RPSEA Onshore Program
Project Results – Environment & Safety

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Hyatt North Houston, Houston, TX
Tuesday, September 25, 2012

Mission & Goals

- **Small Producer Mission & Goals**
  - Increase supply from mature resources
    - Reduce cost
    - Increase efficiency
    - Improve safety
    - Minimize environmental impact
- **Unconventional Gas Mission & Goal**
  - *Economically viable* technologies to allow *environmentally acceptable* development of unconventional gas resources
    - Gas Shales
    - Tight Sands
    - Coalbed Methane

RPSEA Research Partnership to Secure Energy for America

Focus on Safety and Environmental Impact

- Macondo blowout and Deepwater Horizon explosion
- Public reaction to HF and shale gas development
- Need for scientific approach to risk assessment and management
- Build public confidence

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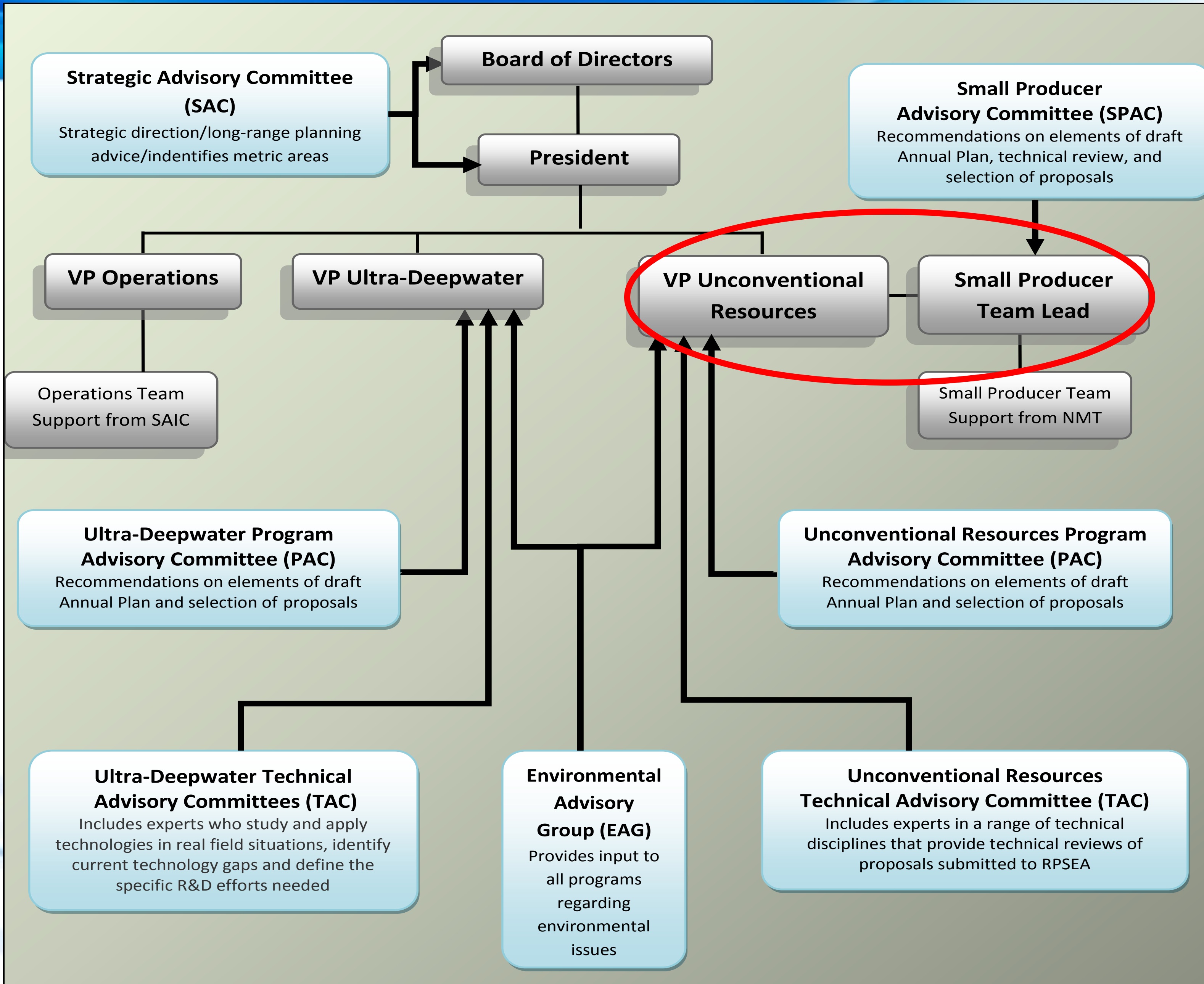
RPSEA Organization



Research Partnership to Secure Energy for America

Integrated Basin Analysis	New Albany (GTI) $3.4 Marcellus (GTI) $3.2 Mancos (UTGS) $1.1 *Technology Integration (HARC) $6.0*		Piceance (CSM) $2.9 *Piceance Permeability Prediction (CSM) $0.5*	None
HF - Stimulation	Cutters (Carter) $.09 Frac (UT Austin) $.69 Refrac (UT Austin) $.95 Frac Cond (TEES) $1.6 Stimulation Domains (Higgs-Palmer) $0.39 Fault Reactiviation (WVU) $0.85 *Cryogenic Frac Fluids(CSM) $1.9* *Geomechanical Frac Containment Anal. (TAMU) $0.65* *Frac Diagnostics (TAMU) $0.76*		Gel Damage (TEES) $1.05 Frac Damage (Tulsa) $.22 Foam Flow (Tulsa) $0.57	10/44
Reservoir Description & Management	Hi Res. Imag. (LBNL) $1.1 Gas Isotope (Caltech) $1.2 Marcellus Nat. Frac./Stress (BEG) $1.0 Frac-Matrix Interaction (UT-Arl) $0.46 Marcellus Geomechanics (PSU) $3.1		Tight Gas Exp. System (LBNL) $1.7 Strat. Controls on Perm. (CSM) $0.1 Fluid Flow in Tight Fms. (MUST) $1.2	None
Reservoir Engineering	Decision Model (TEES) $.31 Coupled Analysis (LBNL) $2.9 Shale Simulation (OU) $1.05		Wamsutter (Tulsa) $.44 Forecasting (Utah) $1.1 Condensate (Stanford) $.52	None
Exploration Technologies	Multi-Azimuth Seismic (BEG) $1.1			None
Drilling	Drilling Fluids for Shale (UT Austin) $0.6			None
Water Management	Barnett & Appalachian (GTI) $2.5 Integrated Treatment Framework (CSM) $1.56 *NORM Mitigation (GE) $1.6*		Frac Water Reuse (GE) $1.1 *Engineered Osmosis Treatment (CSM) $1.3*	
Environmental	Environmentally Friendly Drilling (HARC)* $2.2 *Zonal Isolation (CSI) $3.0*		*	
Resource Assessment	Alabama Shales (AL GS) $.5 Manning Shales (UT GS) $.43		Rockies Gas Comp. (CSM) $.67	None
2007 Projects; 2008 Projects; 2009 Projects; 2010 Projects				

RPSEA PAC Research Recommendation

The RPSEA PAC Recommended R&D Focus:

Technology and Best Practices to Safely Exploit the U.S. Natural Gas Endowment

- **Research** addressing technical issues with the **hydraulic fracturing** process which if resolved will significantly improve the process resulting in fewer fracture treatments, less water usage, less flow back water, diminished truck traffic, reduced land footprint, reduced emissions and better fracturing efficiency.

- **Research** in the overall **water management** area with the primary focus being regional and geographic understanding of favorable geologic conditions for water management including water sourcing and safe disposal options and treatment technologies.

- **Research** addressing the **shallow environmental issues** including sustained casing pressure, gas migration in the shallow geologic environment and induced seismic and its relation to hydraulic fracturing.

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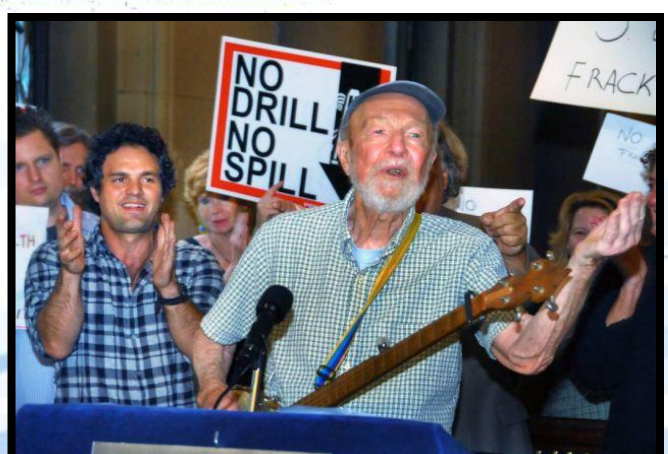
Onshore Program

Environmental Impact

Environmental Issues

> Hydraulic Fracturing
> Land Use
> Air Emissions
> Water Usage
> Water Quality
> Traffic
> Road Damage
> Noise
> Wildlife
> Image Deficit

The New York Times



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Findings indicate that public will accept and support responsible development

However, the public ***will not accept:***

- **Excessive traffic, dust, noise.**
- **Pollution of the land and water**
- **Destroying public roads**
- **Poor choices in well sites, roads, compressor stations**
- **Tank batteries, drilling locations; and "visitors" who do not respect their community.**

Failure to adequately inform and engage all stakeholders results in poor public perception of the oil and gas industry;

…and because a small percentage of companies do not practice proper environmental safeguards in their operations.
The "license to operate" is thus compromised.

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Outreach

- Rutgers University Law Group
- Houston Chamber of Commerce
- Energy Demand Conference
- World Gas Conference
- Shell “Town Meeting”
- Colorado Oil and Gas Association
- Oklahoma Energy Summit
- Wintershall, Ruhrgas, CNOC
- Guoxin Energy
- HF Conference (SPE)
- EPA Produced Water Workshops
- Exhibits and Conferences

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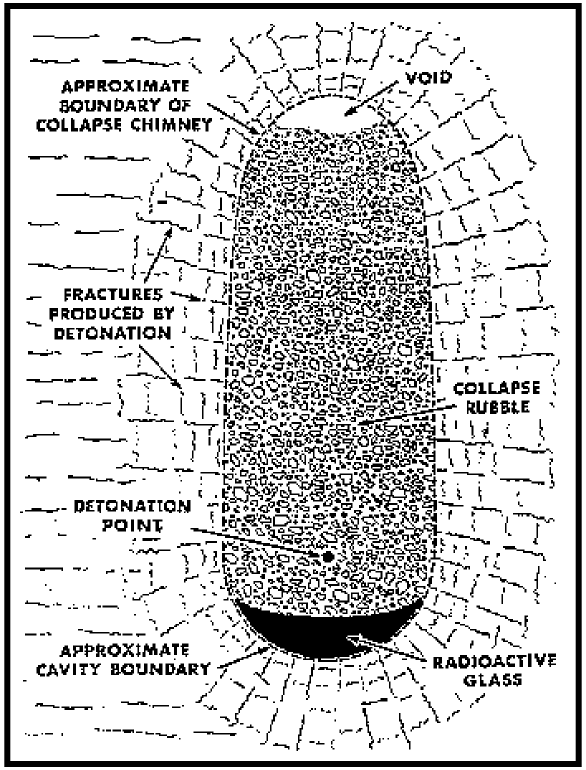
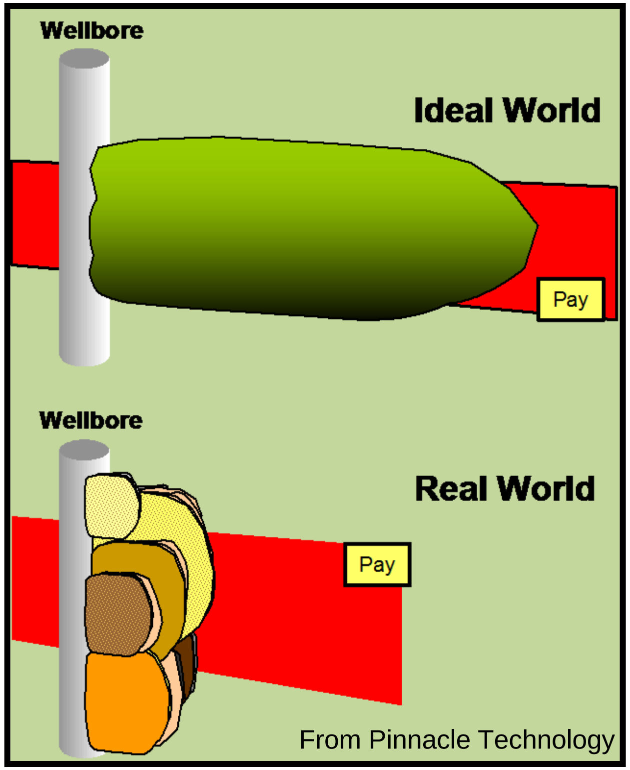
Hydraulic Fracturing

