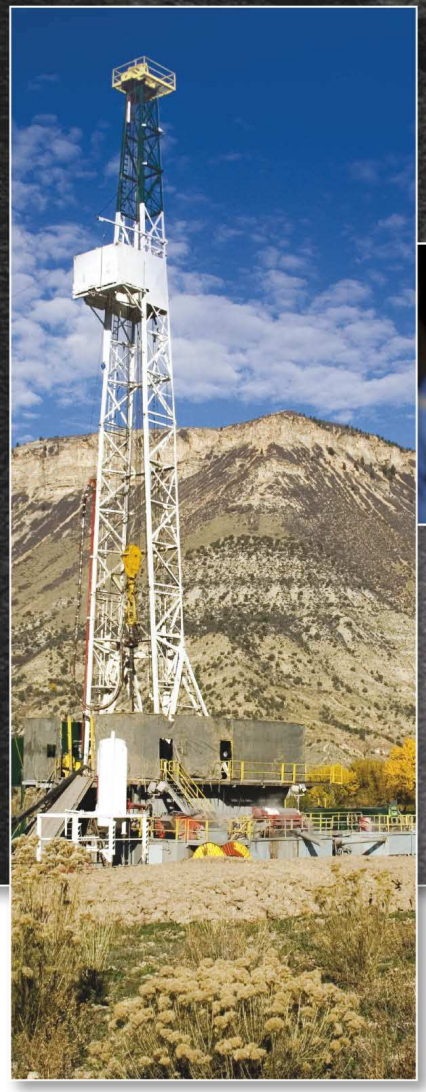
Unconventional Resources



Innovative Stimulation Technology for Future Energy – More with Less

Liu Hai

General Manager, Schlumberger Well Services, North Asia

Schlumberger

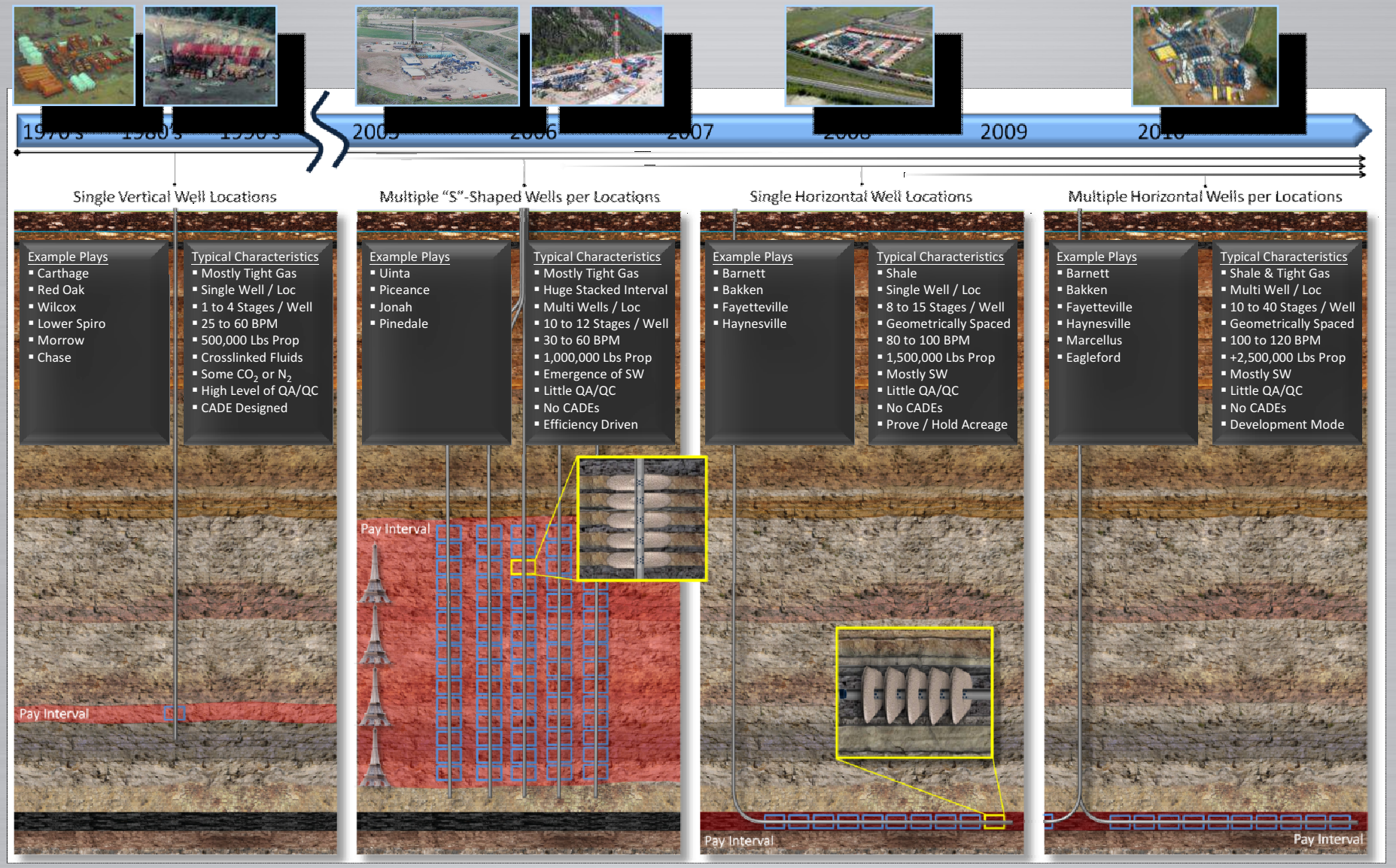
Background of Hydraulic Fracturing

First Generation

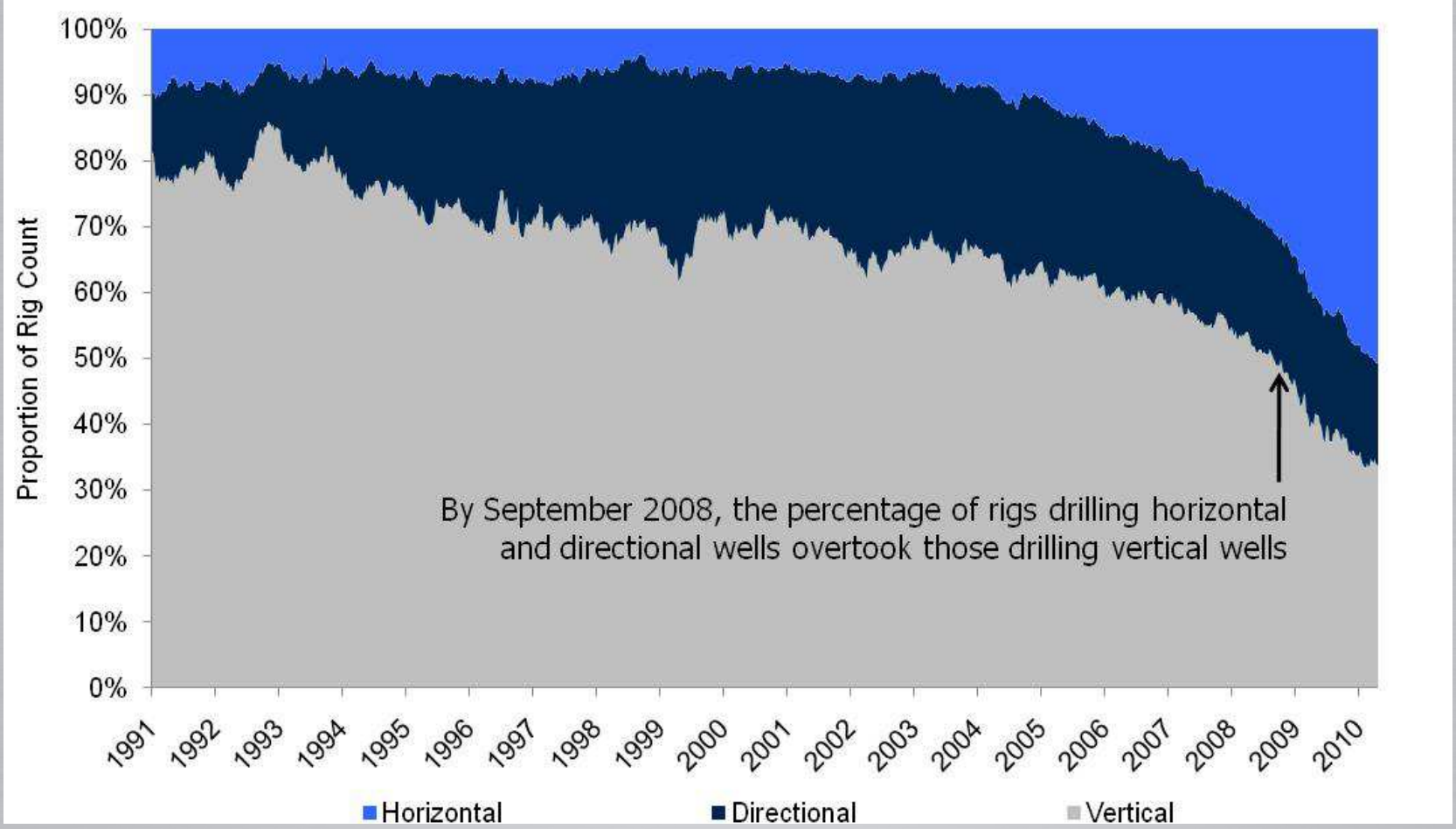
- July 1947: Hugoton Gas Field, Grant County, Kansas
- Small Treatments to Bypass Formation Damage
- Minimal Sophisticated Engineering

