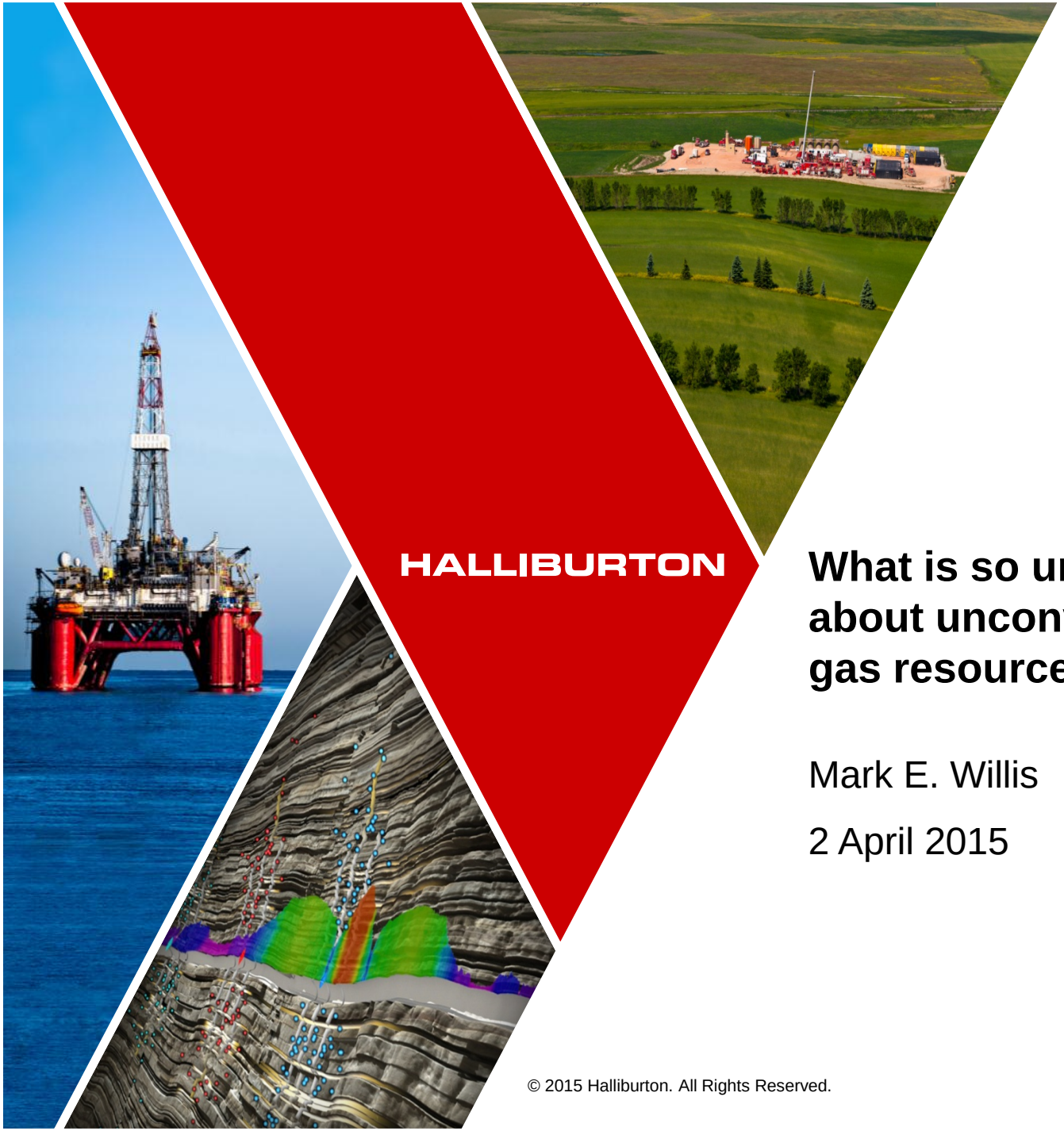

What is so unconventional about unconventional oil and gas resources?

Mark E. Willis

2 April 2015

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Solving challenges.™

Acknowledgements

- Robert Nowack and Purdue for the invitation
- Norm Warpinski, Stephen Galiette, Ken Williams, Ron Dusterholt, and Priyesh Ranjan from Halliburton
- Christine Erlig-Economides from University of Houston

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Outline

- Oil price drop?!—what does that mean?
- What is the difference between resource types?
- Conventional resources
- Unconventional resources

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Outline

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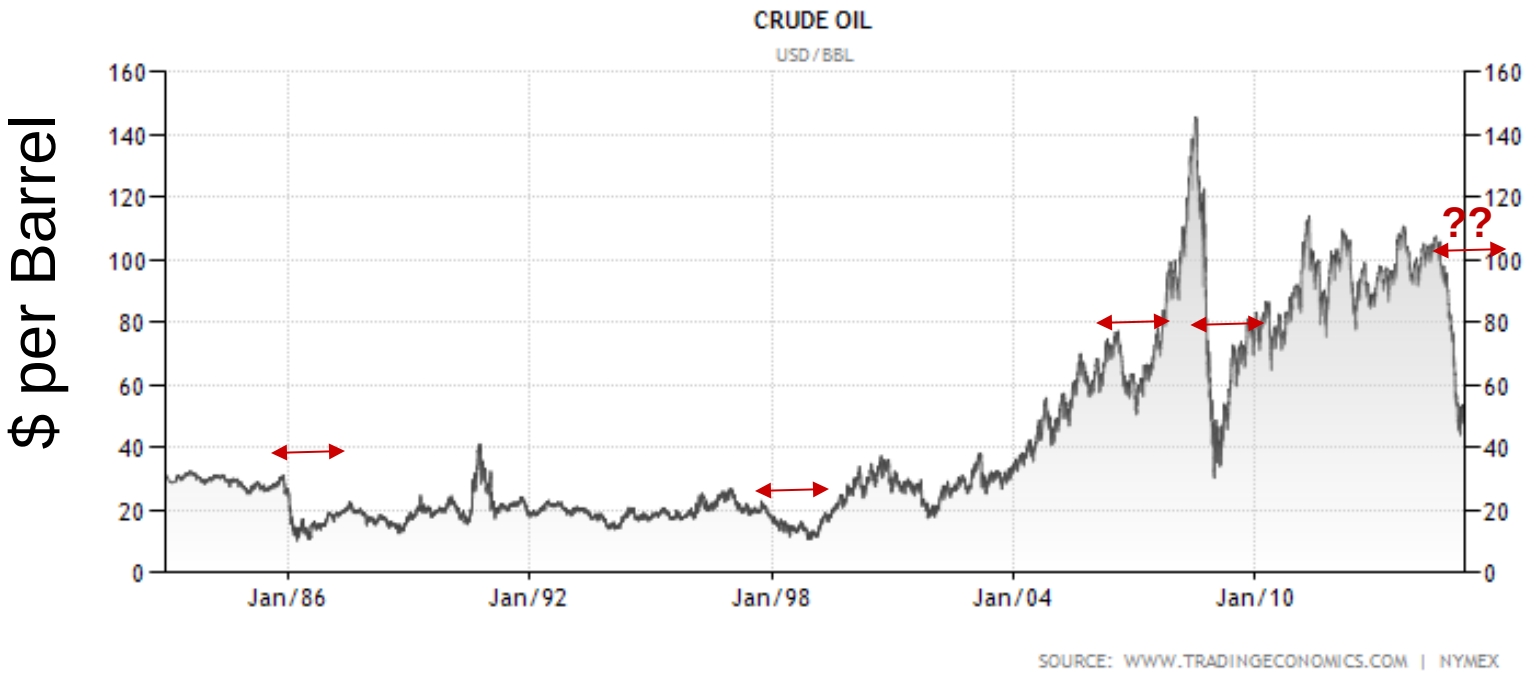
Oil Prices

Some 2 year windows



http://www.tradingeconomics.com/commodity/crude-oil

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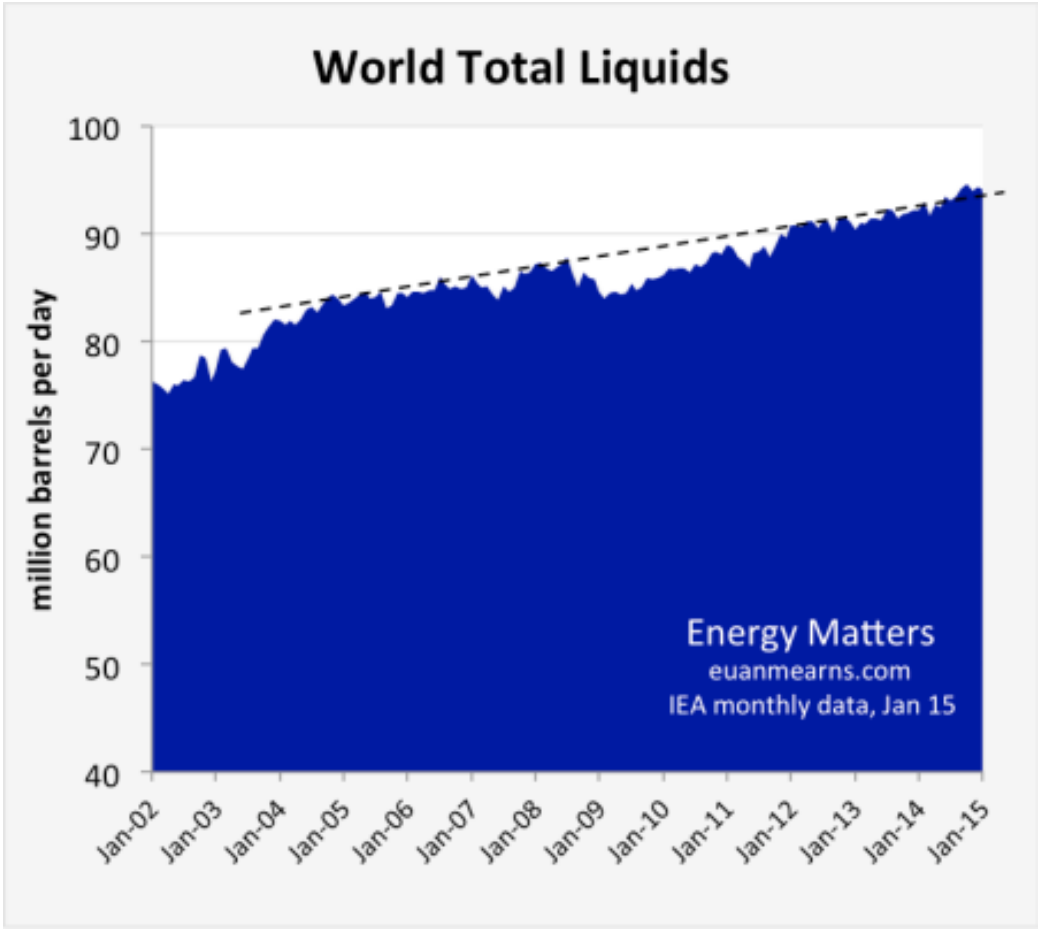
13-Year World Production (2002–2015)



http://oilprice.com/Latest-Energy-News/World-News/Global-Crude-Oil-Production-Growth-Grinding-To-A-Halt.html

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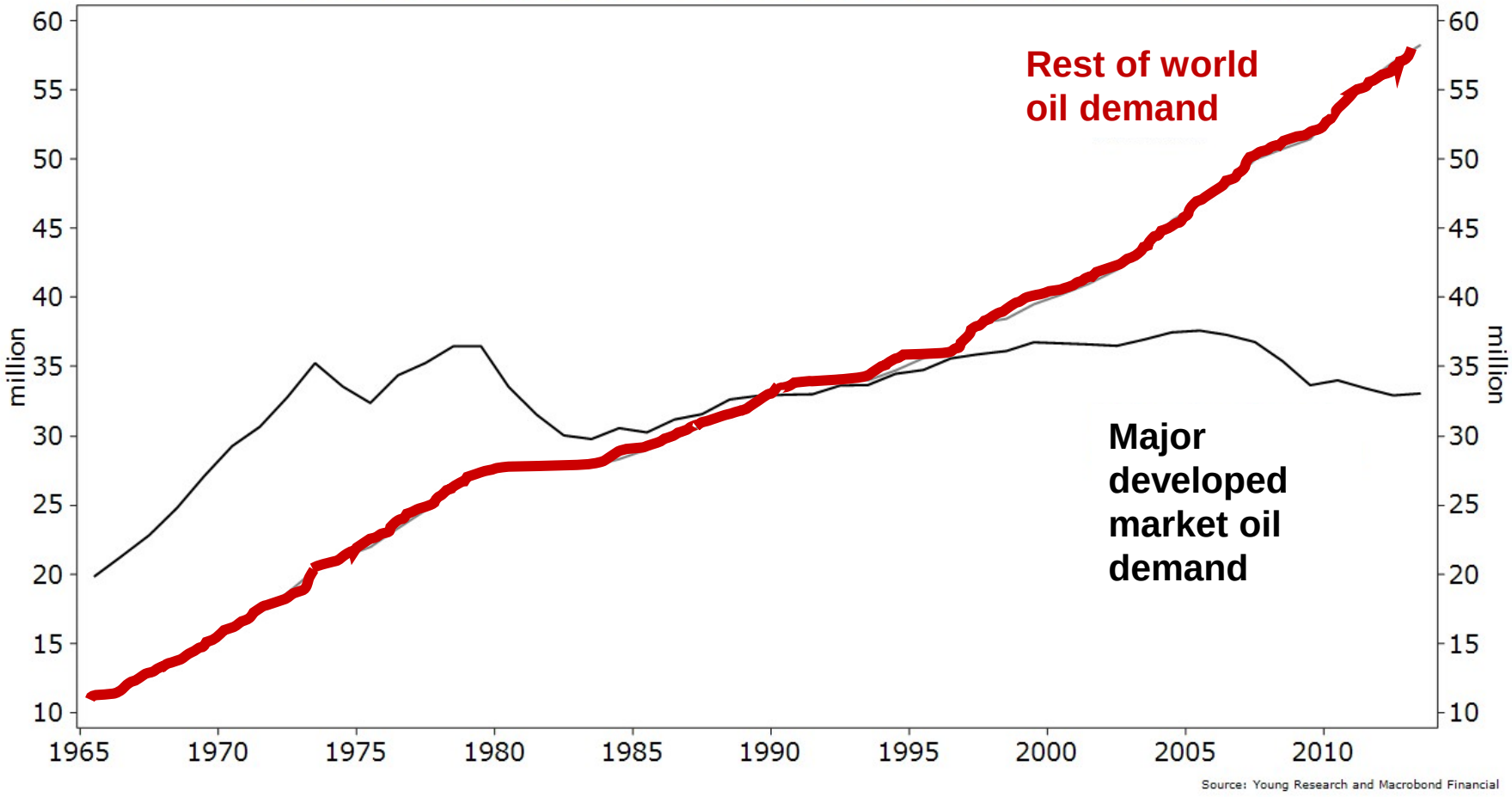
World Oil Consumption (1966-2014)