1960's



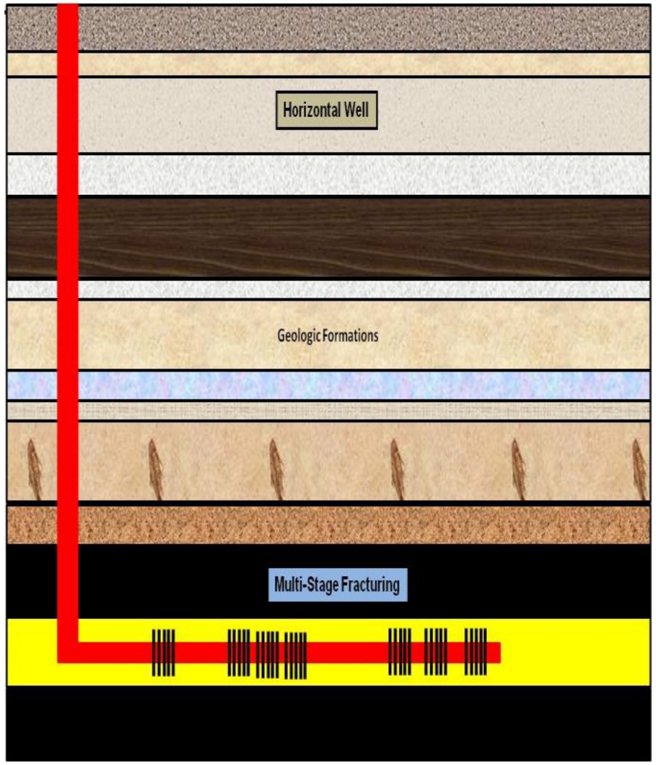
Nuclear Stimulation

1980's



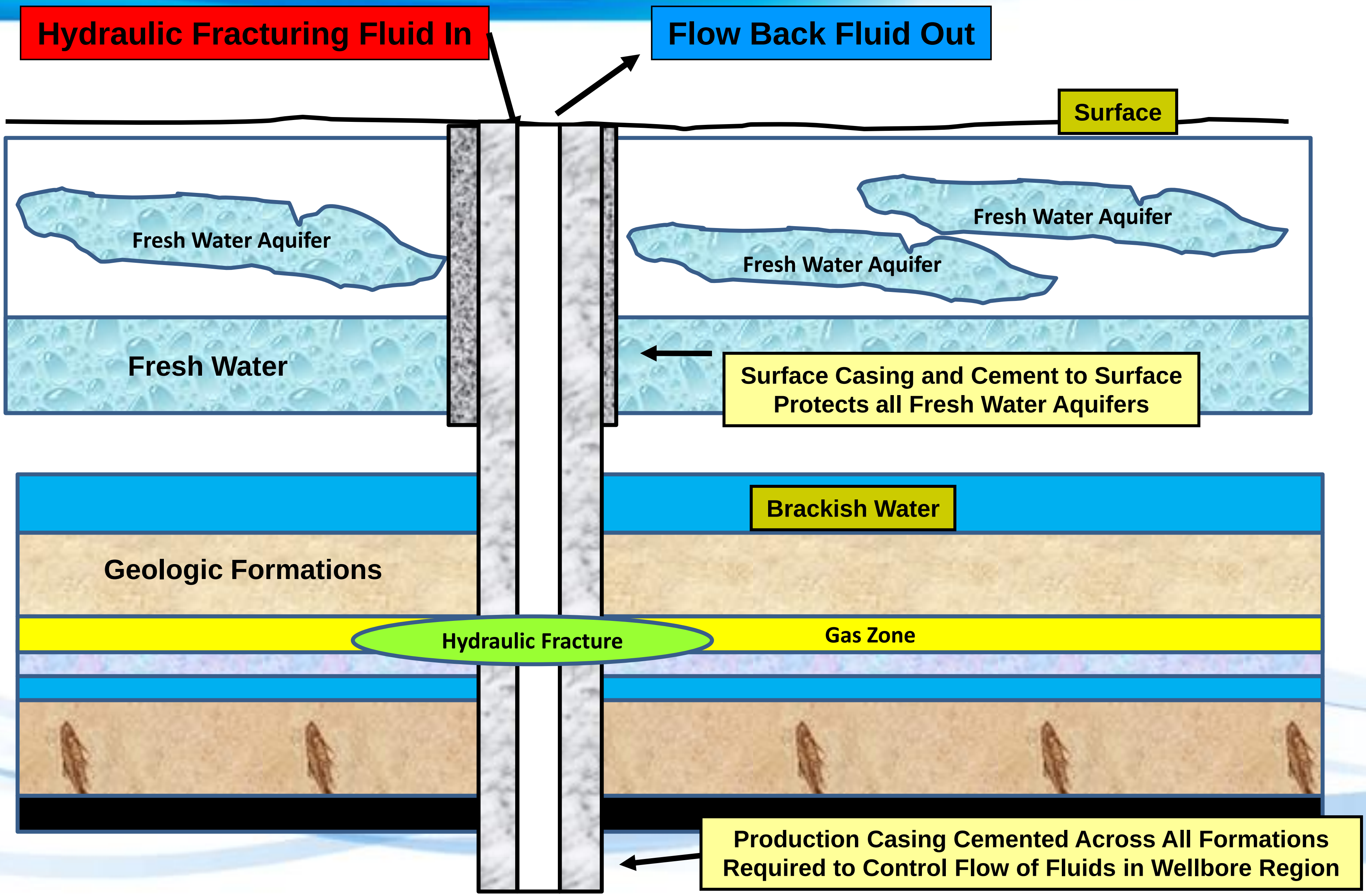
Massive Hydraulic Fractures

2000's

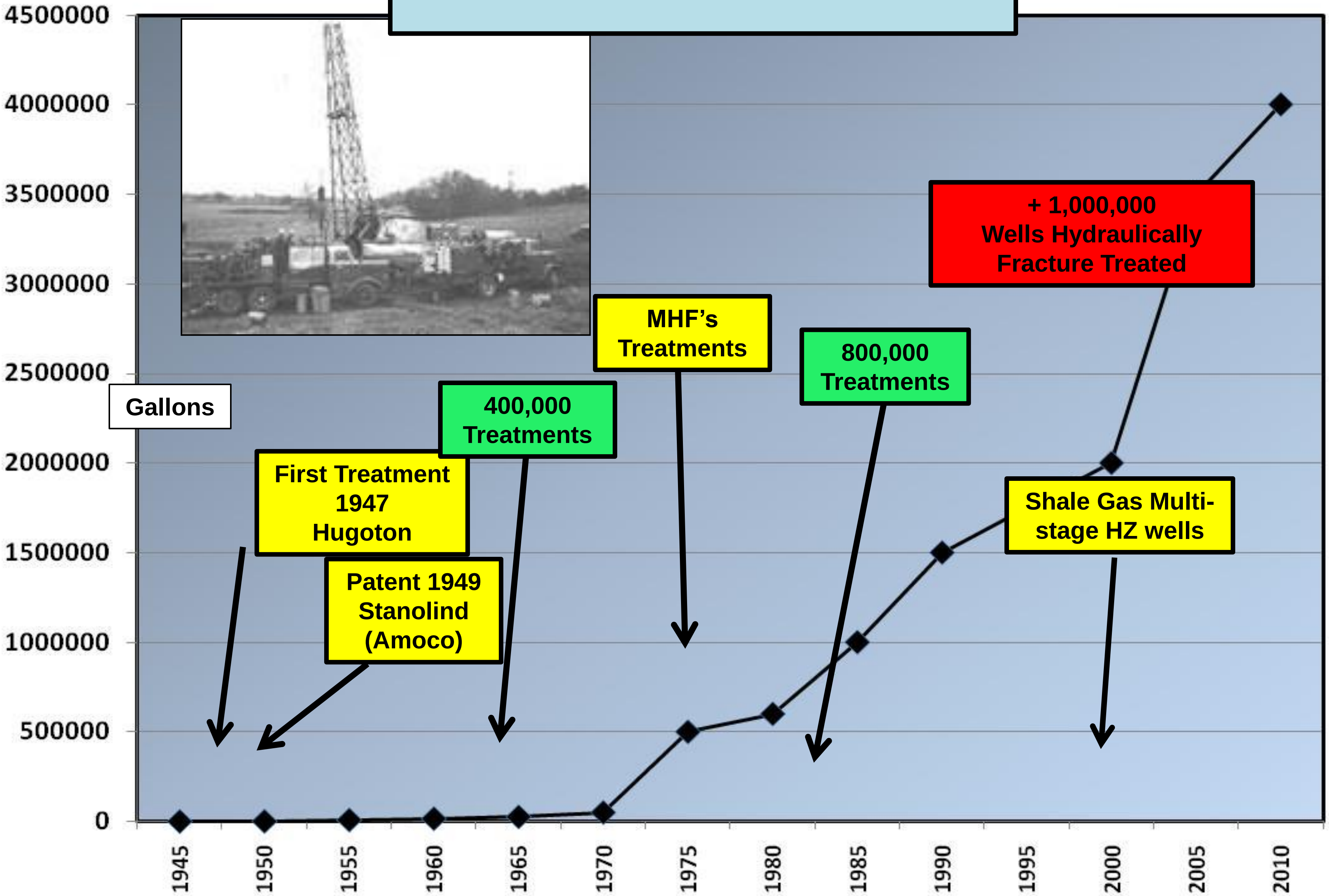


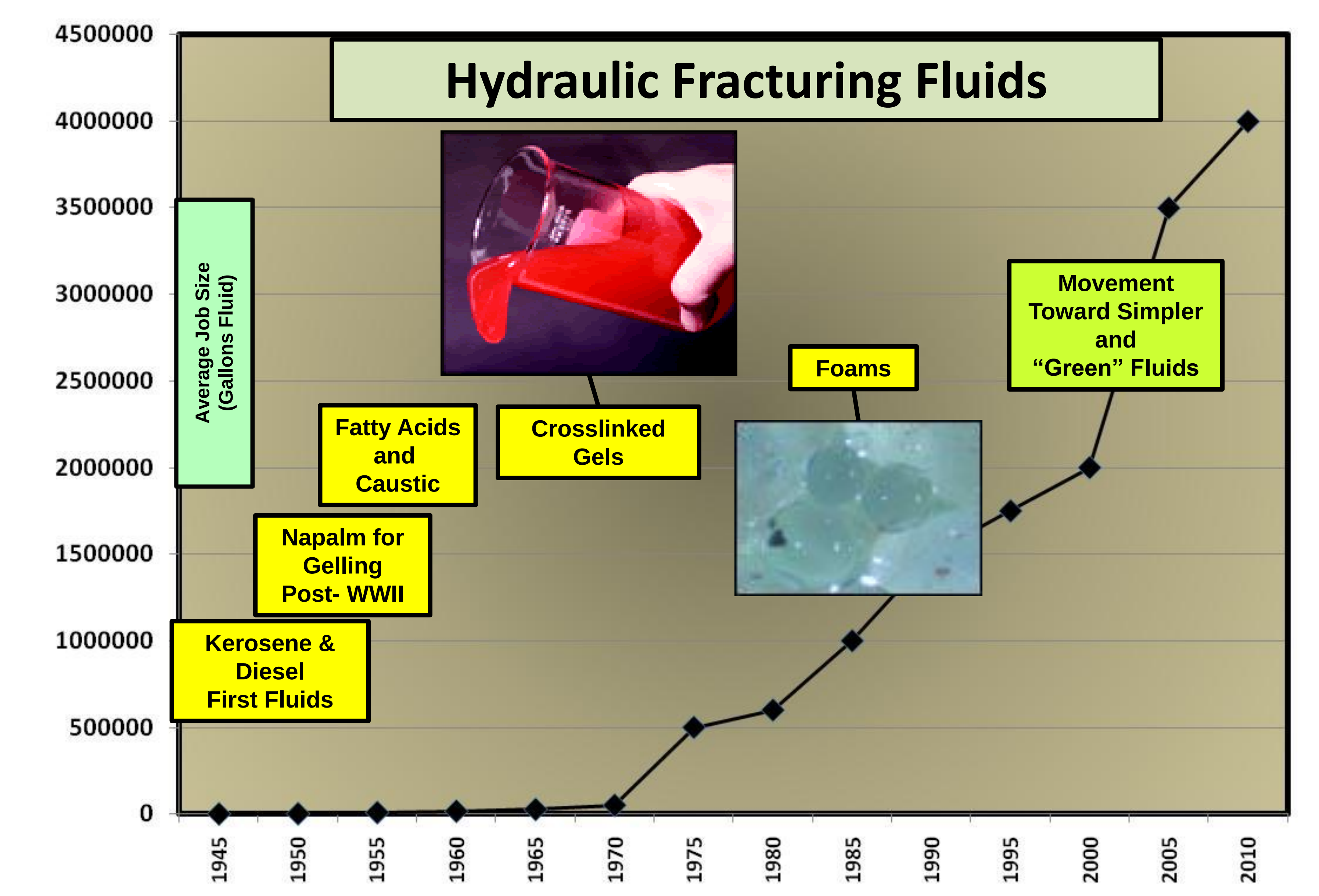
Precise Size & Precise Placement

Hydraulic Fracturing

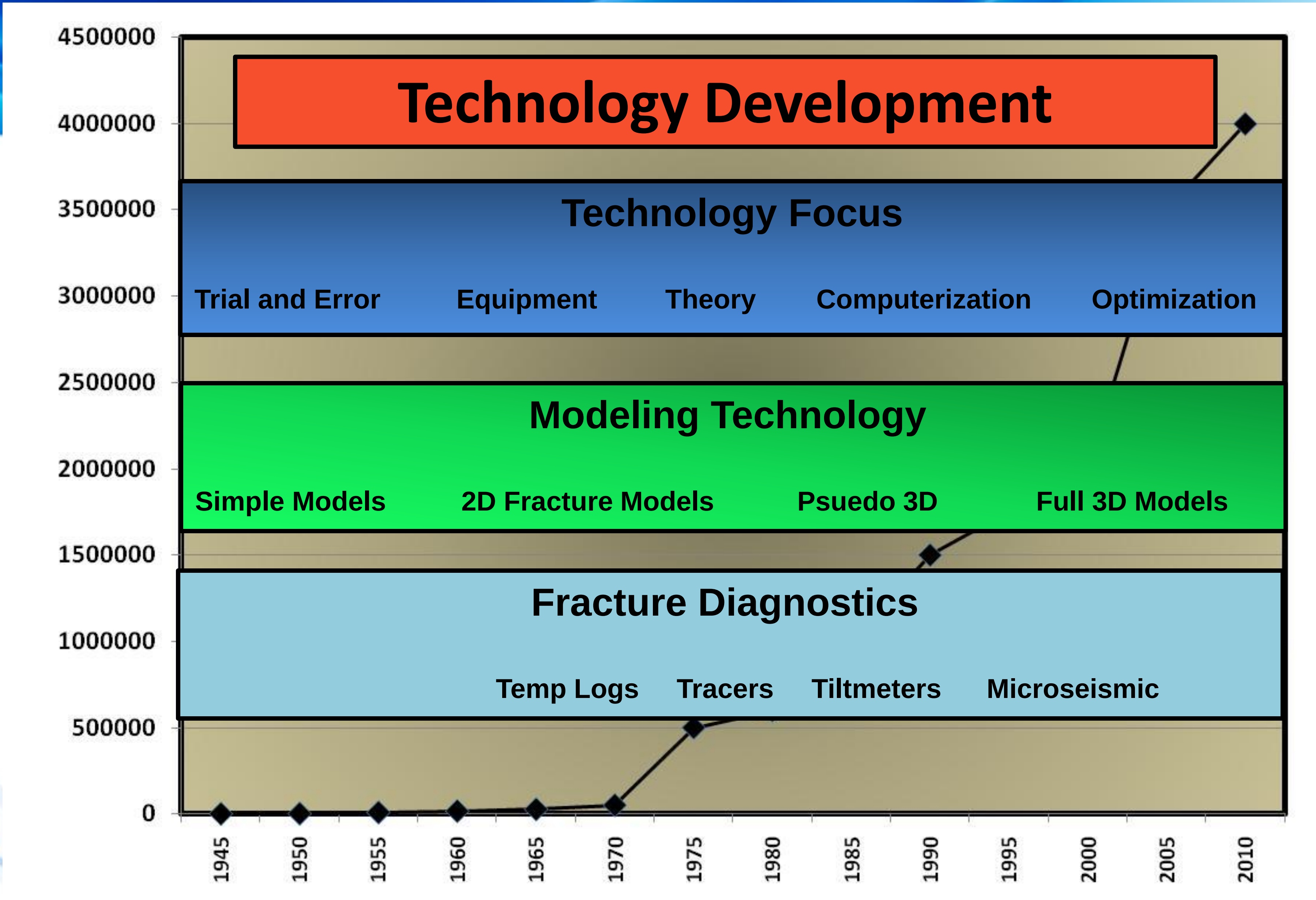


Hydraulic Fracturing Timeline





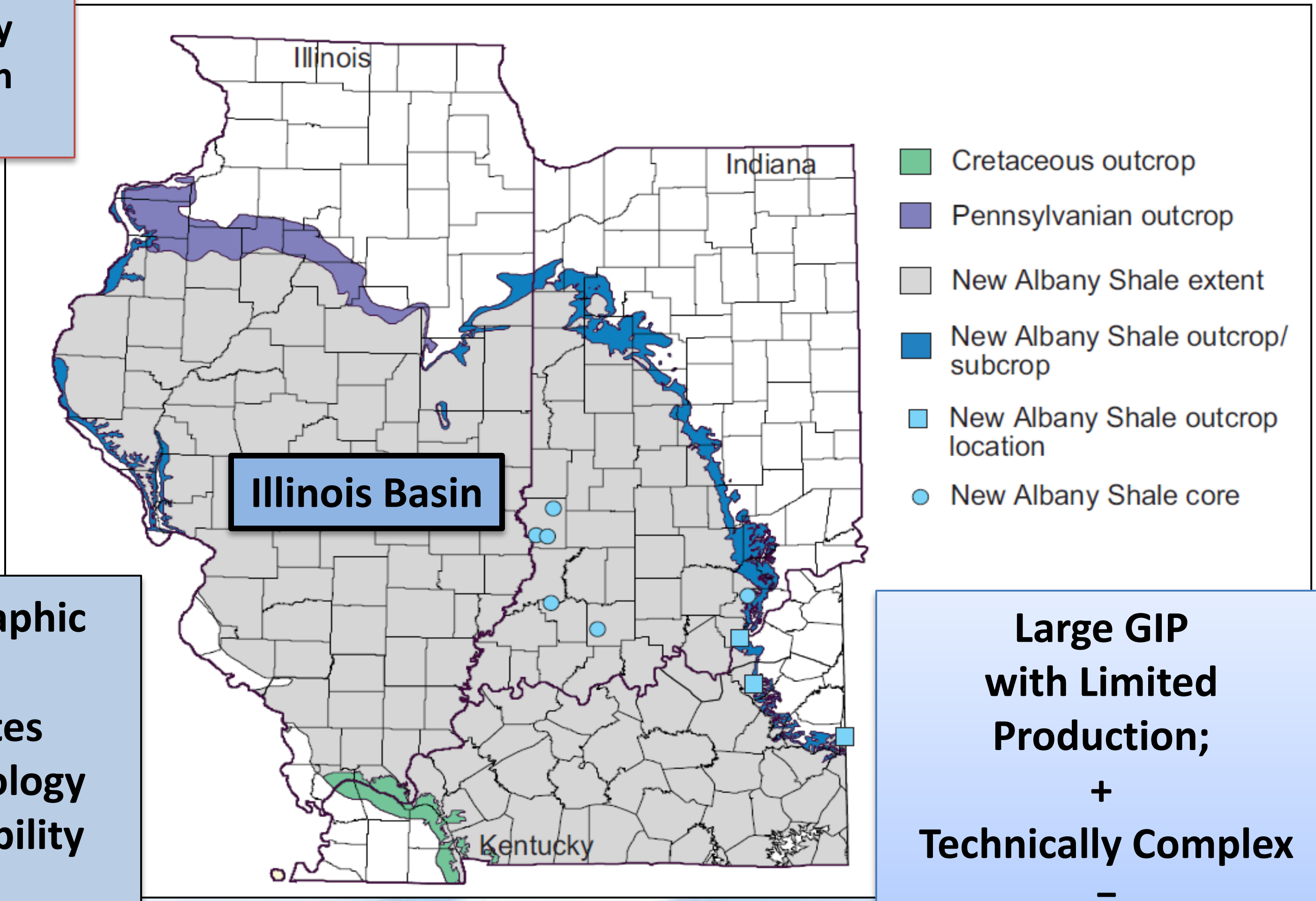
SPE Papers 22392, 36166, Halliburton



SPE 38826 Wolhart et.al.

New Albany Shale Outcrops and Core Locations

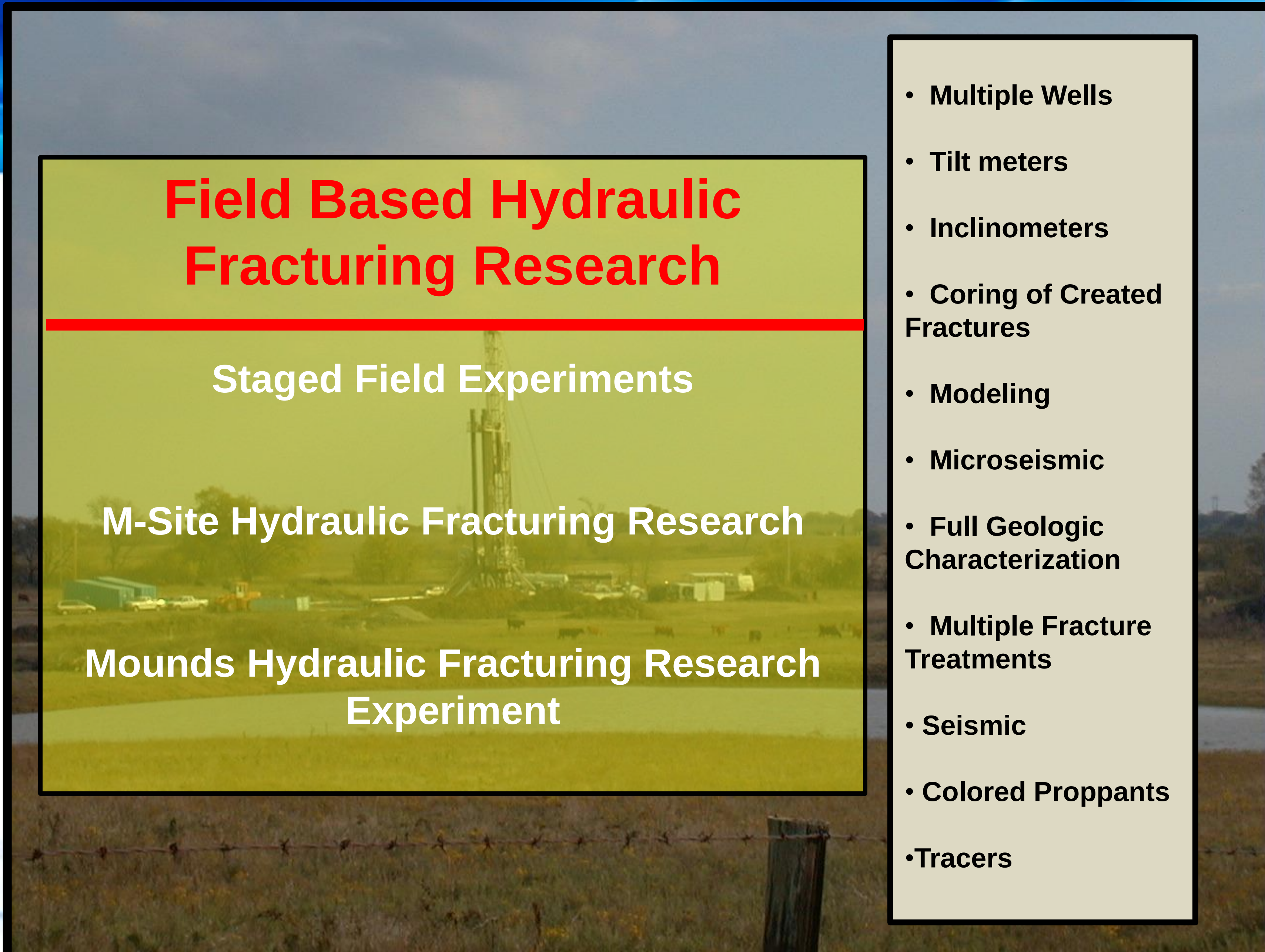
86 to 160 Tcf New Albany Shale Gas in Place



- Large Geographic Area
- Multiple States
- Complex Geology
- Low Permeability

Large GIP with Limited Production;
+
Technically Complex
=
R&D Target

esearch artnership to ecure Energy for America



Field Based Hydraulic Fracturing Research

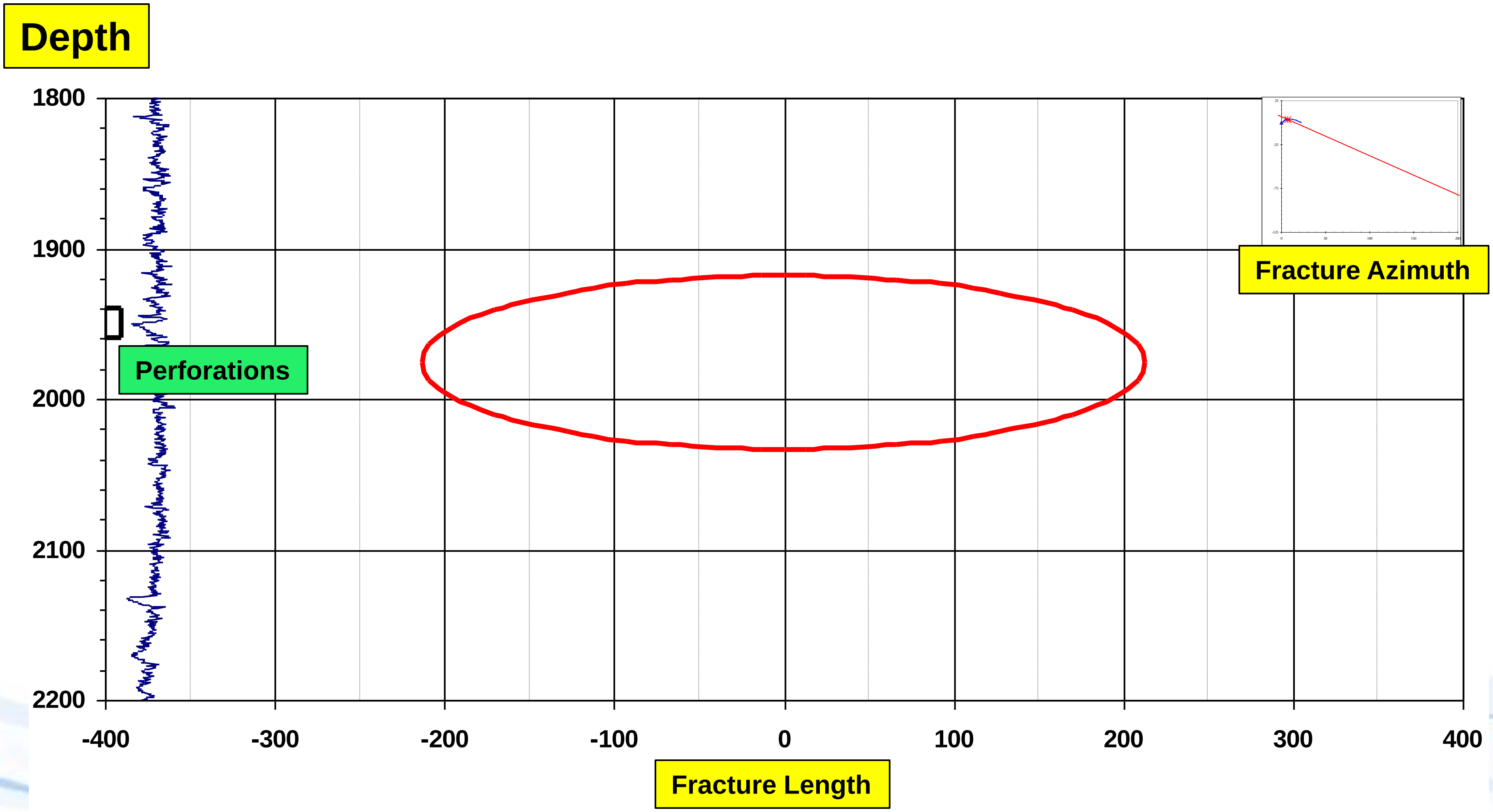
Staged Field Experiments

M-Site Hydraulic Fracturing Research

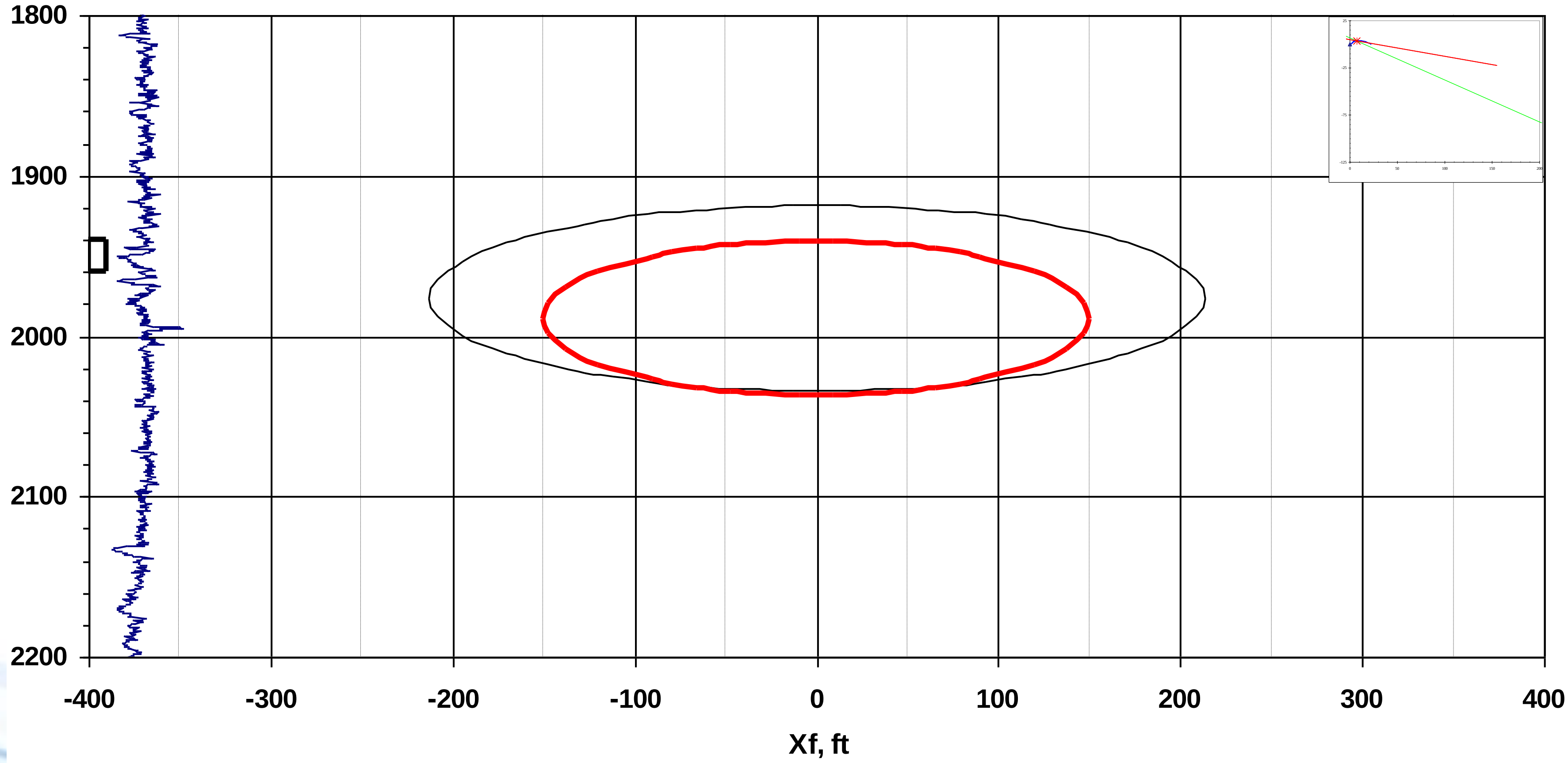
Mounds Hydraulic Fracturing Research Experiment

- Multiple Wells
- Tilt meters
- Inclinometers
- Coring of Created Fractures
- Modeling
- Microseismic
- Full Geologic Characterization
- Multiple Fracture Treatments
- Seismic
- Colored Proppants
- Tracers

Atoka Shale Stage OA



Atoka Shale Stage OB



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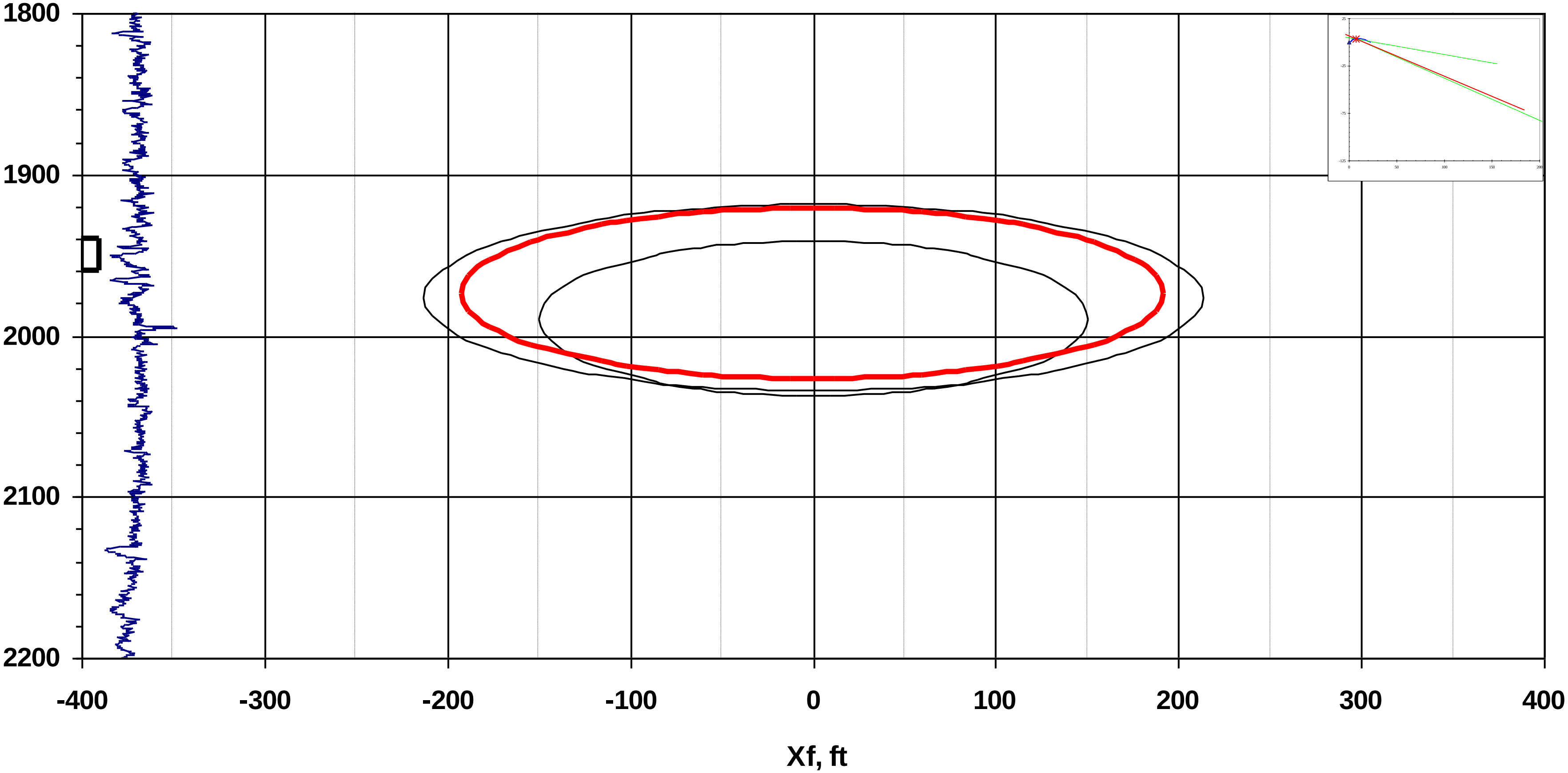
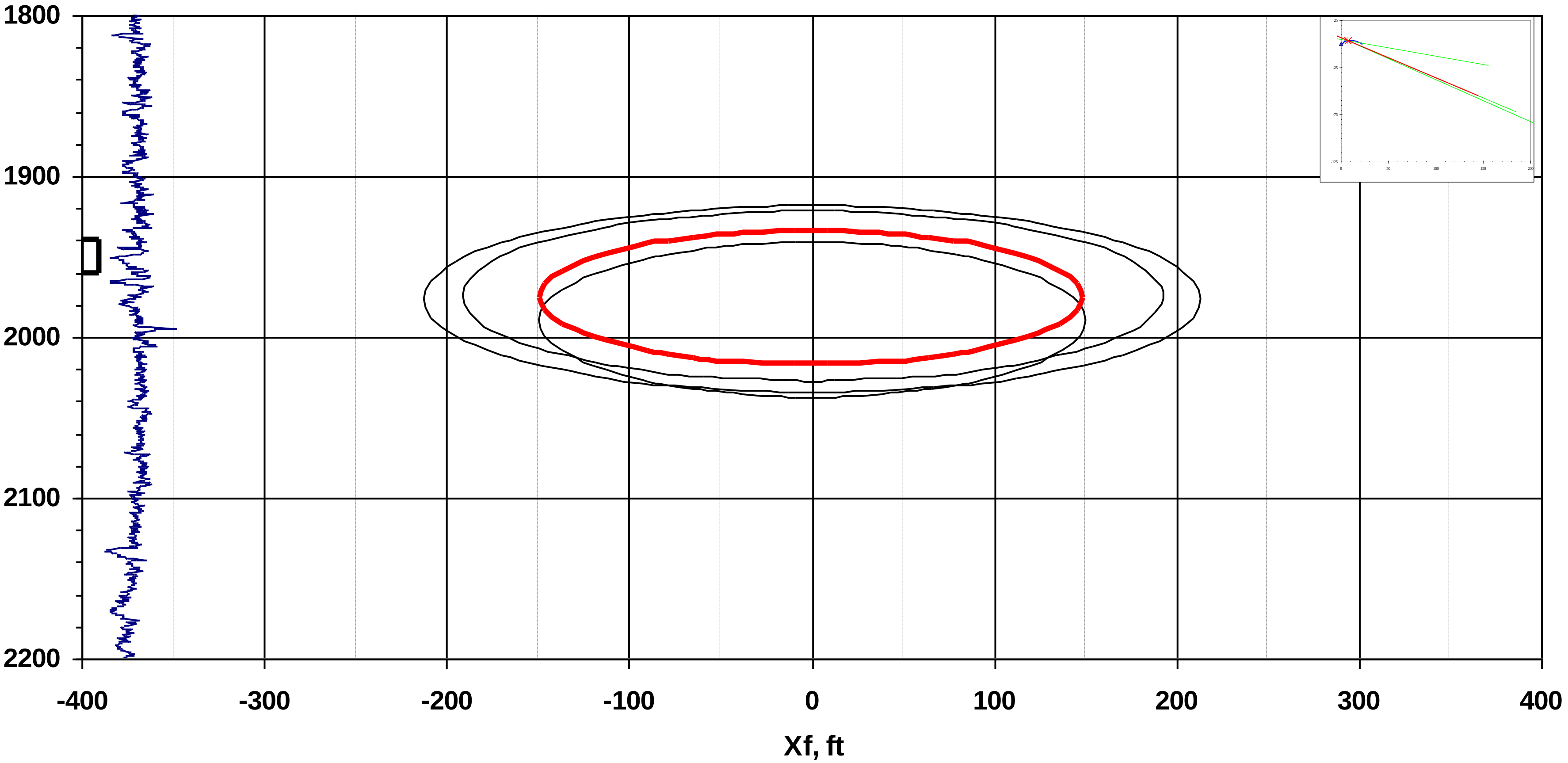


