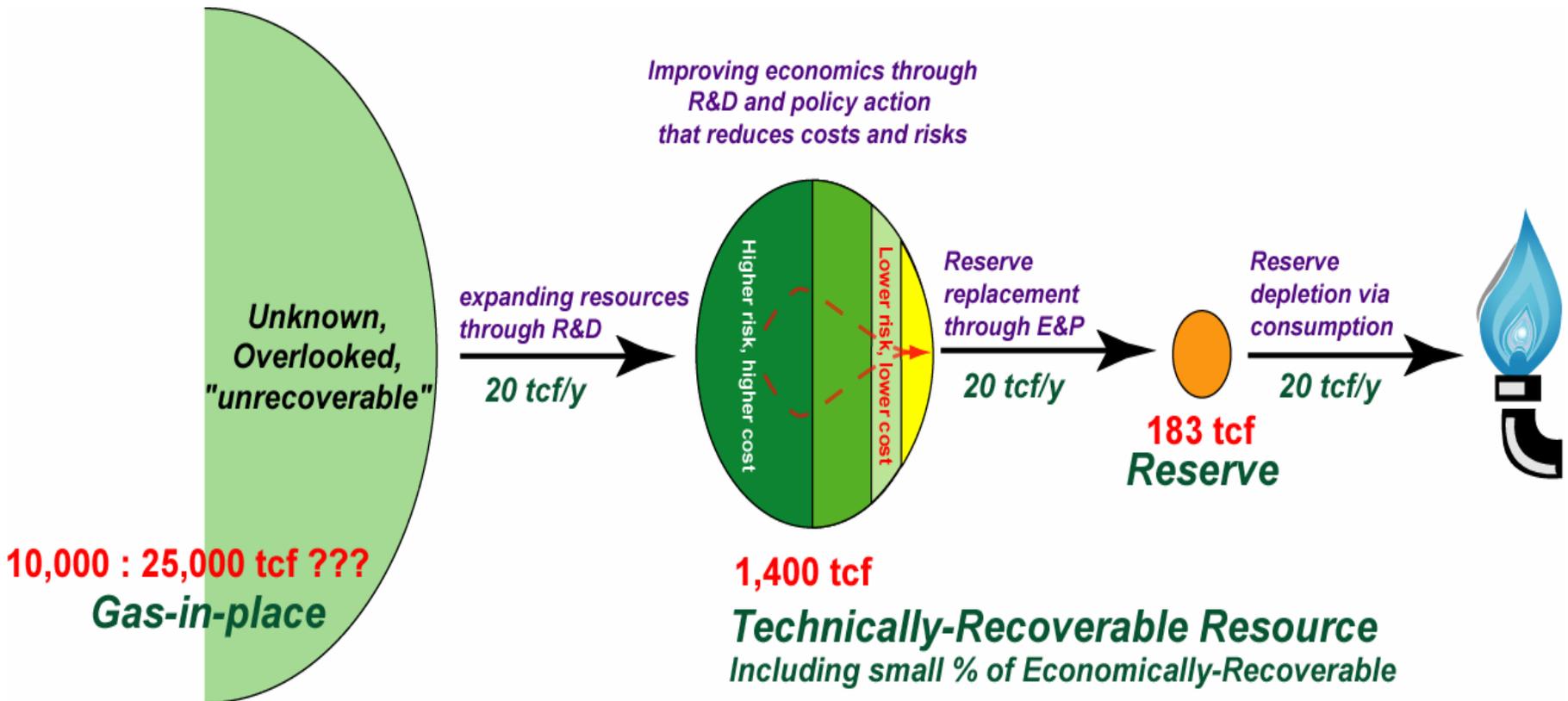
Key Points

- **NETL-OST conducts resource assessments in support of natural gas R&D program planning**
 - Focus on resources that are key program targets
 - Substantial industry interest in the geologic interpretations.
- **NETL resource assessments differ greatly from those conducted by other organizations...**
 - Production of datasets that capture resource potential, not point-in-time estimates of technical recoverability
 - Focus on gas-in-place (TRR presumes the answer)
 - Modeling need necessitates extensive geographic and geologic resource detail to provide sensitivity to changes in conditions