http://www.youngresearch.com/authors/jeremyjones/global-imperative/

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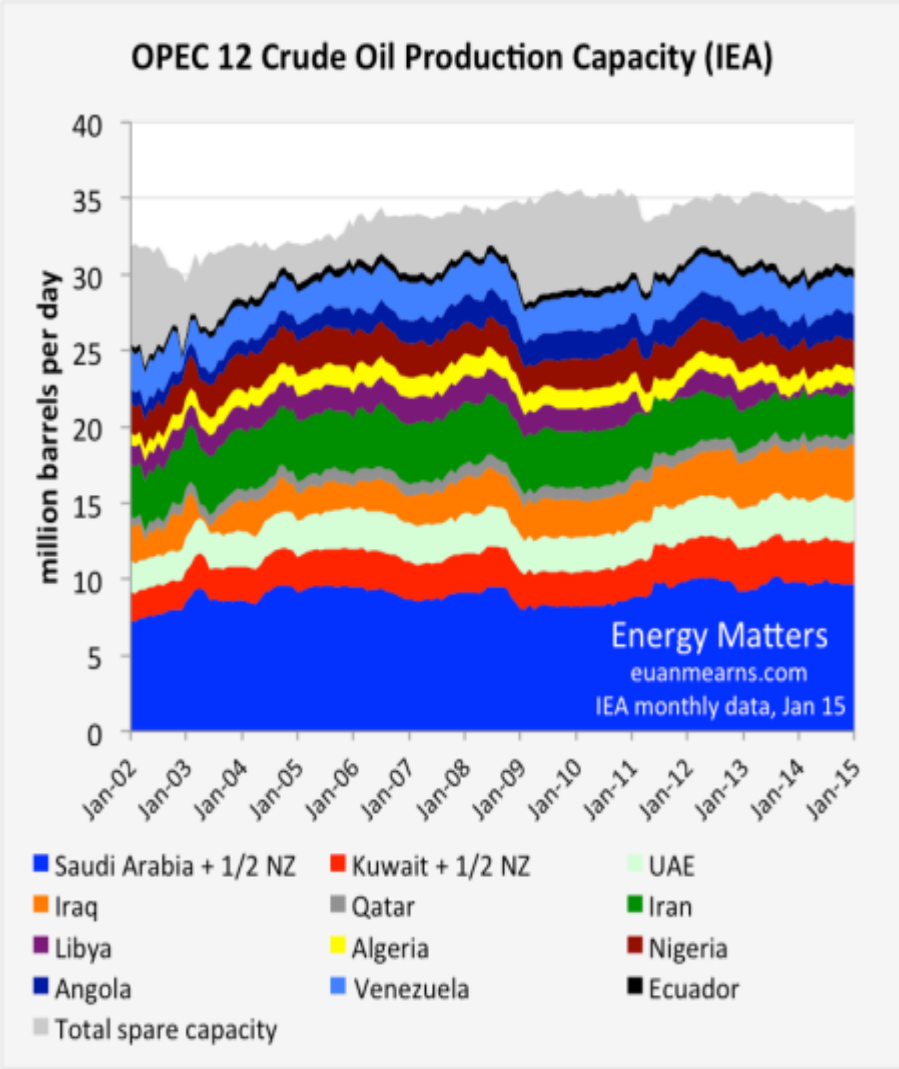
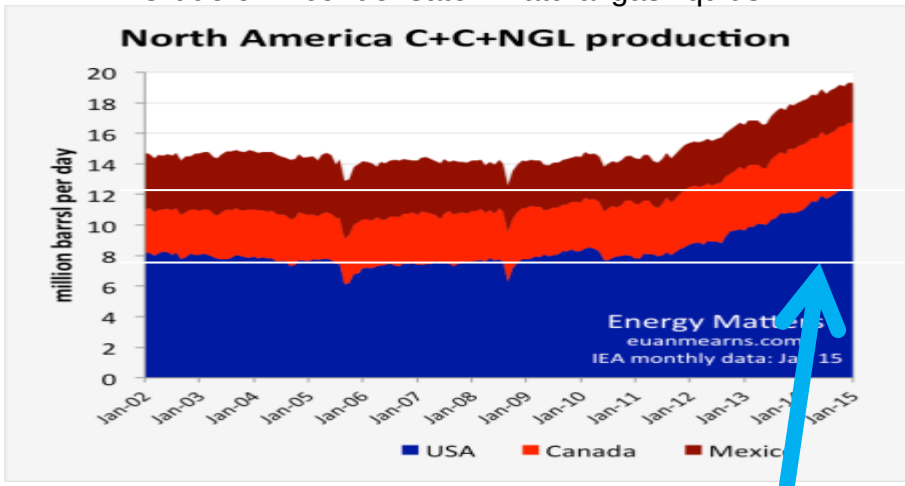
13-Year Production History (2002–2015)



Crude oil + condensate + natural gas liquids



Increase of > 4 million barrels per day

http://oilprice.com/Latest-Energy-News/World-News/Global-Crude-Oil-Production-Growth-Grinding-To-A-Halt.html

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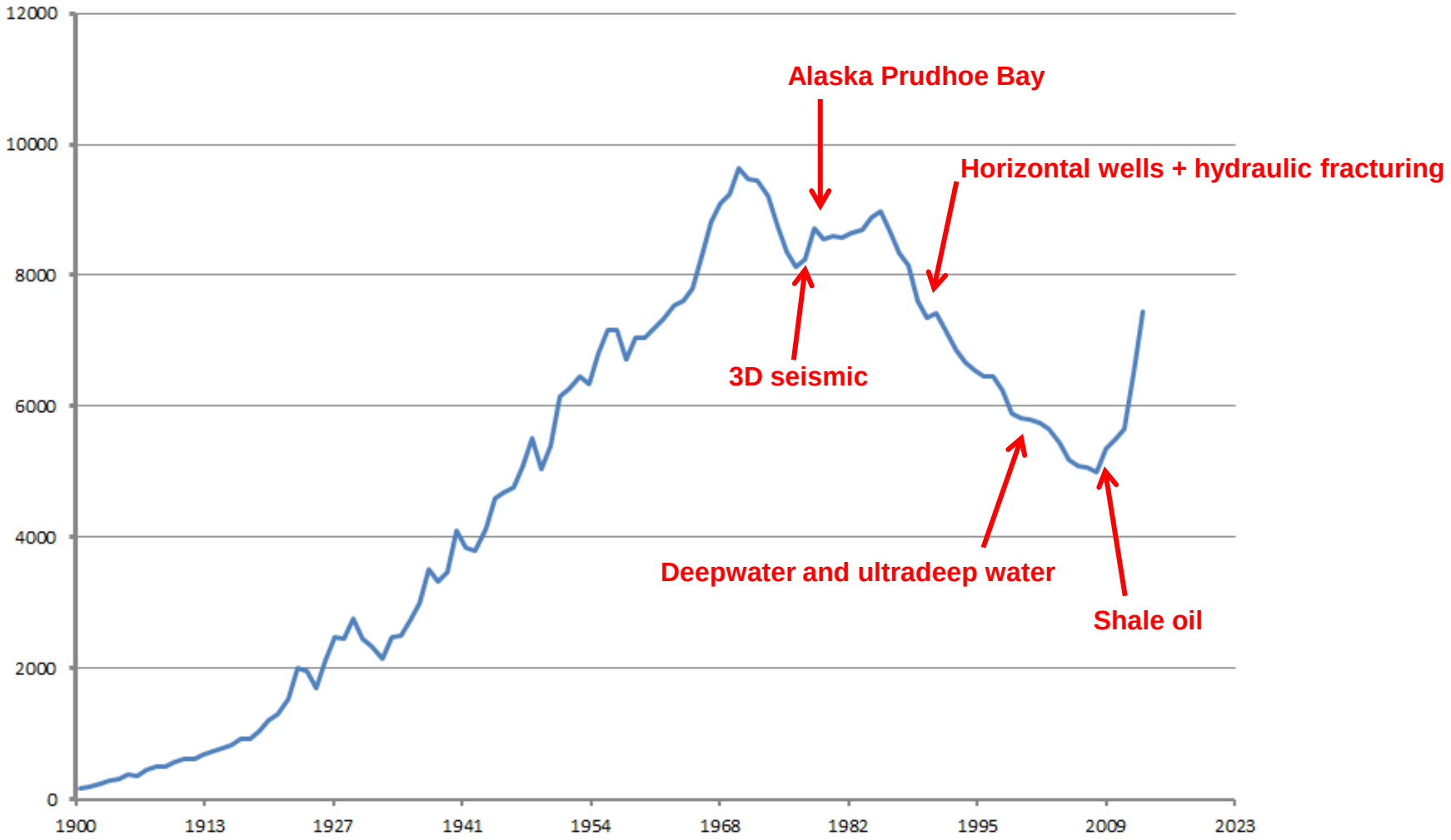
United States (US) Field Production of Crude Oil (Thousands of Barrels per Day)



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A Personal Historical Perspective

- "Early" times (to 1970's)
  - Oil companies – innovate, build, deploy, support, search, drill
  - Academia – builders of foundation
- "Middle" times (1970's to 2000)
  - Rise of service companies – tools, services, products
  - Oil companies – divest technology, become consumers, interpreters
  - Academia – consortia focusing on basic opportunities
- "Current" times (since 2000)
  - Oil companies – consumers, integrators, investors, partners, automation, data mining
  - Independents – rapid uptake, quick moving, low costs
  - Service companies – innovate, acquire, implement, streamline
  - Academia – sparks of innovation, truth seekers/verification, consultants, international influence, interdisciplinary teamwork, targeted R&D

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Likely Effect of Current Oil Price Drop

- Emphasis on short-term cash flow
  - Improving production in existing wells
  - Eliminating low return efforts
  - Market consolidation/redistribution
- Slow down of drilling new wells
- Stop and examine doing a better job
  - Opportunity for innovation

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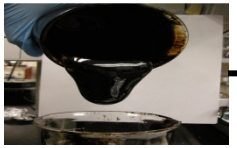
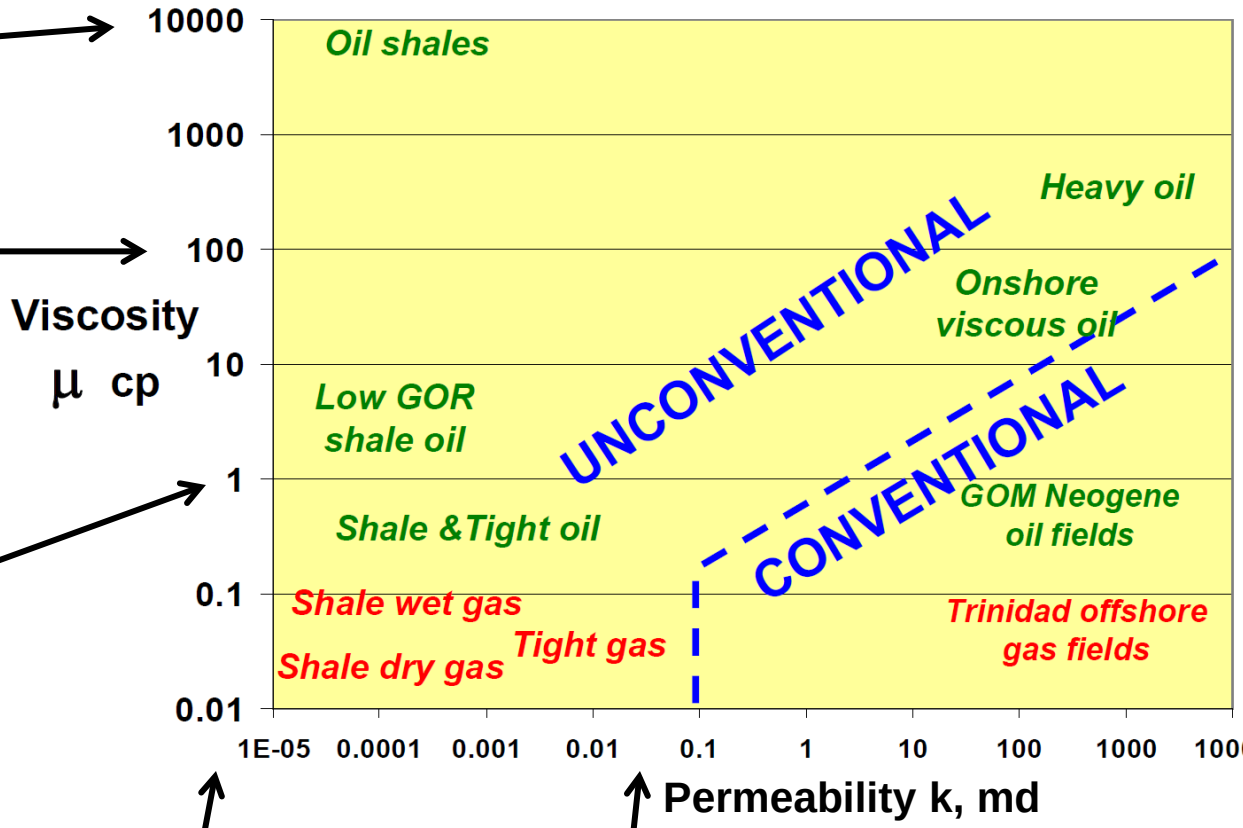
Comparing Resource Types

Bitumen



Heavy Oil

Water



Some common Viscosity values

Water	1.0 cp	
Bitumen	5000 -1mm cp	API 4-10
Heavy oil	100 - 5000 cp	API 10-20
Black oil	2 - 100 cp	API 20-45
Volatile oil	0.25 - 2 cp	API 30-55
Natural gas	< 0.25 cp	

Salt

Brick

Beach Sand

Cander. H., 2012, What are unconventional resources, Search and Discovery #80217

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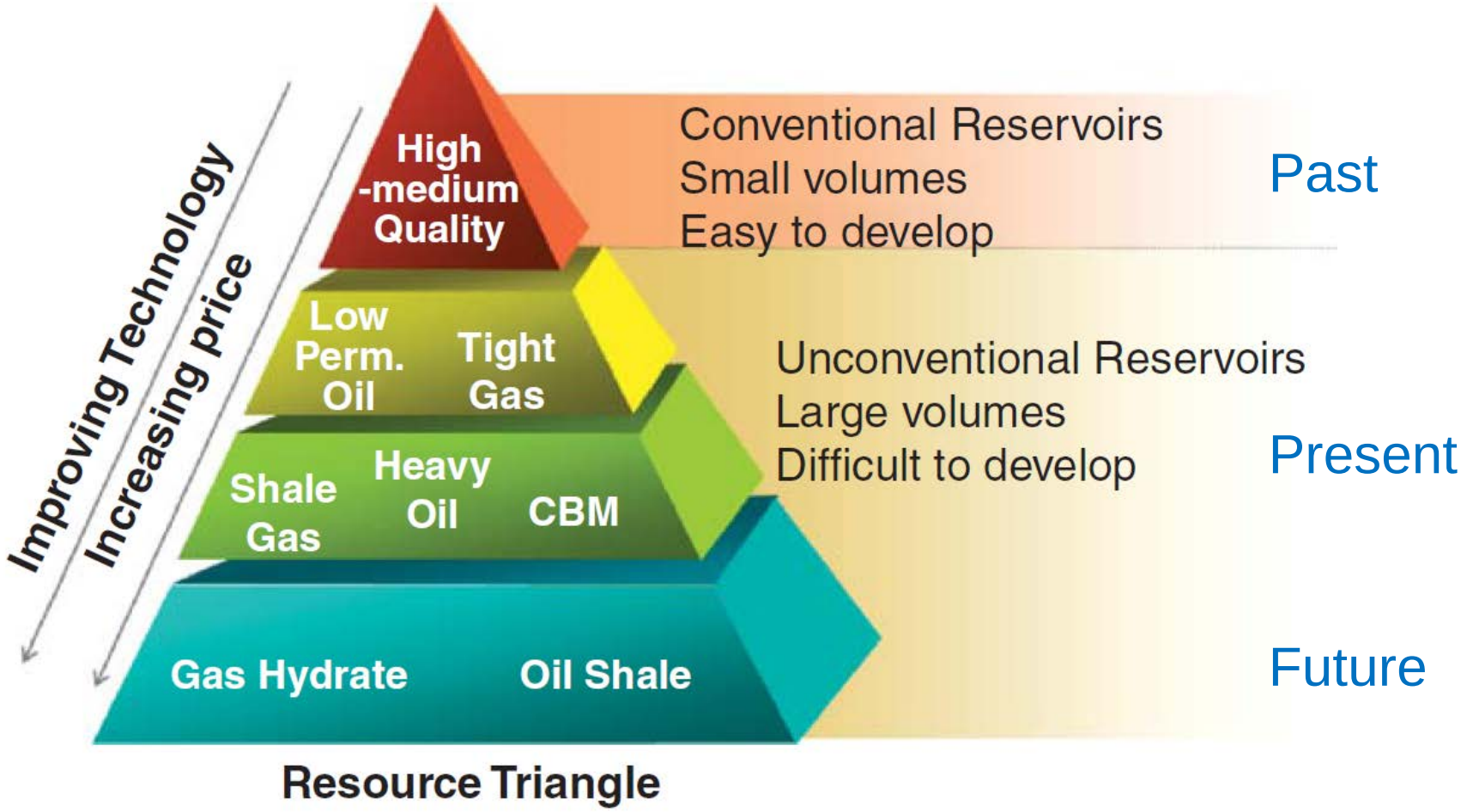
Comparing Resource Types



Dong, Z, et al., 2011, Global unconventional gas resource assessment, SPE 148365, Canadian Unconventional Resources Conference