Second Generation

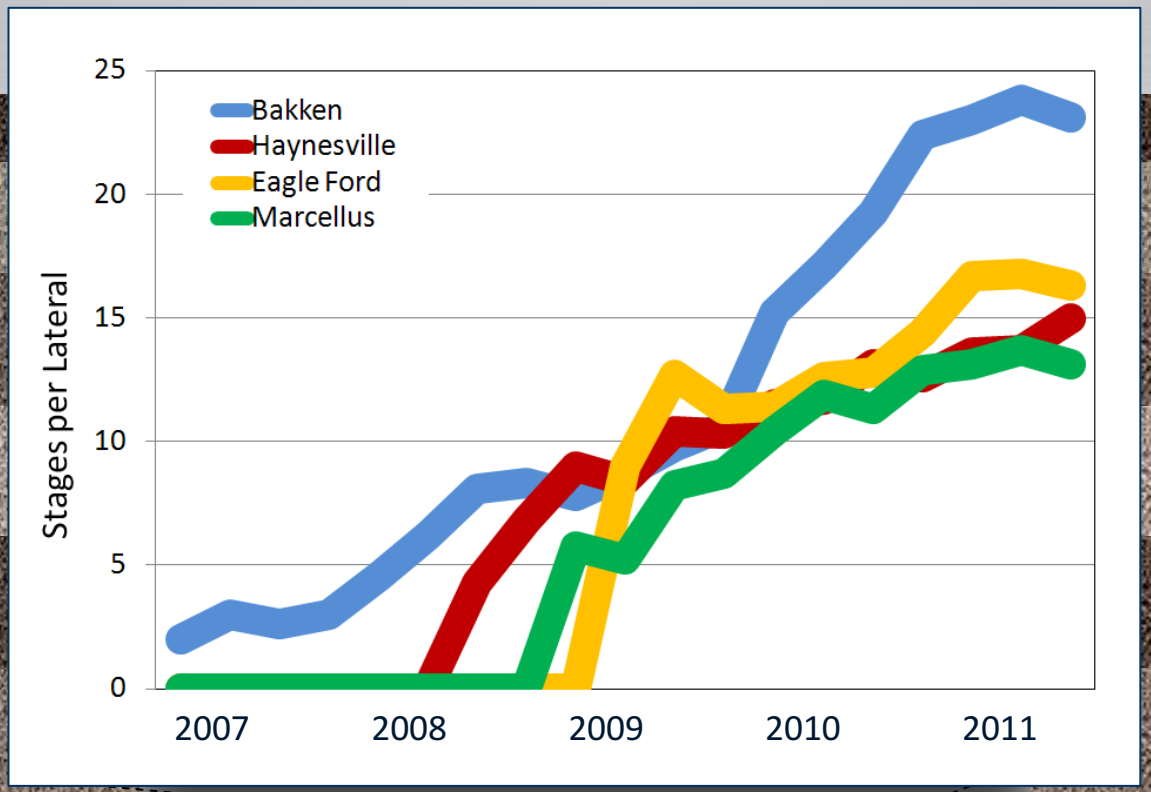
Evolution of Hydraulic Fracturing in N. America



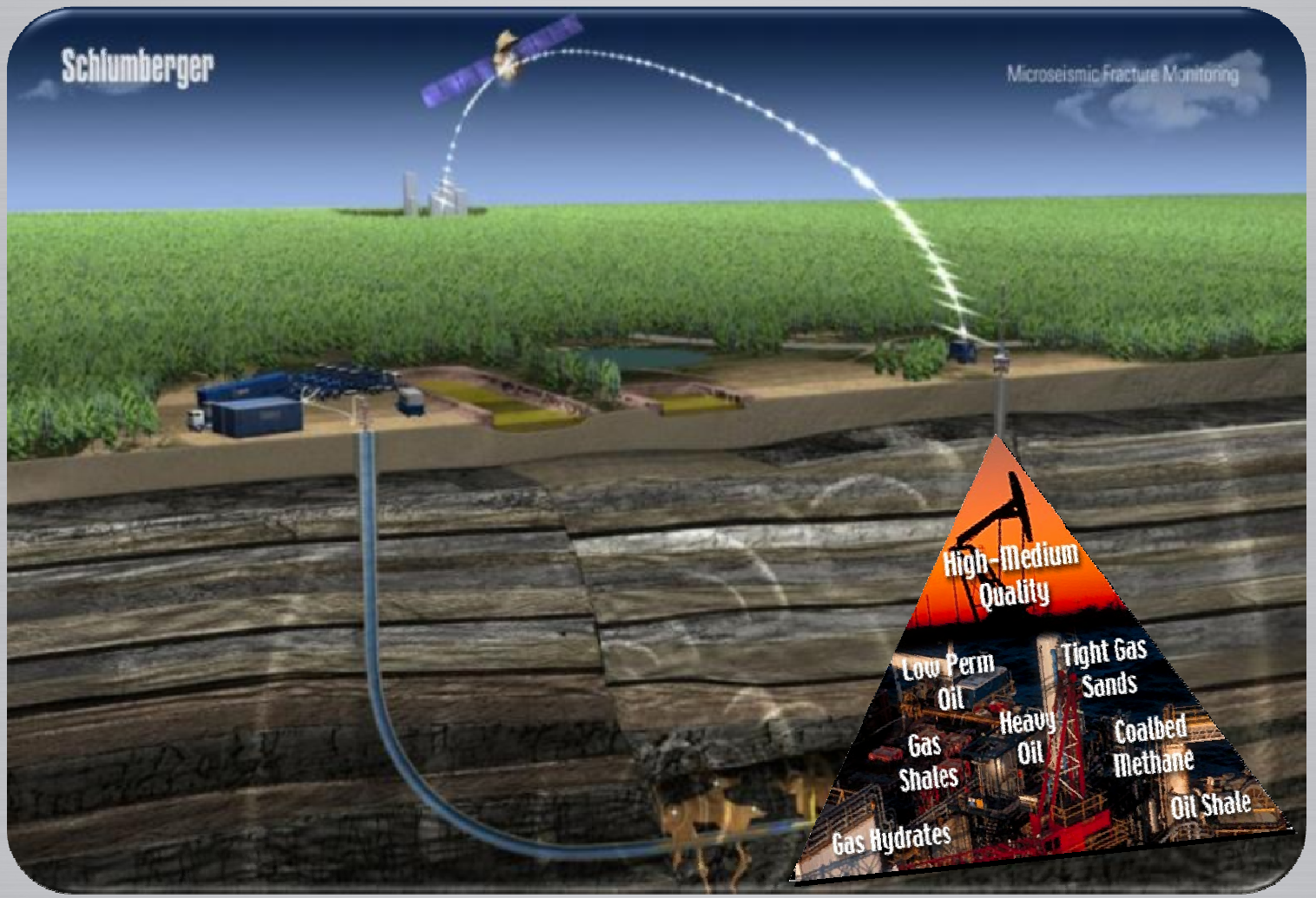
Horizontal rig count started to climb with Shales