Expanded View of Gas Resource

Vast Untapped Resource is Key to Sustainability of Supply



High-risk, high-payout R&D provides for quantum leaps in technology that transition resources from vast in-place storehouse to recoverable resource



Target #1: Vast Resources of the Rocky Mtns

USGS: >98% of GIP in GGRB/WRB is “not recoverable”

Greater Green River Basin			Wind River Basin		
Play	GIP ('89)	Tech. Rec. ('95)	Play	GIP ('96)	Tech. Rec. ('95)
Ft. Union	96	1	Ft. Union	101	Not Assessed
Fox Hills/Lance	707	10	Lance	365	Not Assessed
Lewis	610	19	Meeteetsee	124	Not Assessed
Mesaverde	3,347	52	Mesaverde/Fales Ss.	203	Not Assessed
Frontier-Cloverly	304	37	Cody Sh.	51	Not Assessed
			Frontier	151	Not Assessed
Total	5,064	119	Total	995	Not Assessed

- 2002 USGS update reduces GGRB recoverable estimate to 80 Tcf
- NPC (2003) further reduces GGRB to 70 Tcf. Both still place WRB at 0 Tcf
- 6000 TCF IN PLACE; <100 “RECOVERABLE”
- **What is the nature of the remaining 5,900 Tcf? How much are reasonable targets for fed R&D? What technologies would be most effective?**



Selected Assessment Methodology

for modeling technology impacts in regional accumulations

- **Field Size Distributions (USGS – conventional): NO**
 - **No fields** (Multiple lenticular stratigraphic traps, commingled production)
 - **No size** (Progressive field consolidation: size influenced by costs and technology)
- **Extrapolation of Historical Data (USGS – unconventional): NO**
 - **Past production incorporates operator choices** (*What, How, and If* to produce; decisions influenced by past technology constraints)
- **Cell-based Gas-In-Place analyses (NETL method)**
 - **Divide plays into 100s/1000s of cells**
 - **Determine Gas in Place per cell** (through reference to geology)
 - **Estimate factors affecting productivity** (matrix perm + fracture perm overprint),
 - **Use NETL's GSAM** to estimate recovery as a function of Technology, Costs, and Price

RESULT: A DATASET THAT DOES NOT PRESUPPOSE ANY SINGLE TECHNOLOGY SCENARIO



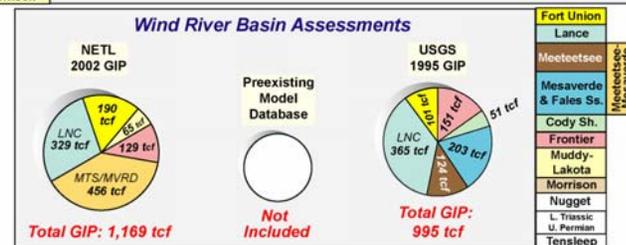
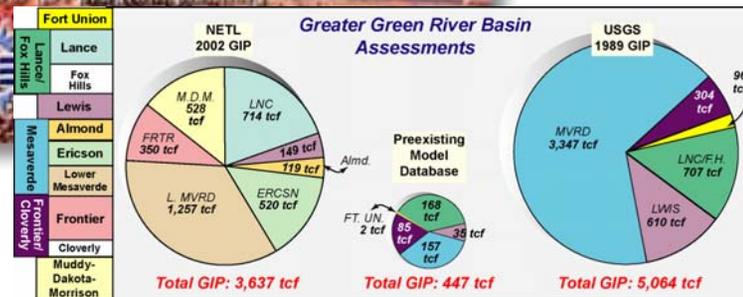
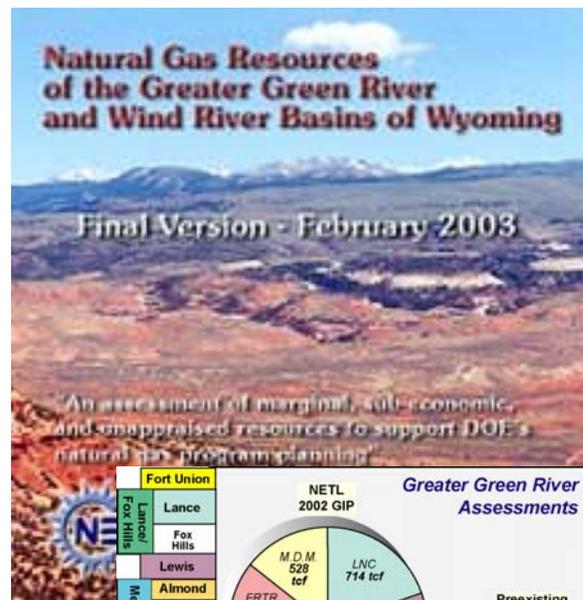
Completed Studies