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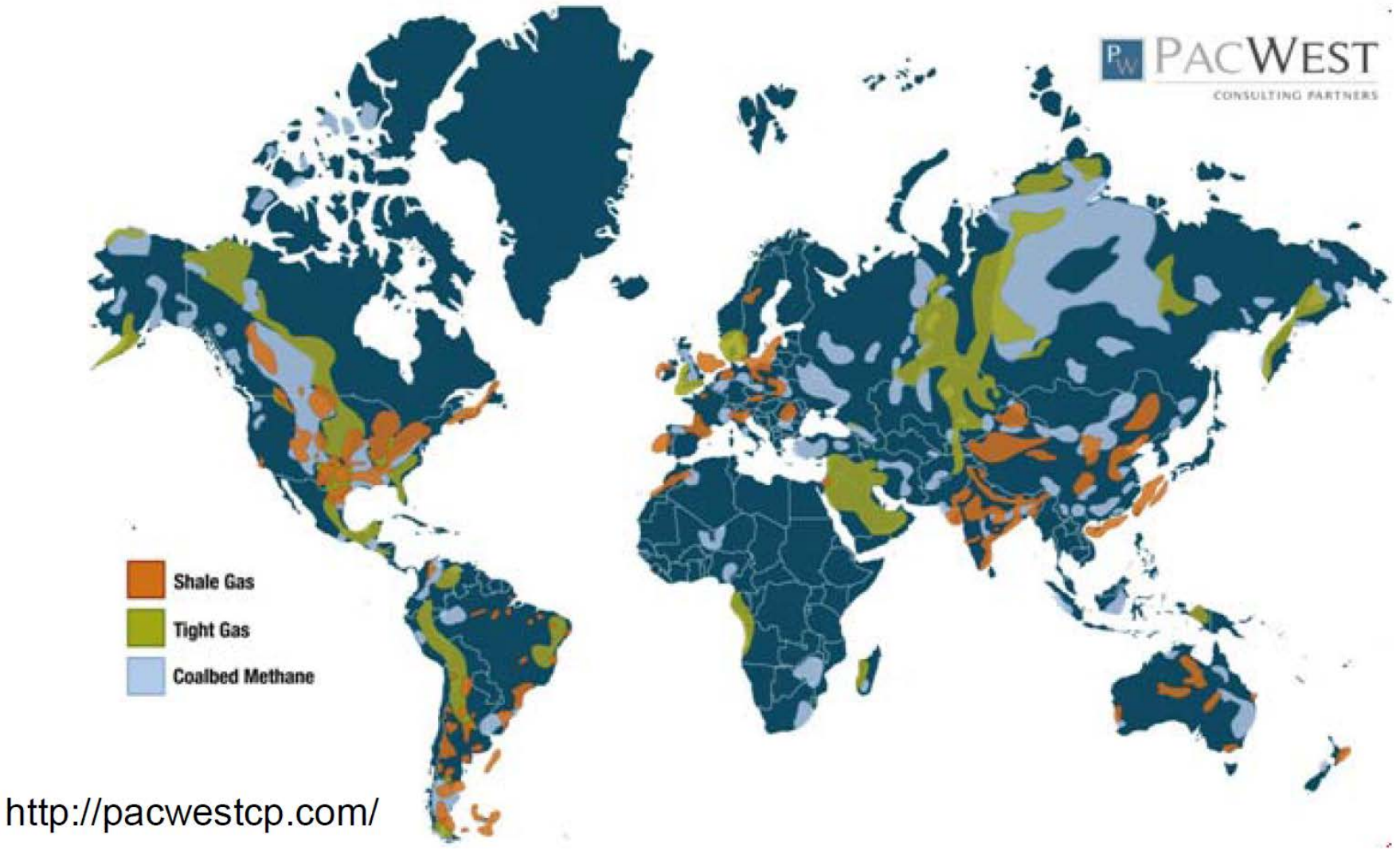
World Unconventional Gas



C. Ehlig-Economides, 2015, Has unconventional become conventional, SPE Luncheon, Houston TX

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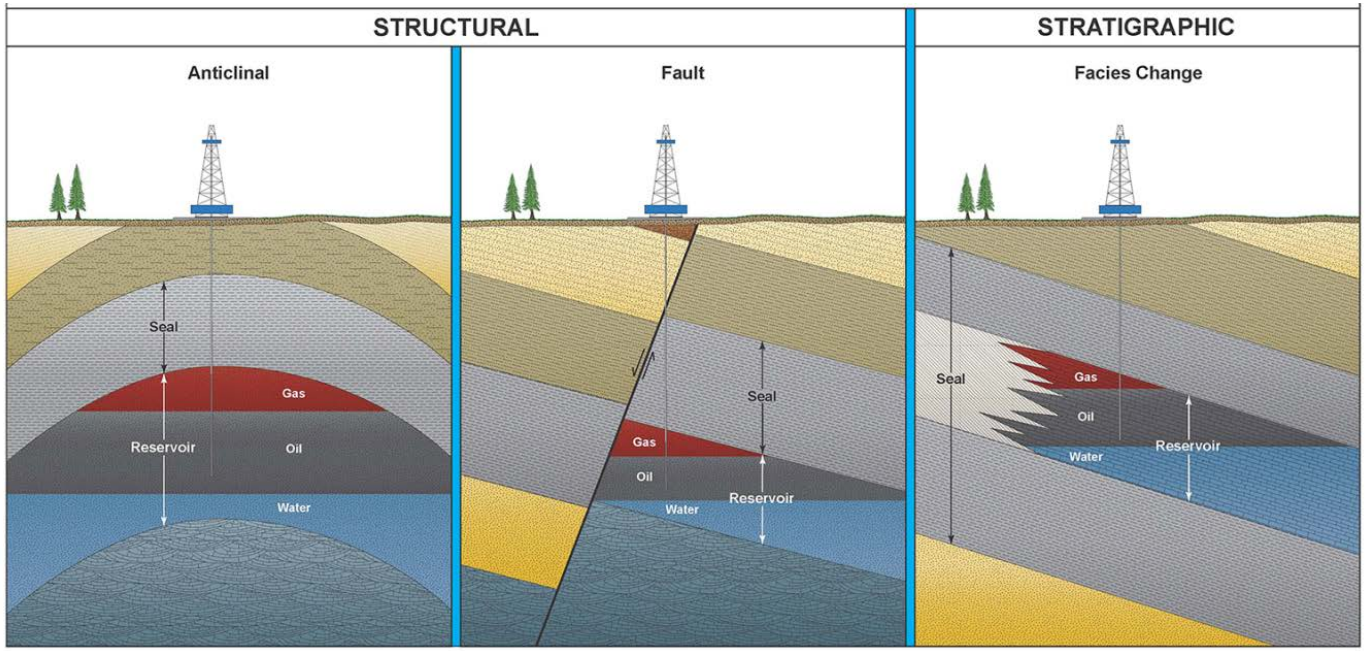
Conventional Reservoirs



http://www.wsgs.wyo.gov/research/energy/oil-gas/images/Traps.jpg

- Explore, find, drill
  - Structural or stratigraphic trap via seismic data
  - Permeability > 0.1 md
  - Oil and gas are produced in shales and migrate to the reservoir
- Produces by
  - Natural reservoir pressure
  - Pumps, artificial lift
- Once pressure drops production is enhanced by:
  - Water or gas injection.

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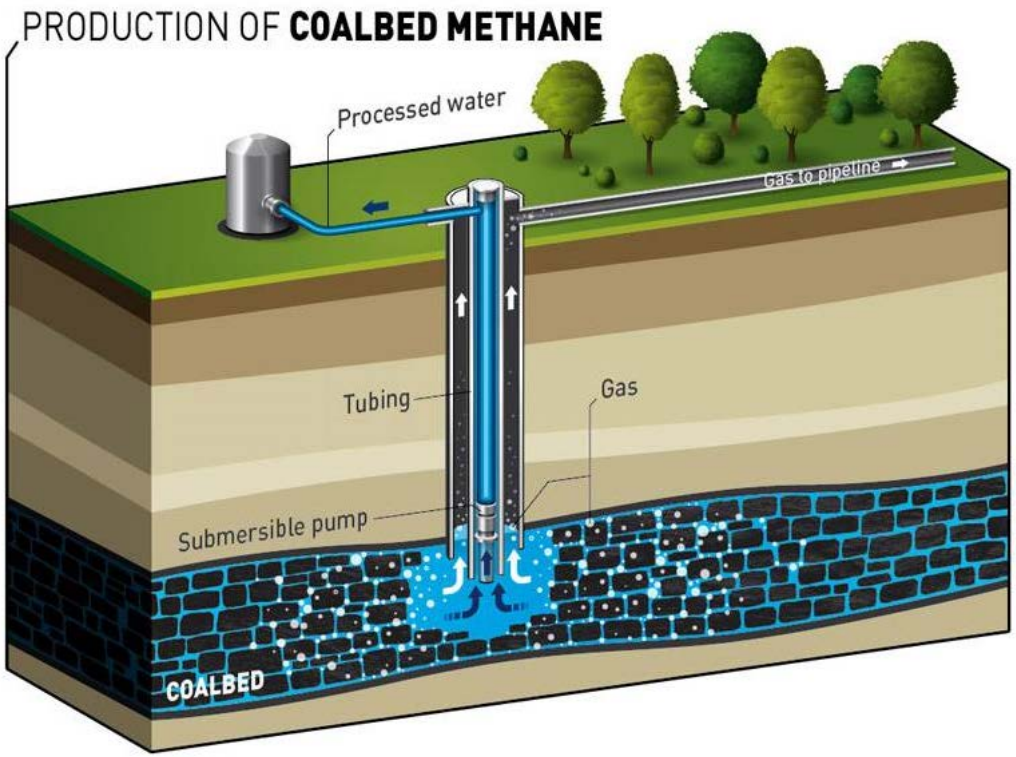
Unconventionals

- Coalbed methane
- Gas hydrates
- Heavy oil/tar sands
- Tight gas
- Shale oil and shale gas



http://www.total.com/en/energies-expertise/oil-gas/exploration-production/strategic-sectors/unconventional-gas/presentation/three-main-sources-unconventional-gas?%FFbw=kludge1%FF

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Unconventionals

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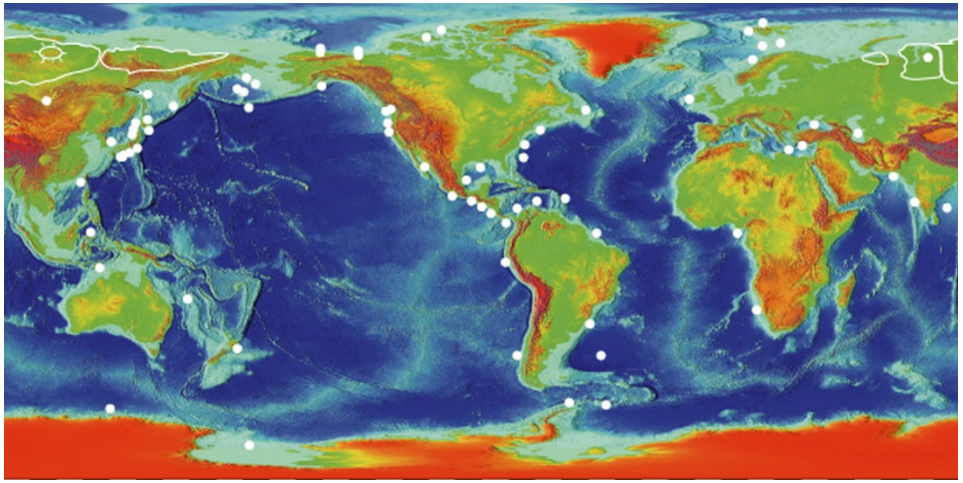
http://www.gns.cri.nz/Home/Our-Science/Energy-Resources/Gas-Hydrates



http://gtresearchnews.gatech.edu/reshor/rh-ss02/e-gas.html

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Unconventionals

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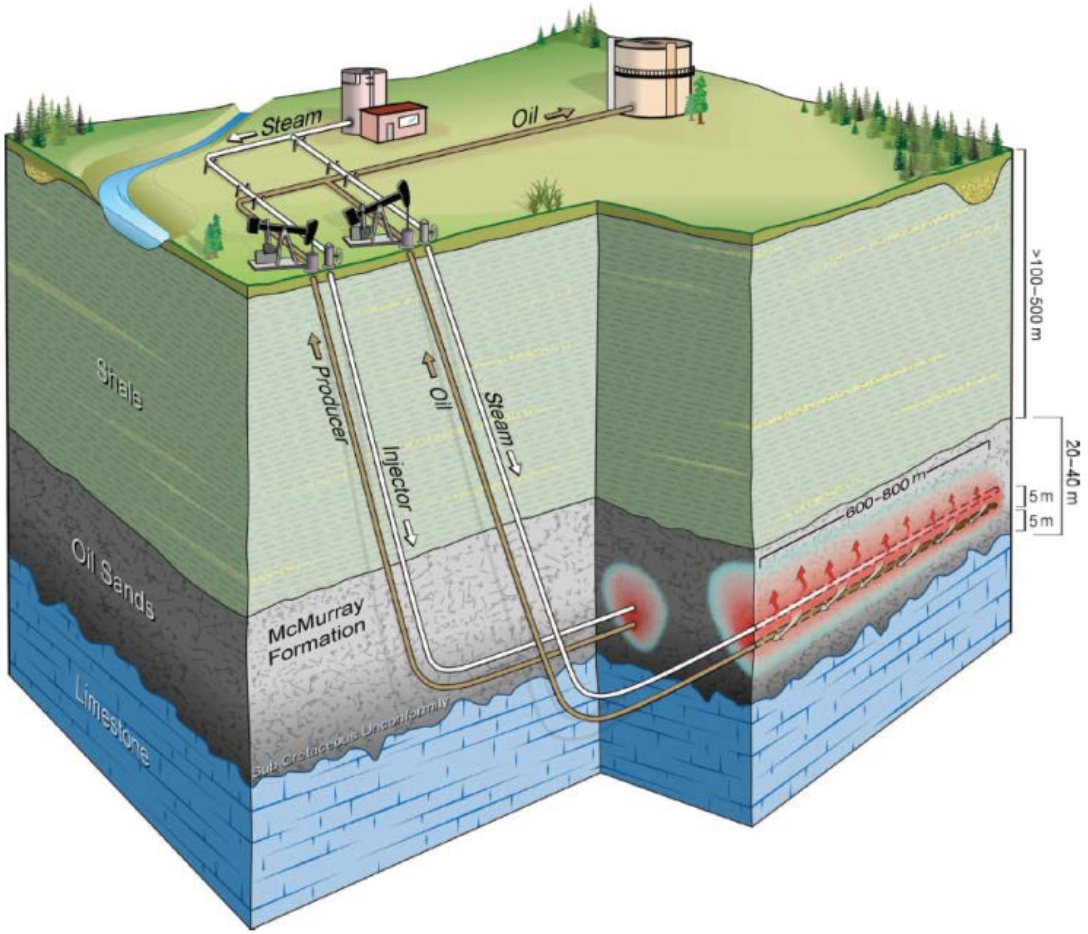
http://www.theguardian.com/environment/2012/feb/23/eu-tar-sands-vote



Hein, Frances J., Dale Leckie, Steve Larter, and John R. Suter, 2013, Heavy oil and bitumen petroleum systems in Alberta and beyond: The future is nonconventional and the future is now, *in* F. J. Hein, D. Leckie, S. Larter, and J. R. Suter, eds., Heavy-oil and oil-sand petroleum systems in Alberta and beyond: AAPG Studies in Geology 64, p. 1–21.