Atoka Shale Stage 1



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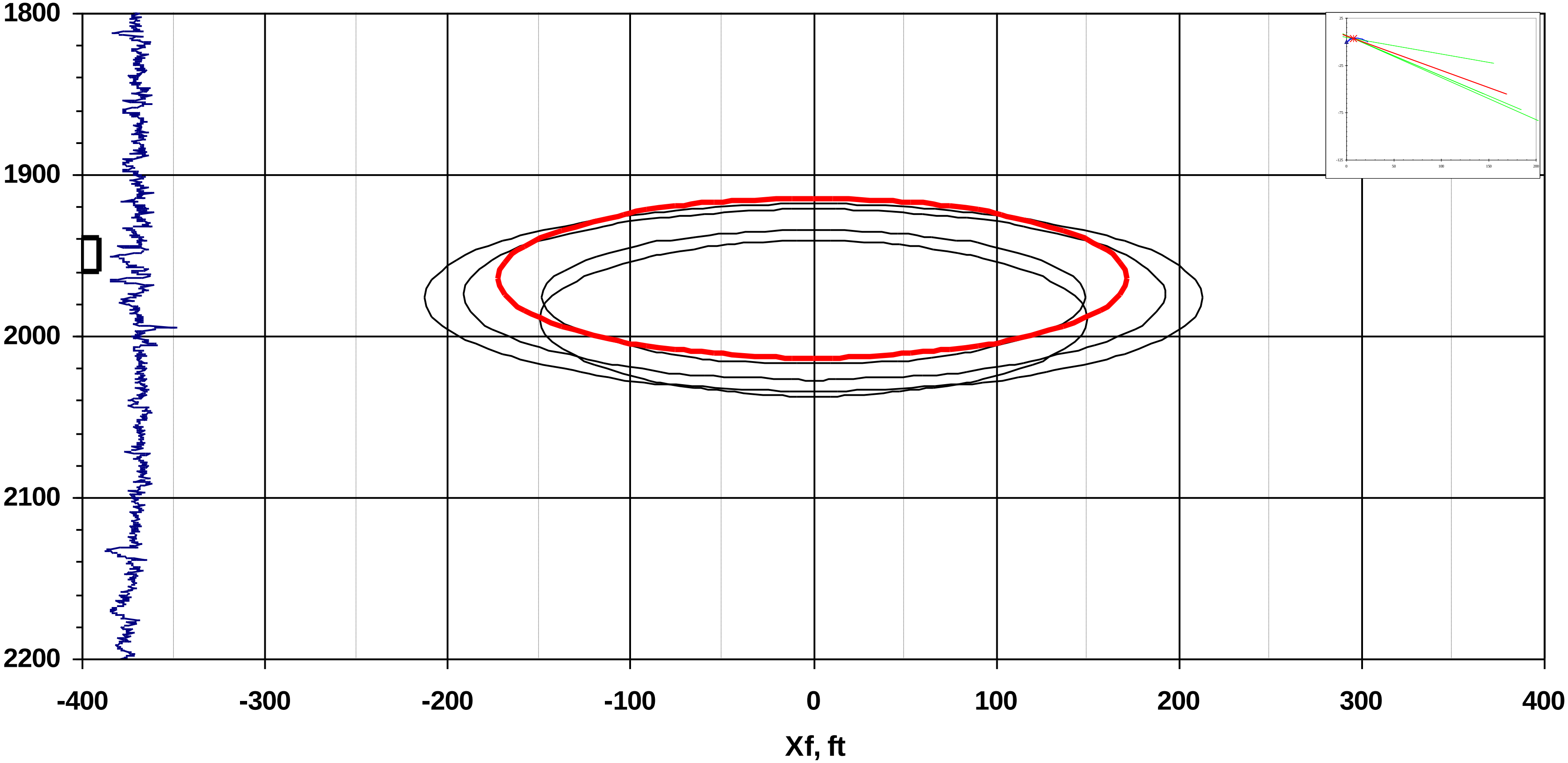
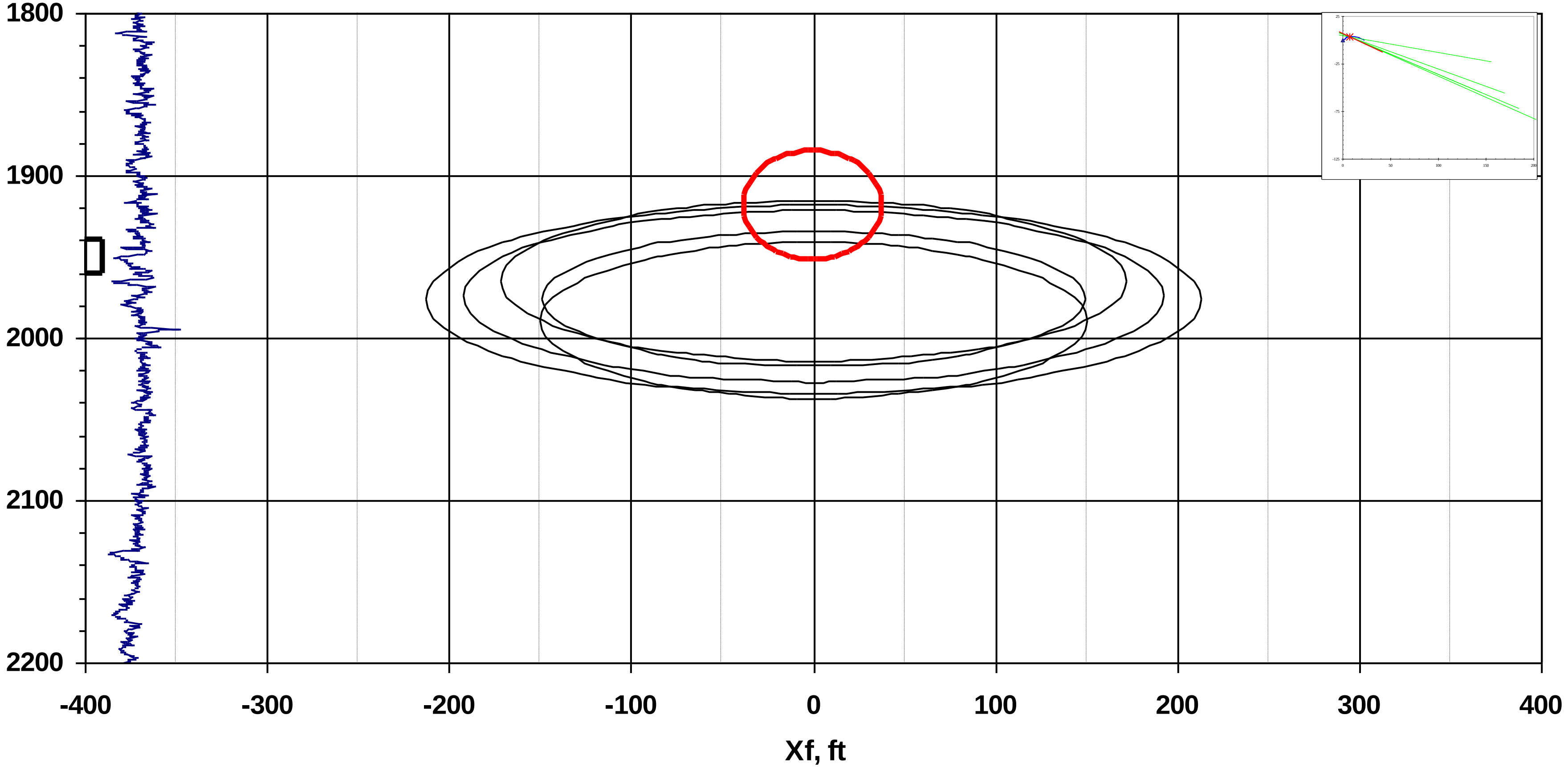


Atoka Shale Stage 3



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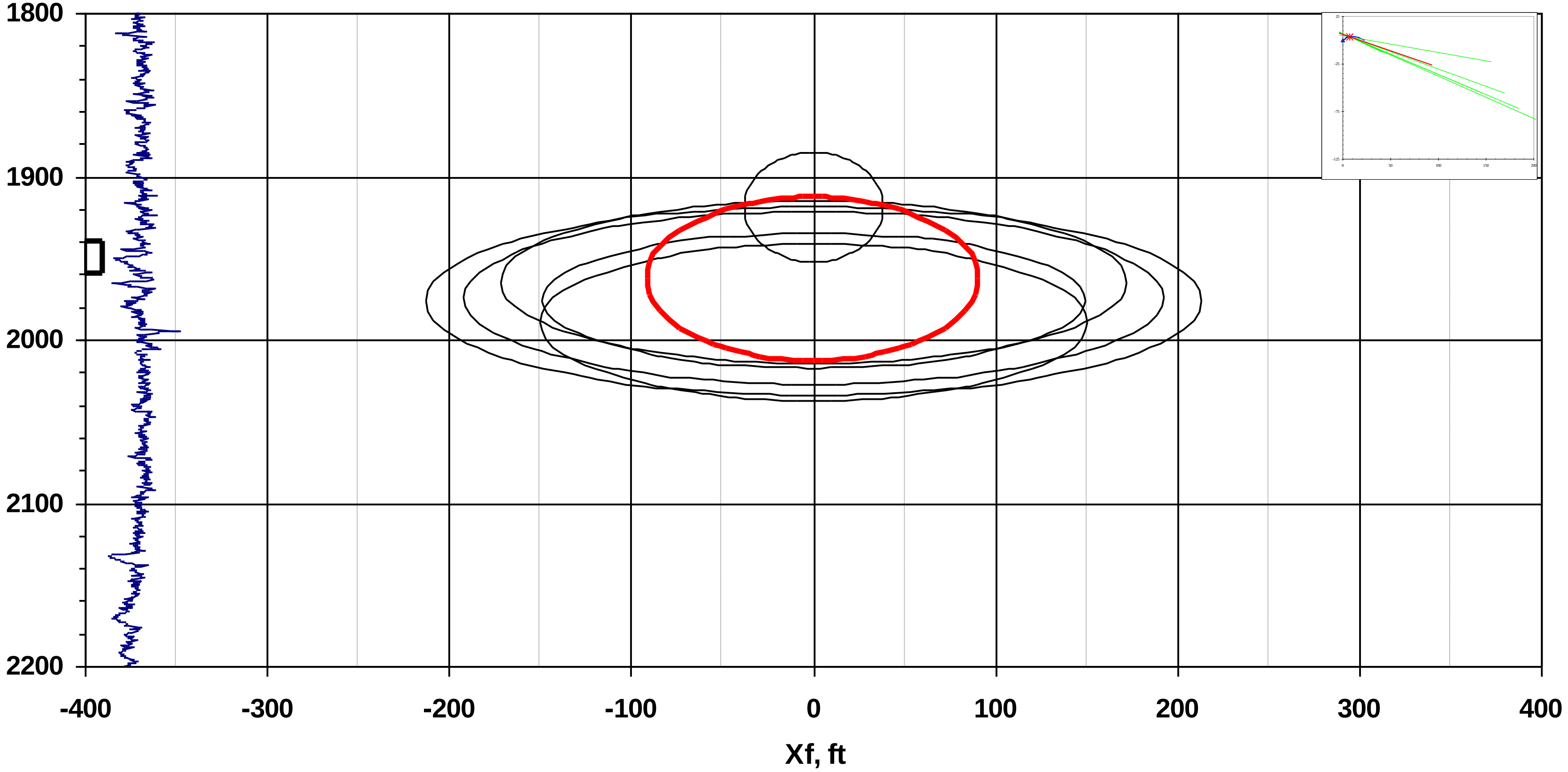

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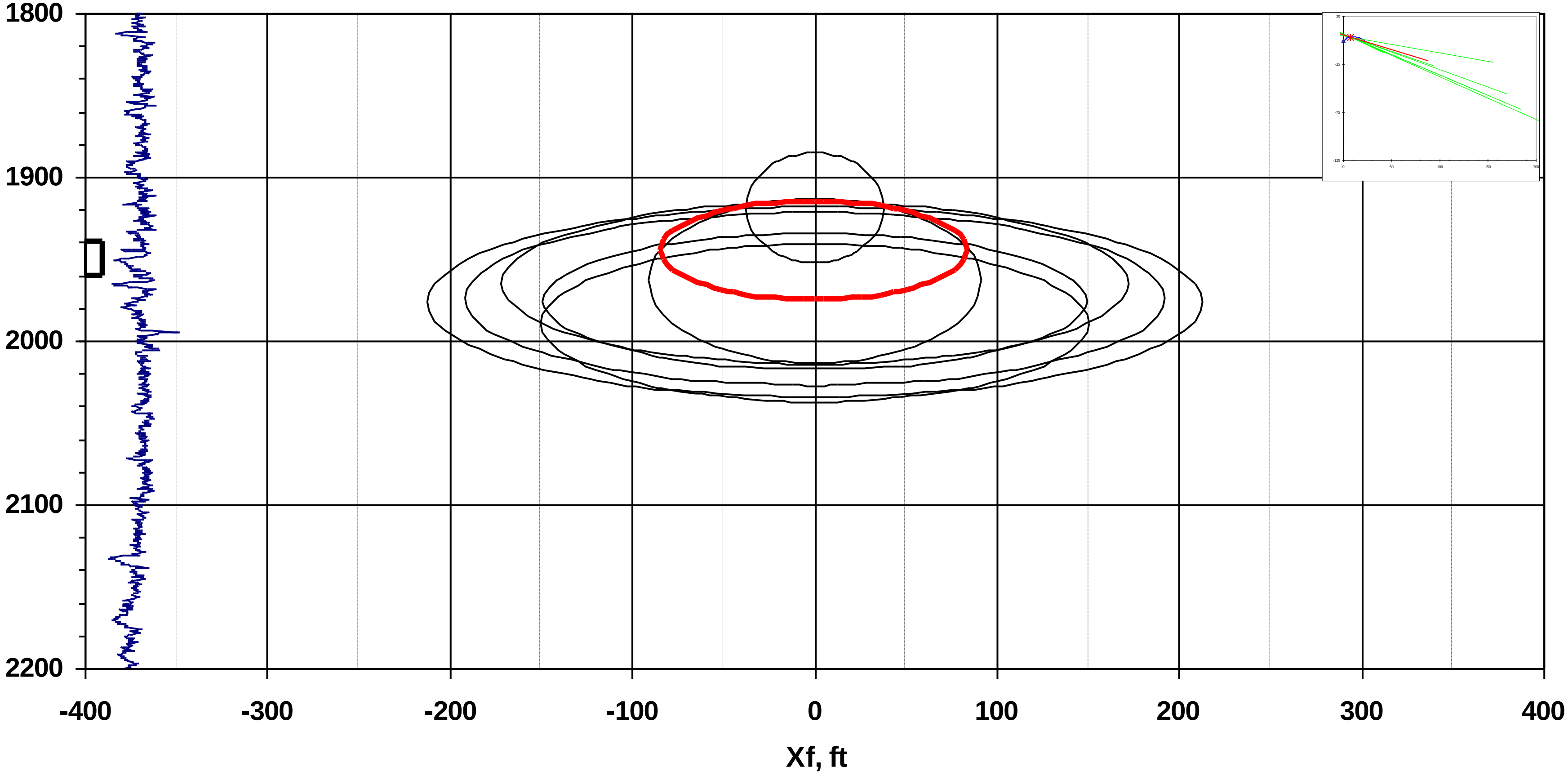
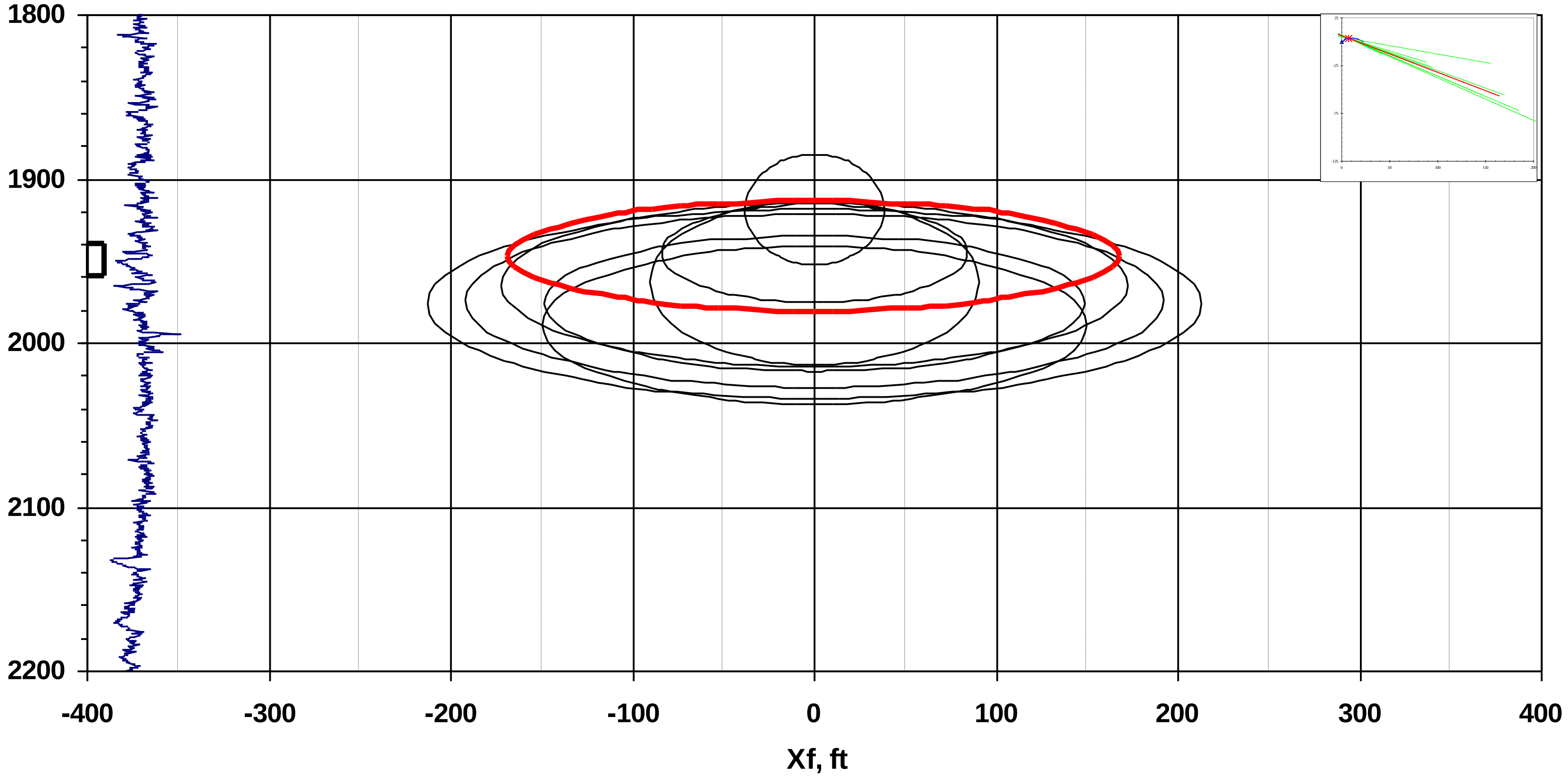
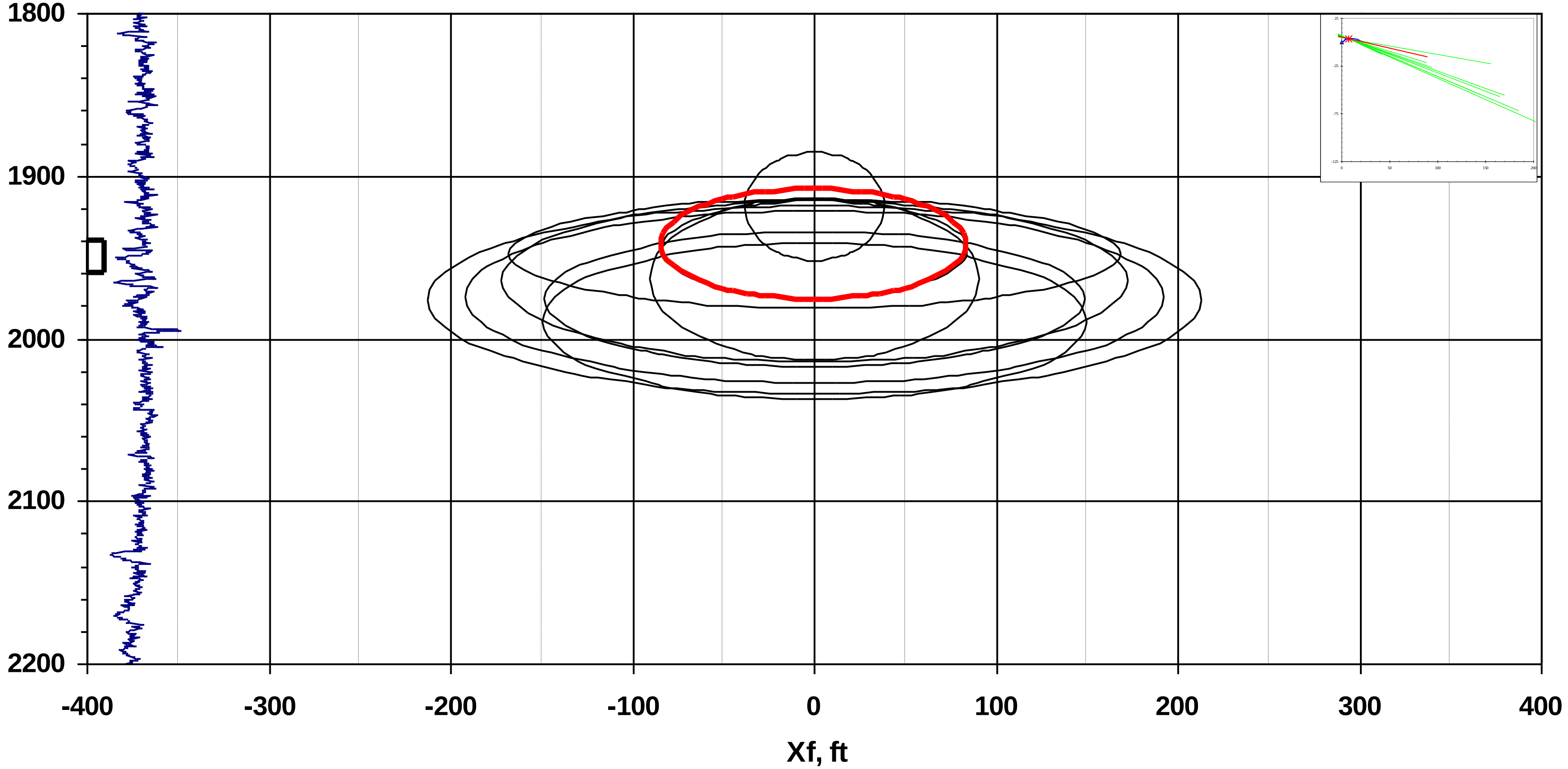