Greater Green River and Wind River basins, Wyoming

- **Completed Feb. 2003**
 - Confirmed USGS determination of vast in-place resources
 - Revealed the sensitivity of recovery to technology
 - Vast improvement in the quality of model databases
- **Results presented...**
 - RMAG/COGA (Aug 2002)
 - National AAPG (April 2003)
 - Regional SPE (May 2003)
 - GasTIPS article (Fall 2002)
- **Data/reports available on CD**
 - Nearly 500 distributed to date

CD Available at:

<http://www.netl.doe.gov/technologies/oil-gas/index.html>



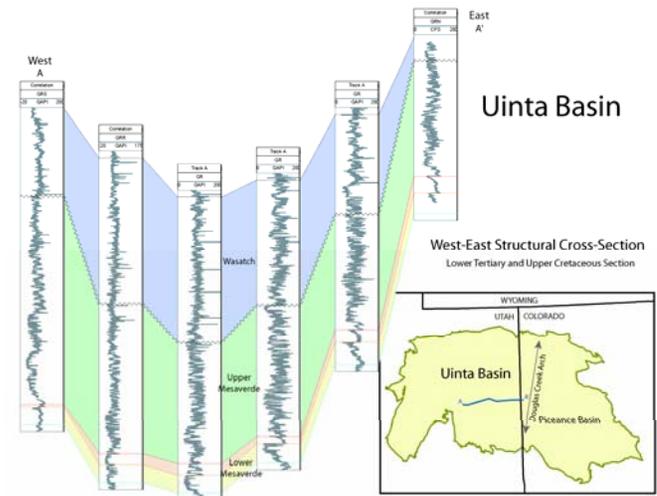
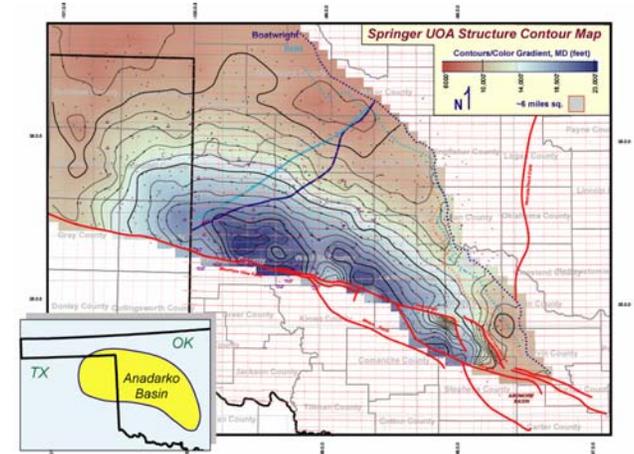
Ongoing Studies

Deep Anadarko Basin (OK/TX) & Uinta Basin, Utah

- **Studies completed Fall 2004**
- **Results Presented at**
 - Ok. Geol. Soc. (March 2004)
 - National AAPG (April 2004)
 - RMAG/COGA (Aug 2004)
 - Overall Program Review at April 2004 AAPG
 - AAPG's online journal, *Search & Discovery*, <http://www.searchanddiscovery.net>
- **CD containing archived maps, cross-sections, datasets released 09/2004**