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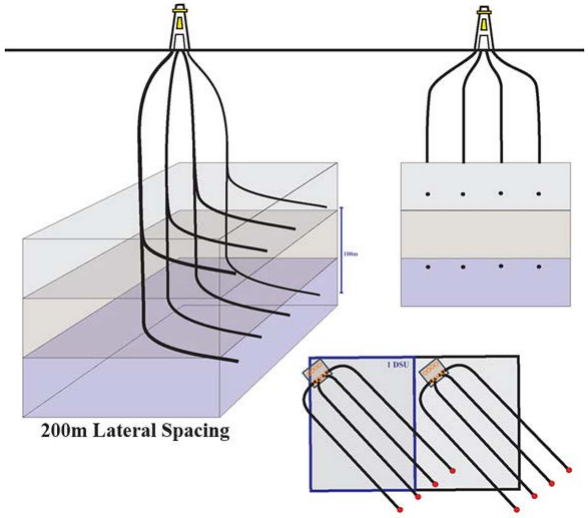
Unconventional (Shale) Reservoirs



- Located on a regional basis
  - Large area
  - Extremely low permeability < 0.1 md
  - Oil and gas are produced in shales and they are the reservoir
- Produced by
  - Hydraulic fracturing
  - Area is “mined” by drilling many horizontal wells
- Production is typically only for a few years
  - Optimal placement of wells critical
  - Refracturing is option for increasing production

https://www.neb-one.gc.ca/nrg/sttstc/ntrlgs/rprt/archive/prmrndrstndngshlgs2009/prmrndrstndngshlgs2009-eng.html

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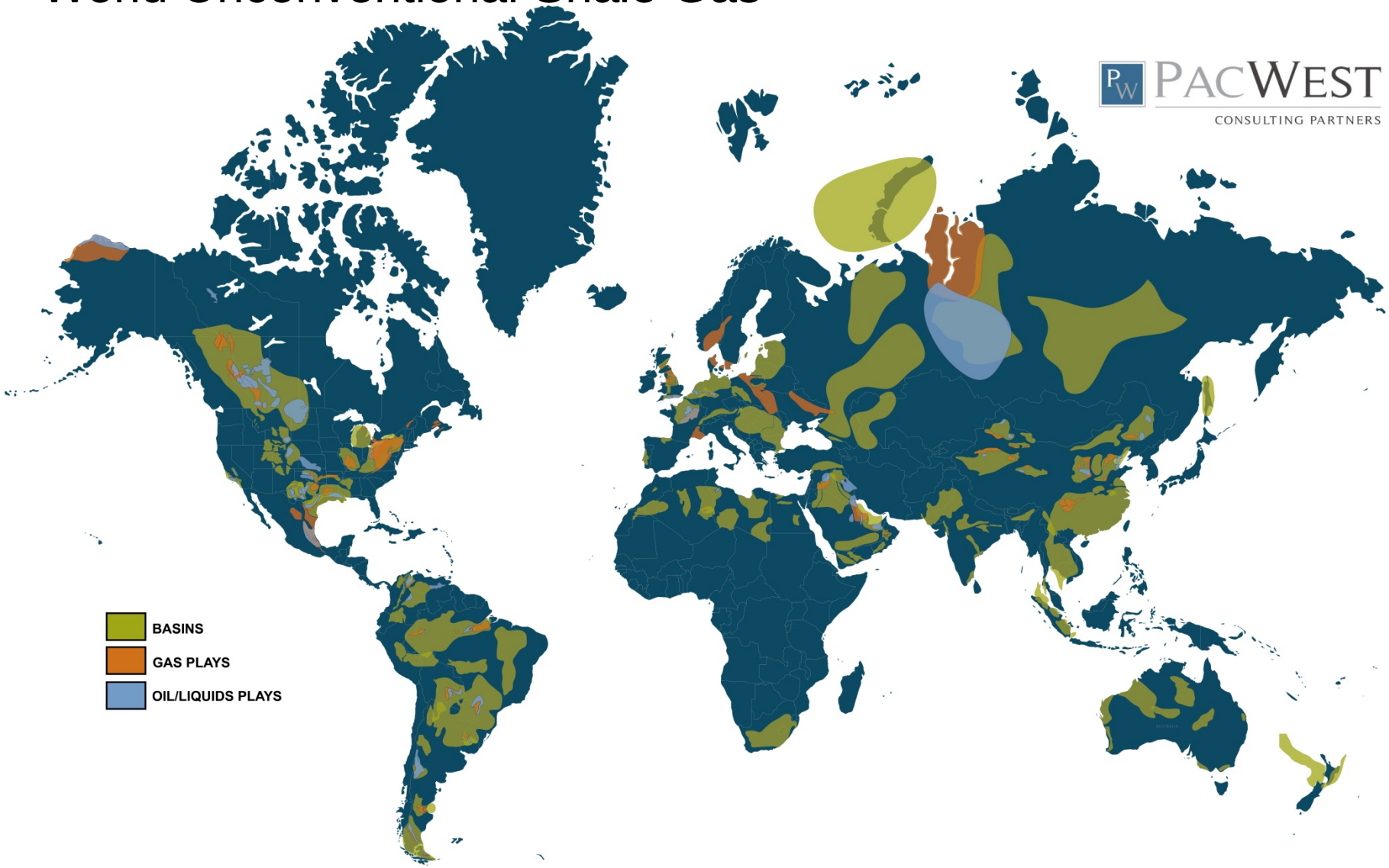
World Unconventional Shale Gas



http://pacwestcp.com/wp-content/uploads/2014/06/PacWest-Global_Plays-Map-2014.jpg

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Outcrop of the Eagle Ford in South Texas

Stephen Galiette

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Close-up Showing Heterogeneity of the Formation

Stephen Galiette

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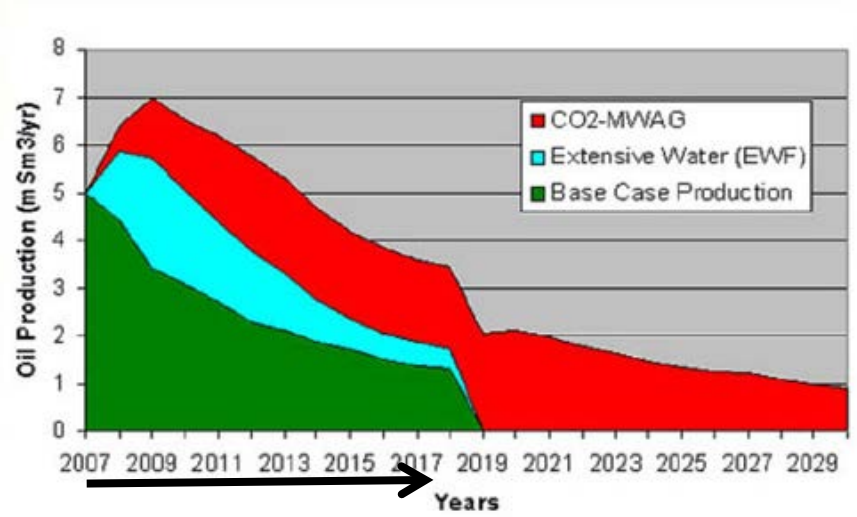
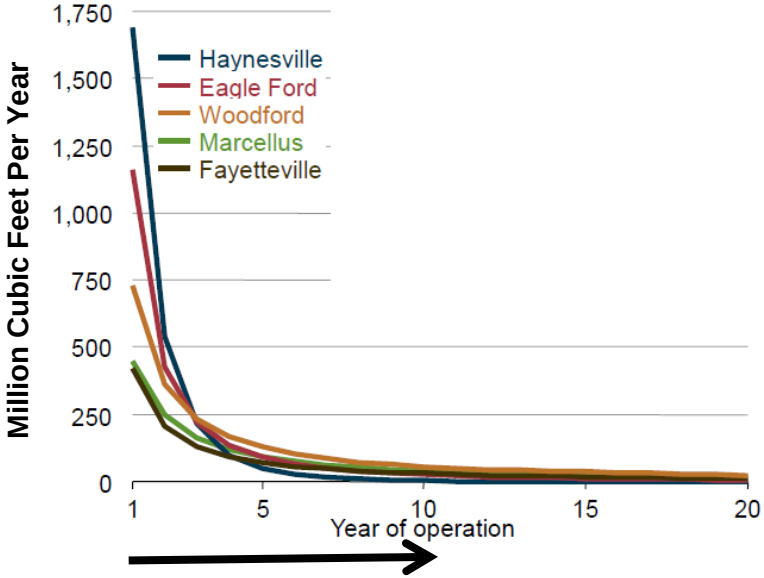
Production Decline Curves

Conventional



10 years

Shale Gas Wells



10 years

http://www.co2.no/default.asp?uid=175&CID=56

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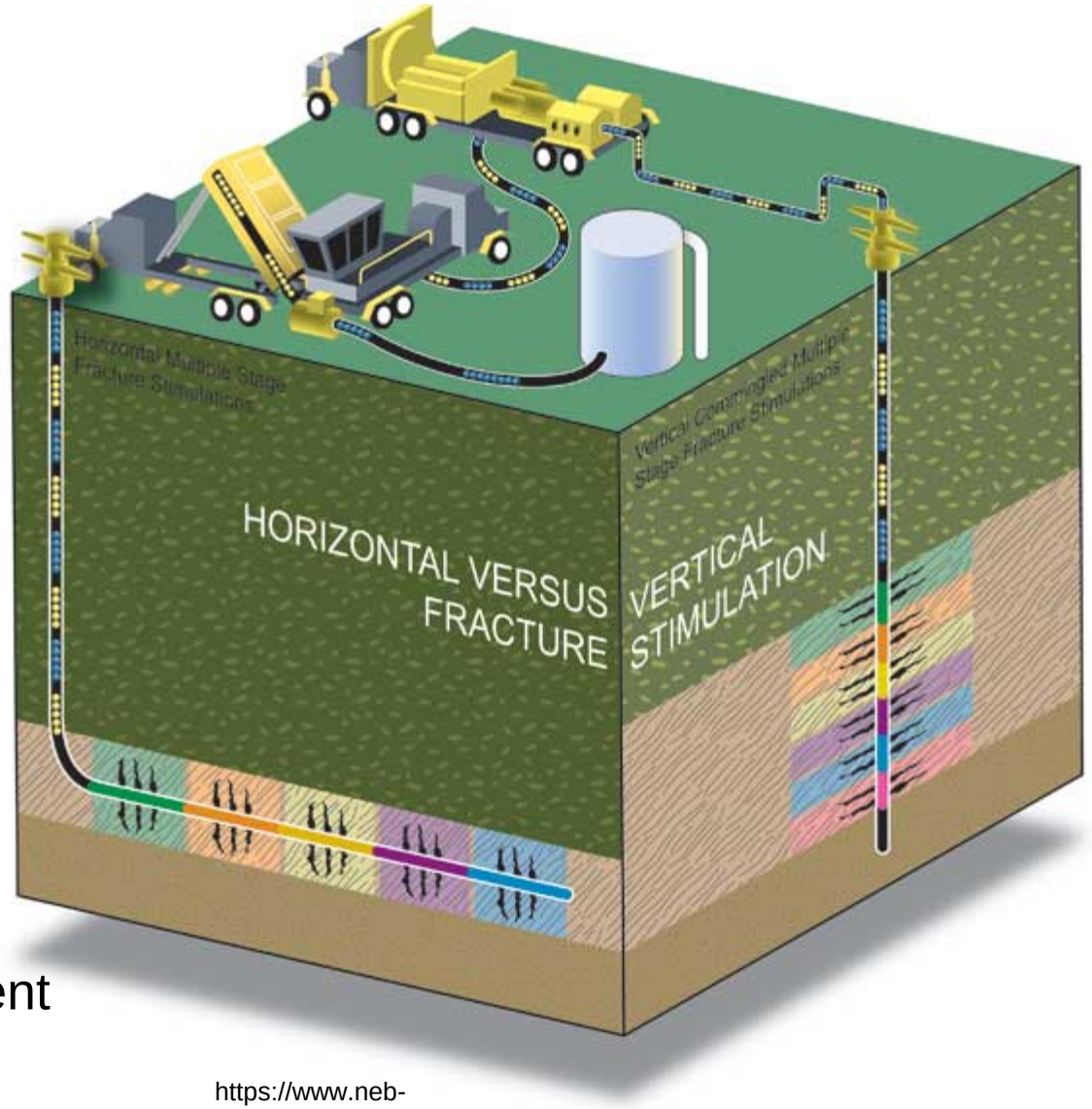
Hydraulic Fracturing – Plug & Perf (or Sliding Sleeve)

- Directional drill well
- Case
- Perforate a zone
- Pump fluids and sand
- Pack it off
- Repeat for next stage

- Goal – create network
  - Limit vertical extent
  - Maximize lateral extent



https://www.neb-one.gc.ca/nrg/sttstc/ntrlgs/rprt/archive/prmrndrstndngshlgs2009/prmrndrstndngshlgs2009-eng.html

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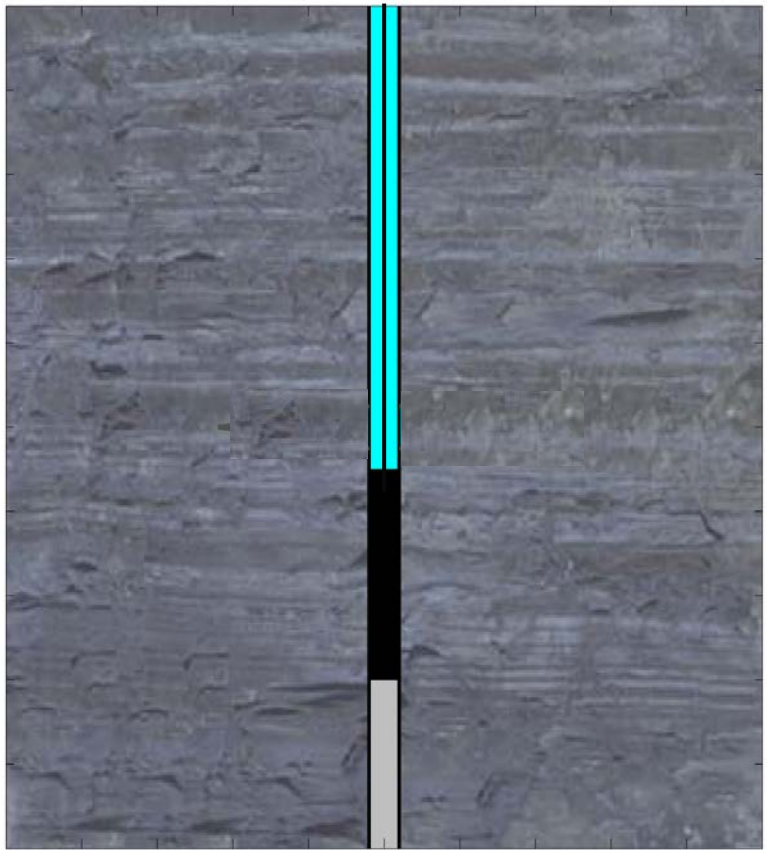
Hydraulic Injection – Set Plug



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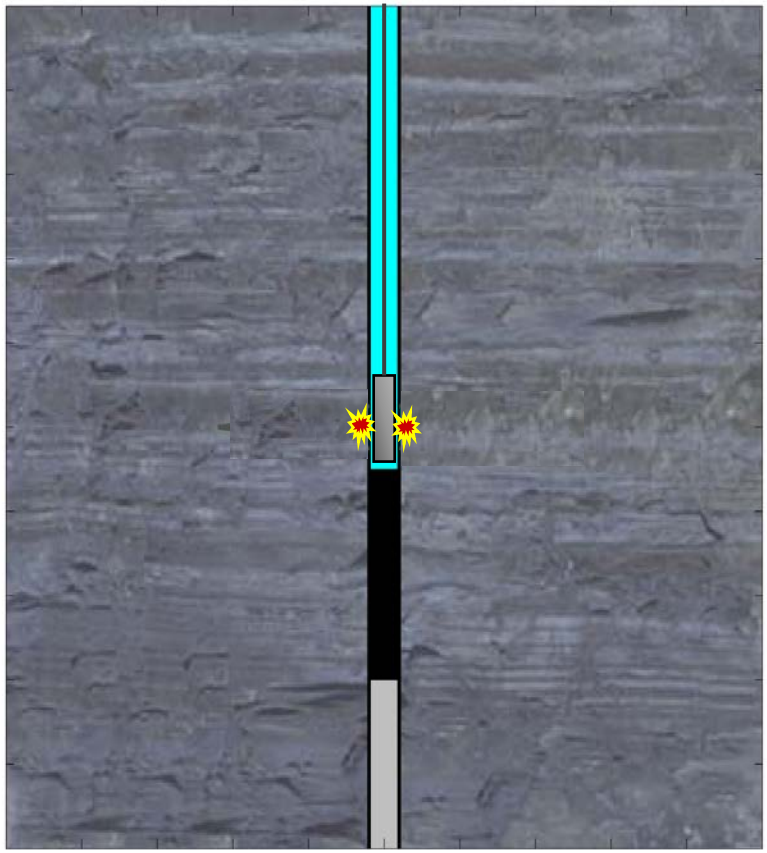
Hydraulic Injection – Perf Gun