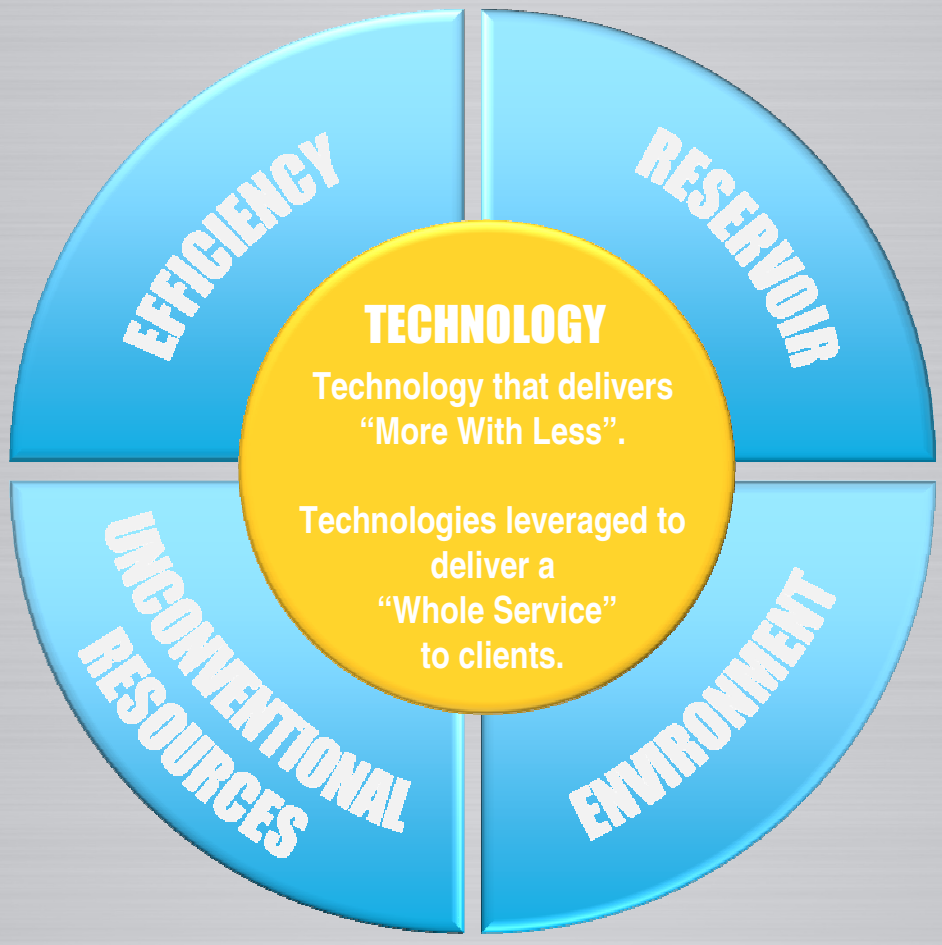
Gas Shale Well Completions



Stimulating the Future of Energy



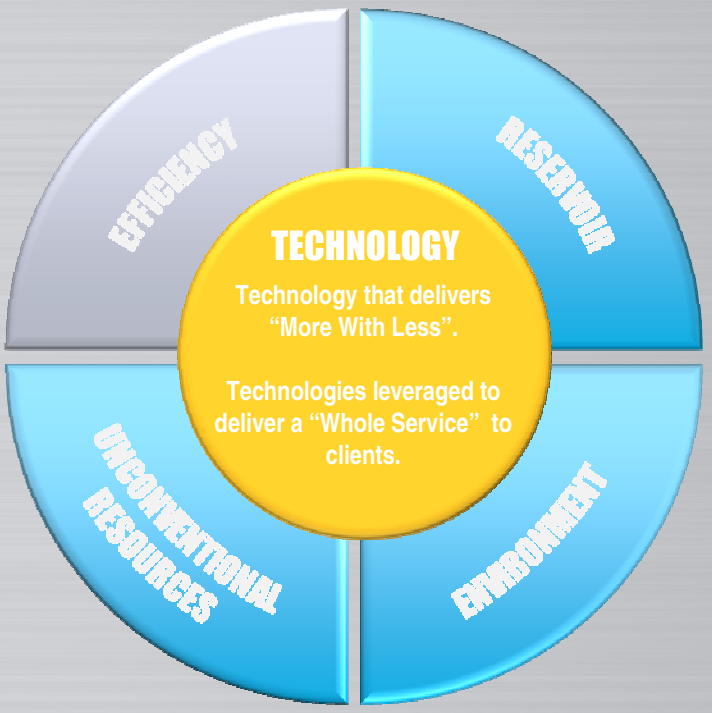
Future Stimulation Vision



Efficiency

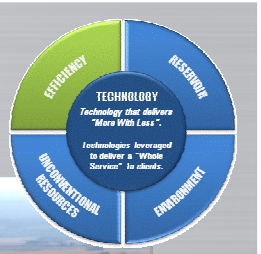
Efficiencies are crucial for unconventional plays…

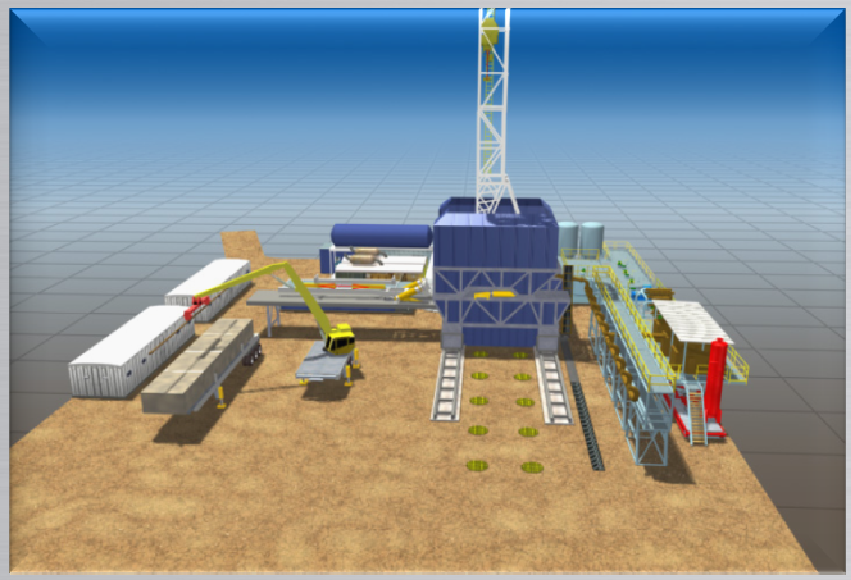
- Surface operations
- Downhole placement
- Treatment effectiveness



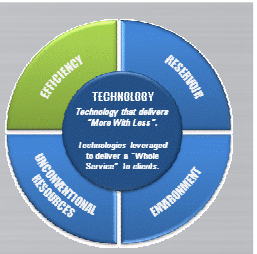
Surface Efficiencies

- 24 Hour Operations
- Factory Completions
- Fit for Purpose Equipment

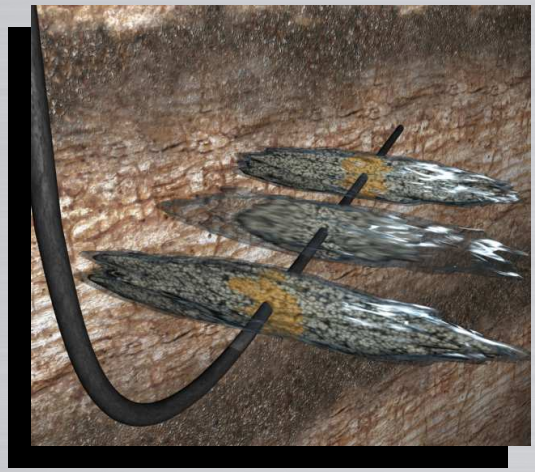


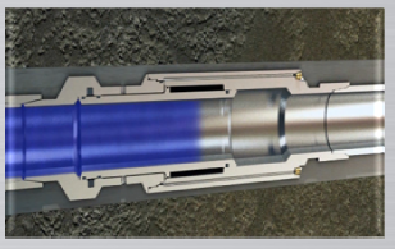


Downhole Placement Efficiency

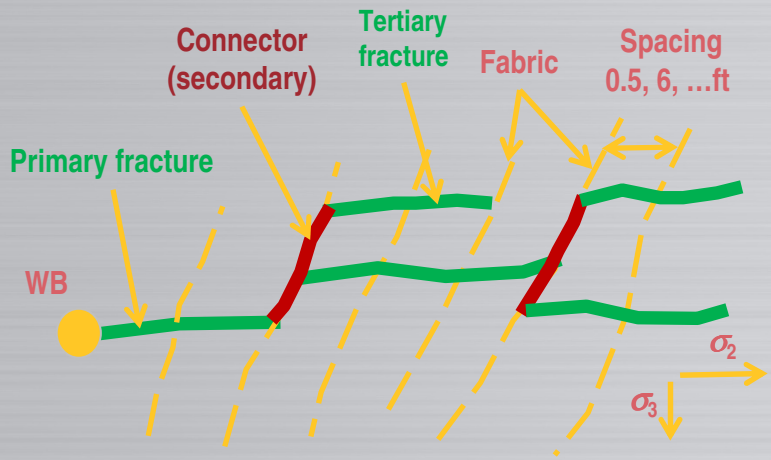


- Unlimited zones/stages
- Open and cased hole independent
- Extend length of horizontal wells
- Short cycle time

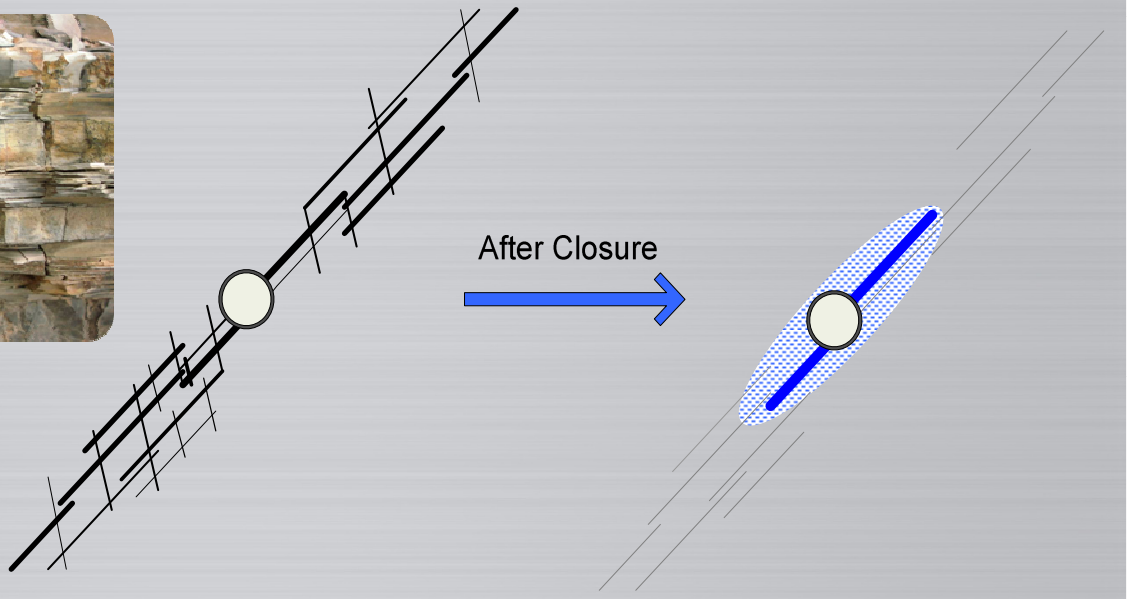




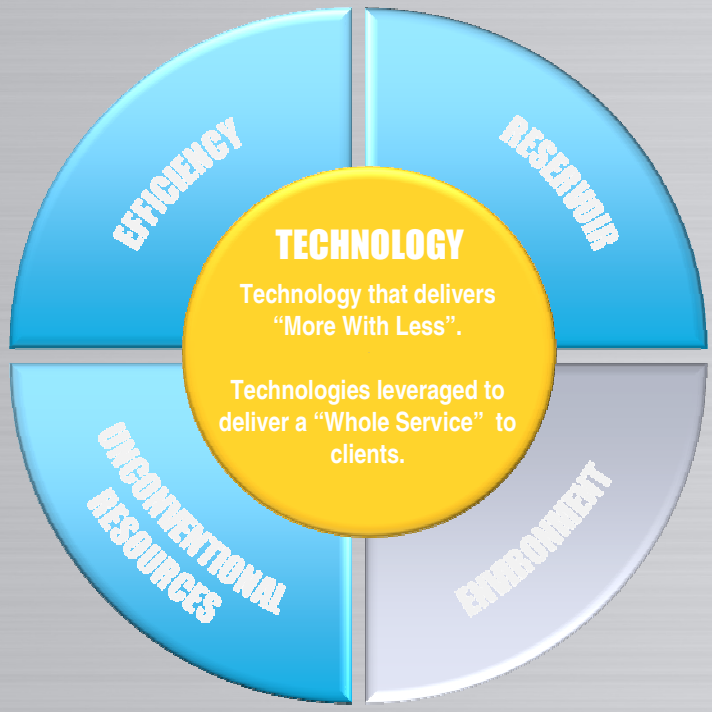
Treatment Efficiency



- Surface area is critical for production
- Efficiency per frac stage has not significantly increased
  - We create 80 – 100 million ft^2 of fracture surface area
  - We produce from 6 – 10 million ft^2