CD Available at:

<http://www.netl.doe.gov/technologies/oil-gas/index.html>



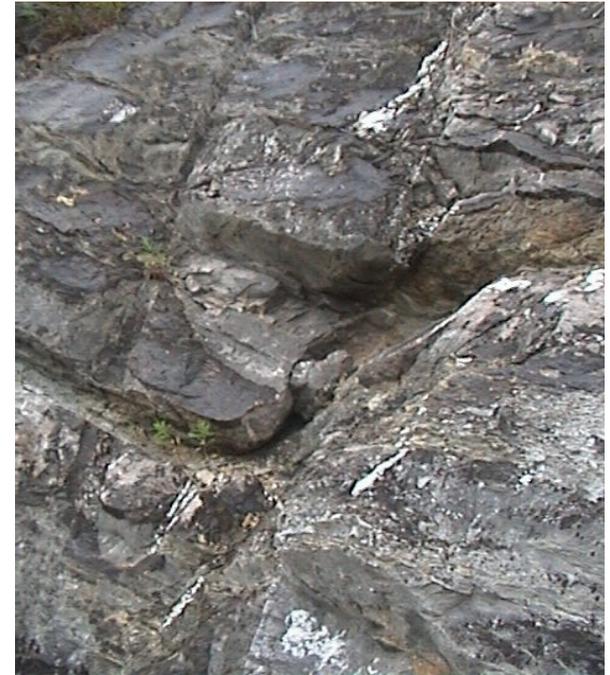
Geologic Play Book for Trenton Black River Appalachian Basin Exploration

West Virginia University Research Corp.

- Develop an integrated, multi-faceted, resource assessment model of Trenton-Black River reservoirs in NY, OH, PA, WV, KY
 - Define fault and fracture fairways leading to further development of the gas resource
 - Develop an integrated structural / stratigraphic / diagenetic model
 - Compile a geologic play book

Schedule/Status:

- Began Oct. '03
- Complete Play Book; March, 06



Partners: Pennsylvania, Ohio, Kentucky Geologic Surveys, New York State Museum

Funding: DOE \$1,012,400; Performer \$656,000



Intelligent Systems Approach to Reservoir Characterization

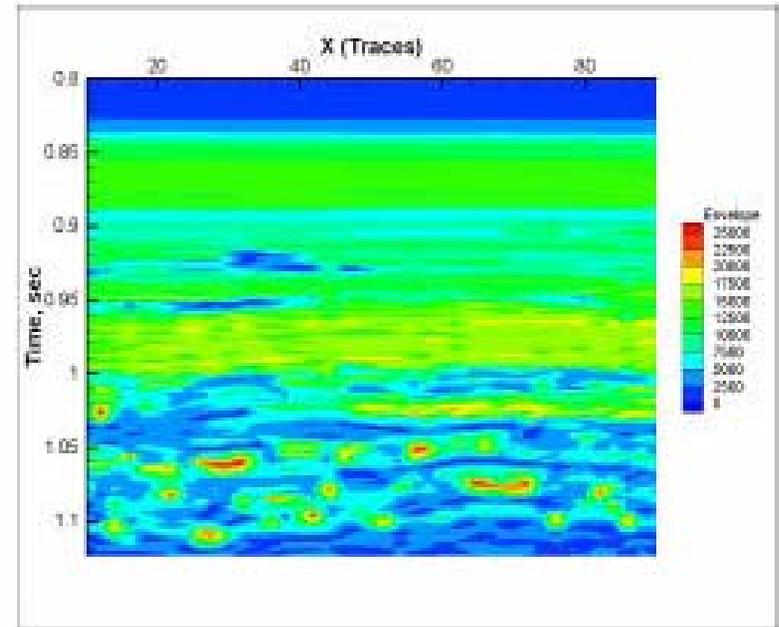
West Virginia University Research Corp.