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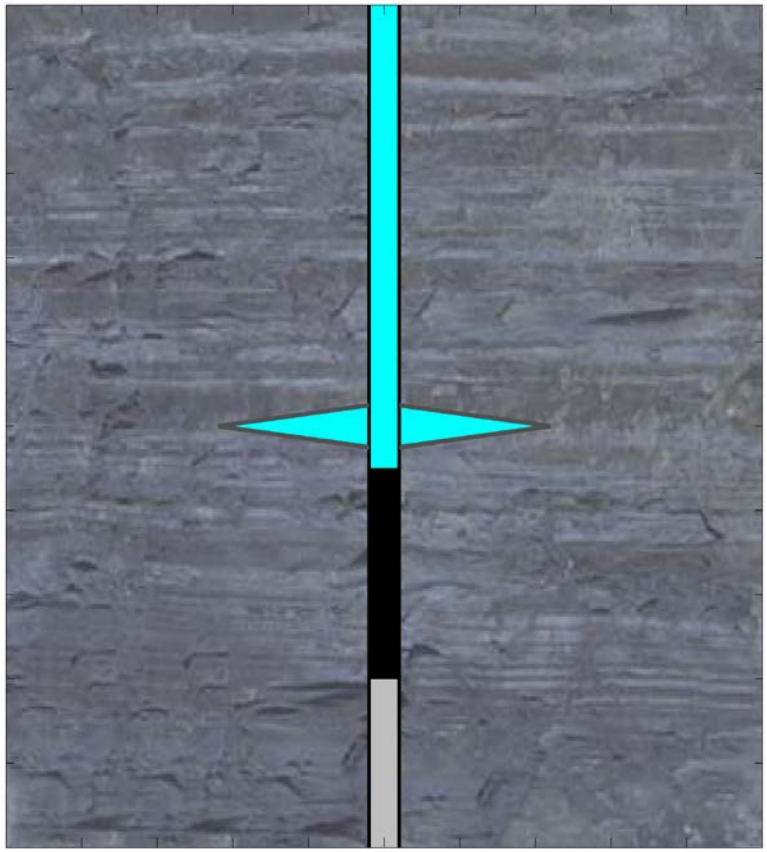
Hydraulic Injection - Fluid



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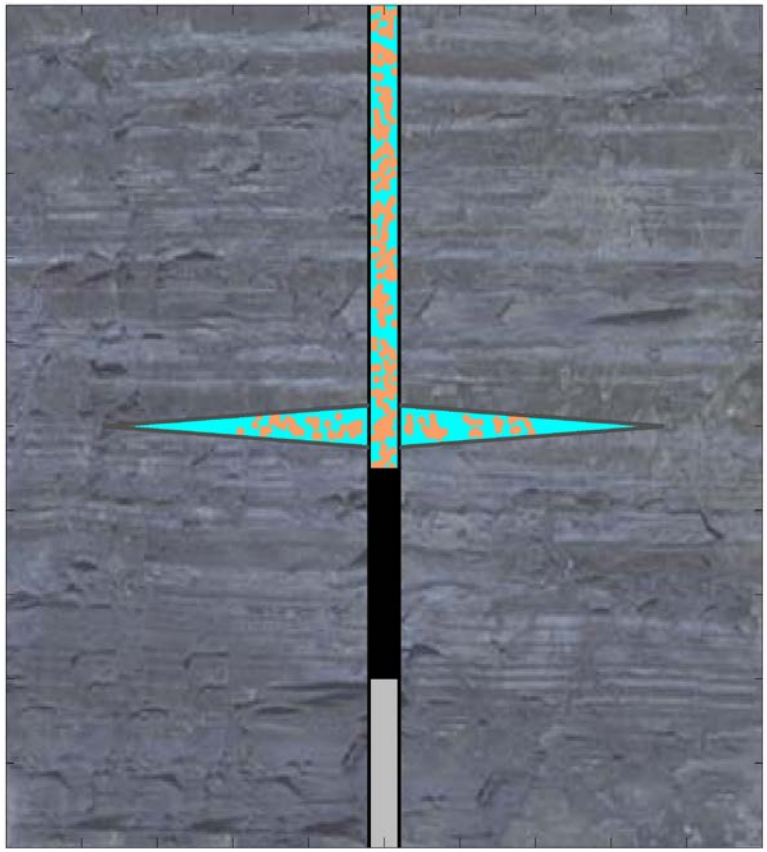
Hydraulic Injection – Fluid + Proppant



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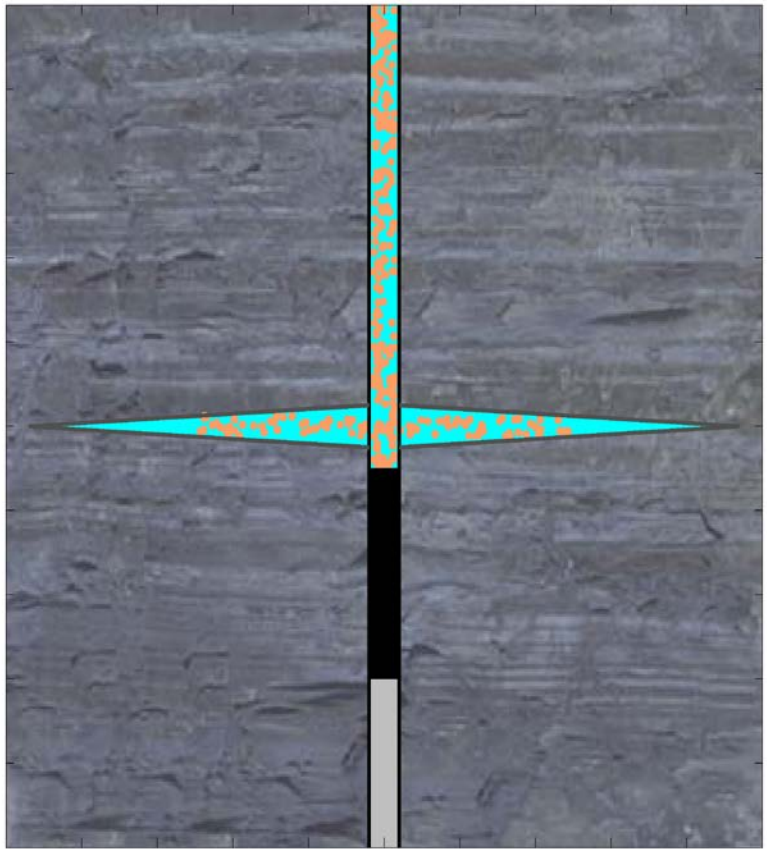

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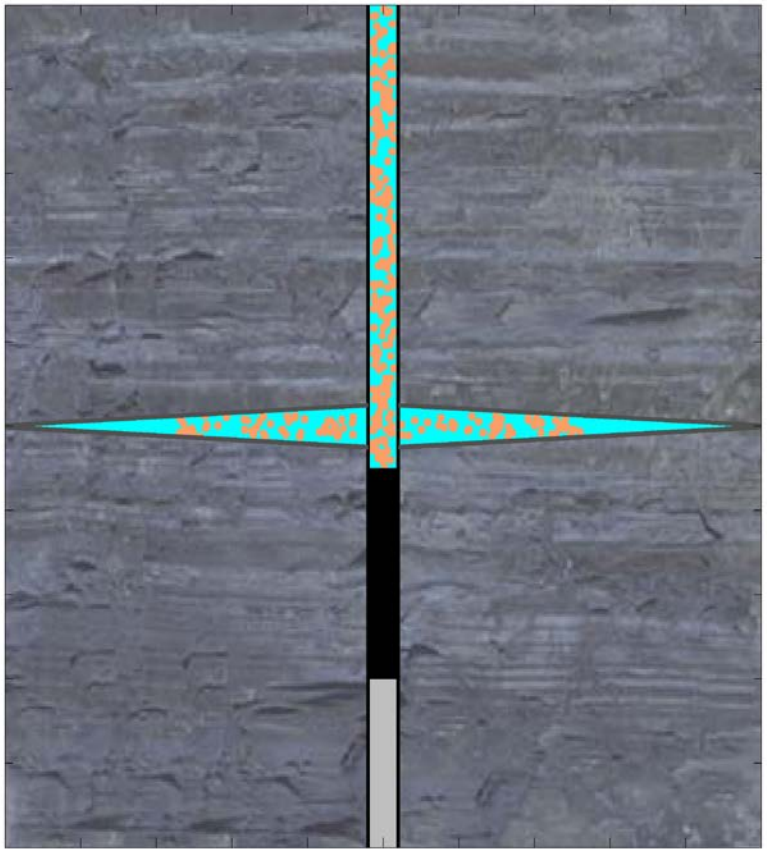
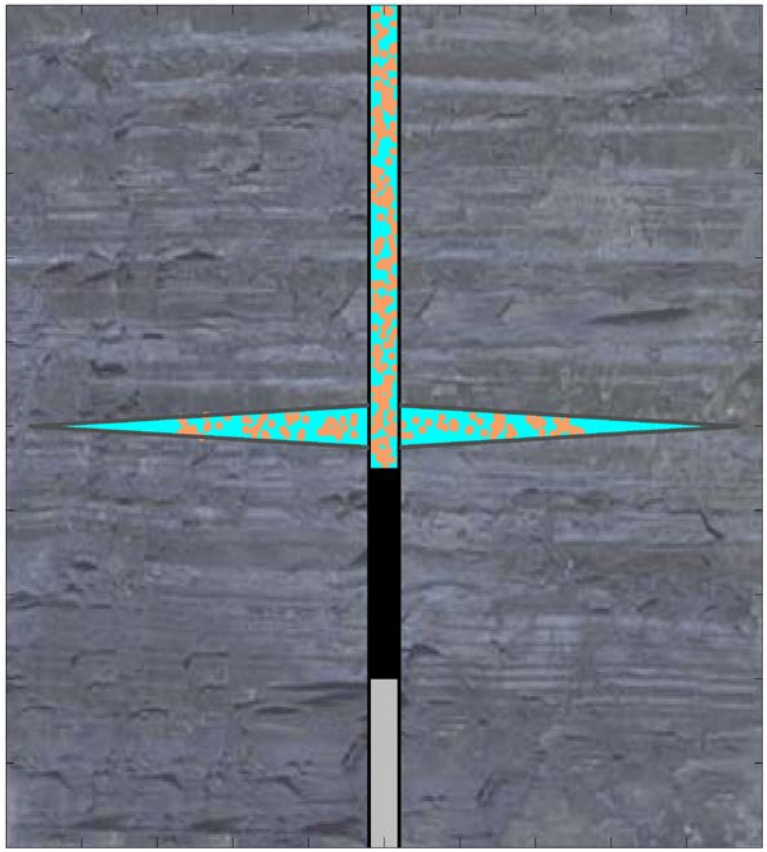
Hydraulic Injection – Fluid + Proppant



Hydraulic Injection – Stop Pumping, Pressure Drop



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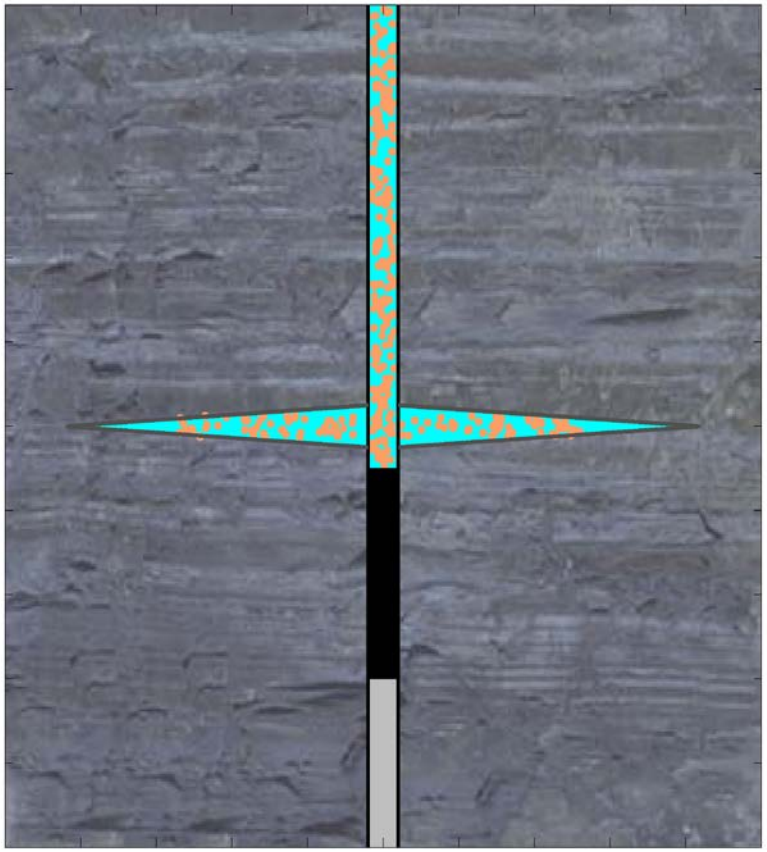

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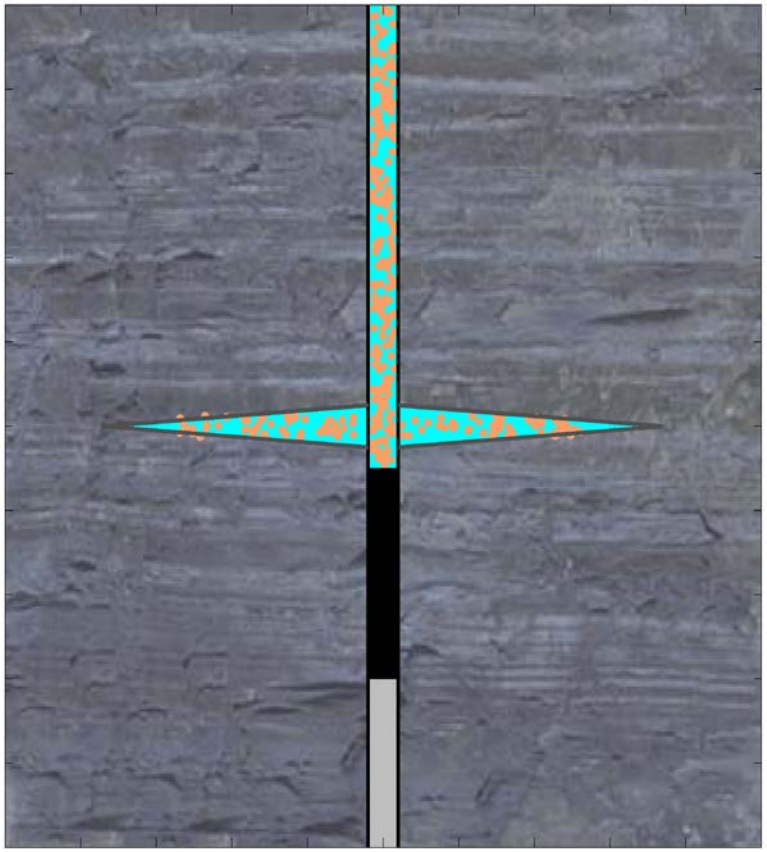
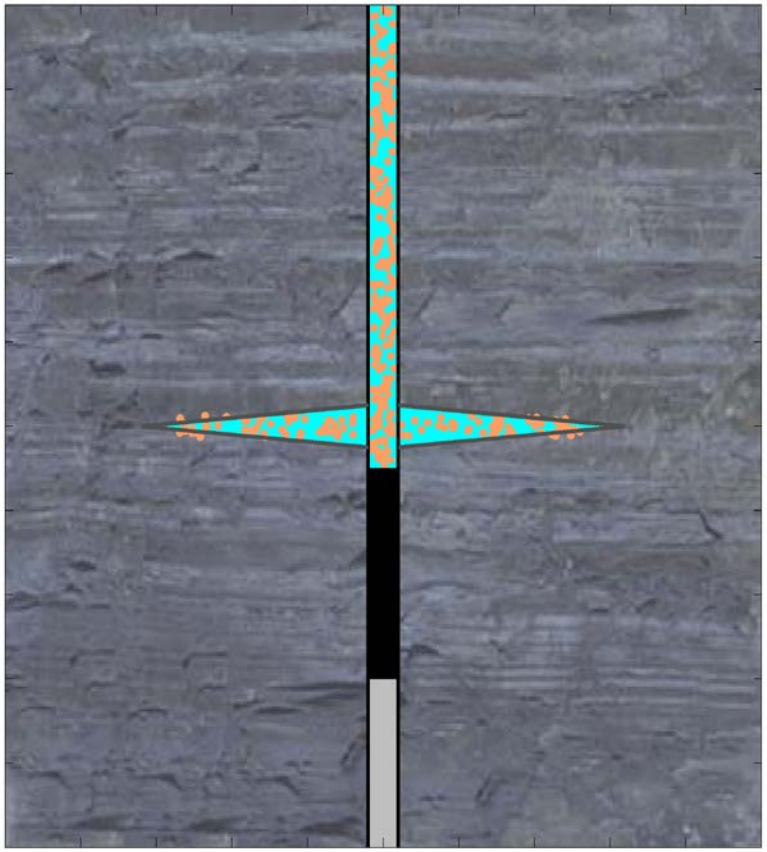