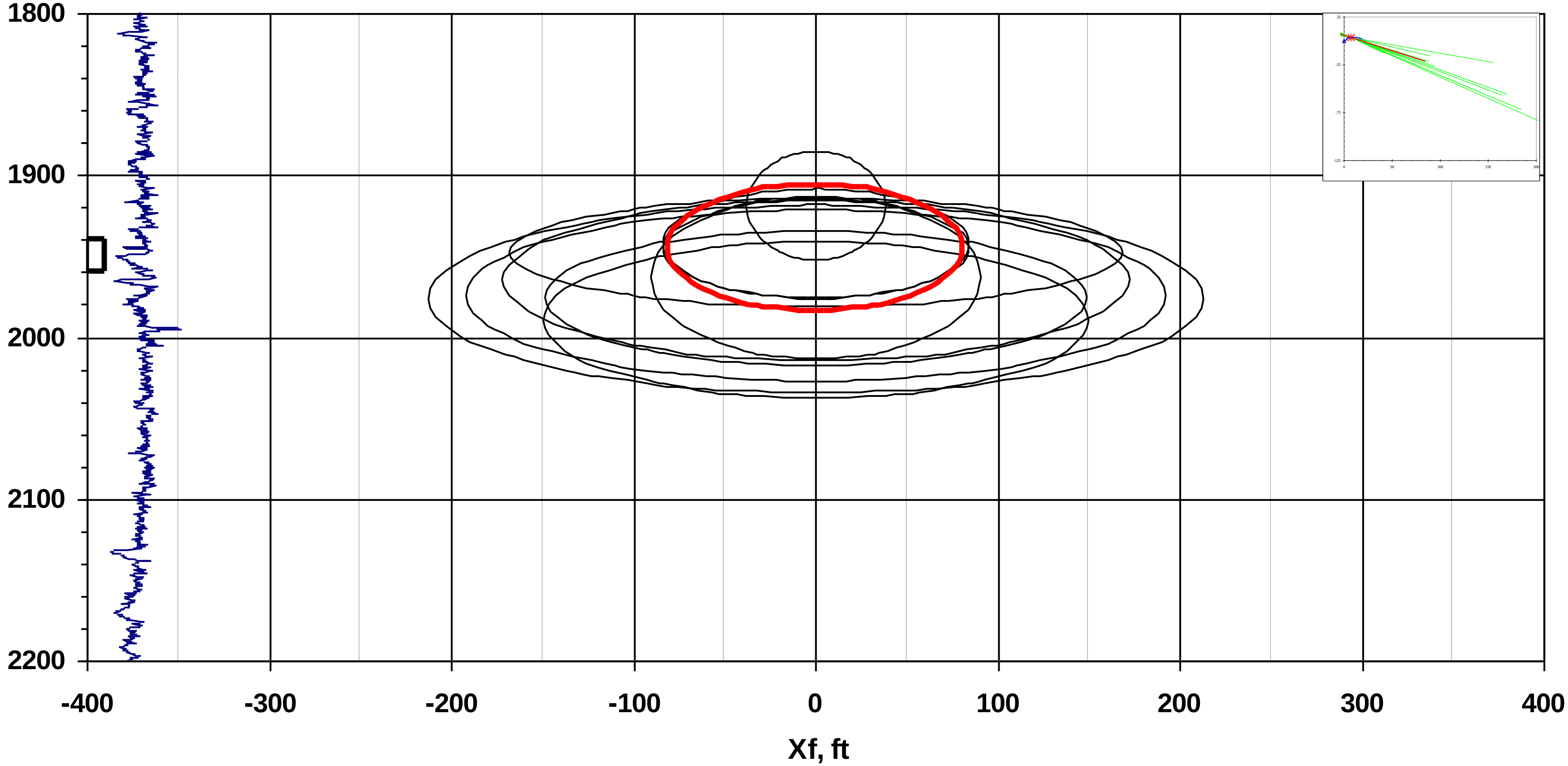
Atoka Shale Stage 6



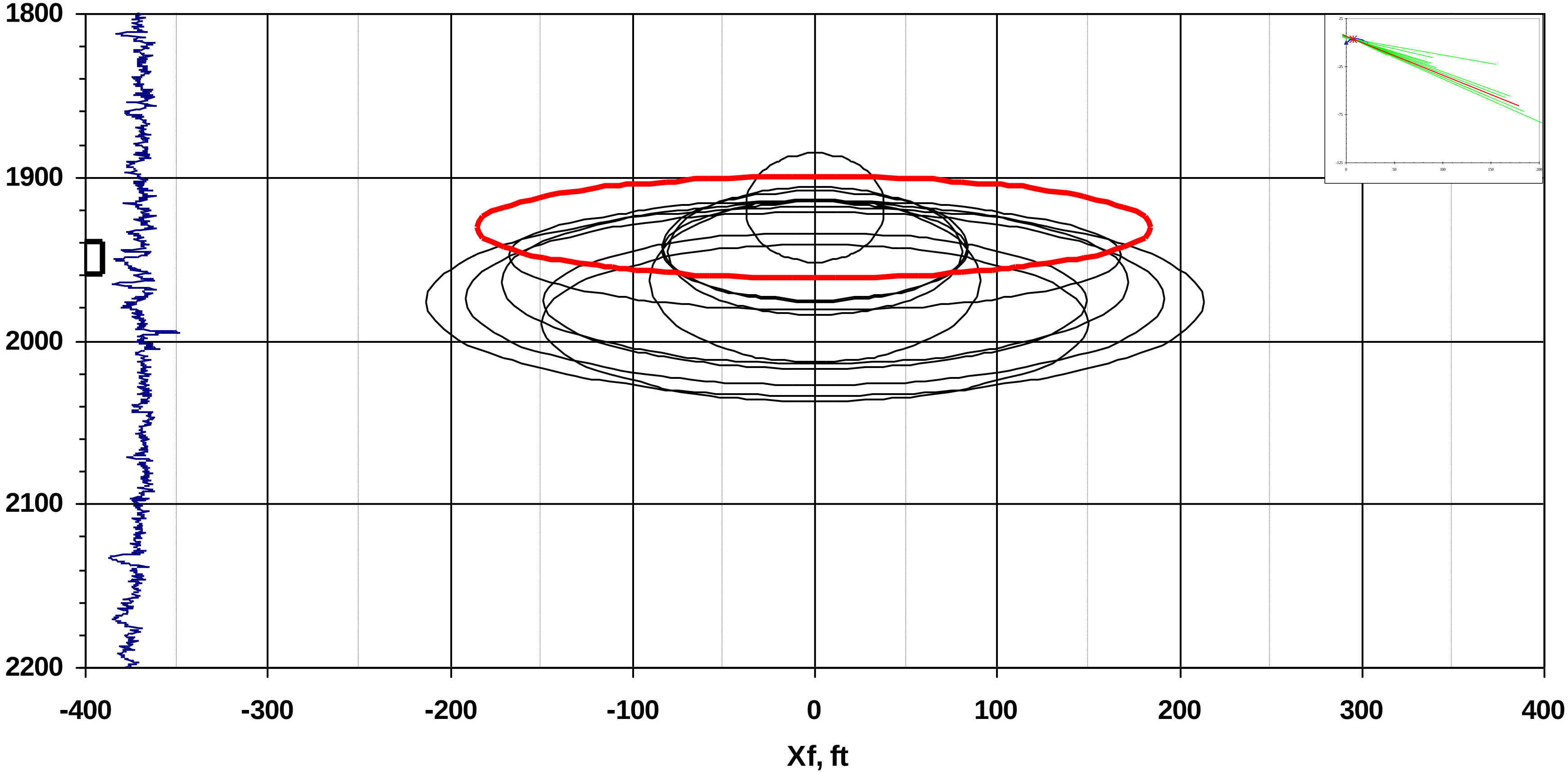
Atoka Shale Stage 7



Atoka Shale Stage 8



Atoka Shale Stage 9



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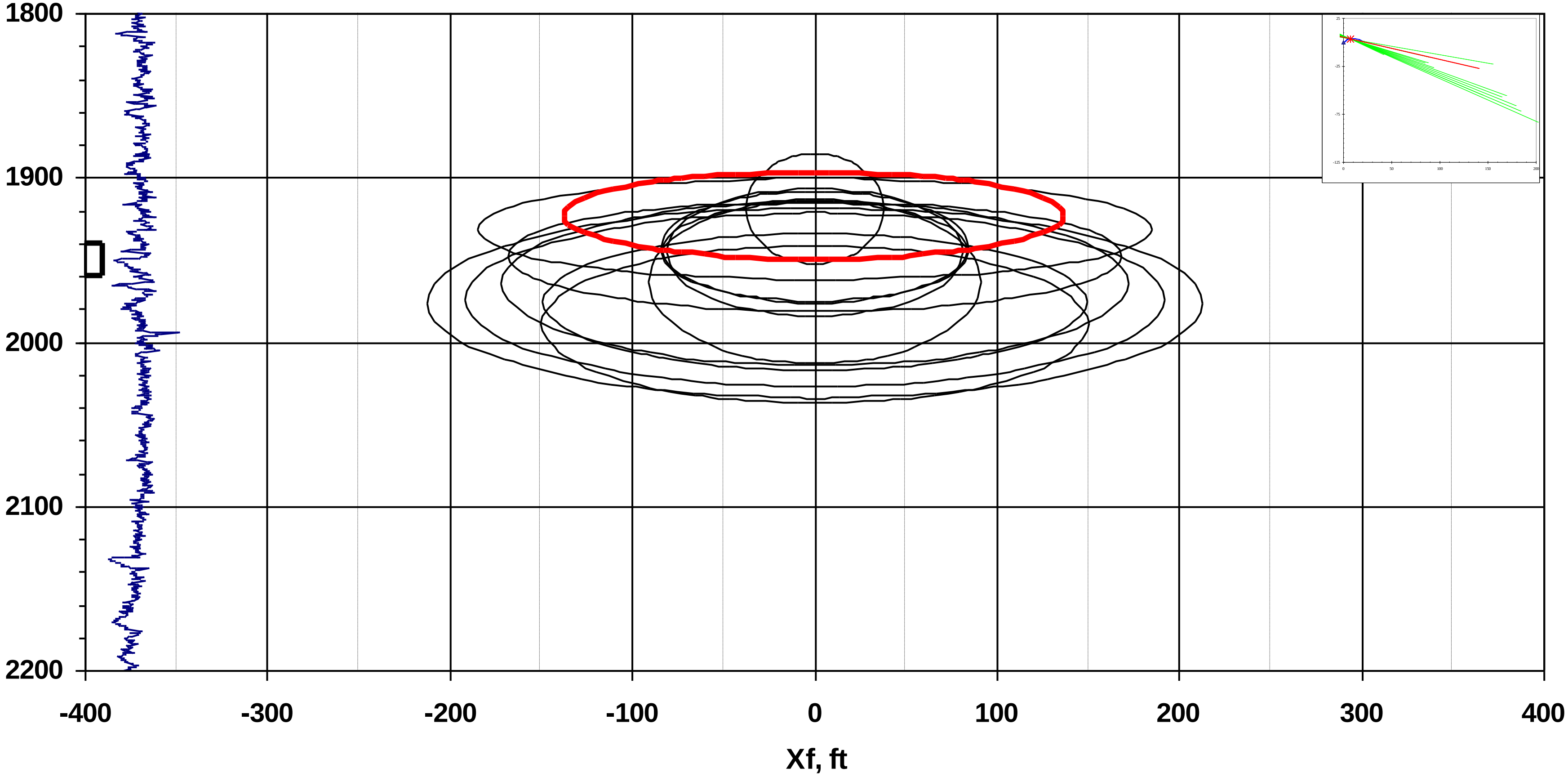

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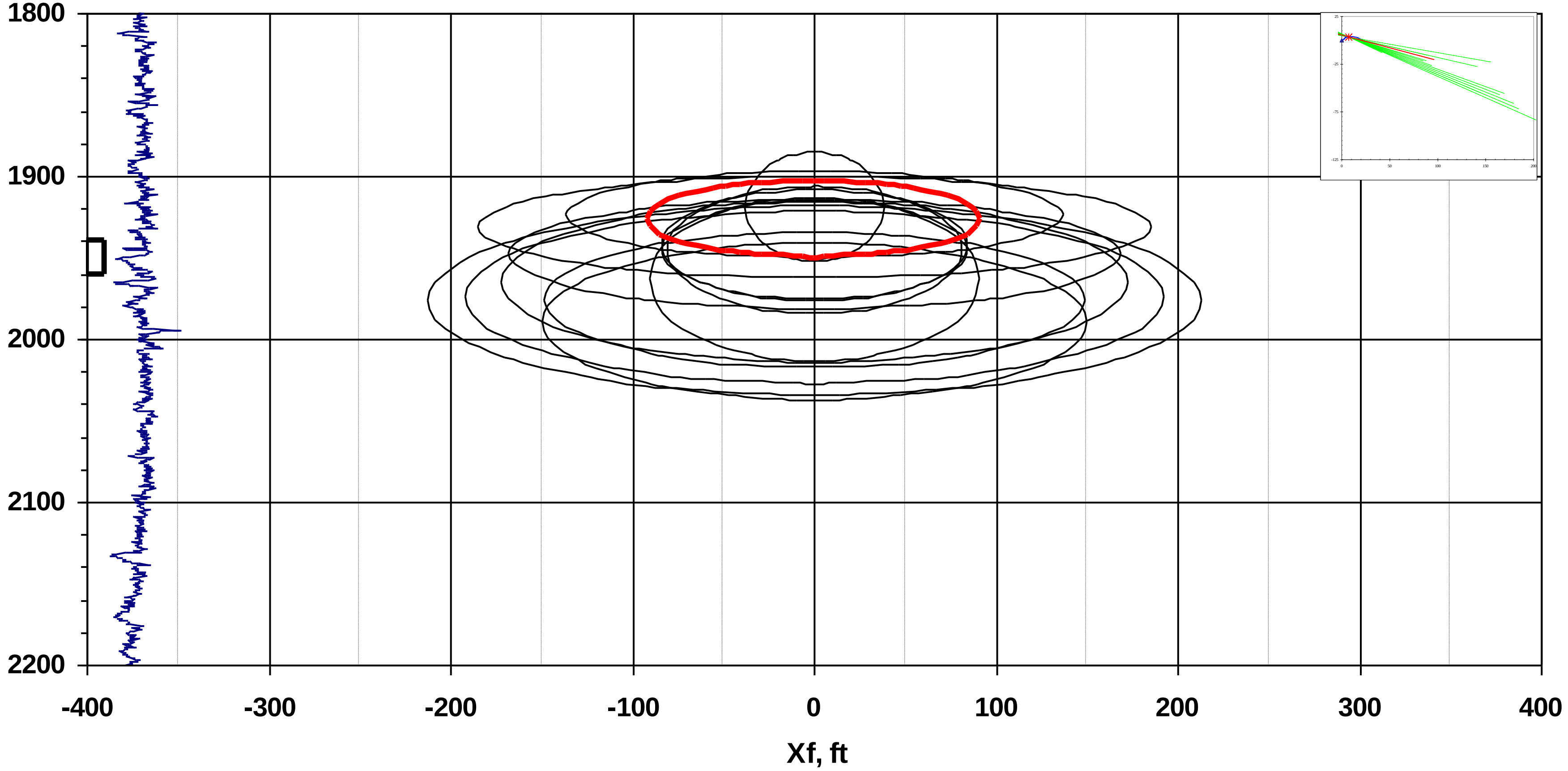

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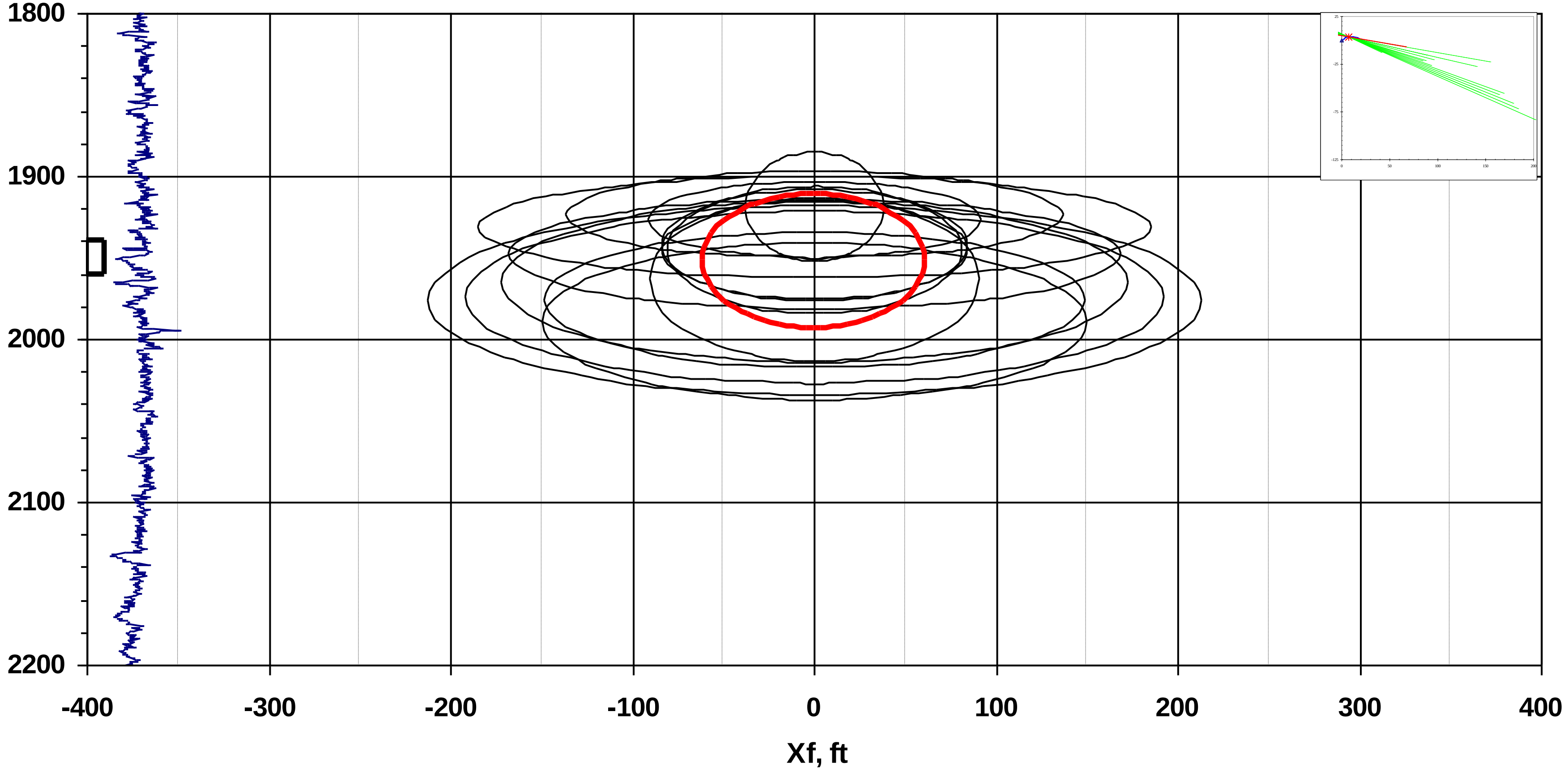

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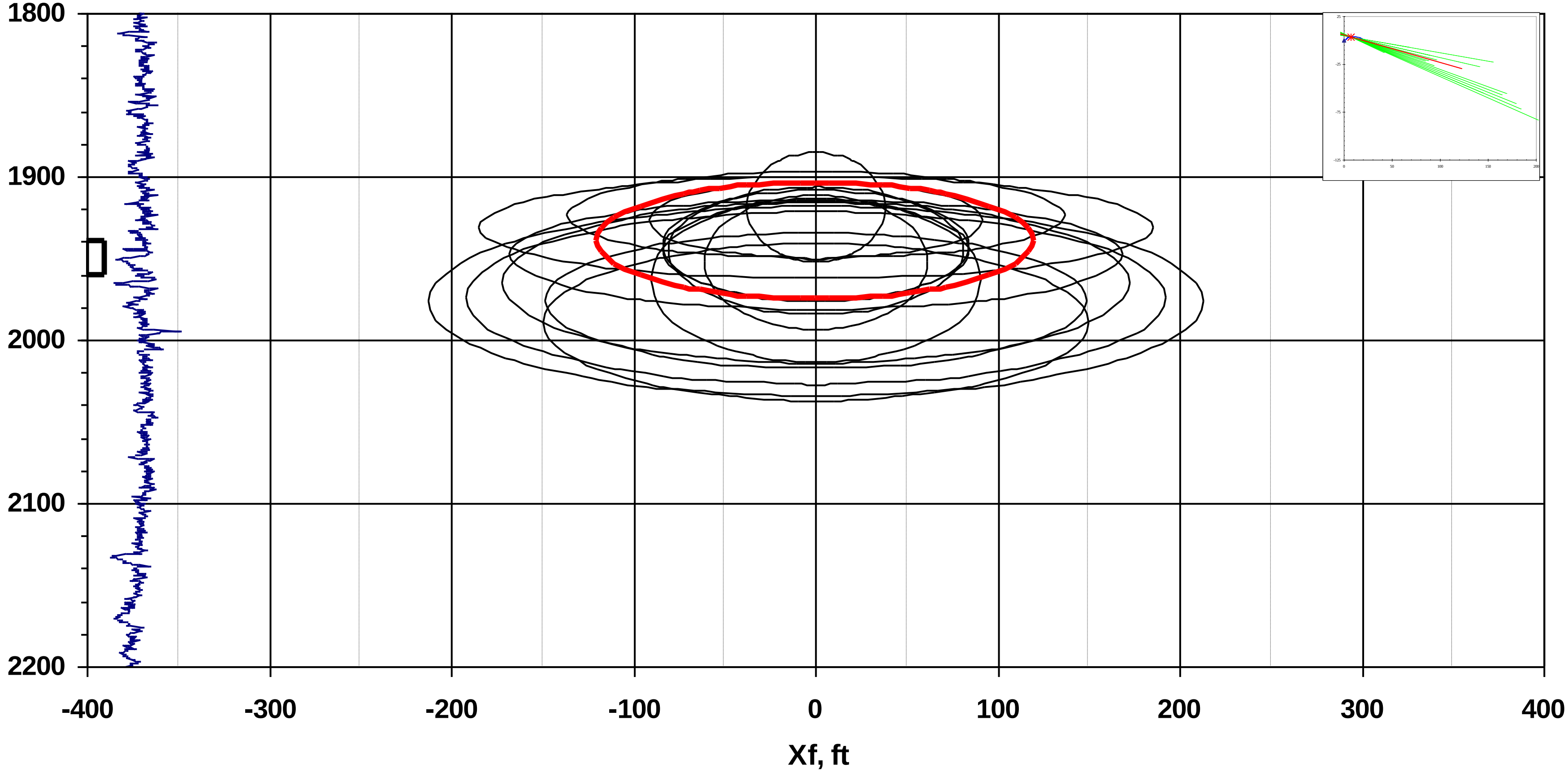

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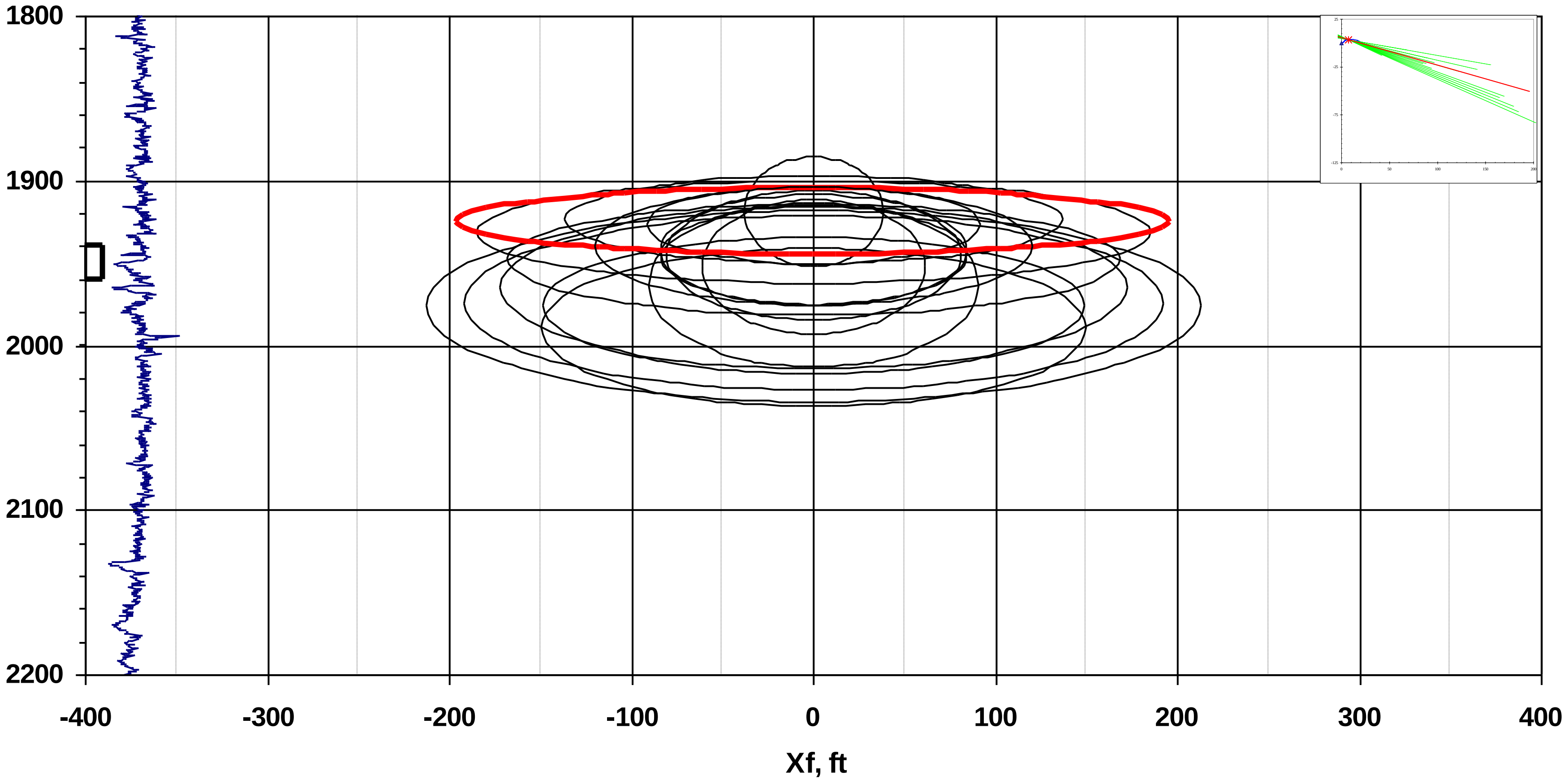