- Develop an Artificial Intelligence System to integrate Seismic and Well Log Data to increase the definition of thin gas bearing horizons.

- Develop a model through geophysical analysis that can utilize well log data for training and identification of reservoir attributes.
- Apply model to a real reservoir case study.
- Compile a final report on the results of the application of the model and success of the method to improve scale definition in thin formations.

- **Schedule/Status:**

- Began, May 2003, September, 2005
- Final Report submitted and reviewed.



**Partners: West Virginia University, Dept of Geology and Geography,
Dept. of Petroleum Engineering and Western Geco**

Funding: DOE ; Performer



Deep Natural Gas Resource Onshore Interior Salt Basins N.C./N.E. Gulf of Mexico

University of Alabama

- **Objective:** The objective is to complete a resource assessment of in-place deep natural gas of onshore interior salt basins of the north central and northeastern Gulf of Mexico, by applying Petroleum system identification, characterization and modeling; petroleum system based resource assessment to estimate the recoverable in-place deep gas resource; identification of interior salt basin areas with high potential to recover commercial quantities of deep gas resource.

- **Schedule:**

- Began Oct. 2003
- Ends Sept '06

- **Partners:** Louisiana State University

- **Funding:** DOE \$745,000; Performer \$209,000

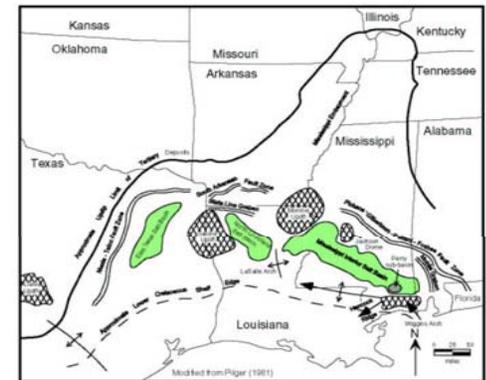


Figure 1 - Interior Salt Basins and Uplifts in the Northern Gulf Coastal Plain



Deep Natural Gas Resource Onshore Interior Salt Basins N.C./N.E. Gulf of Mexico

Accomplishments

Accomplishments

- Oct 2005 Project team successfully completed the Petroleum Systems Analysis of the basins
- Feb 2006 Project team completed a series of volumetric calculations that will serve as the basis for estimating the in-place hydrocarbon resource generated and the potential amount of resource that is classified as deep (>15,000 ft) gas in the North Louisiana Salt Basin, the Mississippi Interior Salt Basin, the Manila Subbasin, and the Conecuh Subbasin.
- Mar 2006 Project is on schedule and on budget

Status

- Sep 2006 Resource Assessment to be completed



Resource Assessment & Production Testing for CBM Development in the Illinois Basin

University of Kentucky Research Foundation.

Objective: To obtain fundamental information on methane content, permeability and well completion data and techniques for Illinois Basin coal beds and associated organic-rich shales.

Original Schedule/ Status:

Project began Oct. 1, 2003

Phase I Geological analysis, exploratory drilling and well completion pilot study ended Sept. 30, 2004

Phase II extension was to end Oct. 31, 2006

Partners: Kentucky, Illinois and Indiana Geological Surveys

Funding: (Phase I only)