Hydraulic Injection – Produce Back



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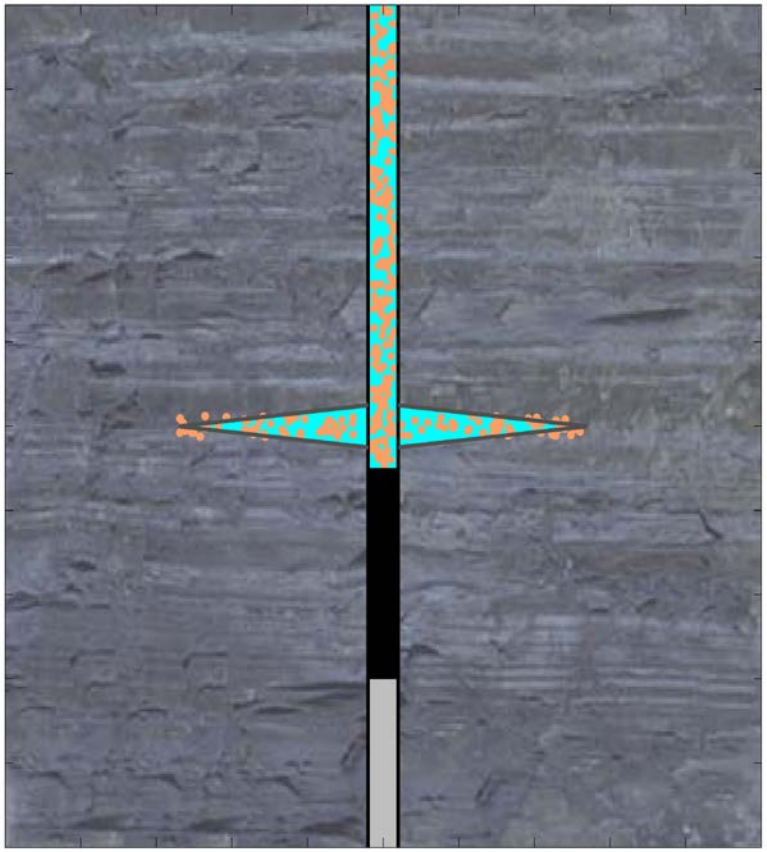

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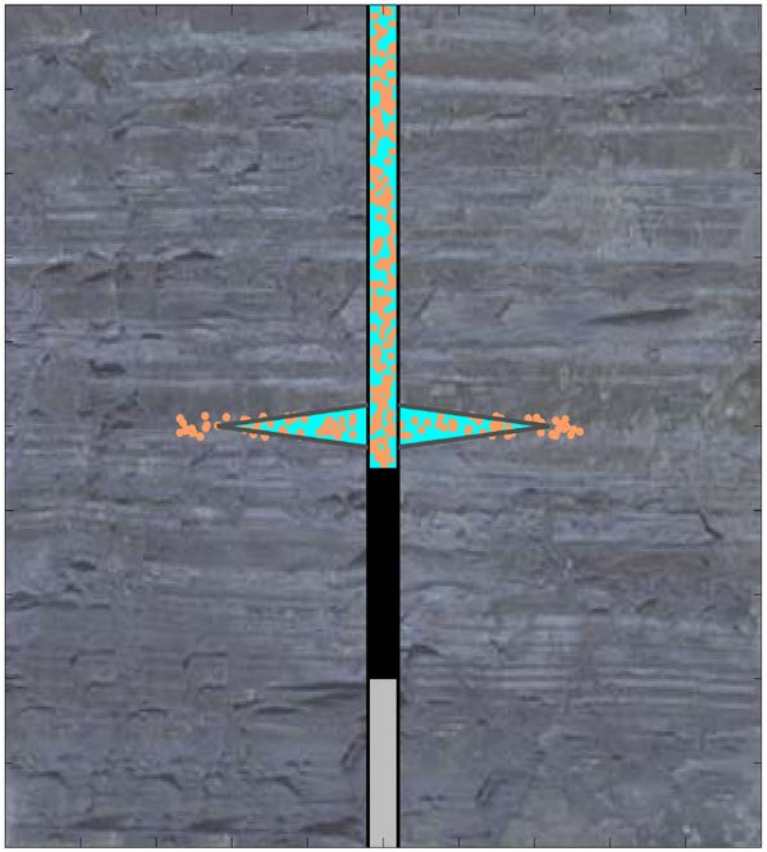
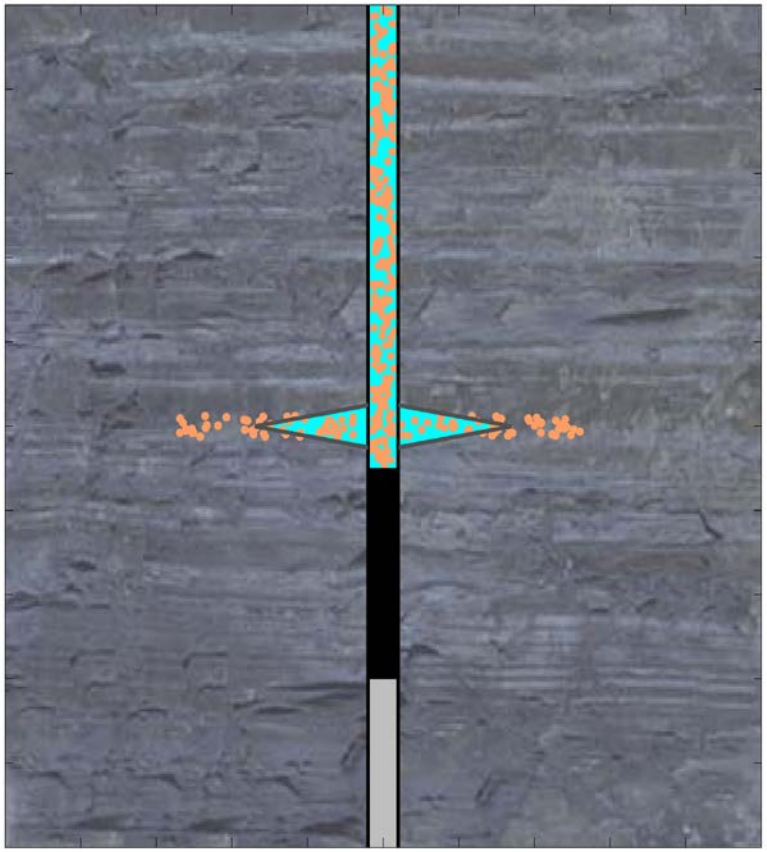
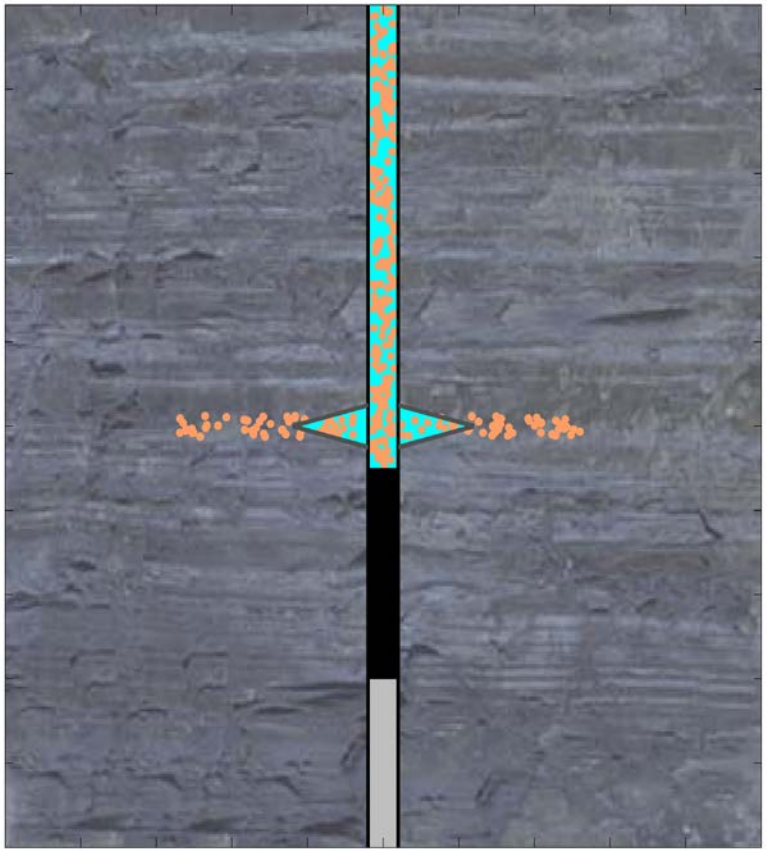


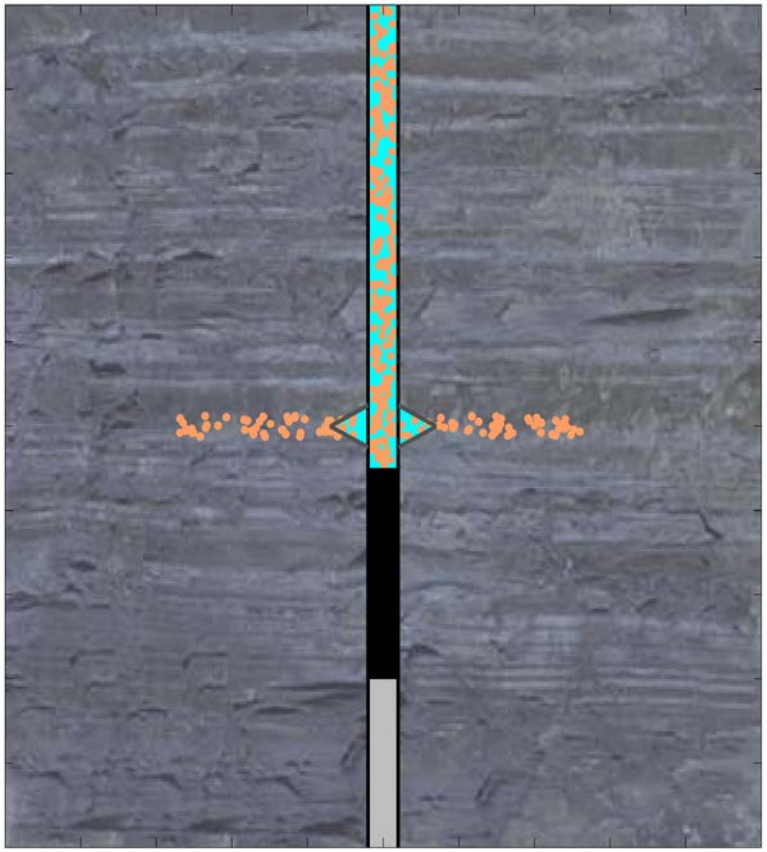
Hydraulic Injection – Produce back



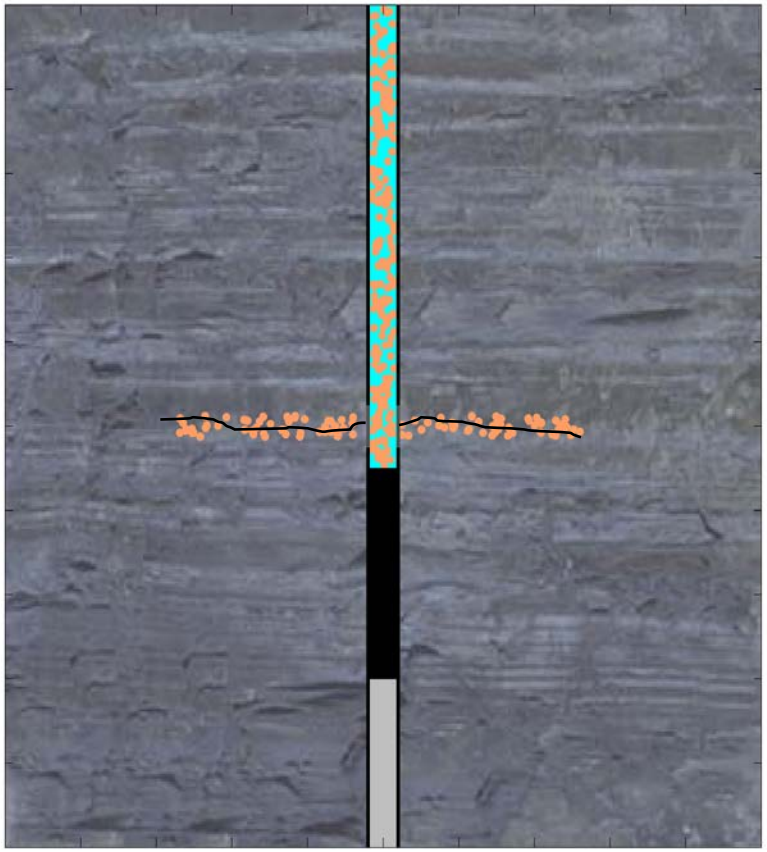
Hydraulic Injection – Pressure Dropping



Hydraulic Injection – Pressure dropping

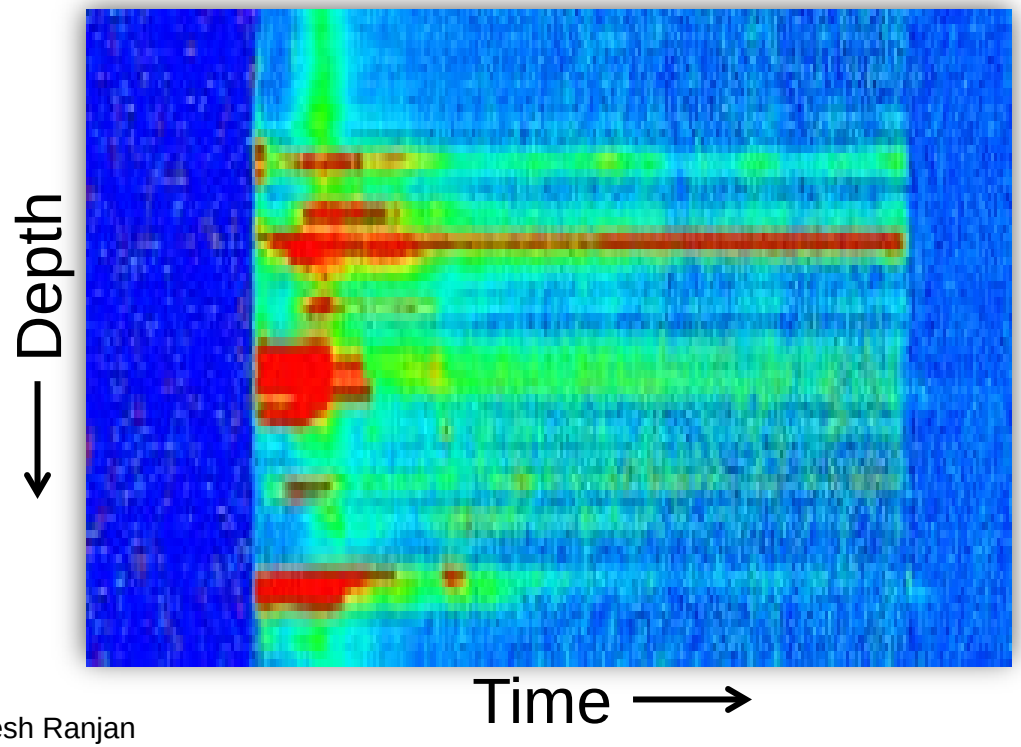


Hydraulic Injection – Frac is Propped Open



Monitoring Fracture Progress With Flow Noise

- Distributed acoustic sensing via fiber optics
- Continuous “microphone” in well bore
- Shows location of perfs and their flow



Priyesh Ranjan

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Key Success Factors for Hydraulic Fracturing

- Prediction of fracture direction, length and height
  - Regional stress maps
  - Experience in area
  - Completion design
- Monitoring of fracture creation
  - Fluid volumes, proppant placed
  - Microseismic monitoring (borehole and surface)
  - Tilt monitoring
  - Flow noise (via fiber optics)
- Evaluation of fracture performance
  - Production logs
  - Tracer measurements
  - Flow noise