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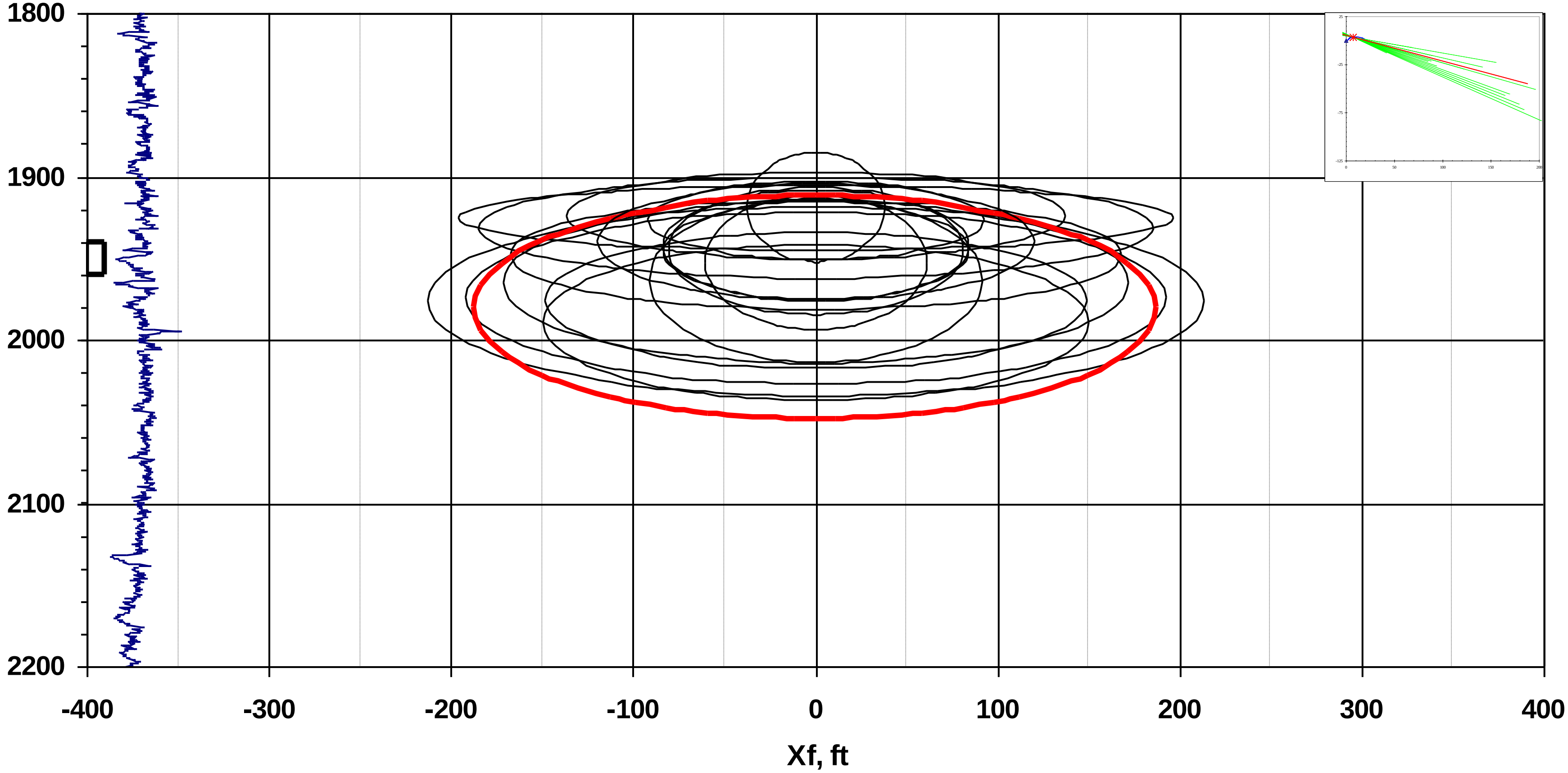
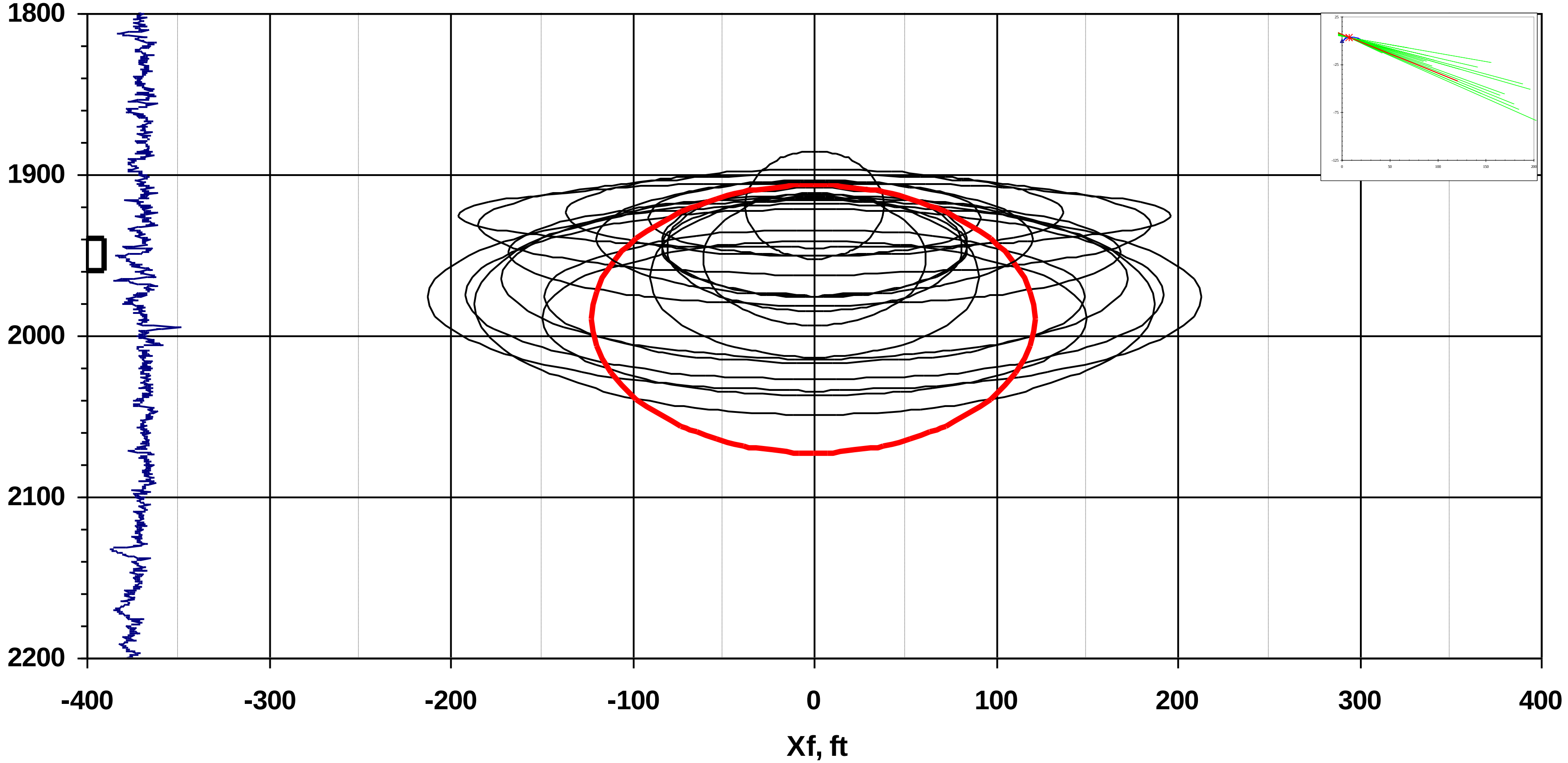


Atoka Shale Stage 16



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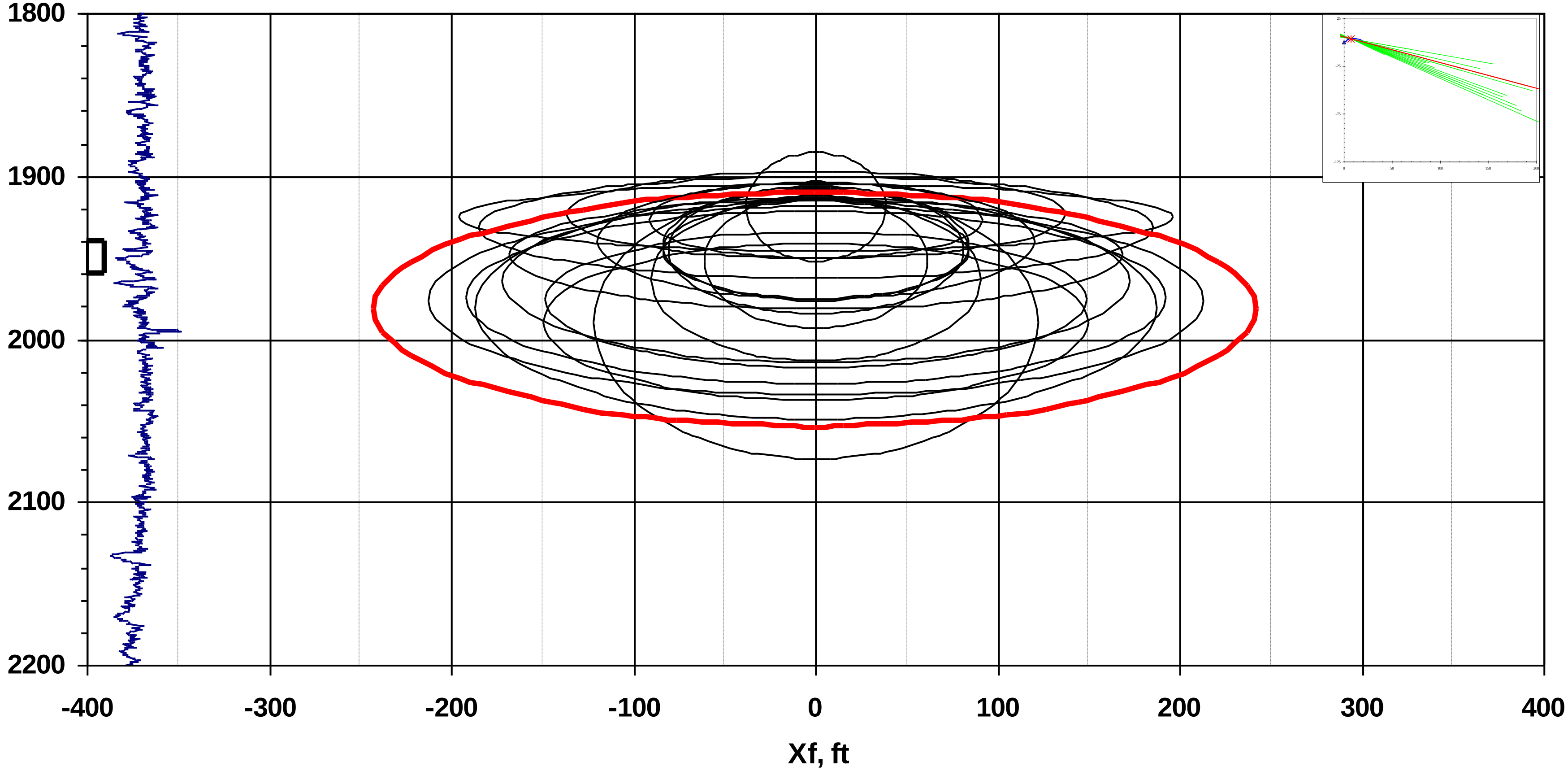

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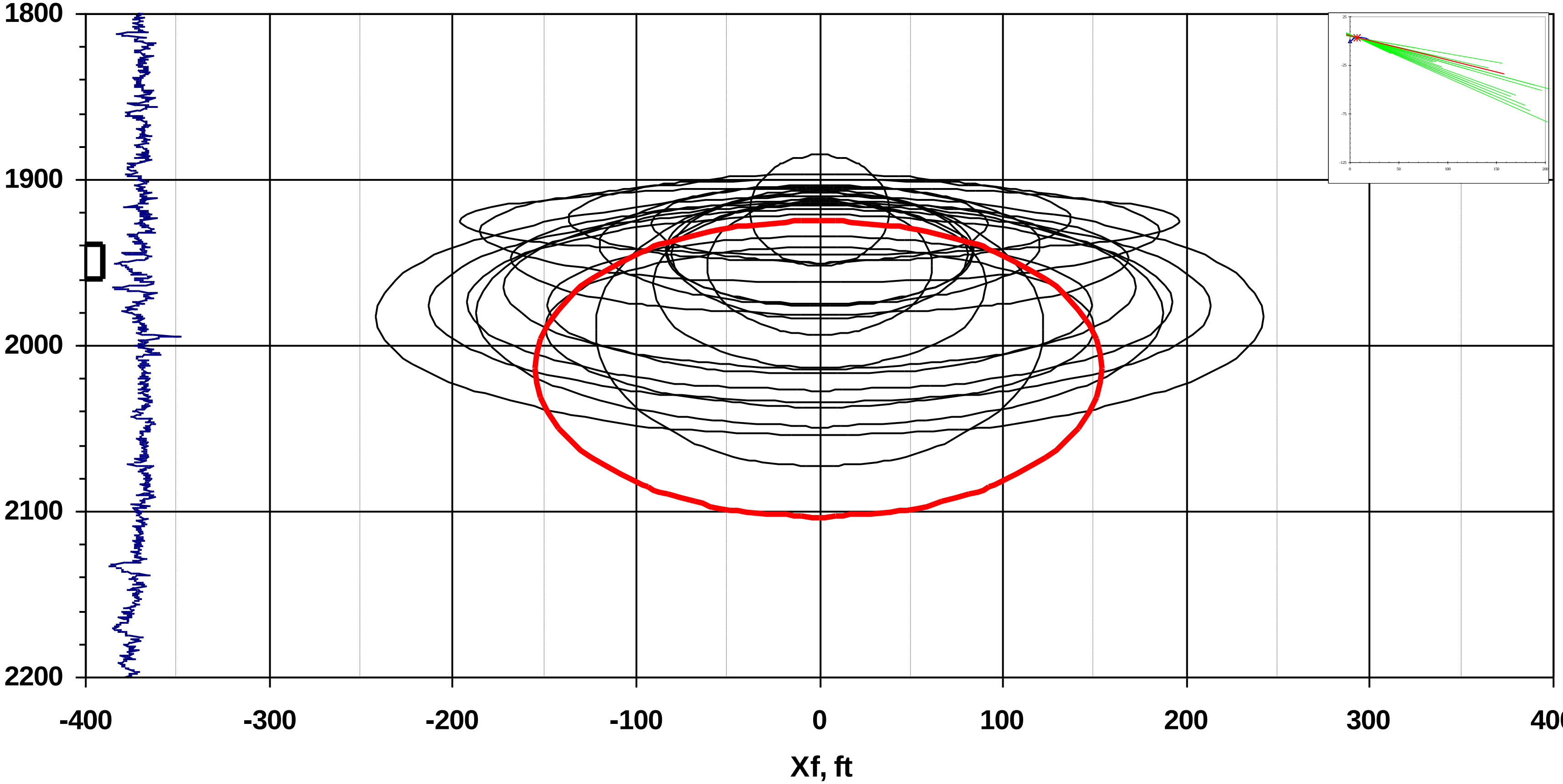

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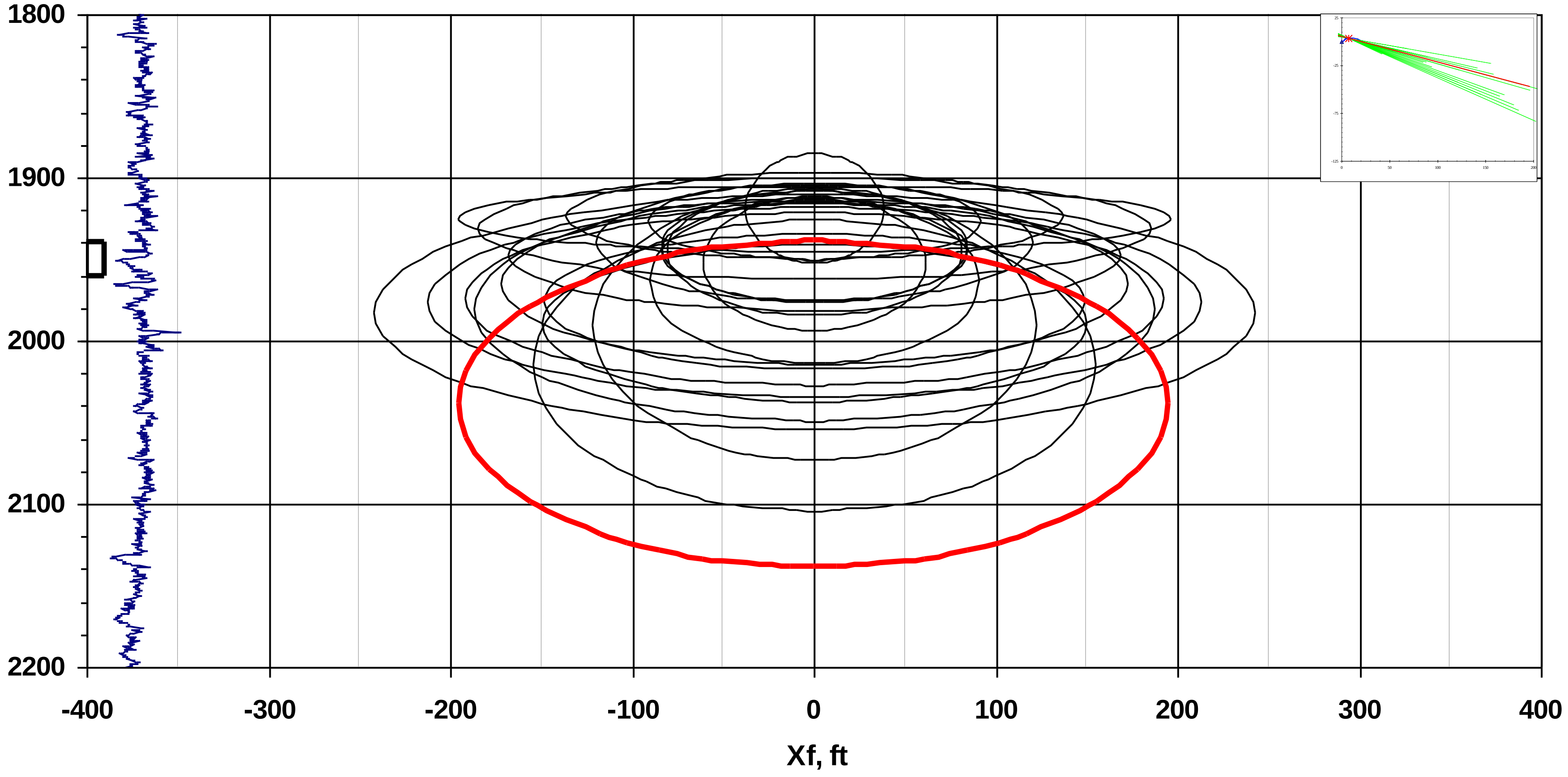
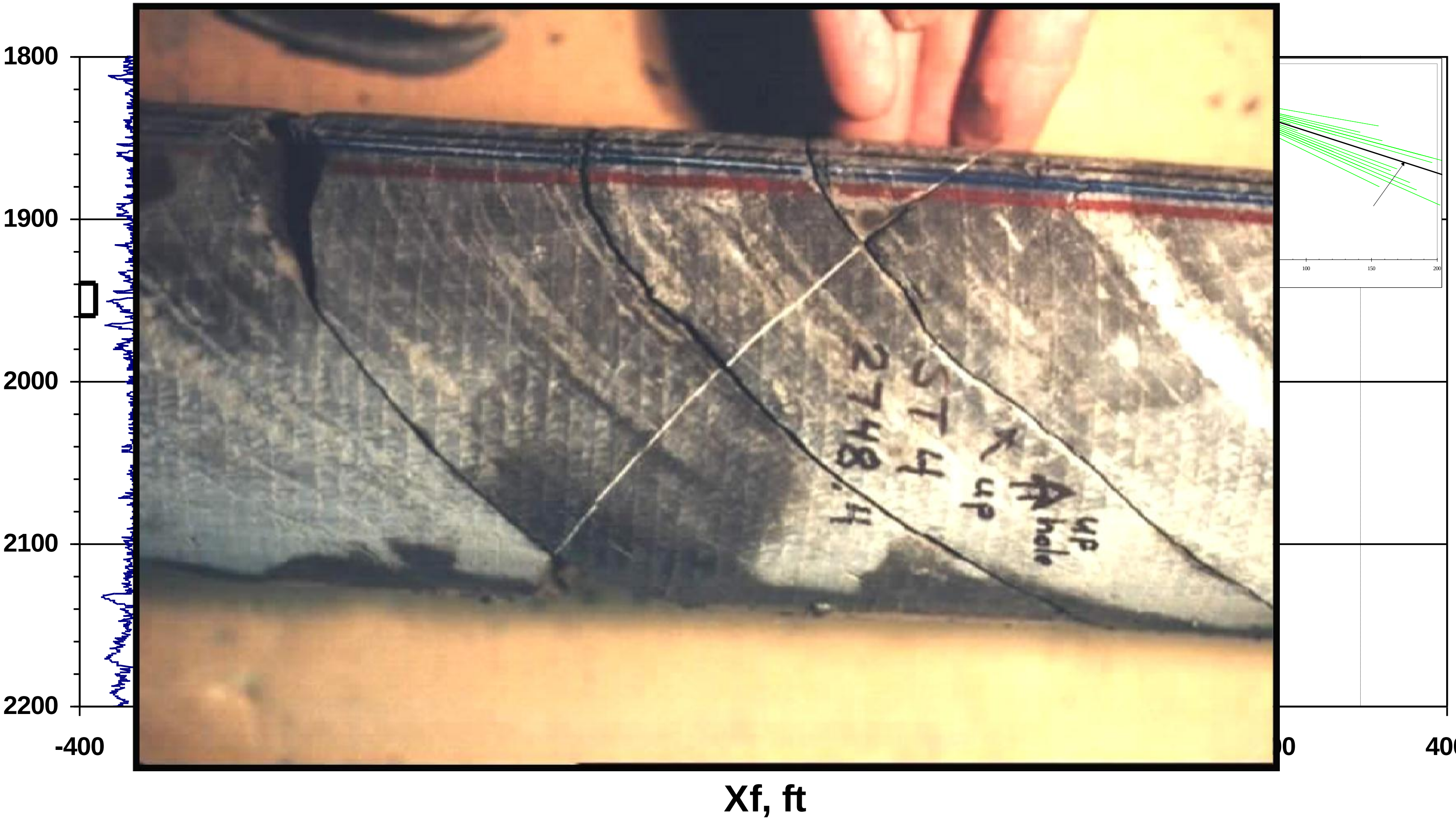