DOE \$500,000; Performer: \$374,440



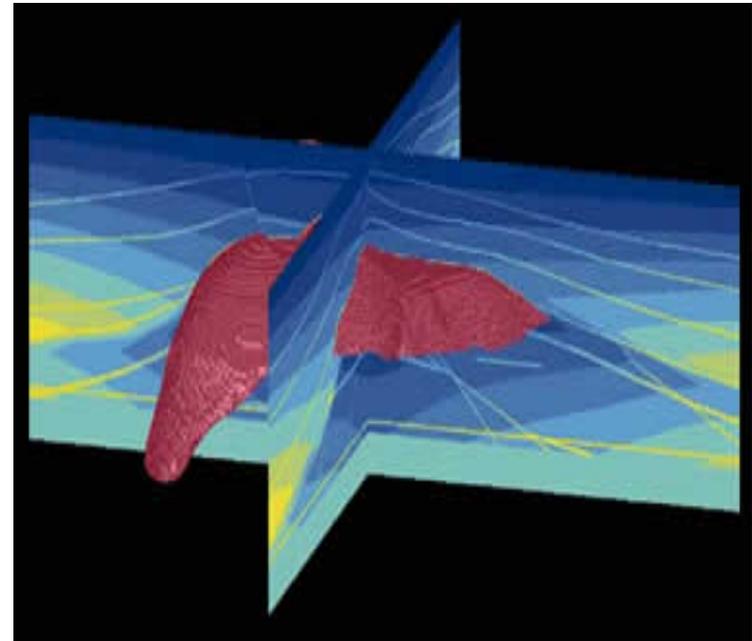
Resource Assessment & Production Testing for CBM Development in the Illinois Basin

- Initial geologic assessment of Illinois Basin has been completed.
- The basin is estimated to contain approx. 11 Tcf of CBM with very limited production to date.
- First well in the Illinois area of the basin was cored in White County, Ill., yielding a cumulative bed thickness of 24.5 ft (individual beds range from 1.4 to 5 ft.). CBM gas contents range from 83.3 to 188.7 scf/ton of coal.
- Very Successful PTTC Meeting featured this project on Nov. 16-17, 2004 (>100 participants from industry).
- Project Final Report Completed & Accepted by DOE



National Laboratory Partnership Program

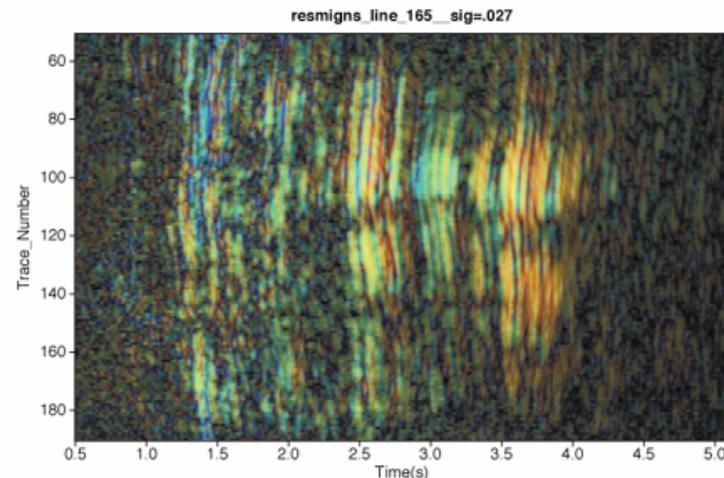
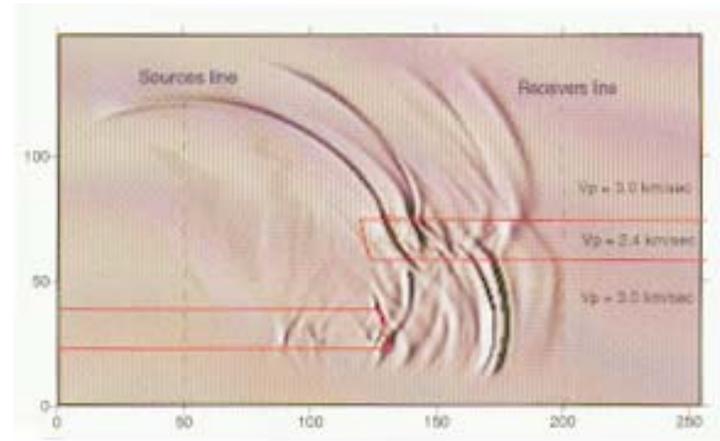
- **Improve exploration and characterization through advances in borehole geophysics and seismic processing and imaging**
 - Real-time fluid imaging using single well EM and seismic
 - 3-D Kirchhoff migration
 - 3-D anisotropic velocity modeling