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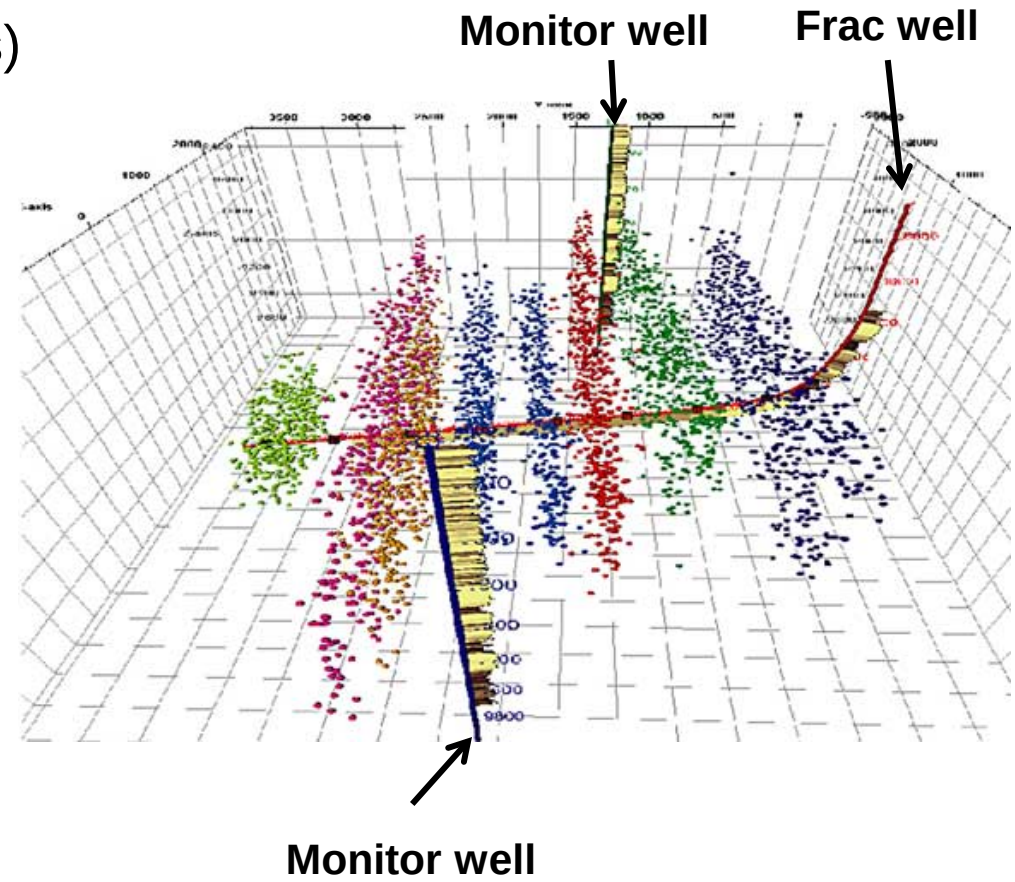
Microseismic Monitoring of Hydraulic Fracturing

- Geophones in a monitor well(s)
- Listen during each frac stage
- Locate the events
- Modify program to ensure you don't frac out of zone



https://www.neb-one.gc.ca/nrg/sttstc/ntrlgs/rprt/archive/prmrndrstndngshlgs2009/prmrndrstndngshlgs2009-eng.html

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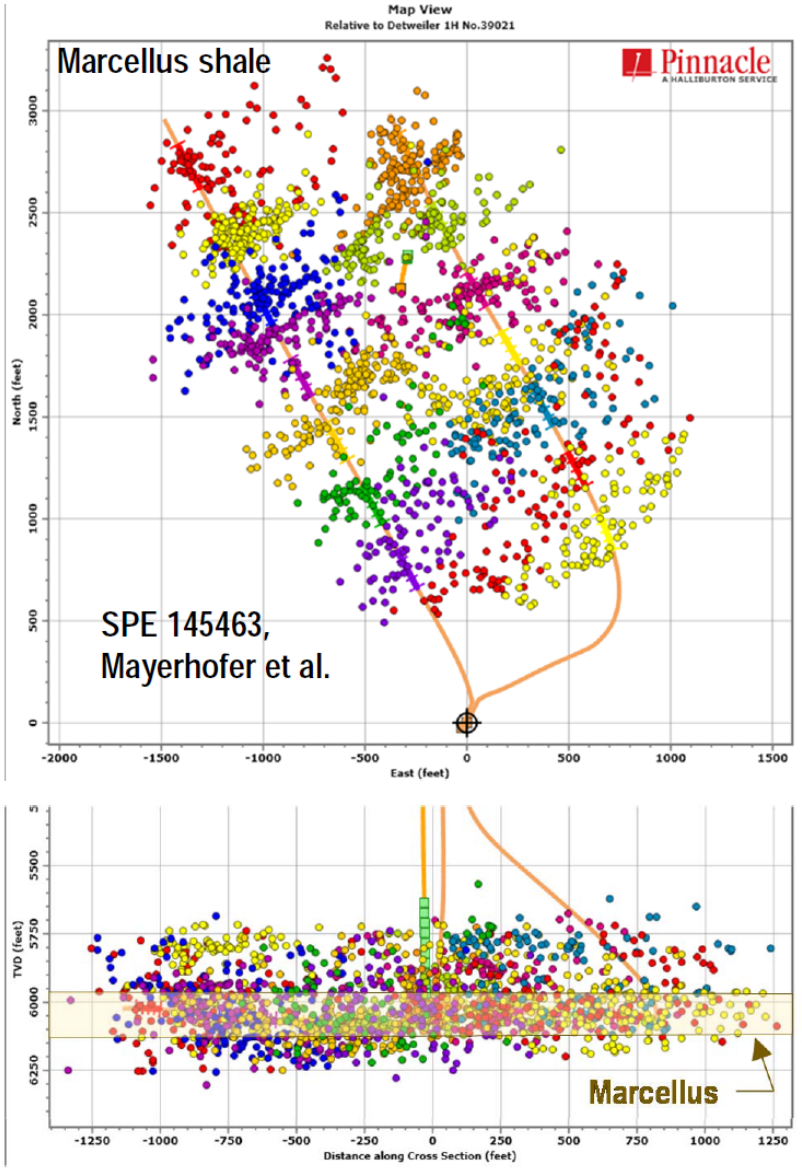
Microseismic monitoring is a valuable tool for optimizing

- Well layout (trajectory)
- Well spacing
- Stage lengths
- Perf clusters and/or valves & packers
- Stimulation design
- Fracture height and length
- Complexity
- SRV



N. Warpinski

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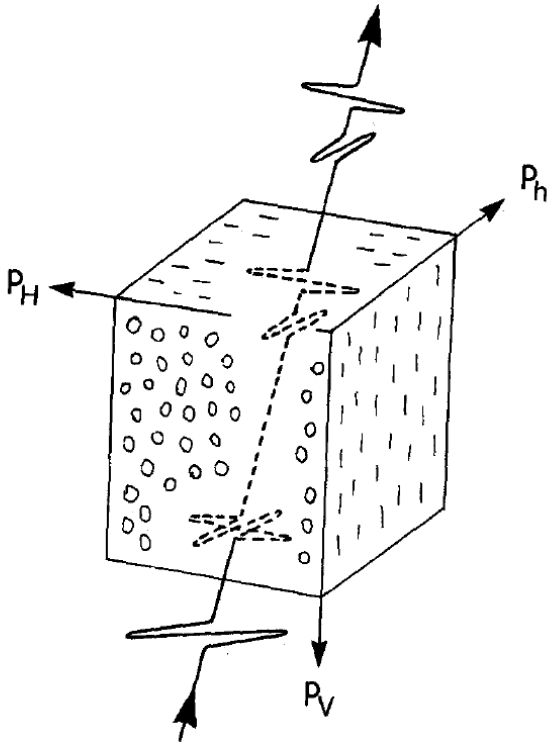
Natural and Induced Aligned Fractures

- Geophysical effects
  - Directional velocity variation
  - Shear wave splitting
  - Attenuation
  - Diffractions
- Geophysical measurements
  - Surface seismic
  - VSP
  - Well logs
  - Cores



E. Liu et al., 1989, Shear wave splitting in cross-hole surveys: modeling, Geophysics 54(1), pp. 57-65.

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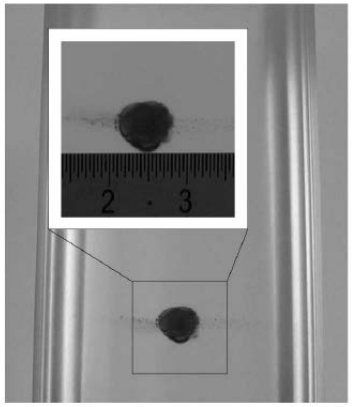
Scale Modeling of Fractures



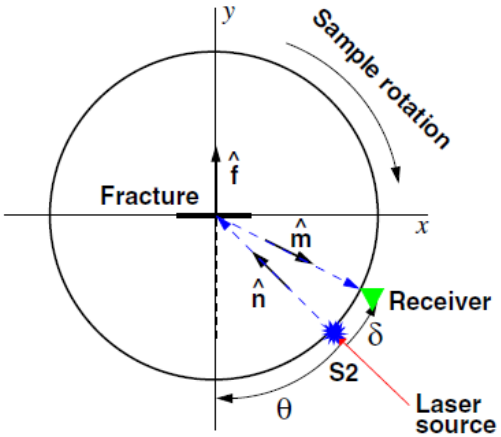
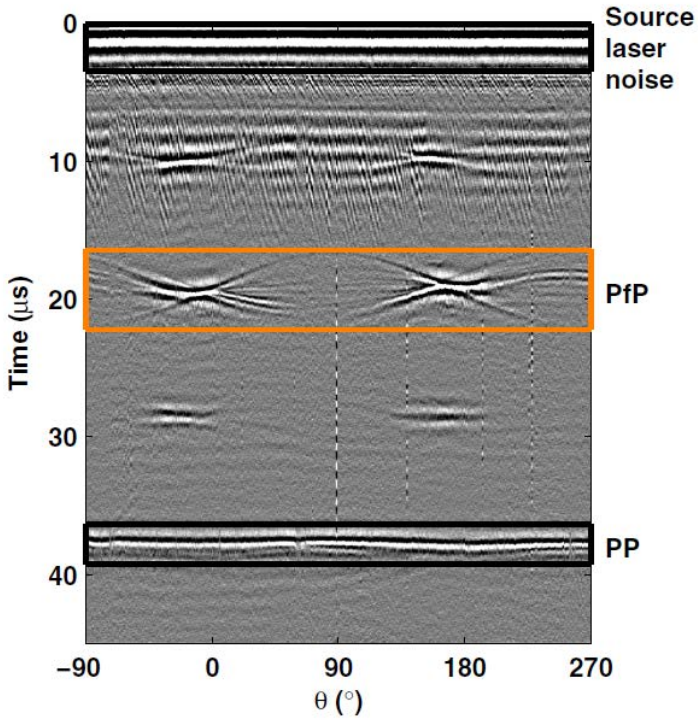


FIG. 1. Photograph of the laboratory sample and zoom around the disk-shaped fracture, with ruler units in cm. The sample is cut in half longitudinally to display the fracture without optical deformation by the curvature of the sample. The diameter of the fracture is ~7 mm, and the diameter of the cylinder is 50.8 mm.



Blum, T.E., K. van Wijk, R. Snieder, and M.E. Willis, 2011, Laser excitation of a fracture source for elastic waves, Physical Review Letters 107, 275501, doi: 10.1103/PhysRevLett.107.275501.

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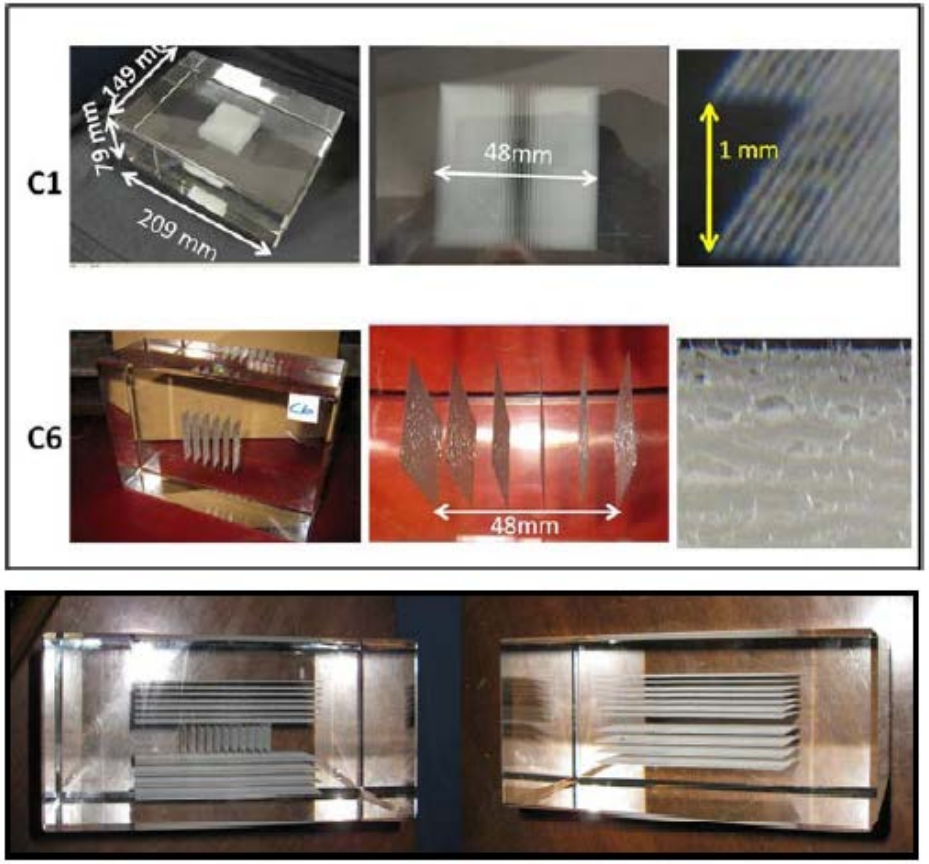
Scale Modeling of Fractures



Physical modeling of anisotropic domains: Ultrasonic imaging of laser-etched fractures in glass

Robert R. Stewart (University of Houston), Nikolay Dyaur (University of Houston), Bode Omoboya (University of Houston), J. J. S. de Figueiredo (Unicamp-Brazil and University of Houston), Mark Willis (ConocoPhillips, Houston), and Samik Sil (ConocoPhillips, Houston)*

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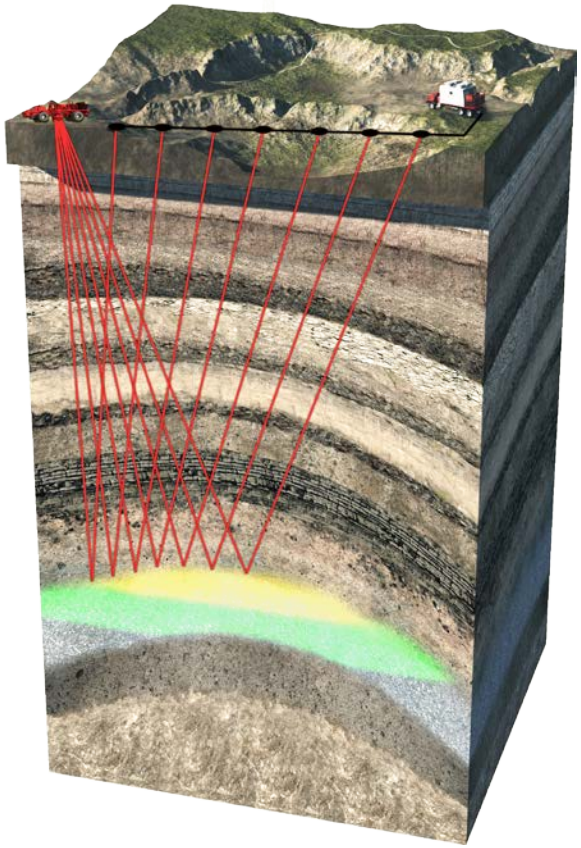
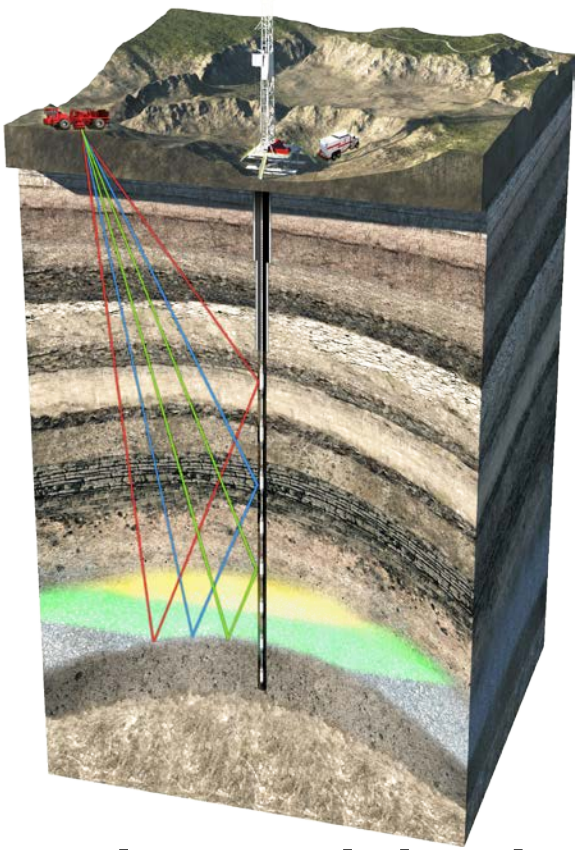
Vertical Seismic Profiles (VSP)