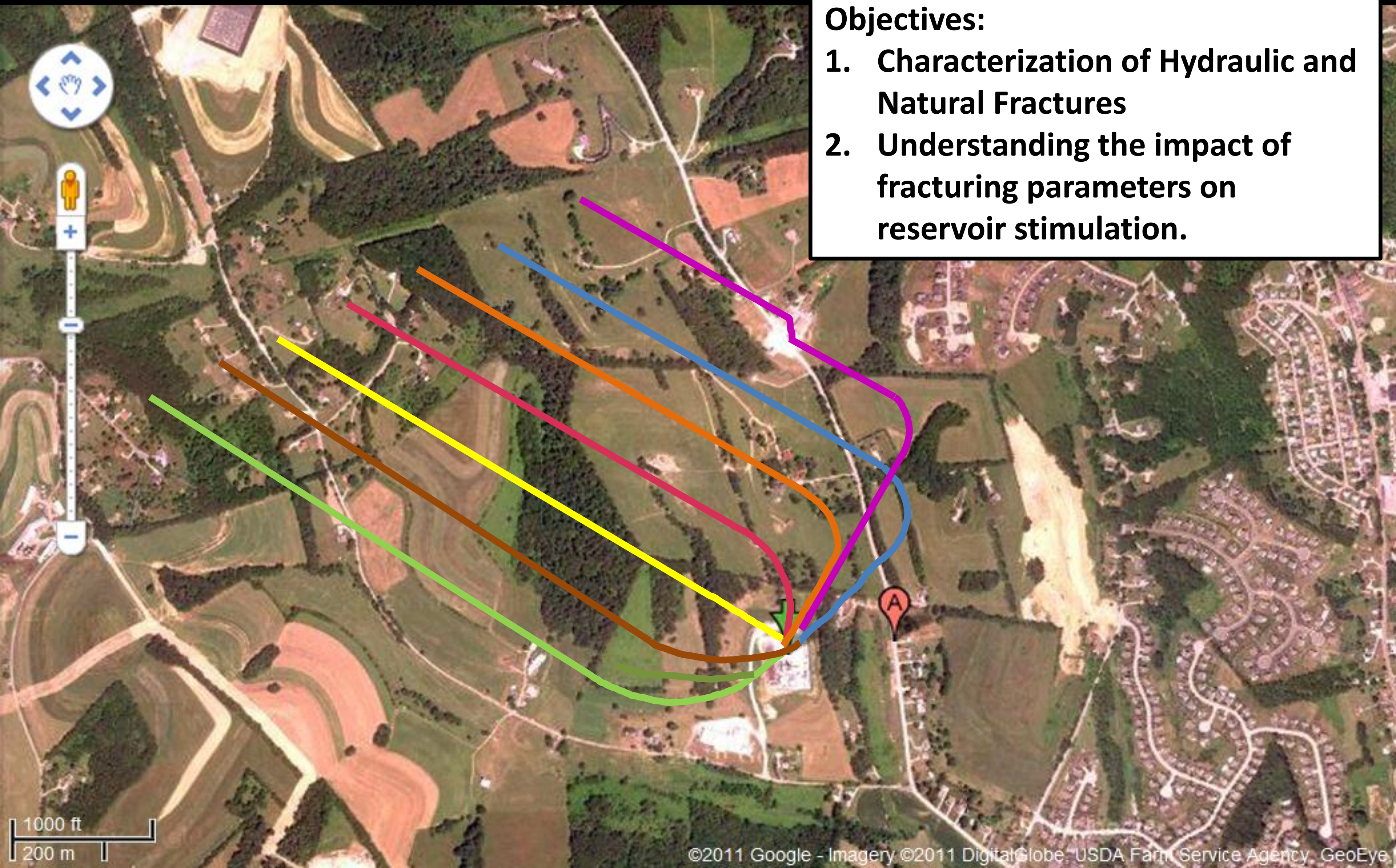
Atoka Shale All

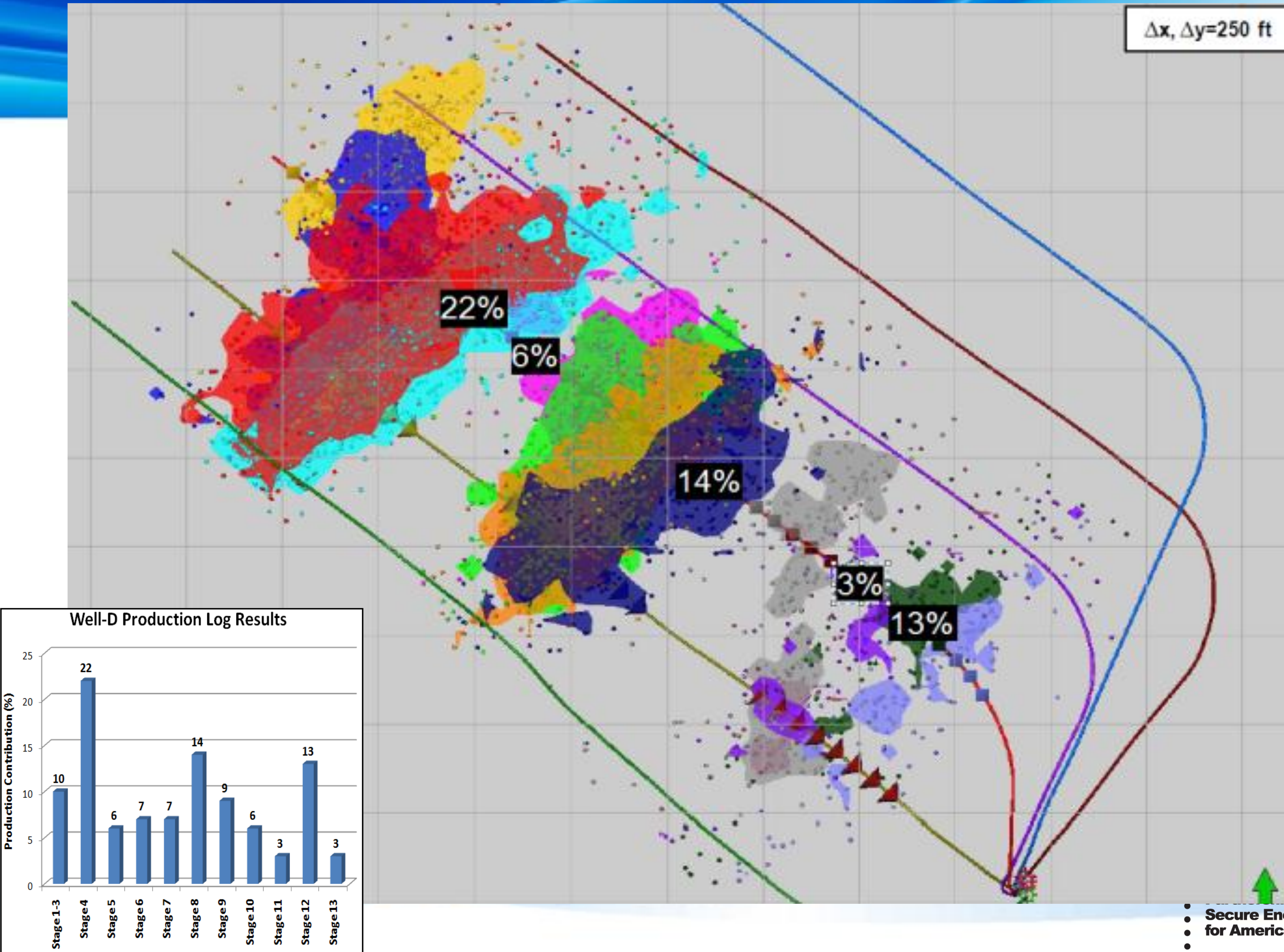


Marcellus Hydraulic Fracturing – Range Resources

Marcellus Shale Project Primary Objectives:

1. **Characterization of Hydraulic and Natural Fractures**
2. **Understanding the impact of fracturing parameters on reservoir stimulation.**

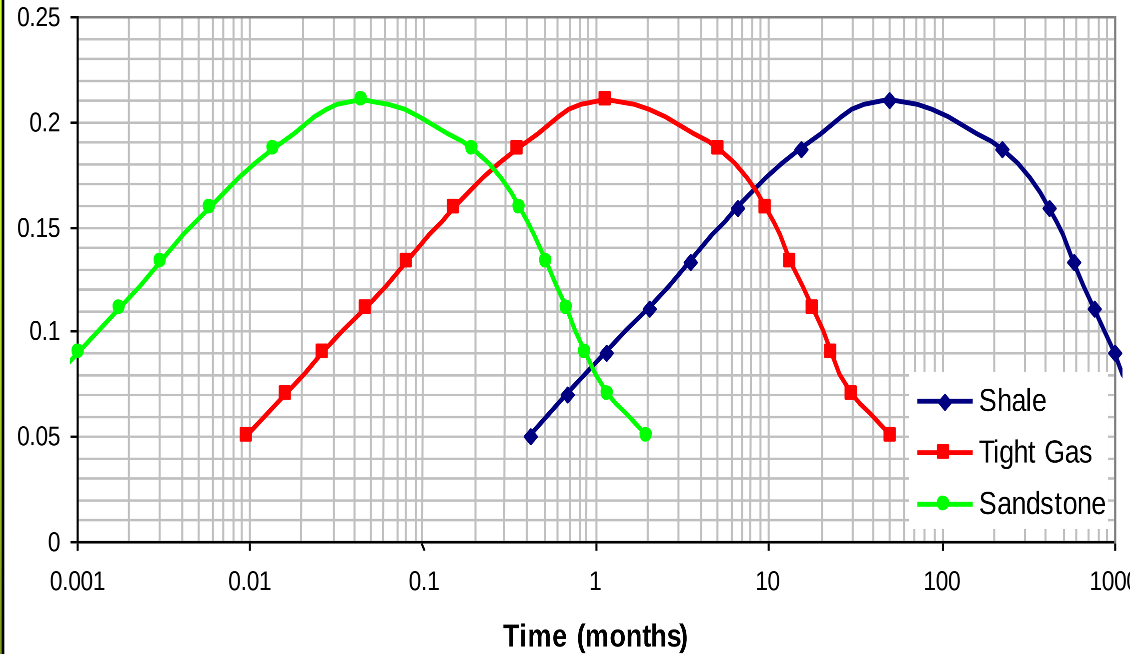



Δx, Δy=250 ft
22%
6%
14%
3%
13%
Well-D Production Log Results
Production Contribution (%)
0
5
10
15
20
25
10
22
6
7
7
14
9
6
3
13
3
Stage 1-3
Stage 4
Stage 5
Stage 6
Stage 7
Stage 8
Stage 9
Stage 10
Stage 11
Stage 12
Stage 13

Wellheads on Pad Location Prior to Fracing

Identification of Refracturing Opportunities

- Methodology for candidate selection based on poro-elastic models and analysis of field data.
- Recommendations for the time window most suitable for re-fracturing
- Re-fracture treatment design for horizontal and deviated wellbores



Optimum time for re-fracturing

University of Texas

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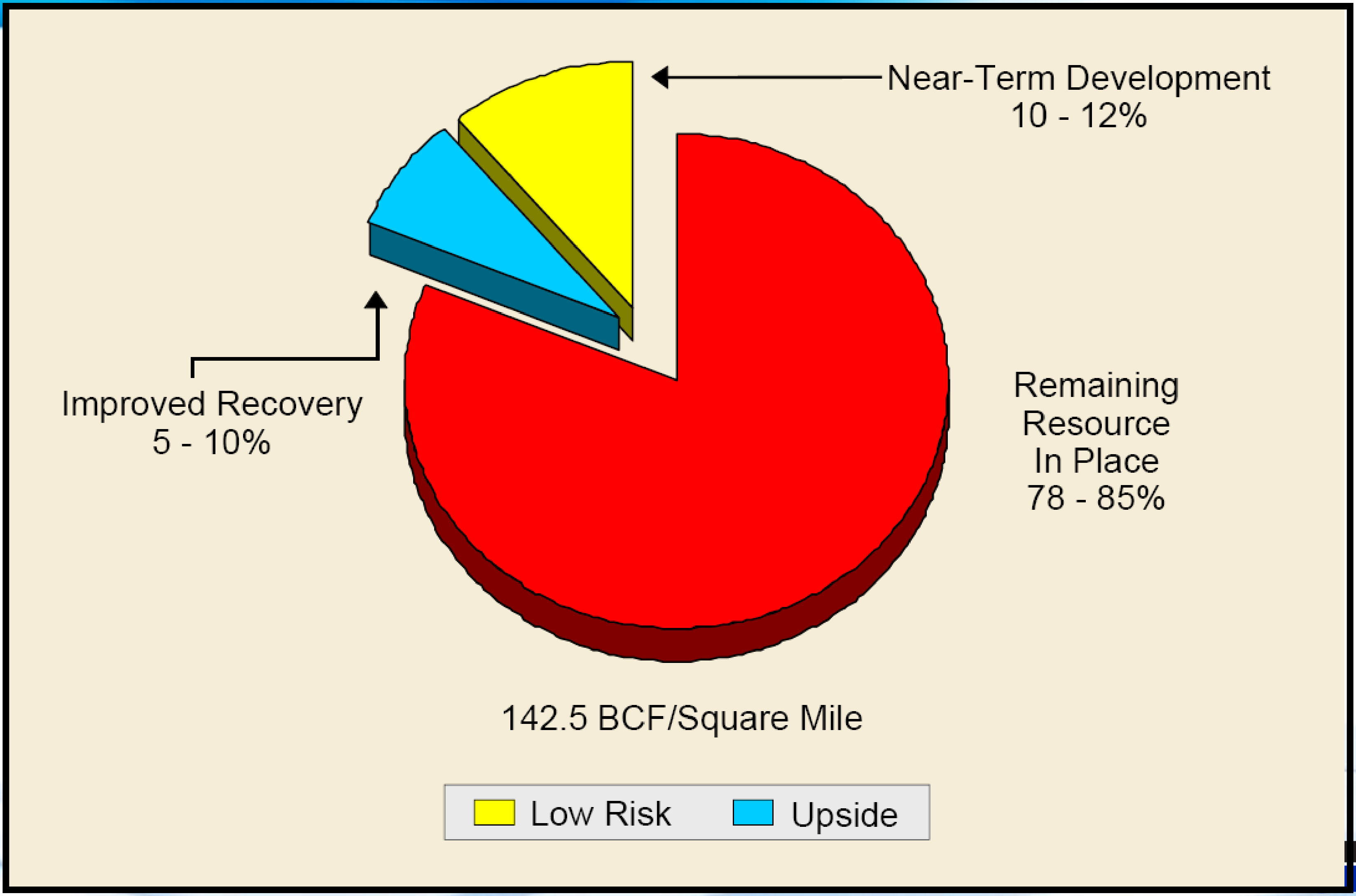
Barnett Reserves and Resource



Hydraulic Fracturing Issues

Over 1 Million Wells Fracture Treated

Billion’s of Gallons of Fluid

+60 Years of Experience

Significant Technology Focus and Development

Issues

Why Now?

Issues – Why Now?

- Significant Activity in New and Populated Areas
- Complex Process
- Environmental Concerns
  - Water Usage
  -
- Pre
- Internet
- Solution = Good Science, Transparency and Information that is Easy to Understand

The Science of Human Behavior as Much as the Science of Fluid Rheology

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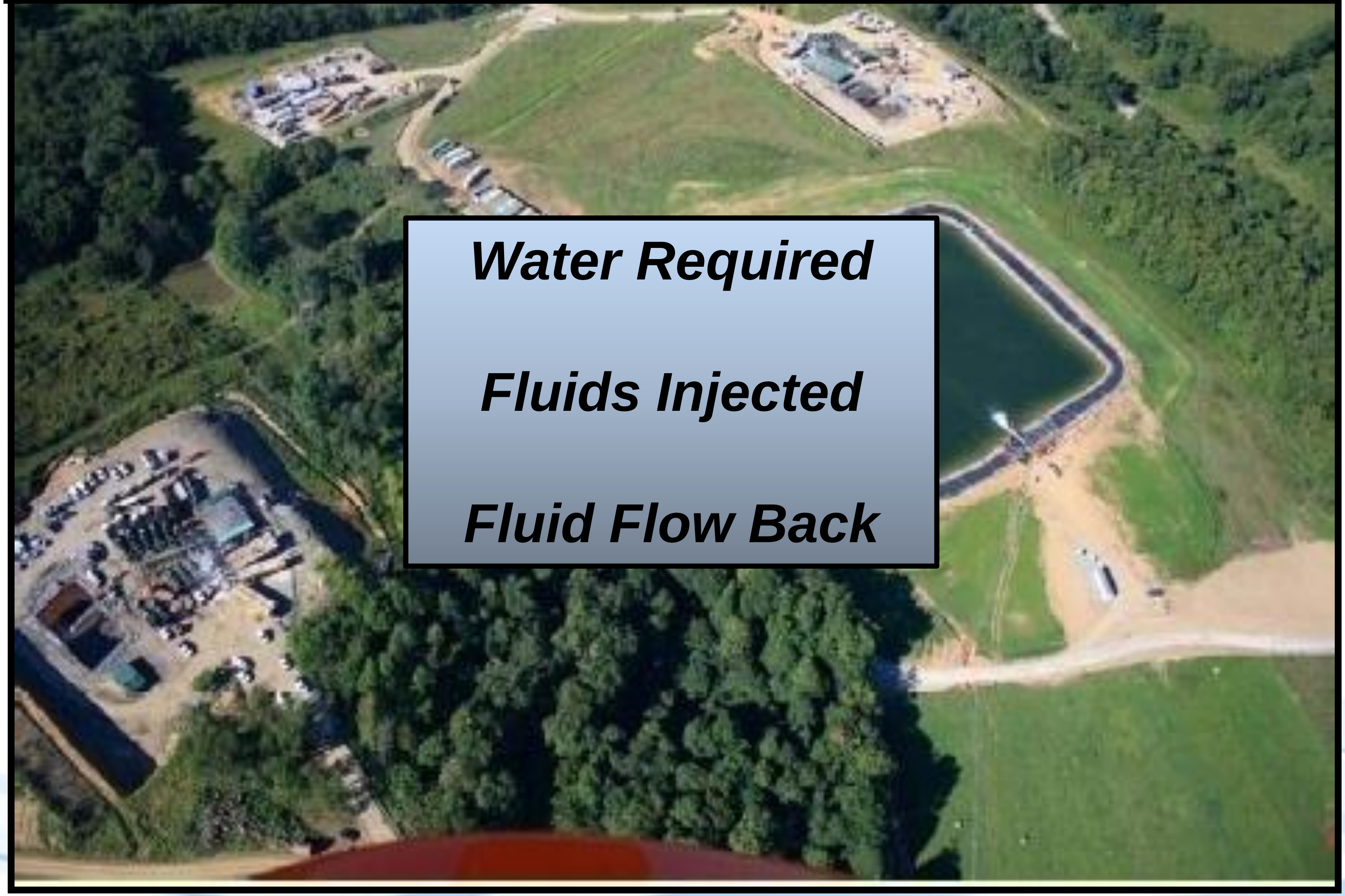
What's Next

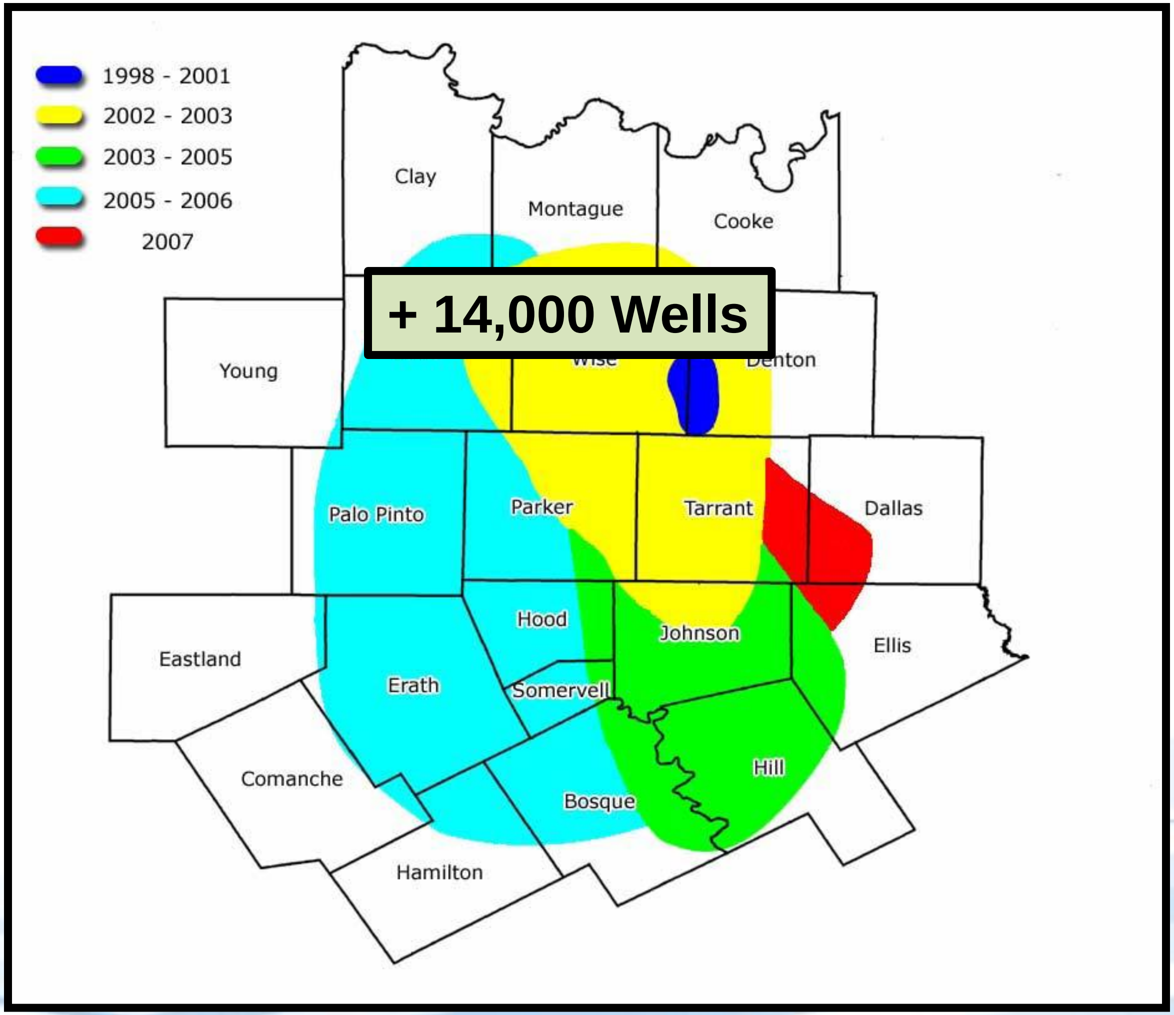
- % of Present Recoverable Reserves Attributable to Fracturing will Grow.
- The Future Will see an Acceleration of Fracturing.
- Research Currently Underway will allow Better Flow Capacity.
- A Wider Range of Formations will be Treated.
- Expansion of Fracturing in Foreign Countries can be Expected.

SPE 801, 1964, Ft. Worth, TX

Water and Hydraulic Fracturing



Barnett Shale Area – North Texas
Stages of Exploration



Perryman Group

Barnett Shale Water Conservation and Management Committee (BSWCMC)

About the Committee

- An industry consortium
- Made up of approximately 20 Barnett Shale Energy Companies
- Initiated in March 2006
- Completed its Charter, Spring 2006
- Status:
  - ➢ Collecting information on industry water use
  - ➢ Review of Reuse/Recycle Technologies
  - ➢ Planning Future Projects for 2007

Founding Members

Chesapeake Energy	Pitts Oil Company
Conoco Phillips	Quicksilver Resources
Denbury Resources	Range Resources
Derrick Resources	Sauder Land Co.
Devon Energy	Shell Oil Company
DTE Gas Resources	Sundance Resources
EnCana Oil and Gas	Williams Production
Harding Company	XTO Energy

Characteristics of the Future Program

- Best Management Practices (BMP's)
- Technology Development
  - ✓ Performance
  - ✓ Reliability and Cost
- Reducing Freshwater Demands Through:
  - ✓ Reuse
  - ✓ Recycle
  - ✓ Alternate Water Sources
- Deployment of Treatment Systems
- Information Sharing / Dissemination to Stakeholders

Mission

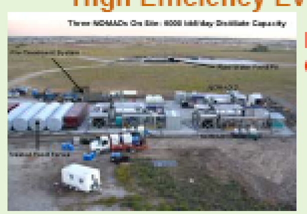
Develop best management practices (BMP's) for the Barnett Shale development in the Fort Worth Basin to ensure that water is managed in an efficient and responsible manner.

To Achieve the Mission, BSWCMC Will ….

- Define best methods and technologies currently used for water management during drilling, completion and production operations
- Promote a Balanced Approach
  - ➢ Efficient and responsible management of water
  - ➢ Conservation
  - ➢ Environmental Protection / Safety
  - ➢ Outreach and Education
- Utilize New Technology (Where Needed)

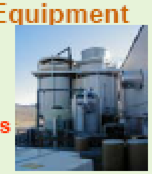
Technologies Considered for Water Reuse

High Efficiency Evaporation Equipment



Fountain Quail

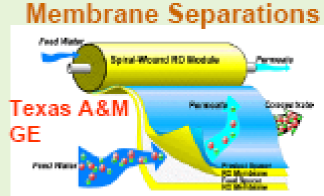
Intevras



Membrane Separations

Texas A&M

GE



Physicochemical Trtmt

Triad

For More Information, Contact:
Tom Hayes, Gas Technology Institute
Phone: 847.768.0722
Mobile: 847.736.1009
E-mail: tom.hayes@gastechnology.org

Goals

1. Determine current and future water demands for the Barnett Region
2. Estimate current and future "waste" water generation for Barnett O&G development
3. Define water quality specifications for drilling and fracturing jobs
4. Identify technologies to provide solutions for water management
5. Determine the feasibility of technical solutions to improve water conservation
6. Conduct a proactive "Best Management Practices" information transfer effort for industry
7. Promote information dissemination to Stakeholders in the Barnett Area
8. Engage in effective responses to inquiries and concerns about water management

Accomplishments

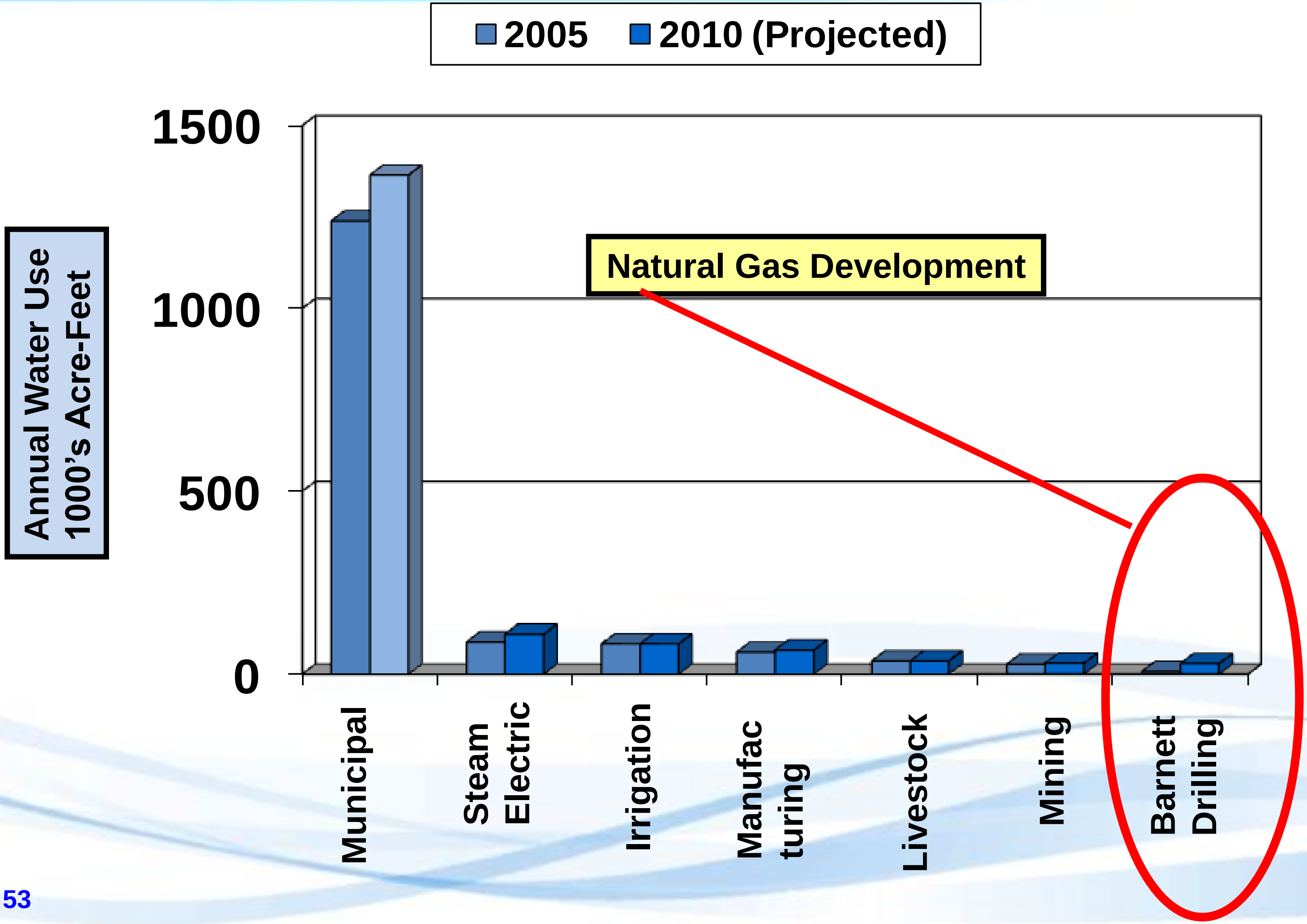
- Conducted a preliminary water use survey among major energy developers
- Obtained information from experts on five treatment technologies for water reuse and recycle
- Launched a preliminary survey on the availability of freshwater in the Barnett
- Prioritized goals and initiated planning of the program

What is Being Done?