Vision of 2025

Solutions Not Data

- True 3-D imaging of subsurface
- Instrumented wellbores and fields
- Time lapse imaging of reservoir changes
- Real time drilling decision capability (e.g., Grant Prideco/Novatek IntelliPipe technology)



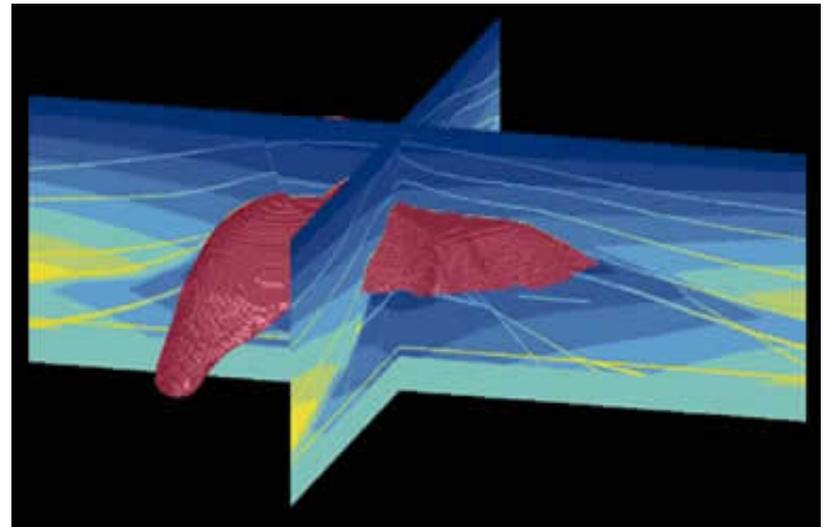
Issues

- **Validation and industry acceptance**
 - Multiple projects in multiple basins are costly
 - Operators that are actively involved in project lead to better acceptance
- **Integrated, multidiscipline project teams**
 - Committed industry partners
 - Consortium or JIP
 - Leverage funding
 - Provide broader spectrum of experts



Future R&D

- **ADIS Solicitation – FY 2005**
 - Tight Gas Imaging
 - Tools and Methodologies
 - Technology areas
 - Tools
 - Processing & modeling
 - Technology Applications
 - Targets
 - Improved resolution
 - Pore pressure prediction
 - Fluid prediction



NETL's Website – Oil & Natural Gas Technologies Section

Use our website to access a wealth of information:

- Program Information
- Current Announcements
- Detailed Information about Each Project
 - Project Reports
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 - ...And Lots More

National Energy Technology Laboratory

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Oil and Natural Gas Supply

Oil and natural gas are the lifeblood of our economy, accounting for more than 60 percent of the energy consumed in the United States. To meet projected demand, our Nation has a vital interest in ensuring that competitively-priced domestic natural gas and oil remain part of the U.S. energy portfolio for decades to come. [Read More.](#)

Announcements

GOM Hydrates JIP/DOE Drilling Data & Hydrate Tool & Protocol Development Workshop - This workshop will be held April 13th & 14th in Houston, Texas and is open to JIP members and others interested in the latest developments in the commercialization of naturally occurring gas hydrates. [Visit the workshop website for more information.](#)

New Natural Gas & Oil Funding Opportunities - There are four open solicitations targeting: Methane Hydrates; Advanced Detection and Imaging of Low Permeability Gas Formations; High Pressure and High Temperature Drilling; and Enhanced Oil and Gas Production through CO2 Injection. [NETL Solicitation Page](#)

Three New Transmission, Distribution & Storage Reports are now available. [Visit the Oil & Natural Gas Reference Shelf](#)

Key Links

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- ▶ [Fire in the Ice - Fall 2005 \[PDF-840KB\]](#)



Internet Address: <http://www.netl.doe.gov/technologies/oil-gas/index.html>

Questions?



*Natural Gas: Energy for a clean, secure,
and prosperous America*