Environment



- Chemical transparency
- Environmental profile
- Footprint reduction

Public Questioning the Industry

SPIEGEL ONLINE - Druckversion - Gasbohrung: US-Konzern presste giftige Chemi... Page 1 of 3

Gasbohrung

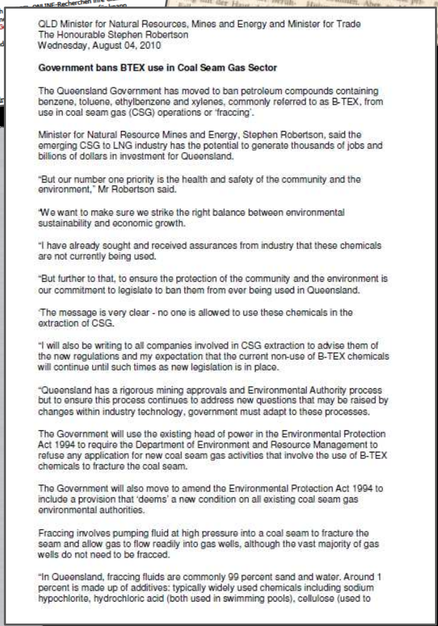
US-Konzern presste giftige Chemikalien in Niedersachsens Boden

Von Stefan Schultz

Gift bei Bohrung beunruhigt Damme

Exxon Mobil setzt bei Erdgas-Suche im Borringhauser Moor gefährliche Chemikalien ein

Da war die Welt noch in Ordnung:



QLD Minister for Natural Resources, Mines and Energy and Minister for Trade
The Honourable Stephen Robertson
Wednesday, August 04, 2010

Government bans BTEX use in Coal Seam Gas Sector

The Queensland Government has moved to ban petroleum compounds containing benzene, toluene, ethylbenzene and xylenes, commonly referred to as B-TEX, from use in coal seam gas (CSG) operations or 'fraccing'.

Minister for Natural Resource Mines and Energy, Stephen Robertson, said the emerging CSG to LNG industry has the potential to generate thousands of jobs and billions of dollars in investment for Queensland.

"But our number one priority is the health and safety of the community and the environment," Mr Robertson said.

"We want to make sure we strike the right balance between environmental sustainability and economic growth.

"I have already sought and received assurances from industry that these chemicals are not currently being used.

"But further to that, to ensure the protection of the community and the environment is our commitment to legislate to ban them from ever being used in Queensland.

"The message is very clear - no one is allowed to use these chemicals in the extraction of CSG.

"I will also be writing to all companies involved in CSG extraction to advise them of the new regulations and my expectation that the current non-use of B-TEX chemicals will continue until such times as new legislation is in place.

"Queensland has a rigorous mining approvals and Environmental Authority process but to ensure this process continues to address new questions that may be raised by changes within industry technology, government must adapt to these processes.

The Government will use the existing head of power in the Environmental Protection Act 1994 to require the Department of Environment and Resource Management to refuse any application for new coal seam gas activities that involve the use of B-TEX chemicals to fracture the coal seam.

The Government will also move to amend the Environmental Protection Act 1994 to include a provision that 'deems' a new condition on all existing coal seam gas environmental authorities.

Fraccing involves pumping fluid at high pressure into a coal seam to fracture the seam and allow gas to flow readily into gas wells, although the vast majority of gas wells do not need to be fracced.

"In Queensland, fraccing fluids are commonly 99 percent sand and water. Around 1 percent is made up of additives: typically widely used chemicals including sodium hypochlorite, hydrochloric acid (both used in swimming pools), cellulose (used to

6° Six Degrees
Coal & Climate Campaign

Moratorium on CSG and fracking in US: Queensland government must follow suit

6th of Aug, 2010

A critically important precedent has been set in the US state of New York, with an overwhelming majority of Senators calling for a moratorium on coal seam gas extraction until the environmental impacts can be determined.

The onus is now on the Queensland Government to heed this emerging global consensus.

The Bligh Government must impose an identical moratorium on the controversial process of fracking in the extraction of coal seam gas in Queensland. The process used and the risks of this technology in Queensland and the US are identical. As we have consistently maintained, there is no justification for rushing ahead with gas extraction in Queensland before the science is known and the impacts understood.

The New York State Senate voted 48 to 9 Tuesday night to issue a moratorium on a type of natural gas exploration that uses hydraulic fracturing and the injection of millions of gallons of chemically treated water underground, following public protests about drilling occurrring in the catchment of New York's water supply.

The moratorium will be put in place to give time for a comprehensive review of safety and environmental concerns since fracking (or hydraulic fracturing) has been blamed for contaminating water supplies and endangering human health, especially in the Rocky Mountains states. In effect, the moratorium will prevent new drilling permits from being issued until May 15, 2011 at the earliest.

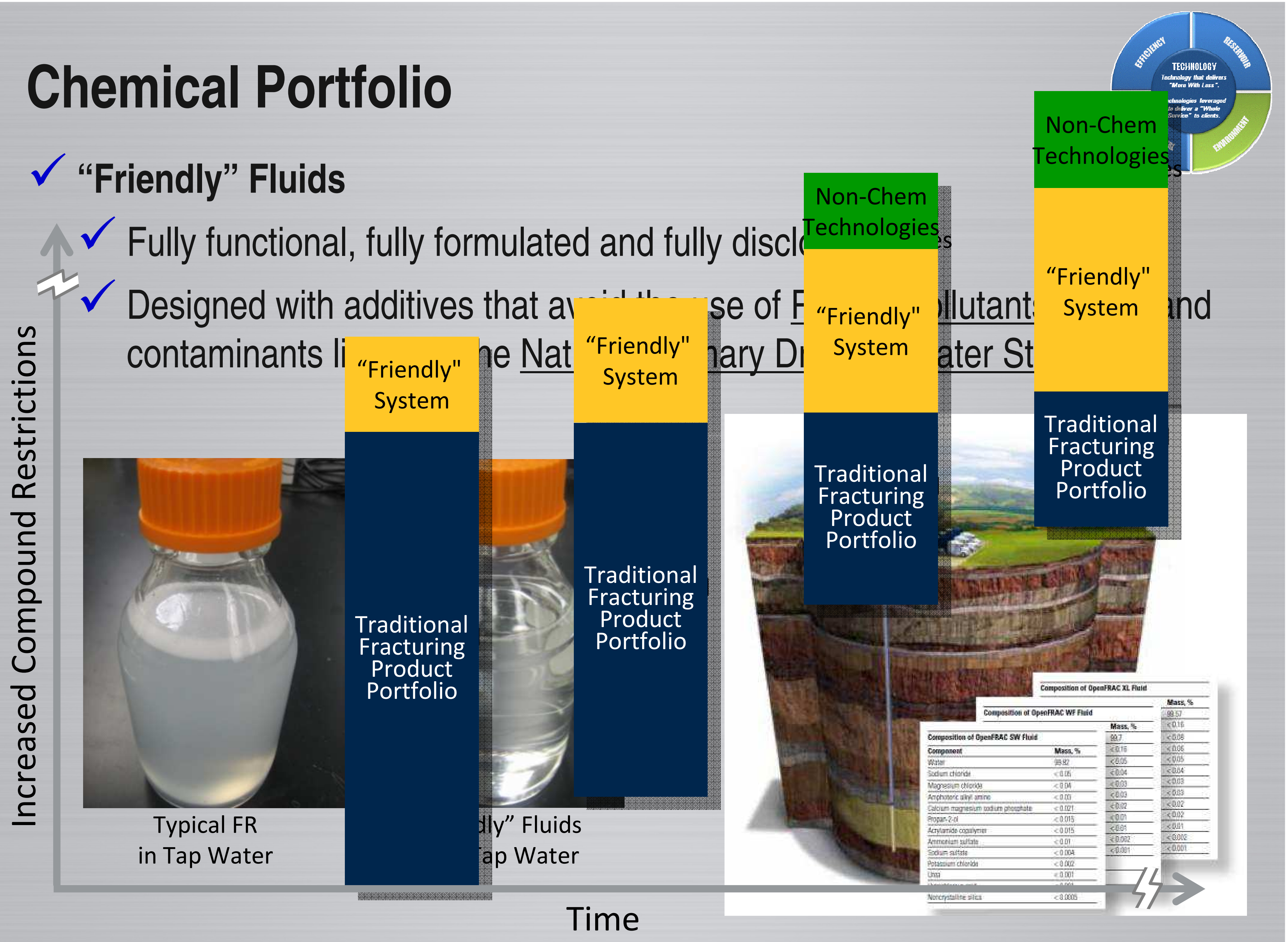
Queensland farmers and environmentalists alike are highly concerned the process, which involves setting off explosions underground to better release the coal seam gas, will increase the inter-connectedness of aquifers and could contaminate fresh groundwater supplies used for farming and town water.