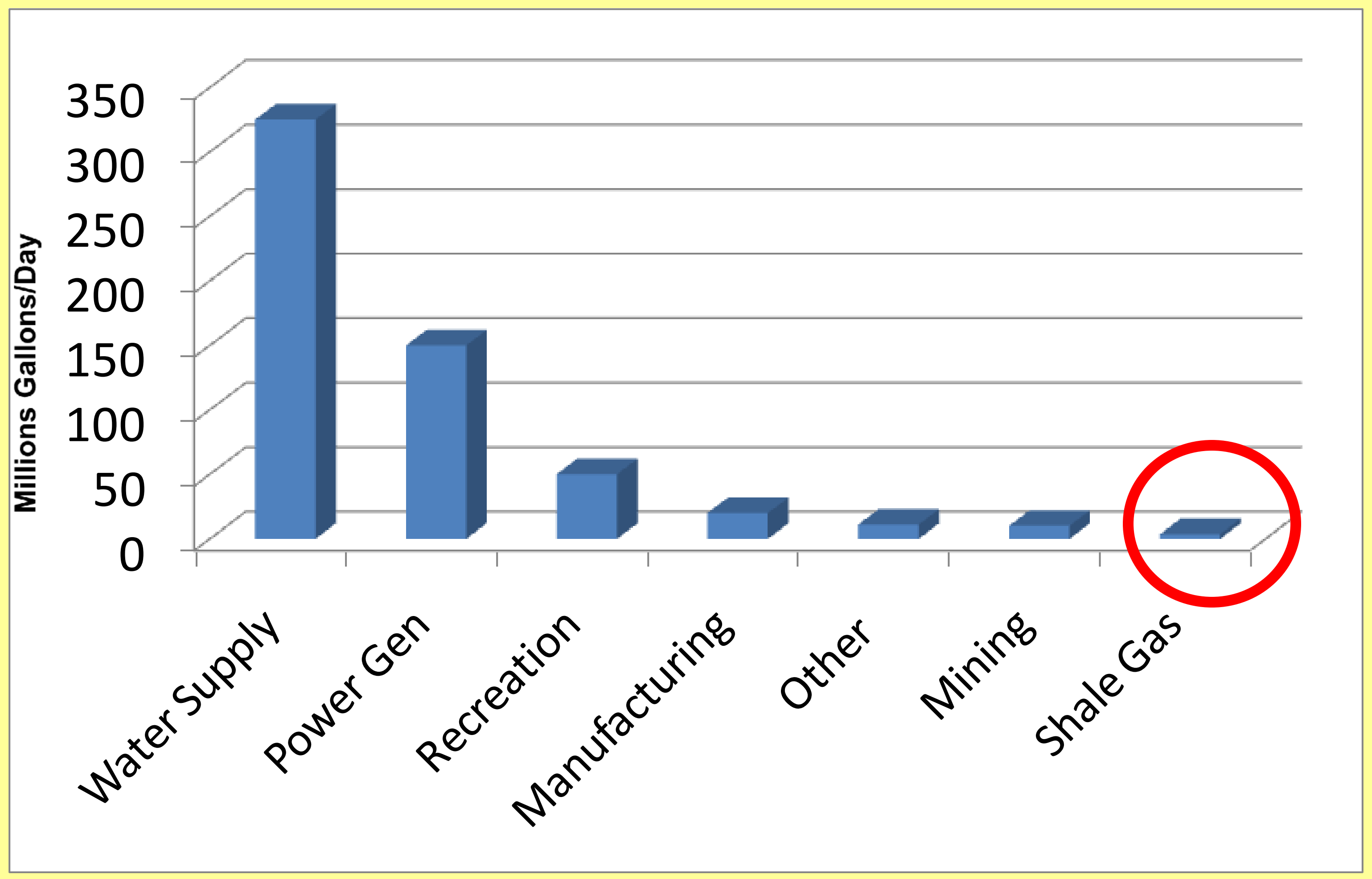
<u>Barnett & Marcellus Water Committees</u>

Mission of the Committees is to develop best management practices (BMP's) and technical solutions for shale developments to ensure that <u>water is managed in an efficient and environmentally responsible manner</u>.

Freshwater Users in the Barnett Shale Region



Marcellus - Susquehanna River Basin



Source: SRBC, Aug 2008

What Flows Out – Is it a Witch's Brew of Toxins?

Sampling and Analysis of Flow back Water

- Sampling from 19 Marcellus Locations.
- Includes Chemistry and Analysis of Constituents of Interest.
- Lists of Constituents Provided by USEPA, WV-DEP and PA-DEP.
- Over 250 Determinations Performed on Samples.

http://www.rpsea.org/attachments/contentmanagers/5820/08122-05-FR-Barnett_Appalachian_Shale_Water_Management_Reuse-Technologies-03-30-12_P.pdf

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Metals

- Mercury
- Arsenic
- Boron
- Trivalent Chromium
- Hexavalent Chromium
- Copper
- Nickel
- Zinc
- Lead
- Selenium
- Cobalt
- Iron
- Manganese
- Lithium
- Tin

Selected Metals in Flow Back Water - Samples from Two Locations

Metal **	Location A 14-d FB	Location B 14-d FB
Chromium (Cr^{3+})	ND	ND
Copper	ND	0.023
Nickel	ND	0.033
Zinc	0.06	0.18
Lead	ND	ND
Cadmium	ND	0.002
Mercury	0.000049	0.000027
Arsenic	0.05	0.017

* mg/l; ND=Non Detect

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Selected Metals in Flow Back Water - Samples from Two Locations

	Location A	Location B	POTW Sludges**	
Metal **	14-d FB	14-d FB	Median	95th % ile
Chromium (Cr^{3+})	ND	ND	35	314
Copper	ND	0.023	511	1,382
Nickel	ND	0.033	22.6	84.5
Zinc	0.06	0.18	705	1,985
Lead	ND	ND	65	202
Cadmium	ND	0.002	2.3	7.4
Mercury	0.000049	0.000027	1.5	6.0
Arsenic	0.05	0.017	3.6	18.7

* mg/l; ND=Non Detect

** Penn State, 2000

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Flowback Summary

Flowback Water is Consistent with Ranges Observed with Conventional Produced Water.

Produced Water is Salt Water – Which is Managed

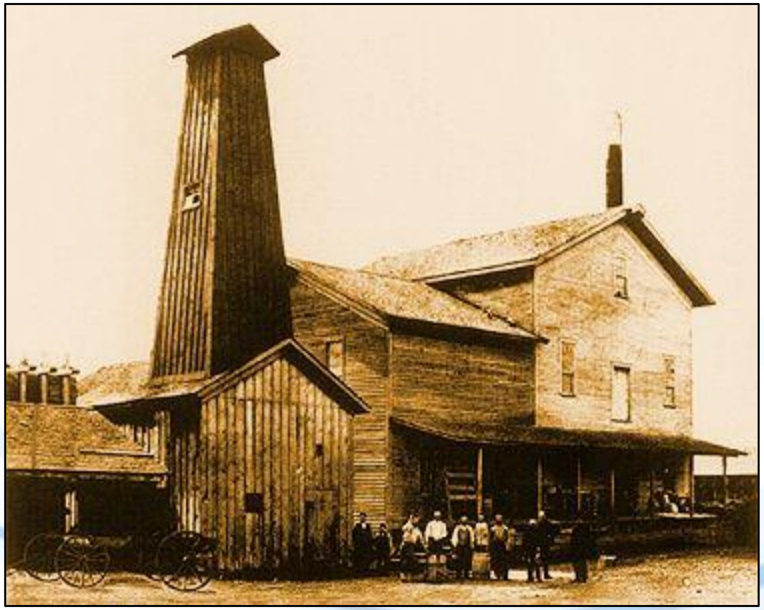
Measurement	Value
pH	5.89
Sodium, mg/l	54,629
Calcium, mg/l	15,200
Magnesium, mg/l	4,730
Barium, mg/l	98
Iron, mg/l	92
Manganese, mg/l	1.8
Bicarbonate, mg/l	195
Sulfate, mg/l	60
Chloride, mg/l	125,000
Sulfide, mg/l	na
Total Dissolved Solids, mg/l	200,006

SPE 119898

20 Billion Pounds of Salt Spread per Year for Snow and Ice Control

Beneficial Use

Deep under the flatlands of Midland, Michigan, lie *salt-rich rocks*, rich in magnesium, chlorine, calcium, sodium and bromine. Inside these rocks, Herbert Dow found the raw materials of creative chemistry (1897).



Road Salt –	**$56 per ton**
Road Brine –	**$.63 per gallon**
Bromine -	**$1,128 per ton**
Fresh Water	**$?**

RPSEA Research Program
Integrated Approach to Beneficial Use

Beneficial Uses	Regulations	Stakeholders	Water Handling Techniques	Water Quality Issues	Water Treatment Processes
Municipal Habitat Restoration Irrigation Livestock Production Groundwater Recharge Industrial Utilization Aquaculture Chemicals Recovery New Uses Drought Relief	State and Federal NPDES Permit Clean Water Act (CWA) Underground Injection Control (UIC) CWA Resource Conservation Recovery Act (RCRA) State and Industrial Specifications for Beneficial Use Water Quality	Public Landowners BLM States Producers Local Government (e.g. municipal) Federal Agencies Indian Nations Ranchers and Farmers	Trucking Pipelines Surface Discharge Reinjection Storage ReUse	Oil and Grease Soluble Organics Hardness and Scale Formation Dissolved Solids Metals Inorganic Content	Ion Exchange Electrodialysis Reverse Osmosis Freeze Thaw Evaporation Artificial Wetlands Capacitive Desalinization High Efficiency Evaporation/ Condensation Land Application Microfiltration & Nanofiltration Biotreatment

An Integrated Framework for Treatment and Management of Produced Water

Research Objectives

- Compile data on quality and quantity of produced water associated with unconventional gas production
- Explore most appropriate and cost-efficient water treatment technologies

- **Assess requirements to minimize environmental impacts and reduce institutional barriers**

- **Compile findings into a decision analysis framework for management of produced water**

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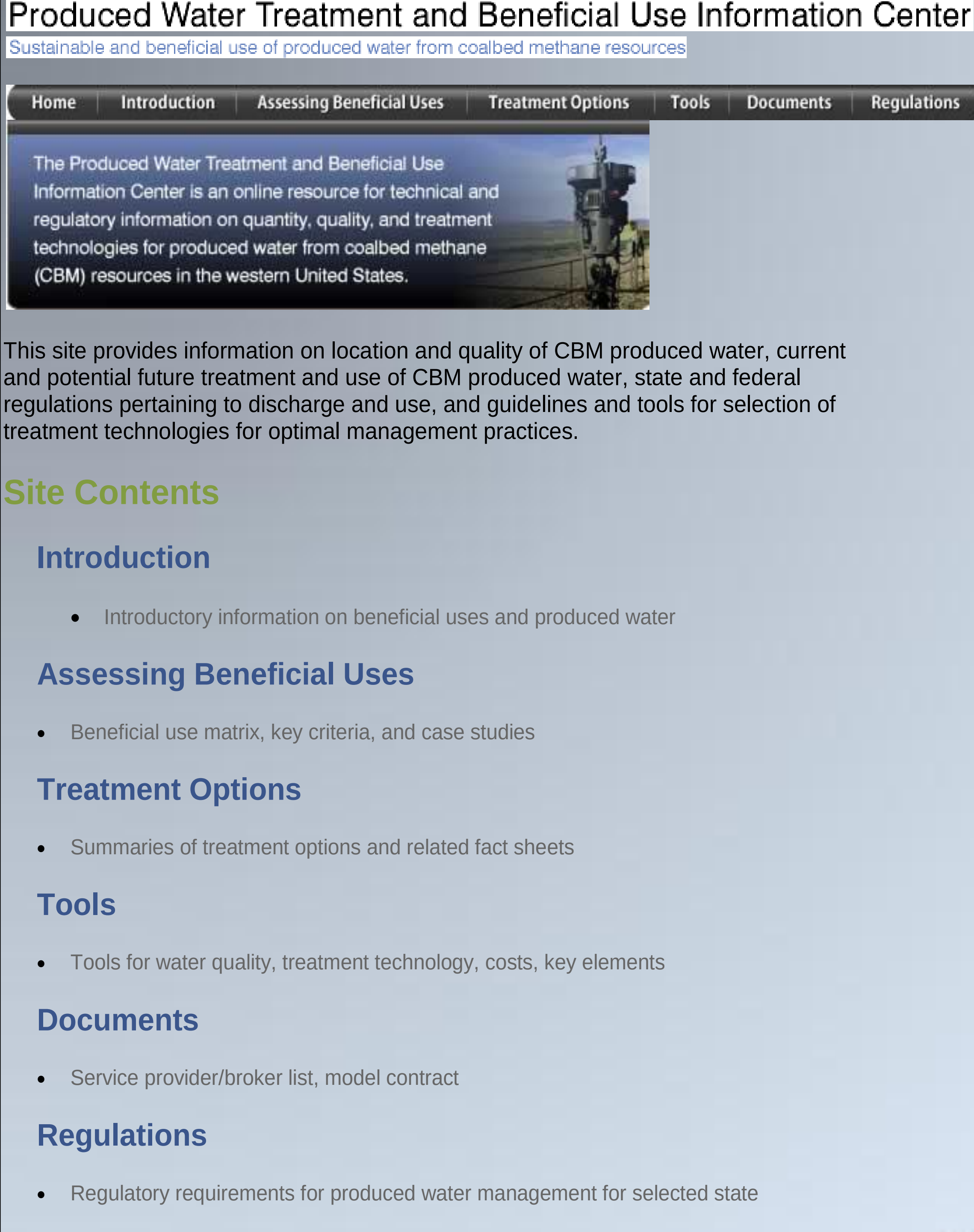
Colorado School of Mines



Produced Water Treatment and Beneficial Use Information Center

Sustainable and beneficial use of produced water from coalbed methane resources

Home | Introduction | Assessing Beneficial Uses | Treatment Options | Tools | Documents | Regulations

The Produced Water Treatment and Beneficial Use Information Center is an online resource for technical and regulatory information on quantity, quality, and treatment technologies for produced water from coalbed methane (CBM) resources in the western United States.

This site provides information on location and quality of CBM produced water, current and potential future treatment and use of CBM produced water, state and federal regulations pertaining to discharge and use, and guidelines and tools for selection of treatment technologies for optimal management practices.

Site Contents

Introduction

- Introductory information on beneficial uses and produced water

Assessing Beneficial Uses

- Beneficial use matrix, key criteria, and case studies

Treatment Options

- Summaries of treatment options and related fact sheets

Tools

- Tools for water quality, treatment technology, costs, key elements

Documents

- Service provider/broker list, model contract

Regulations

- Regulatory requirements for produced water management for selected state

CSM Produced Water Interactive Website

http://aqwatec.mines.edu/produced_water/index.htm

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54 Water Treatment Technologies

<table>
<tr><th>Stand-alone/primary</th><th>Multi-technology processes</th></tr>
<tr><td>

Basic Separation
- Biological aerated filters
- Hydroclone
- Flotation
- Settling
- Media filtration

Membrane Separation
- High pressure membranes
  - Seawater RO
  - Brackish water RO
  - Nanofiltration (NF)
  - VSEP
- Electrochemical charge driven membranes
  - Electrodialysis (ED), ED reversal (EDR)
  - Electrodionization (EDI)
- Microfiltration/ultrafiltration
  - Ceramic
  - Polymeric
- Thermally driven membrane
  - Membrane distillation (MD)
- Osmotically driven membrane
  - Forward osmosis (FO)

</td><td>

Enhanced distillation/evaporation
- GE: MVC
- Aquatech: MVC
- Aqua-Pure: MVR
- 212 Resources: MVR
- Intevras: EVRAS evaporation units
- AGV Technologies: Wiped Film Rotating Disk
- Total Separation Solutions: SPR – Pyros

Enhanced recovery pressure driven
- Dual RO w/ chemical precipitation
- Dual RO w/HEROTM: High Eff. RO
- Dual RO w/ SPARRO
- Dual pass NF
- FO/RO Hybrid System

Commercial treatment RO-based processes
- CDM
- Veolia: OPUS™
- Eco-Sphere: Ozonix™
- GeoPure Water Technologies

</td></tr>
</table>

54 Water Treatment Technologies (cont'd)

Thermal Technologies
- Freeze-Thaw
- Vapor Compression (VC)
- Multi effect distillation (MED)
- MED-VC
- Multi stage flash (MSF)
- Dewvaporation

Adsorption
- Adsorption
- Ion Exchange

Oxidation/Disinfection
- Ultraviolet Disinfection
- Oxidation

Miscellaneous Processes
- Evaporation
- Infiltration ponds
- Constructed wetlands
- Wind aided intensified evaporation
- Aquifer recharge injection device (ARID)
- SAR adjustment
- Antiscalant for oil and gas produced water
- Capacitive deionization (CDI) & Electronic Water Purifier (EWP)
- Gas hydrates
- Sal-Proc™, ROSP, and SEPCON

Commercial Treatment IX-based processes
- EMIT: Higgins Loop
- Drake: Continuous selective IX process
  Eco-Tech: Recoflo® compressed-bed IX process
- Catalyx/RGBL IX

Freeze Thaw Evaporation
Jonah Field, Wyoming

75,000 Bbls Reduced to 25,000 Bbls for Disposal

Thermal Processes being Utilized

- **Energy Intensive; Therefore Expensive**

- **Potential for Scaling and Fouling**

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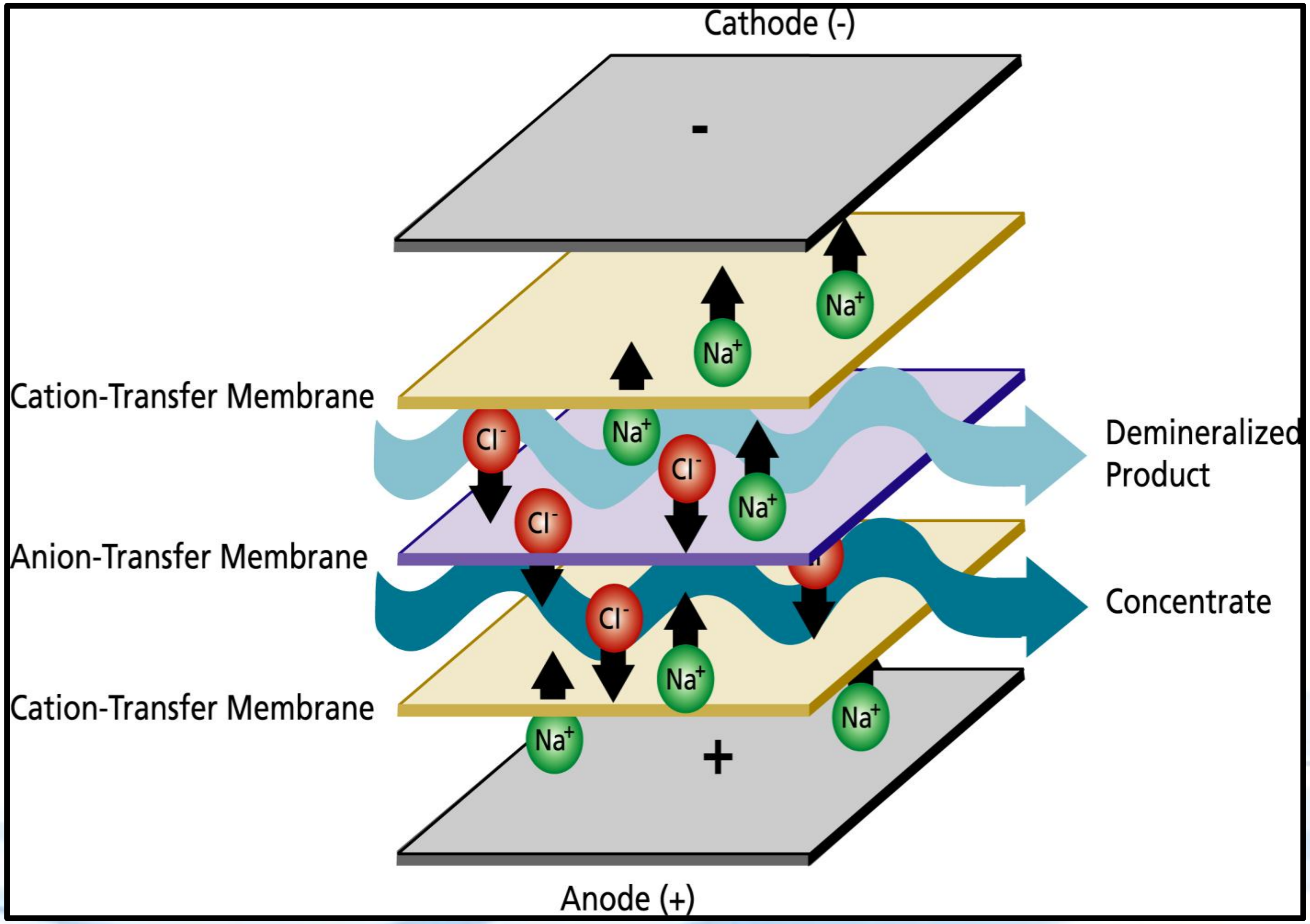
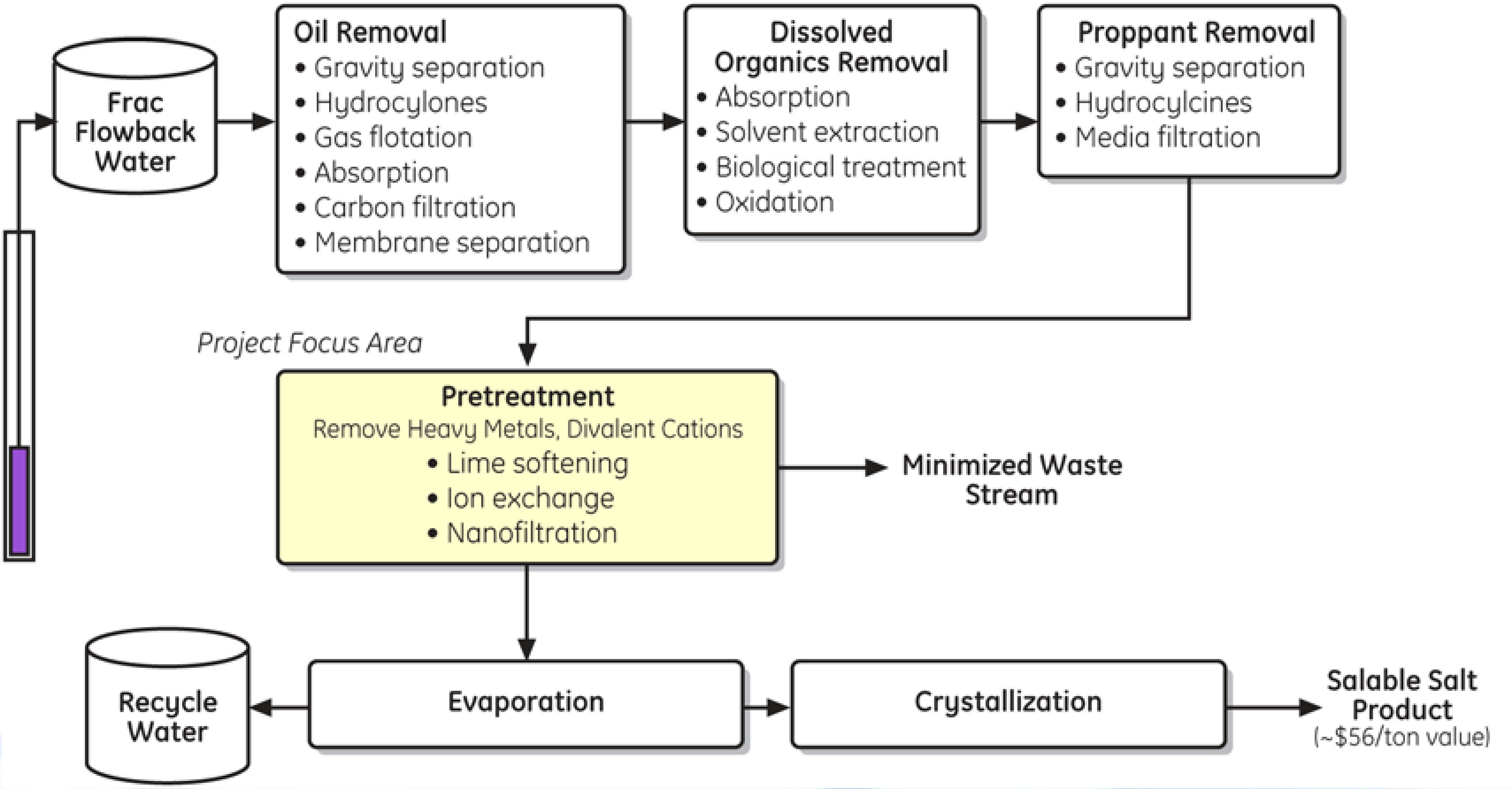
RPSEA Research Project

Water Treatment Dialysis – Lower Cost by Factor of X5



Pretreatment and Water Management for Frac Water Reuse and Salt Production



Summary of Pretreatment Processes Analyzed

Pretreatment Process	$/bbl produced water (Design Case)	Issue
Ion Exchange	> 6	High chemicals cost
Nanofiltration	7.7	High cost, low recovery
Sulfate precipitation	17	NORM in sludge; must dispose as LLRW
Lime-soda precipitation	63	
Modified lime-soda precipitation	3.5	Lab development needed Benefits: cost, Ra, Ba disposal by UIC[a]
MnO_2 adsorption	1.7-2.4	

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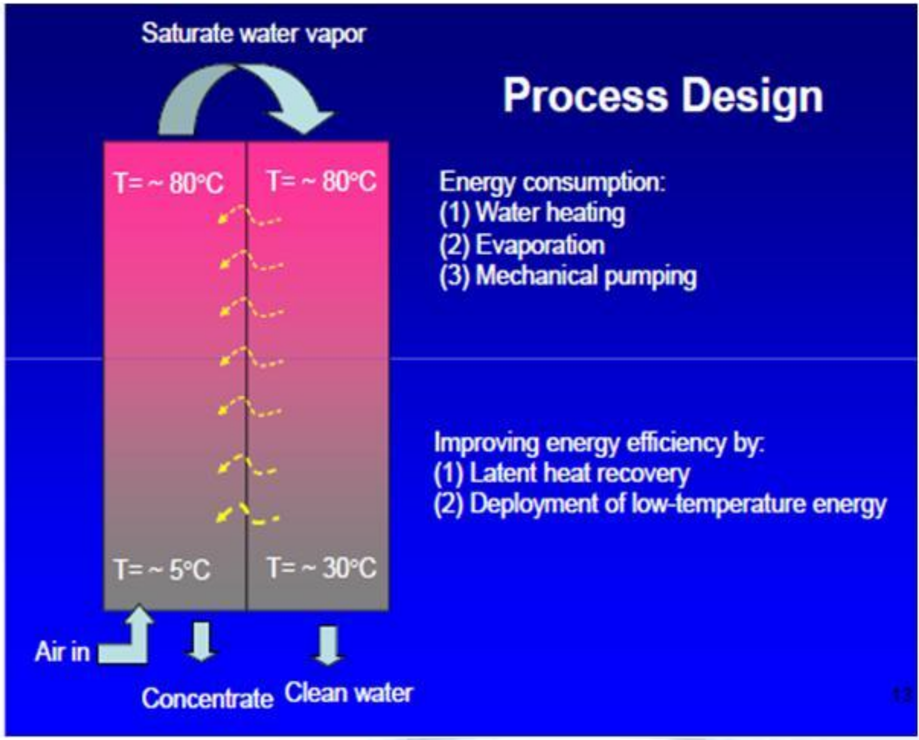
Cost-Effective Treatment of Produced Water Using Co-Produced Energy Sources for Small Producers

Environmental, Safety and Regulatory

Project goal: Development and demonstration of a low-temperature distillation using co-produced energy sources for produced water purification at wellhead.