Surface seismic



In time

VSP



Time and depth

Logs

In depth

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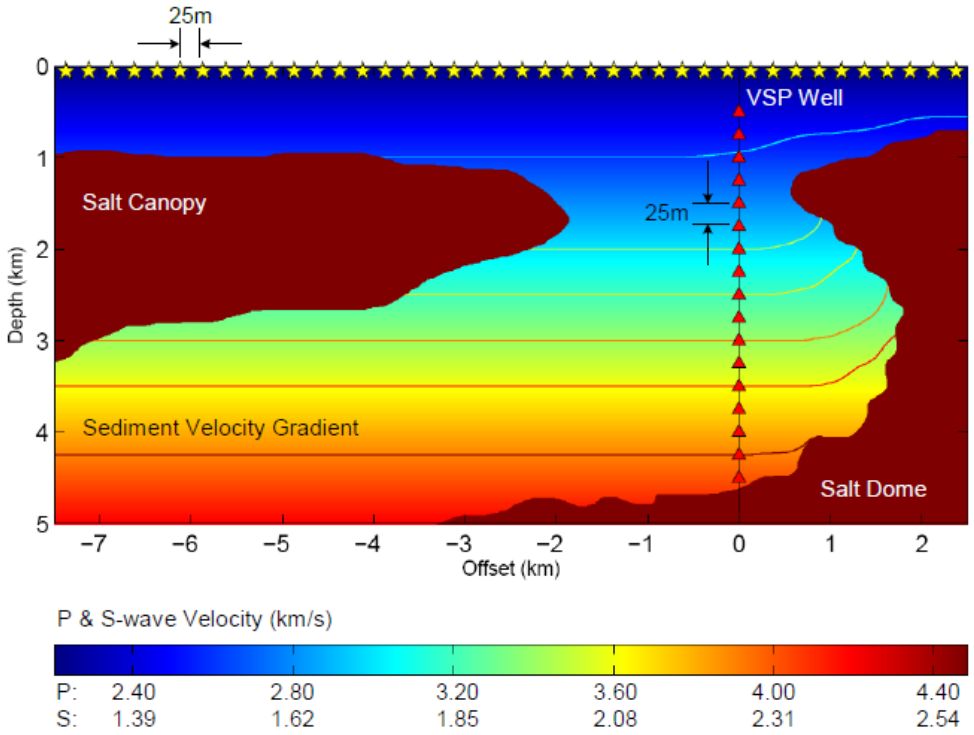
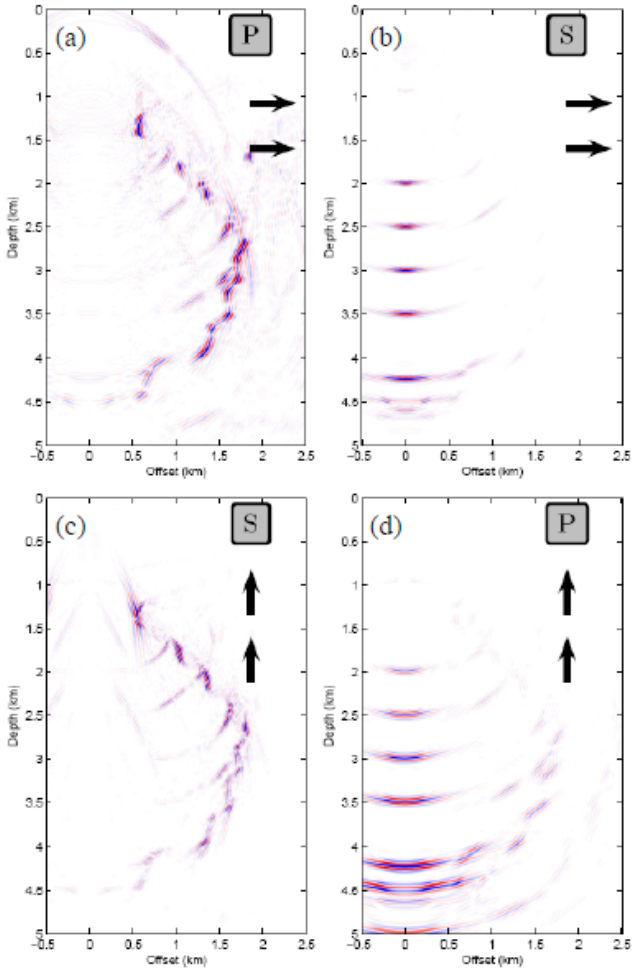
Interferometric Imaging of Salt Flanks With VSP data





Lu, R., Willis. M. E., Campman, X., and Toksöz, M.N., 2009, Evaluation of Elastodynamic interferometric redatuming: a synthetic study on salt dome flank imaging, Geophys. J. Int. 176(3), 889-896, doi: 10.1111/j.1365-246X.2008.04019.x.

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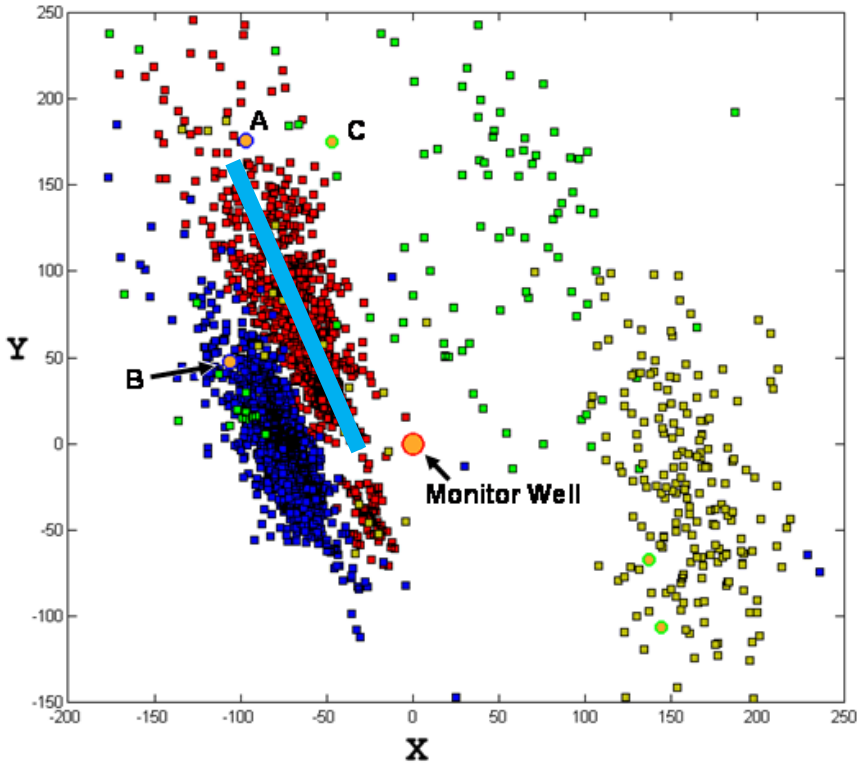
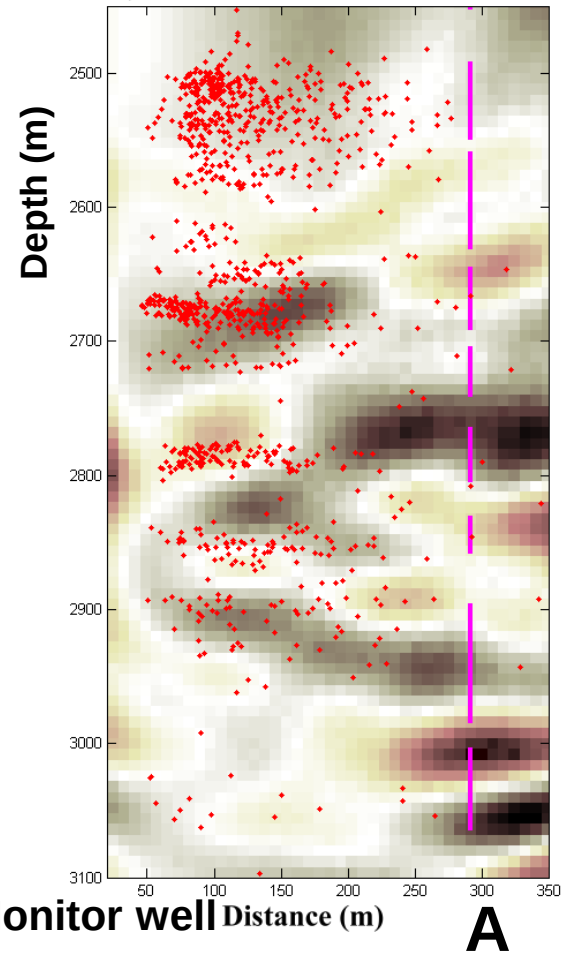
Diffractions From Hydraulic Fracturing

MEQ Event Locations

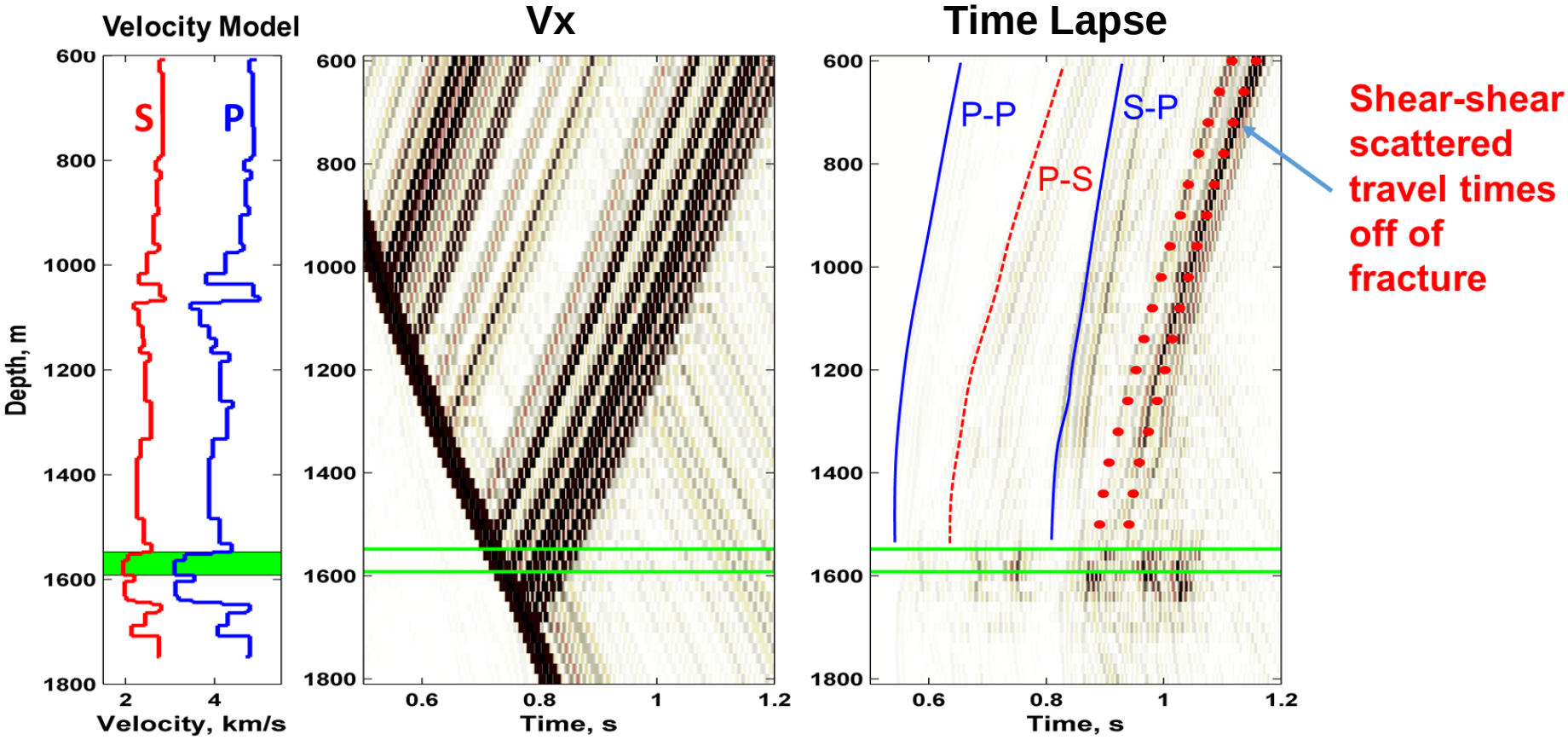


PP Time-Lapse Image with MEQ Dots



Willis, M.E., K.M. Willis, D.R. Burns, J. Shemeta, and N.J. House, 2009, Fracture quality images from 4D VSP and microseismic data at Jonah Field, WY, 79th annual SEG meeting, Expanded Abstracts, 4110-4114.

Diffractions Off Fractures



M.E. Willis, 2014, Estimating frac fluid pathways from rapid time-lapse VSP and microseismic events, SEG Annual Meeting.

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Some Innovation Opportunities – Thesis Topics!

- Characterization of unconventional reservoir rocks
  - Lab measurements of shales, tight gas, oil sands, heavy oils
  - Numerical modeling of fractured systems
- Determination of reservoir physical properties (before and after stimulation)
  - Advanced time lapse analyses
- Locating sweet spots
  - How to measure and quantify lateral changes
- Real-time monitoring of fracturing
  - Integrated fiber optic DAS monitoring of flow and seismic properties
  - Better microseismic monitoring methods
- Determination of propped area (stimulated reservoir volume)
  - How to detect proppant, how to dope the proppant
  - What measurements reveal the stimulated volume
- Prediction of missed pay
  - How to locate unfractured and unpropped areas
- How to reduce costs while getting better reservoir properties
  - How can we streamline our processes

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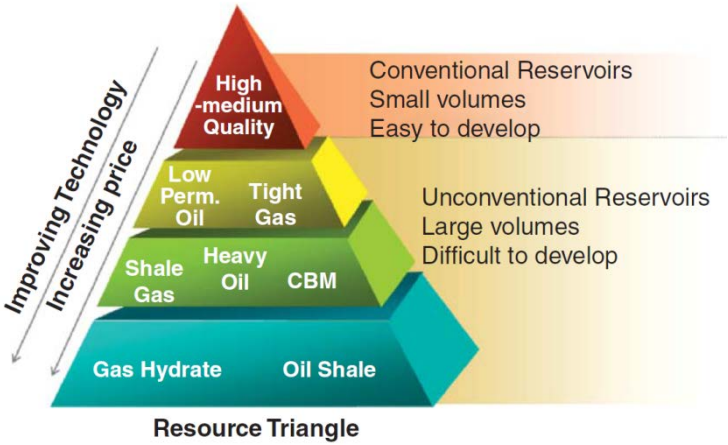
Summary



- Conventional resources
  - Small size
  - Structural or stratigraphic
  - High permeability and low viscosity
  - Easy to produce
- Unconventional resources
  - Expansive
  - Locked resource
  - Low permeability and viscosity
  - Requires technology and money to produce

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Questions

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