According to Six Degrees spokesperson Drew Hutton, the decision of the New York State Senate sends a powerful message to the Queensland Government about the need for due process:

> *There is no difference between the fracking process in the US and here in the Surat Basin.*
>
> *The same companies are doing it, the same chemicals are being used and there is a similar reluctance on the part of the companies to tell communities, or even the regulators, what chemicals are in the fracking fluids.*

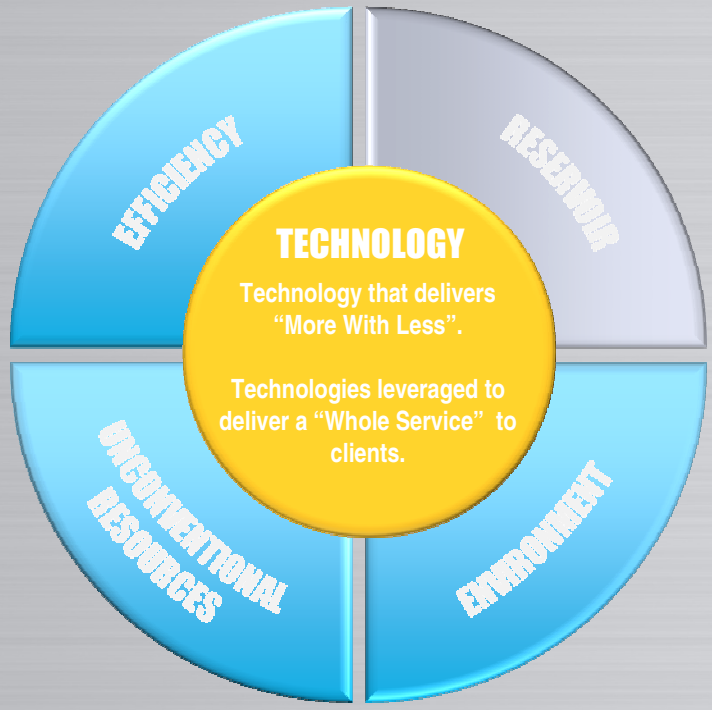
Chemical Portfolio

- ✓ **“Friendly” Fluids**
  - ✓ Fully functional, fully formulated and fully discl
  - ✓ Designed with additives that av se of P llutants and contaminants li he Nat ary Dr ater St



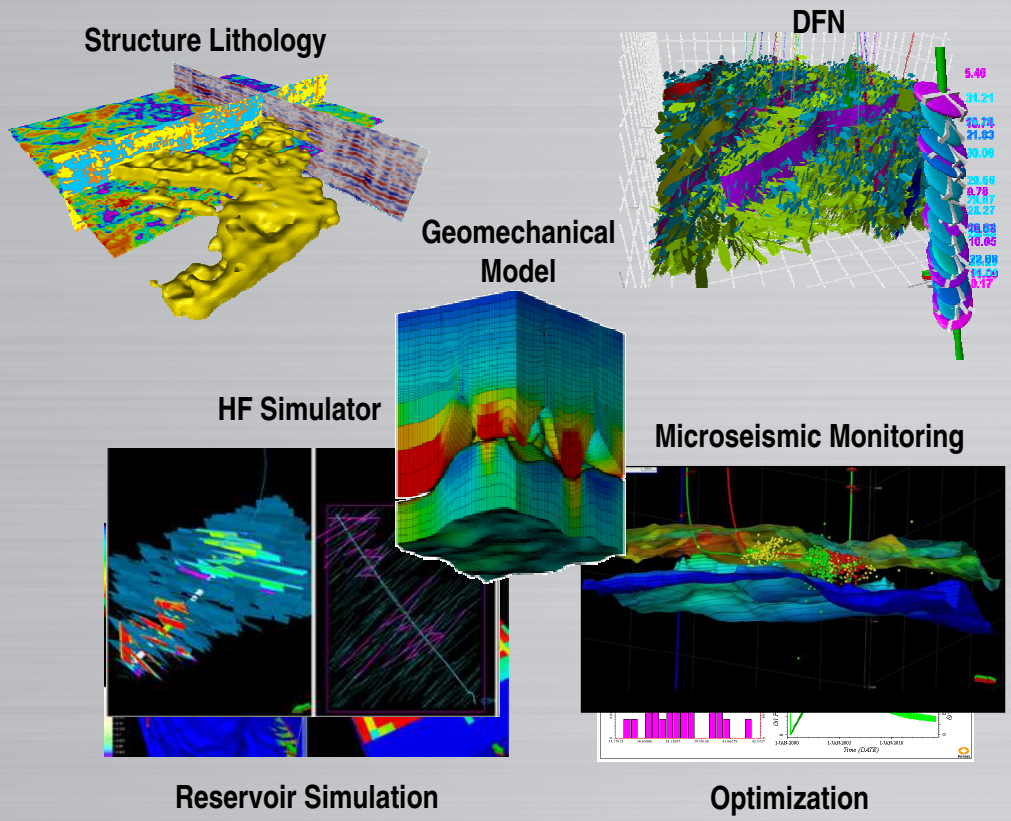
Environmentally Engineered Fracturing

Reservoir Focused Stimulation Methodology



- *Workflows and optimization*
- *Reservoir specific technology*
- *A stimulation domain*

Establishing Fracturing in Reservoir Workflows
Leveraging Petrel



Leverage Seismic-to-simulation modeling workflow

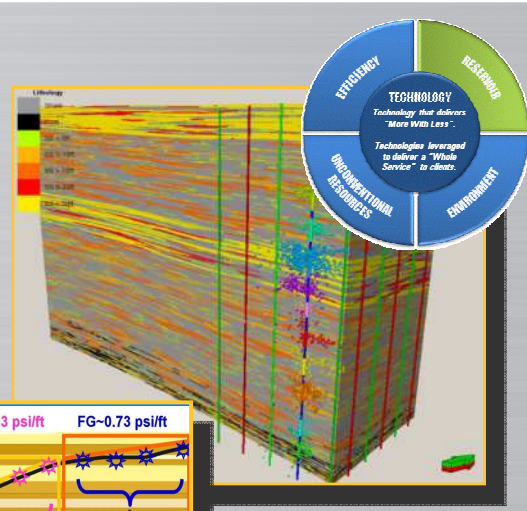
New HF stimulator:

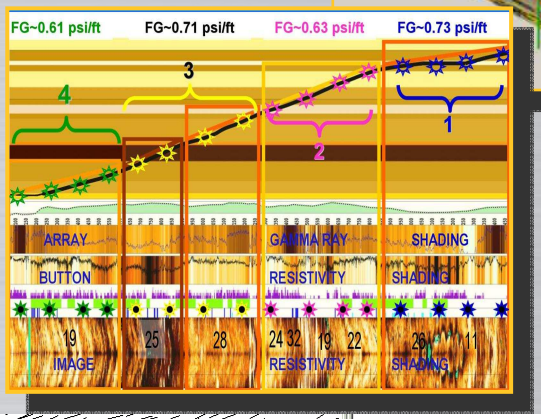
- Inserts stimulation tools and workflows into the reservoir context
- Enables evaluation of the effect of optimized multi-stage stimulation treatments

New HF Simulator: Key Components

Multistage Optimization

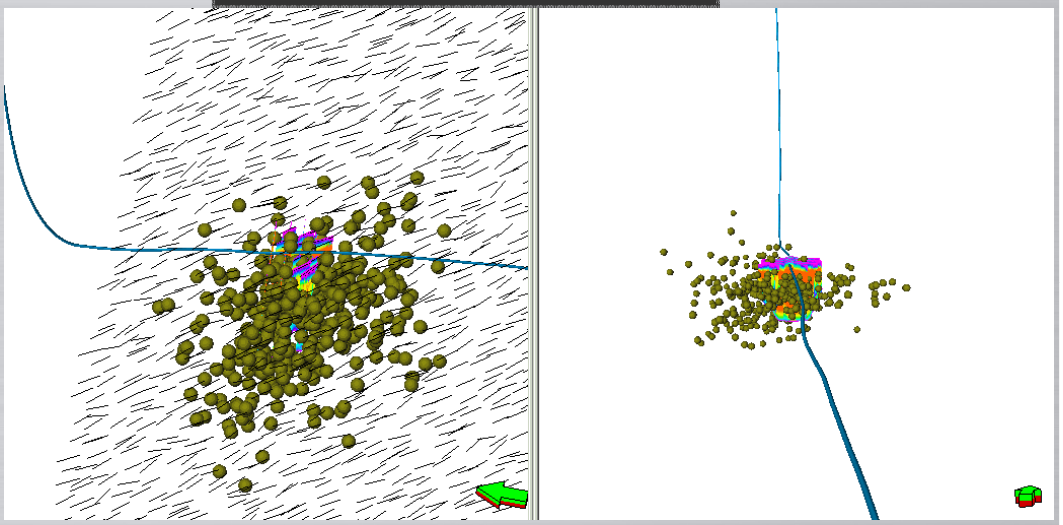
- Staging and perforation design based on reservoir characterization for
  - Horizontal wells
  - Vertical wells