- Prototype design capacity 20 bbl/day
- TDS reduced from 1.98×10^4 to 76.75 mg/L
- Total organic carbon was reduced from 470.2 to 17.83 mg/L.
- Purified produced water is suitable for alternative uses, such as agriculture, irrigation and industrial processing.



Harvard Petroleum Company

New Mexico Institute of Mining & Technology

The Environmentally Friendly Drilling Systems Program

EFD

University/NL Alliance

- ***Texas A&M*** *– Systems Engineering Design Methodology: Low Impact Well Design Optimization*
- ***University of Colorado*** *– Best Practices Database*
- ***University of Arkansas*** *– Dissemination and Decisions Support*
- ***University of Wyoming*** *– Western Mountain States Studies*
- ***Utah State University/Sam Houston State University*** *– Public Perception*
- ***West Virginia University*** *– Eastern Mountain States Studies*
- ***Los Alamos National Laboratory/Argonne National Laboratory*** *– Technology Partnership*

integrating advanced technologies into systems that significantly reduce the impact of drilling and production in environmentally sensitive areas.

www.efdsystems.org

Houston Advanced Research Center

Engineering Designs for Low Impact Drilling and Fracturing

- *Application for Semi Arid Ecosystem*
- *Disappearing Roads*
- *Prototype Small Footprint Drilling Rig*
- *NOx Air Emissions Studies*
- *Reduced Fracturing Footprints*
- *Measuring Effectiveness of EFD*

HARC

Environmentally Friendly Drilling (EFD) Overview

Focus on unbiased science and technologies for **environmentally sensitive development** of **energy sources**.

Identify, **develop** and **transfer** critical, **cost effective**, new technologies that can provide policy makers and industry with the ability to develop reserves in a **safe** and **environmentally friendly** manner.

What gets measured, gets done.
What gets identified, gets dealt with.
What gets expected, gets respected.

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EFD Team

Co-funded by RPSEA, Dept. of Interior, USAID, Industry, Environmental Organizations

SPONSORS

MANAGEMENT TEAM

ENVIRONMENTAL ORGANIZATIONS

COLLABORATORS

ALLIANCE MEMBERS

EFD Results

- Highlighted in the August Hart Energy's Supplement to Hart's E&P; entitled Hydraulic Fracturing. 56 articles/publications, 111 presentations, 19 workshops, 6 exhibits.
- IOGCC 2009 Environmental Partnership/Chairman's Stewardship Award
- University of Colorado, School of Law www.oilandgasbmps.org site. Has over 8,500 best practices. Over 5,000 unique visitors per month.
- Through the EFD Program's Disappearing Road competition, a lay-down road system first developed by the University of Wyoming is now being offered by Wyocomposites.

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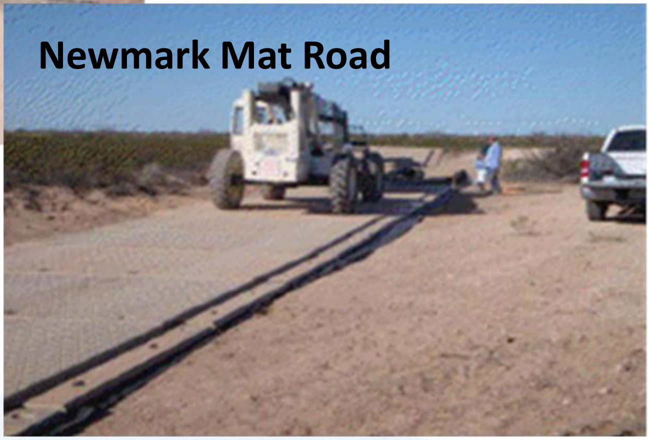
Truck Traffic

Gas Well Drilling Traffic and Impact on Roads

Field Site Testing of Low Impact Oil Field Access Roads: Reducing the Footprint in Desert Ecosystems

Environmental, Safety and Regulatory

Project Goal:
Testing innovative, minimal impact road designs for reducing the environmental footprint of field development in sensitive desert ecosystems



Texas Transportation Institute,
Texas A&M University
Scott Environmental Services
Newpark Mats & Integrated Services
Inland Environmetal
McFaddin Ranches

Texas A&M University

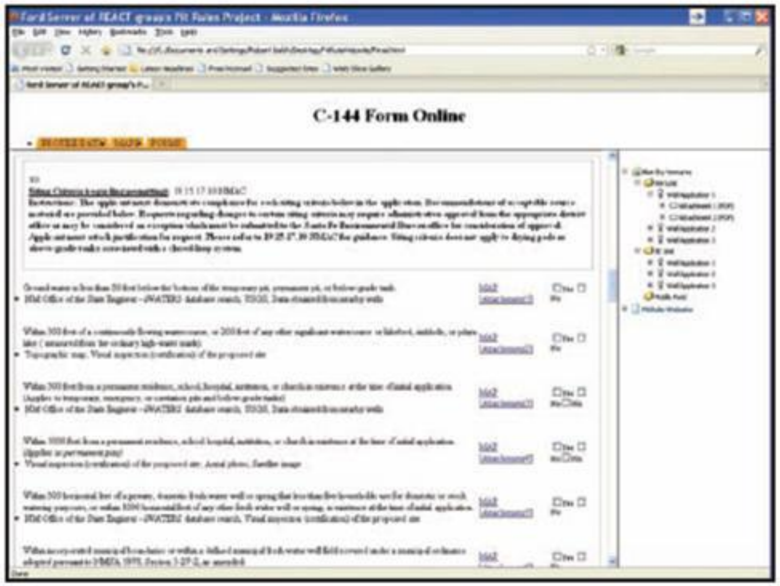
Backyard Drilling

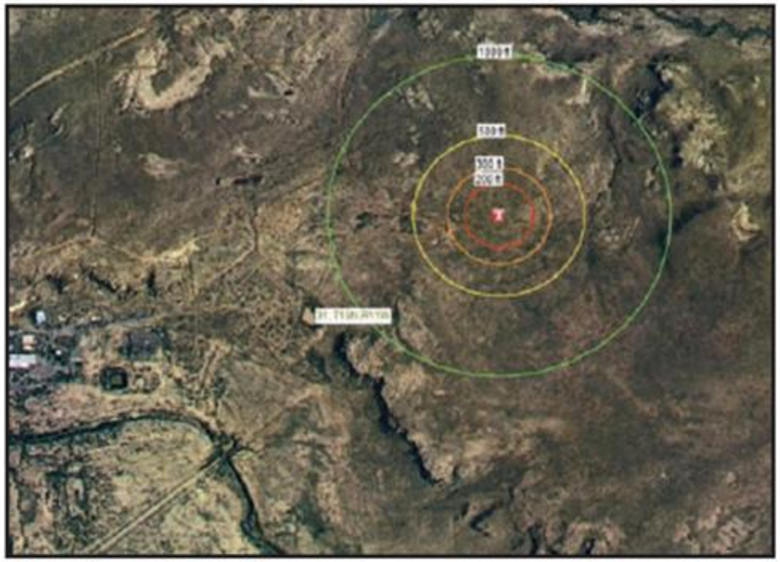
Hydraulic Fracturing

Reducing Impacts of New PIT Rules on Small Producers

Environmental, Safety and Regulatory

Project Goal: to provide a web portal allowing users to easily obtain a variety of data required in filling out various O&G permits in New Mexico

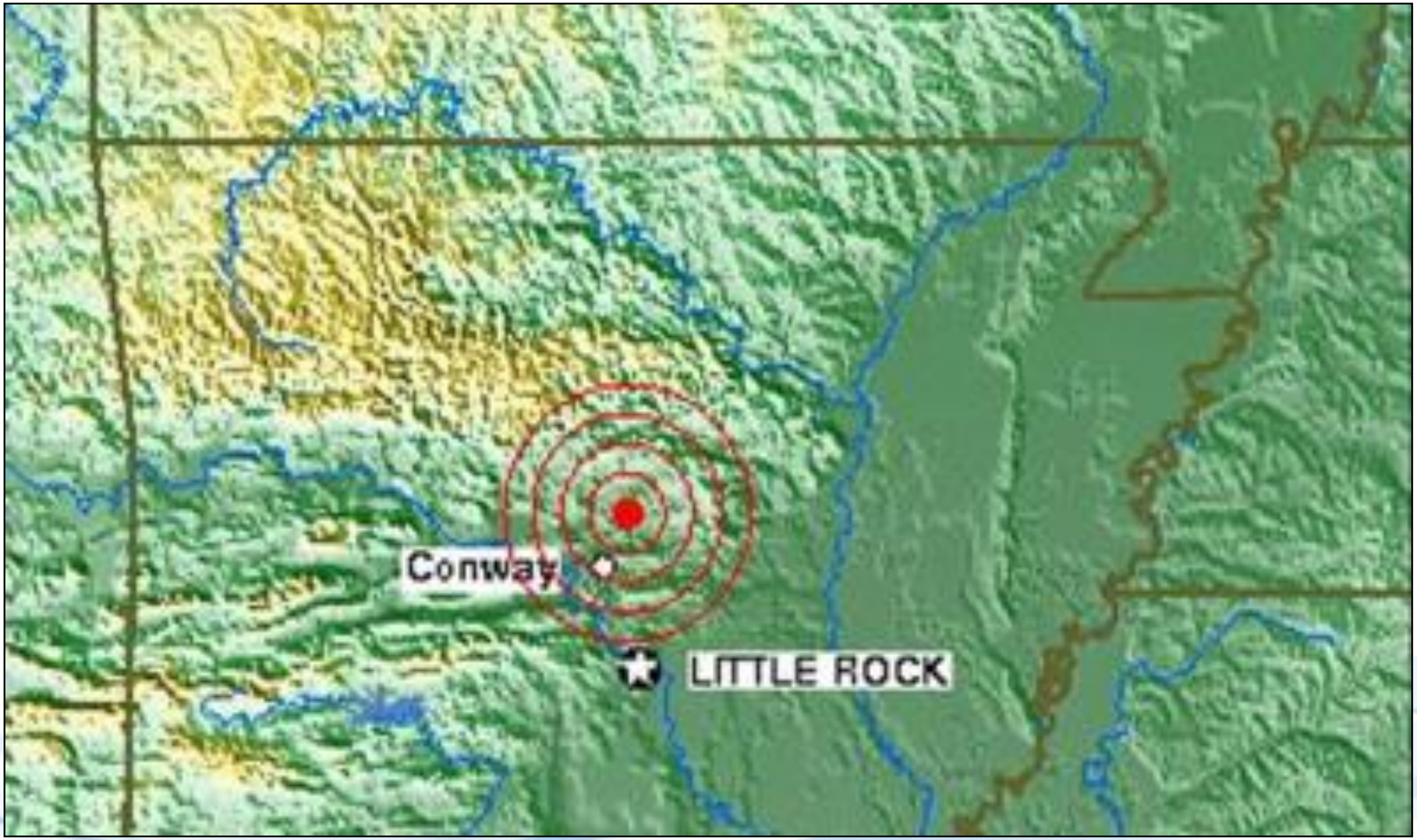




The electronic NMOCD C-144 form on the portal. The application may be submitted electronically, and questions may be answered and supporting maps generated and attached to document the site application.

New Mexico Institute of Mining & Technology

Induced Seismicity



RPSEA Activities - Induced Seismic

- Participants in USC Induced Seismicity Consortium
- SPE Forum on Induced Seismic
- Proposals being Reviewed on the Topic
- RPSEA Advisory Body Input (USC, Stanford)

Risk from Hydraulic Fracturing and/or Water Disposal Being Assessed.

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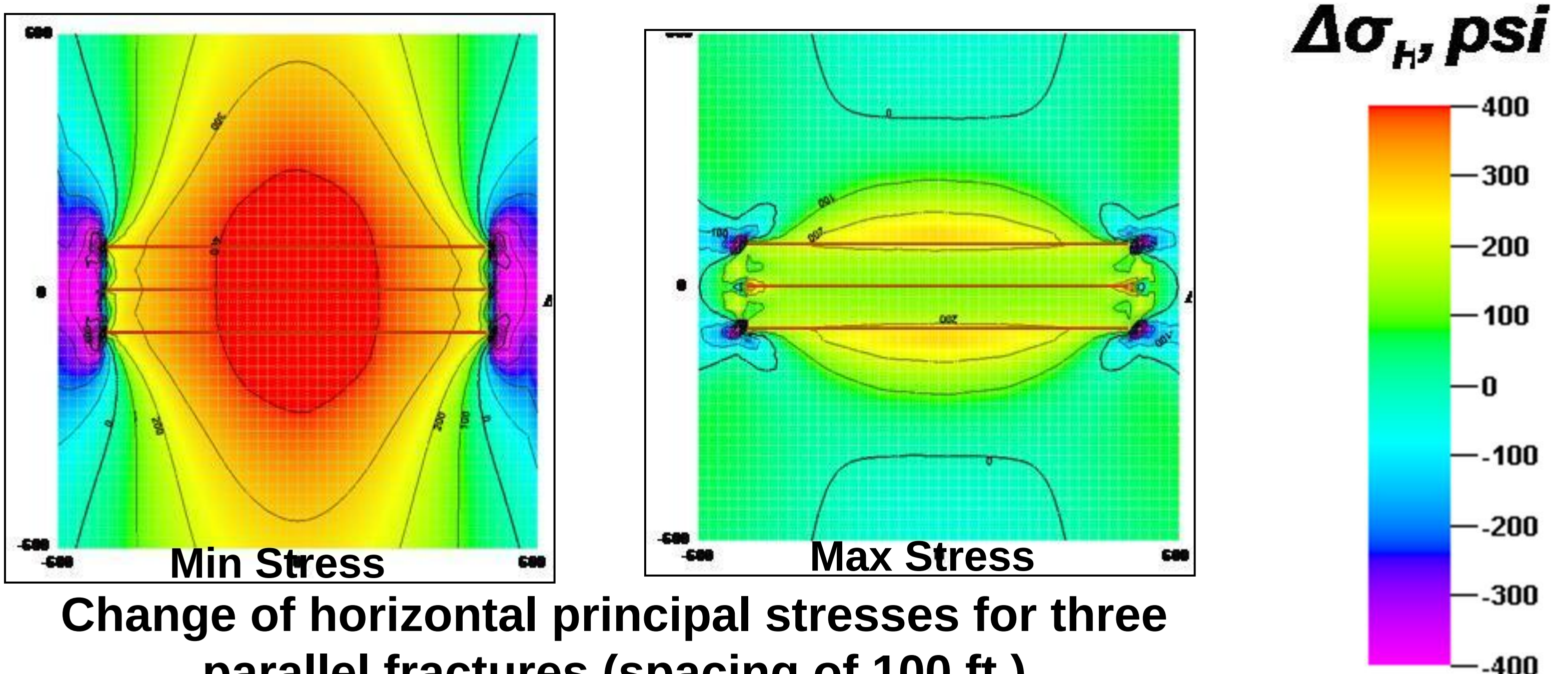
What Really Happens During Stimulation?

- 7 Wellbores; 100 HF Treatments; Thousands of Microseismic Events
- Formation Properties, Clay, Lubricity, Fault Size and Geometry.

Video

Prediction of Fault Reactivation in Hydraulic Fracturing of Horizontal Wells in Shale Gas Reservoirs



Change of horizontal principal stresses for three parallel fractures (spacing of 100 ft)

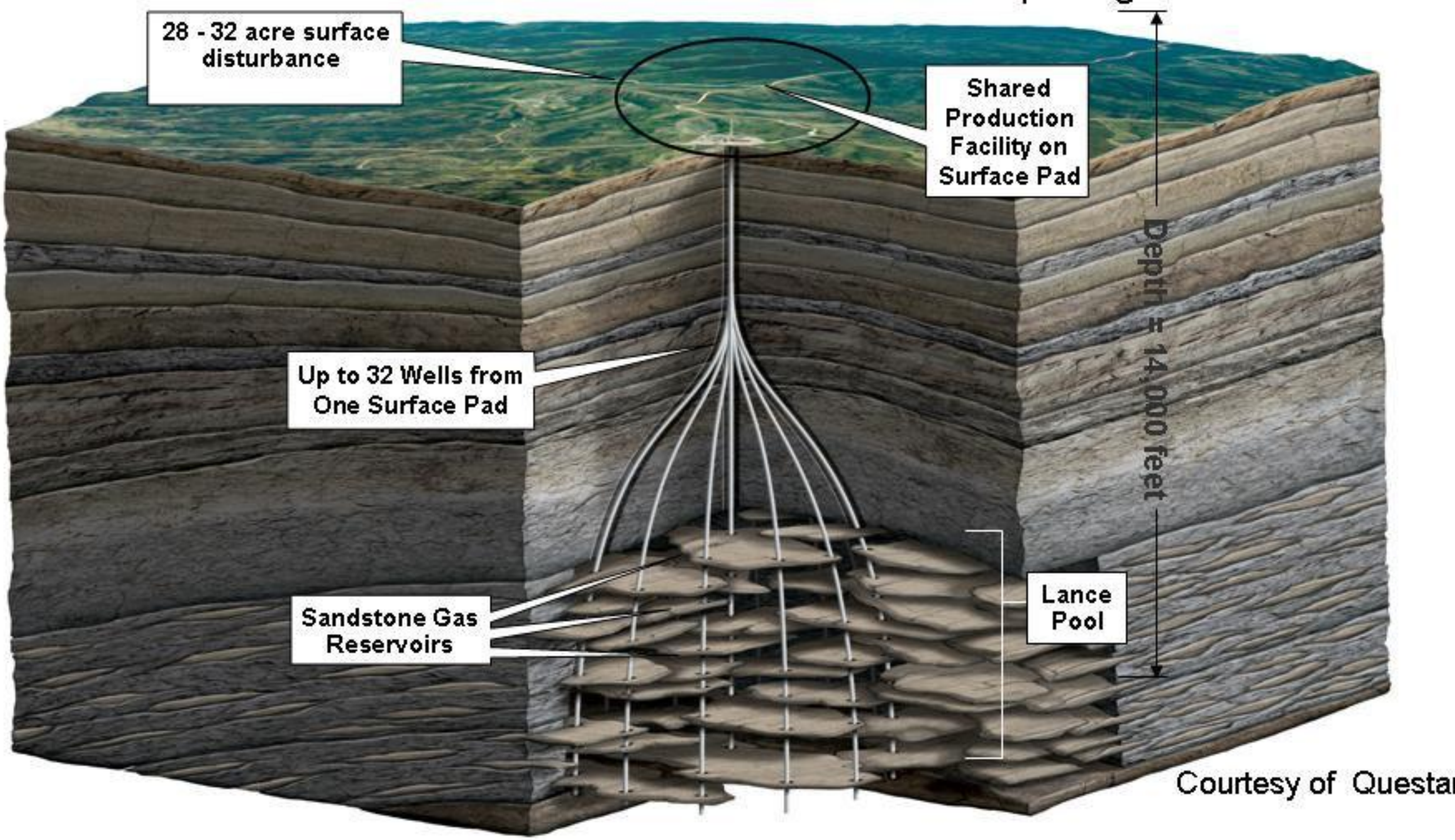
Both maximum and minimum horizontal principle stresses have been significantly changed after one stage

The induced stress field change in the fracturing process has significant effects on the geometries of created multiple fractures

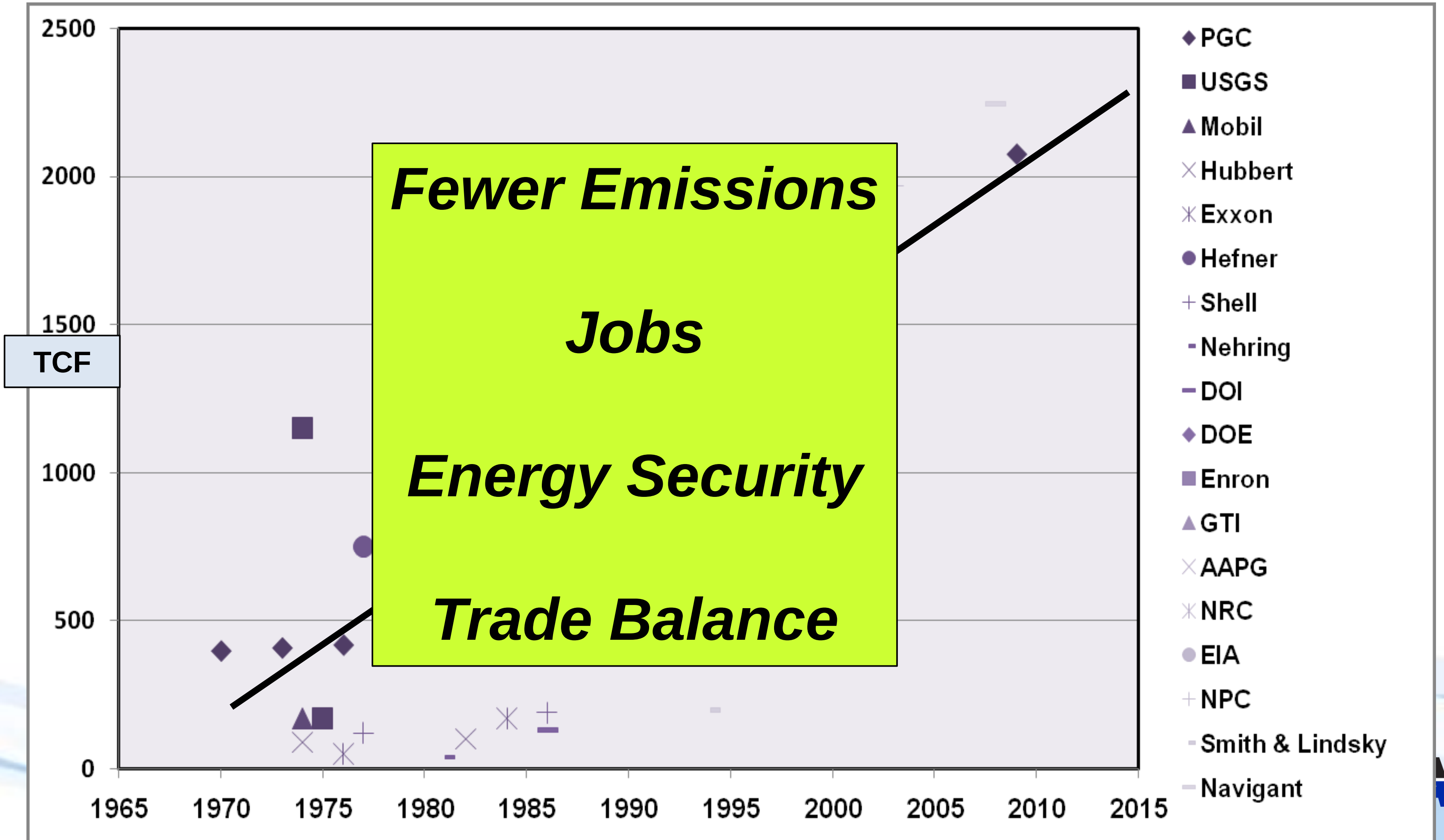
Responsible Energy Development = It can be done

Multiple directional wells from one pad:

- Minimizes surface disturbance
- Identical surface disturbance for 20 or 40 ac. bottom-hole spacing



U. S. Technically Recoverable Gas Resource Base - Tcf



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Thank You

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