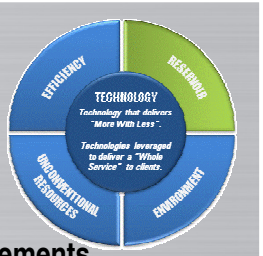


Fracture Models

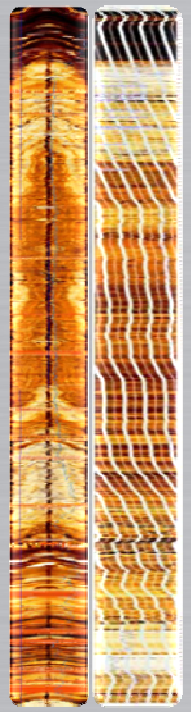
- Fit-for-purpose and Rigorous
  - Natural fractures
  - Stress anisotropy differences

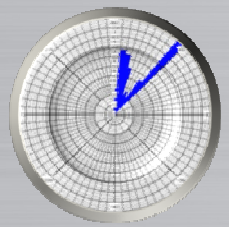


Technology is Changing the Landscape

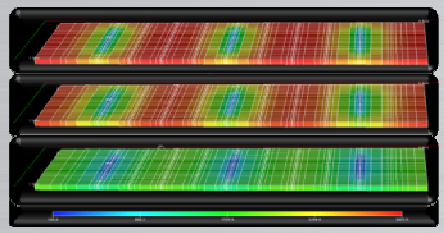


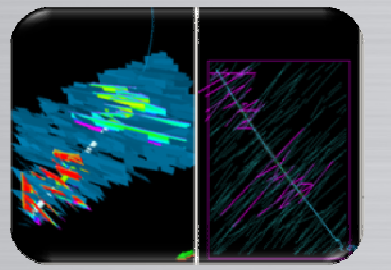
Evaluation

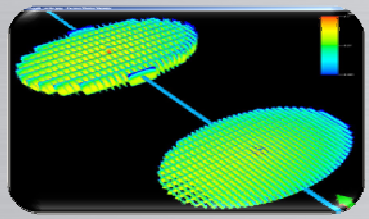




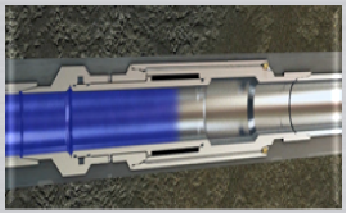
Modeling & Design



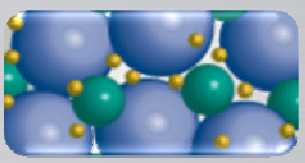


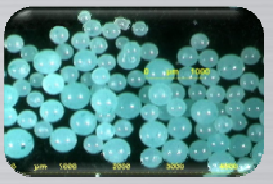


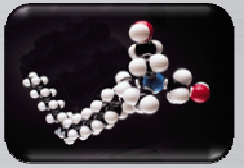
Placement



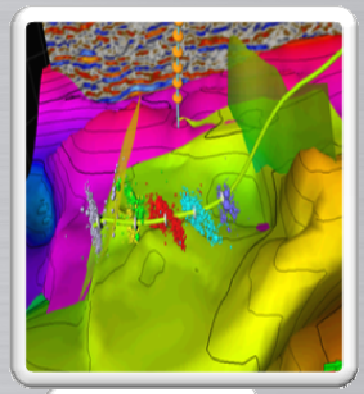
Chemistry & Materials

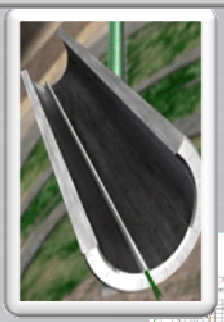


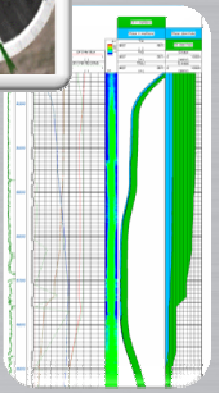




Measurements

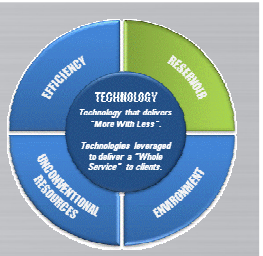




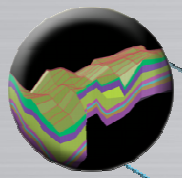


The Stimulation Domain:

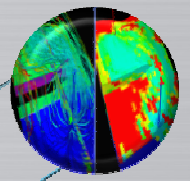
Connecting the Pieces and Delivering the Value of Technology



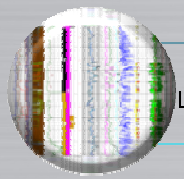
Fracture Stimulation
Conductivity, fluids, chemistry



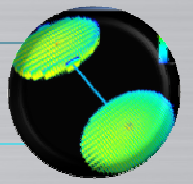
Geomechanics
Stress anisotropy, Fracture Mechanics



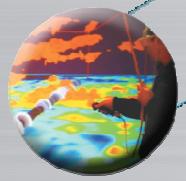
Reservoir Engineering
Permeability, Pore pressure, Reservoir Fluids



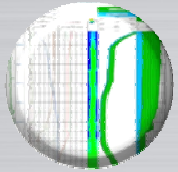
Petrophysics
Lithology, Porosity, Fabric, Natural fracture density



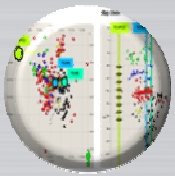
Modeling
Complex fracture models
Well & Reservoir Performance



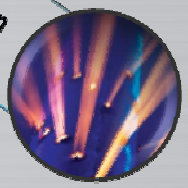
Well Placement
Staying in zone, Short radius



Evaluation
HFM, Production logs, Production history matching

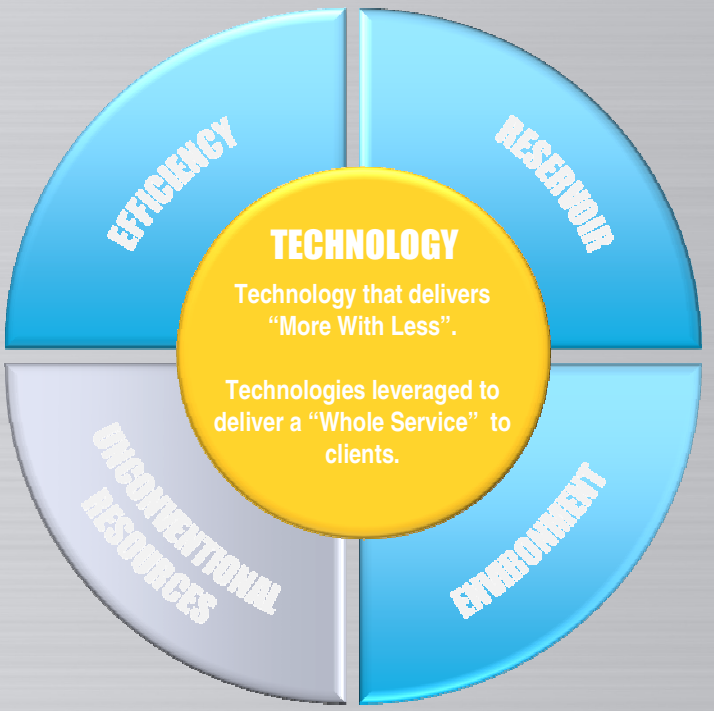


Wellbore Connection
Perforation, slots, sleeves



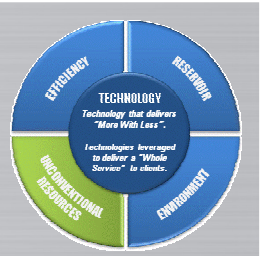
Unconventional Reservoirs

- Largest growth market
- Largest dependency on stimulation
- Dependency on technology advancement

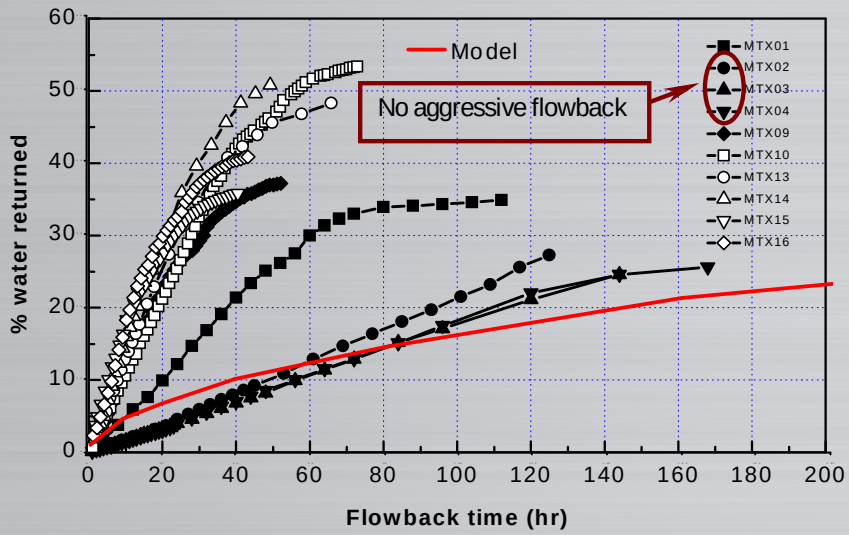


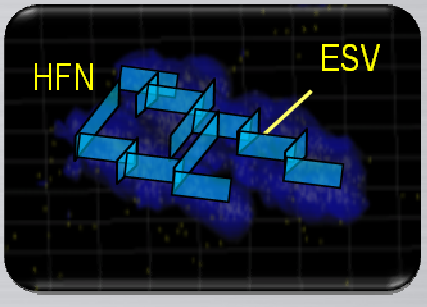
Tight Gas Carbonate CBM Shale Gas

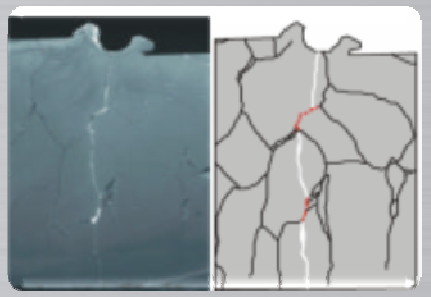
Unconventional Production Mechanisms

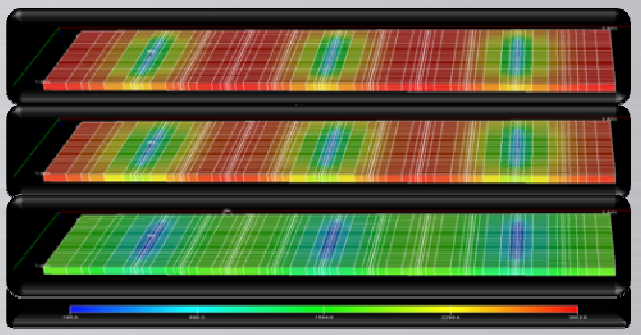


- Shale Gas Flow Mechanisms
- Cleanup, Flowback Mechanisms and Modeling

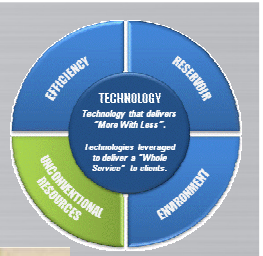






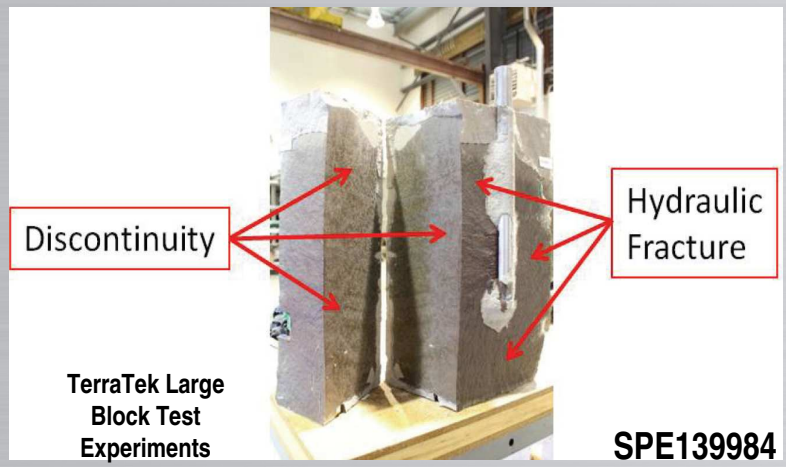


Fracture Geomechanics and Modeling



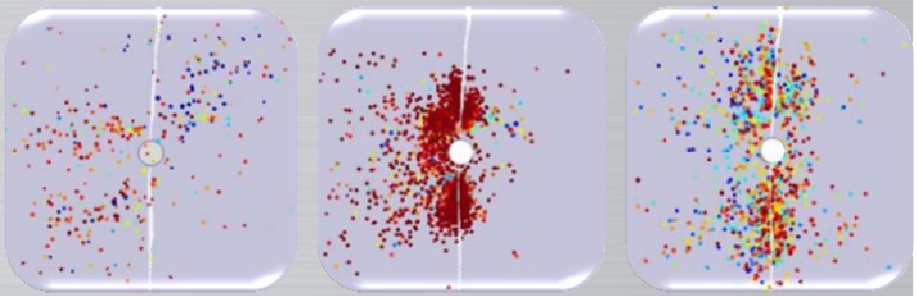
Geomechanics

- Hydraulic Fracture Geometry Prediction
- Proppant Placement
- Impact of :
  - Geometrical complexity (existing NFs)
  - Heterogeneity (variation in properties)
  - 3D stress field



TerraTek Large Block Test Experiments

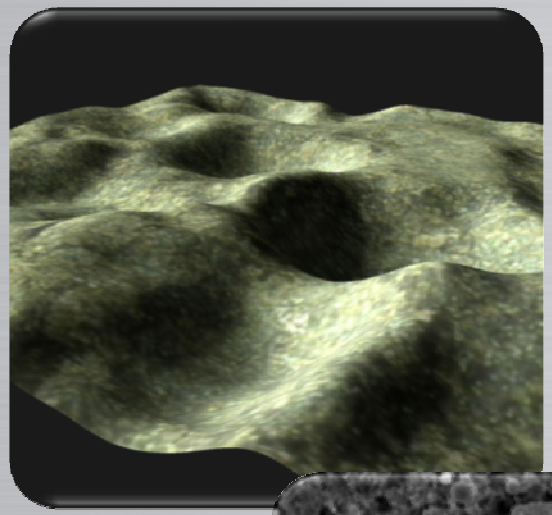
SPE139984



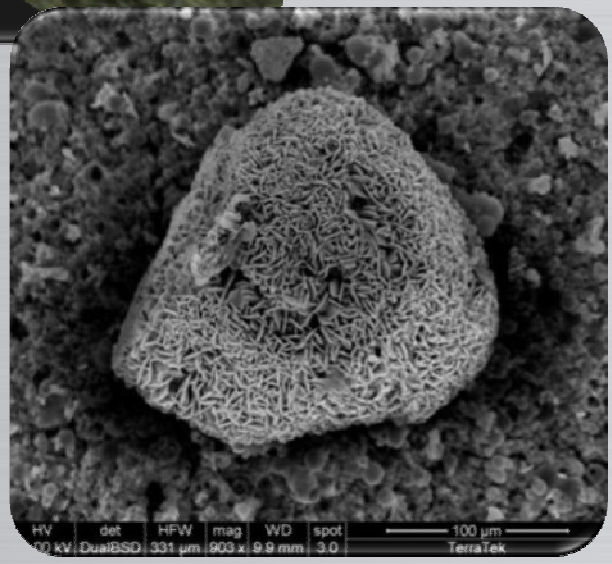
SPE140253

Unconventional Reservoir Chemistry

Improving Productivity in Hydraulic Fractures



A 3D optical microscope image of 40/70 proppant embedment into a Haynesville shale sample



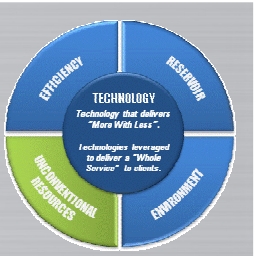
$BaSO_4$ scale deposition on proppant grains recovered during flowback from a Haynesville well

Fluid retention and partitioning

Chemo-mechanical rock failure

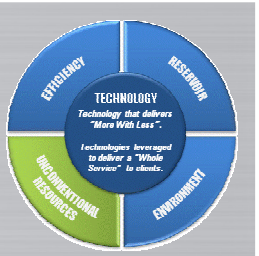
Chemical scale deposition

Geothermal Well Integrity Challenge

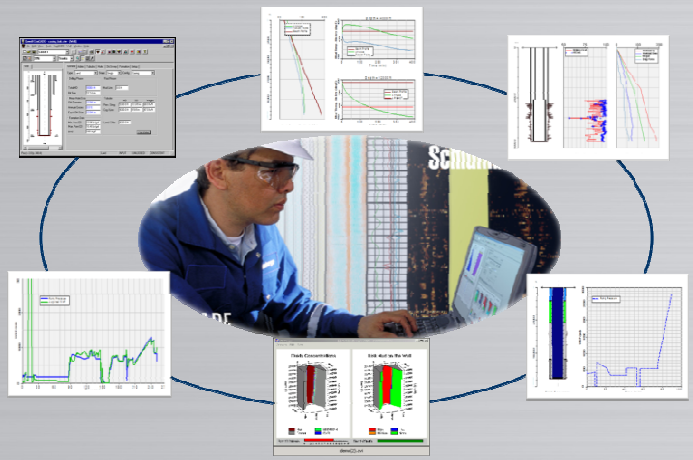


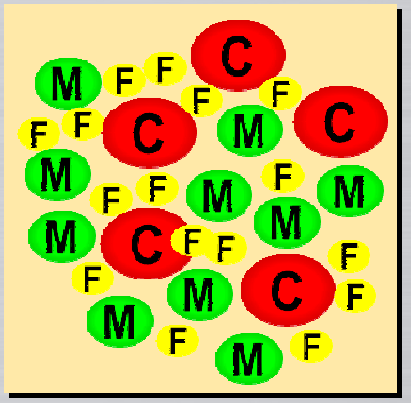
- Challenge
  - Produce hot water or steam
  - Geothermal reservoirs generally naturally fractured
  - Chemistry of Produced fluid
- Consideration on cementing design
  - Potential casing creep
  - HT reservoir
  - Salinity of produced brines/Possibility of dissolved CO2
  - Potential lost circulation

Geothermal Well Integrity Solution

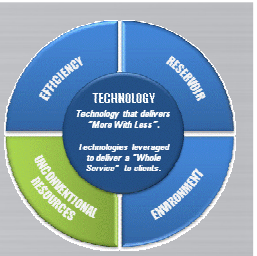


- Casing must cemented to surface
- Best cement practice with engineered design
- Lost circulation solution
- Thermal stable cement with resistance to corrosive brine/CO2



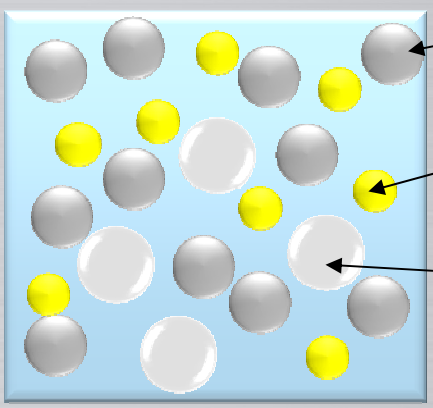


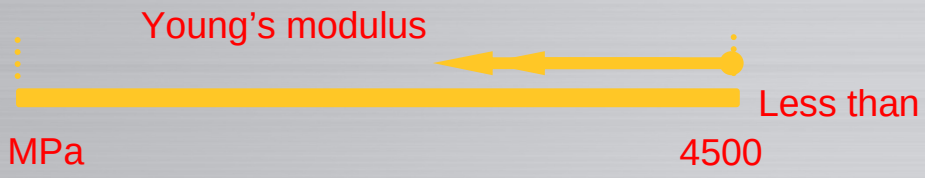
Thermal Stable Cement



Optimized cement based blend

- Thermal Stable
- Low Permeamibility
- High Coefficient of Thermal Expansion
- Utilizes standard cementing equipment





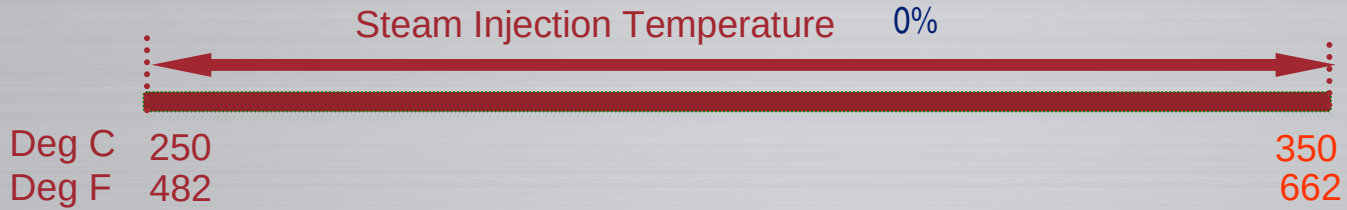


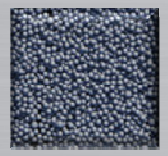
Photo courtesy of EnCana

Innovation for a Step-Change in Conductivity

Incremental improvements in:

- Fluid technology (gel loading, polymer-free)
- Proppant (size, mesh, strength)

Channel Fracturing:
A Paradigm Shift in Hydraulic Fracturing



1950
- **1947** First hydraulic fracturing job
- **1950** Fracturing using gelled oil

1960
- **1960** Water-based, non crosslinked fluids

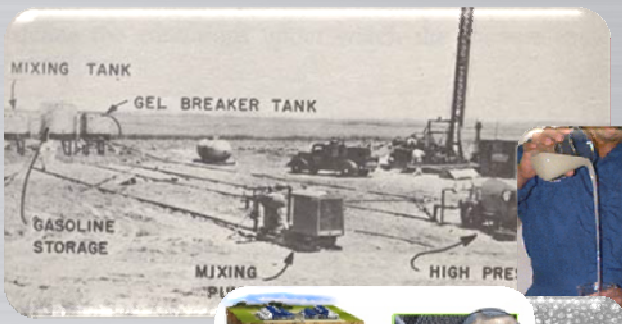
1970
- **1968** Borate crosslinked fluids
- **1973** Crosslinked derivatized guars (HPG, CMHPG, etc)

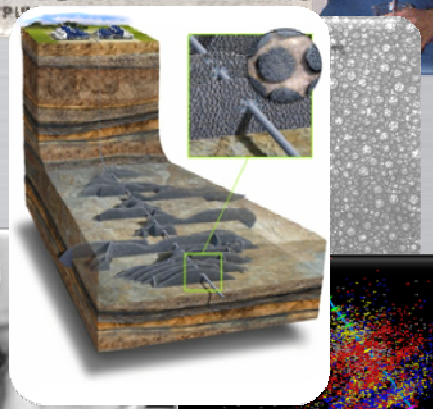
1980
- **1977** High-strength ceramic proppants
- **1980** Foamed fracturing

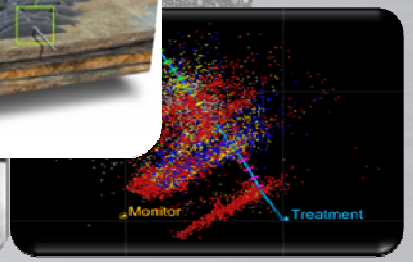
1990
- **1988** Encapsulated breakers
- **1990** Fiber based flowback control
- **1994** Low polymer loadings
- **1997** Viscoelastic surfactants (VES)

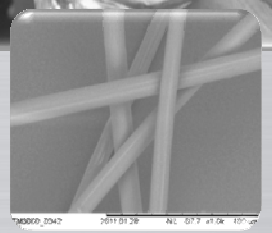
2000
- **2001** Micro-seismic used to monitor frac jobs
- **2003** Horizontal well, multistage fractures
- **2005** Fiber based proppant transport

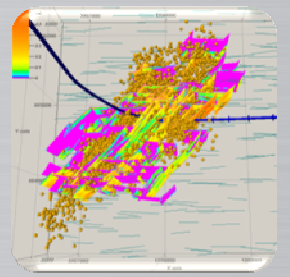
2010
- **2010 Flow-Channel Fracturing**
- **2011** Complex fracture modeling





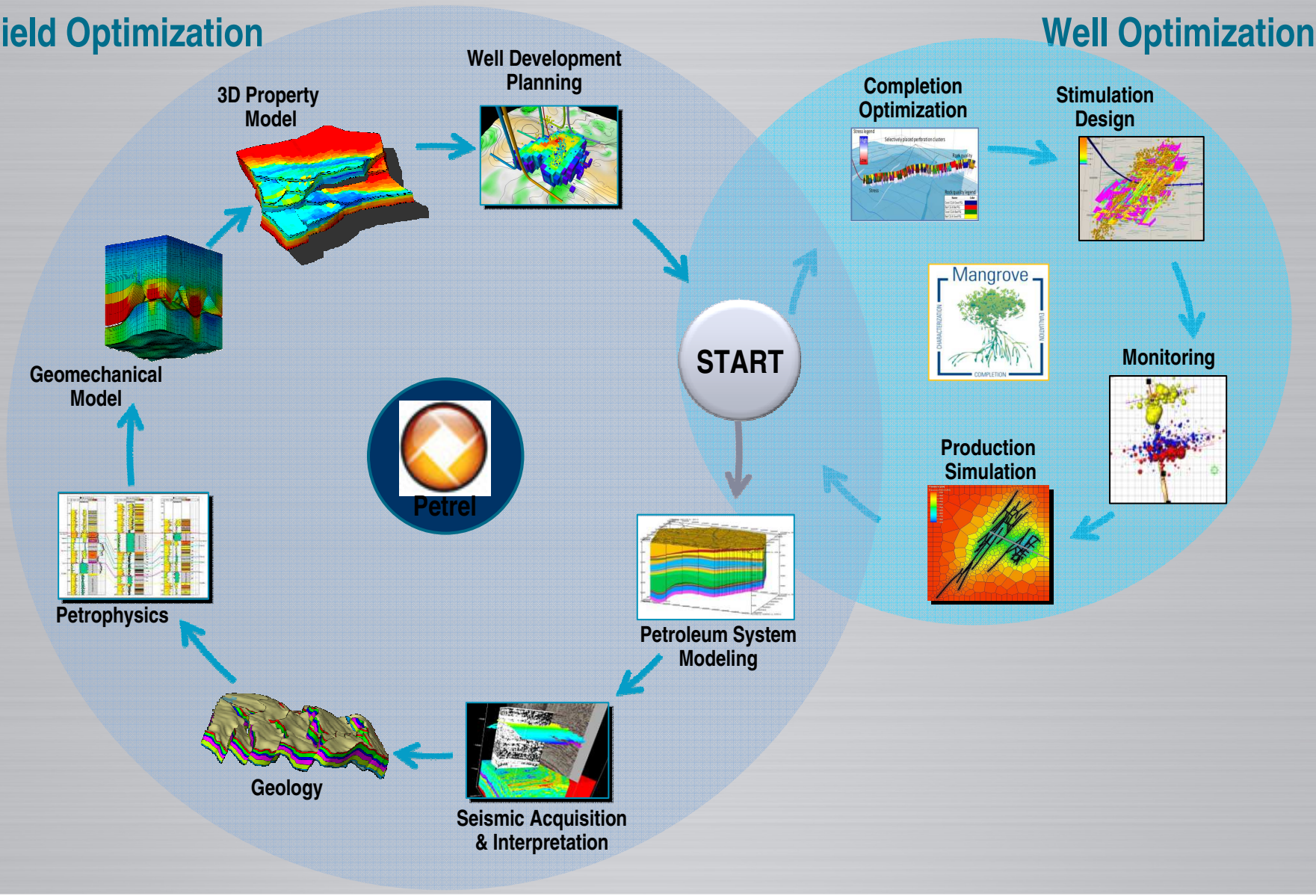






Integrated Technology to Improve Completion

More Optimization Less Waste



Questions & Answers

Thank you for your attention