What Does Environmental Justice Have to Do With Me?

A Student's Guide to the Responsibilities of Engineers

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ENGINEERING	ETHICS
Risk	Acceptable Risk
Uncertainty	Plurality
Modeling	Inquiry into Values

Deliberation

Pedagogy

ENGINEERING

ETHICS

Workshop 1, November 2014

Engineering, Modeling and Risk

Workshop 2, April 2015

Ethics, Policy and Pedagogy

A Framework

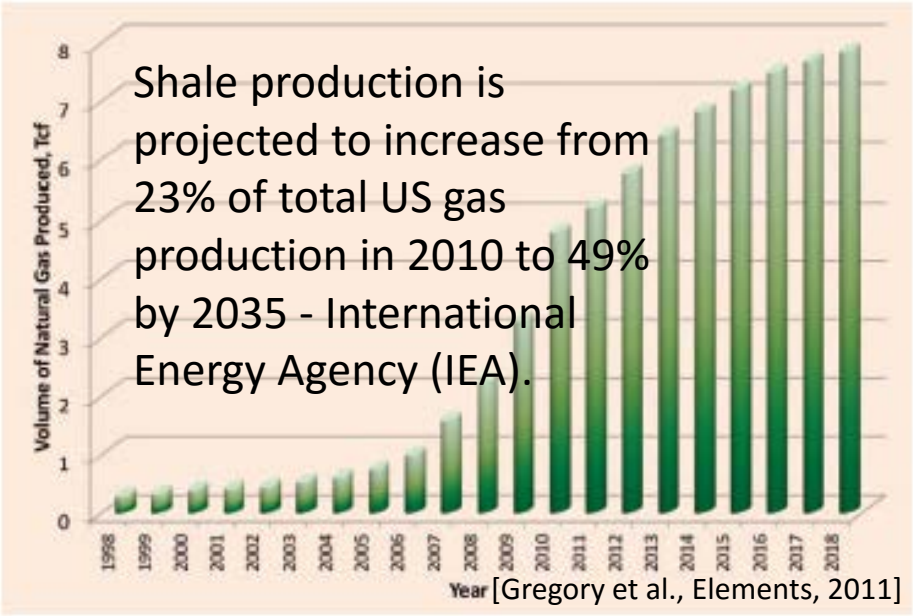
the Lab

the Field

the Forum

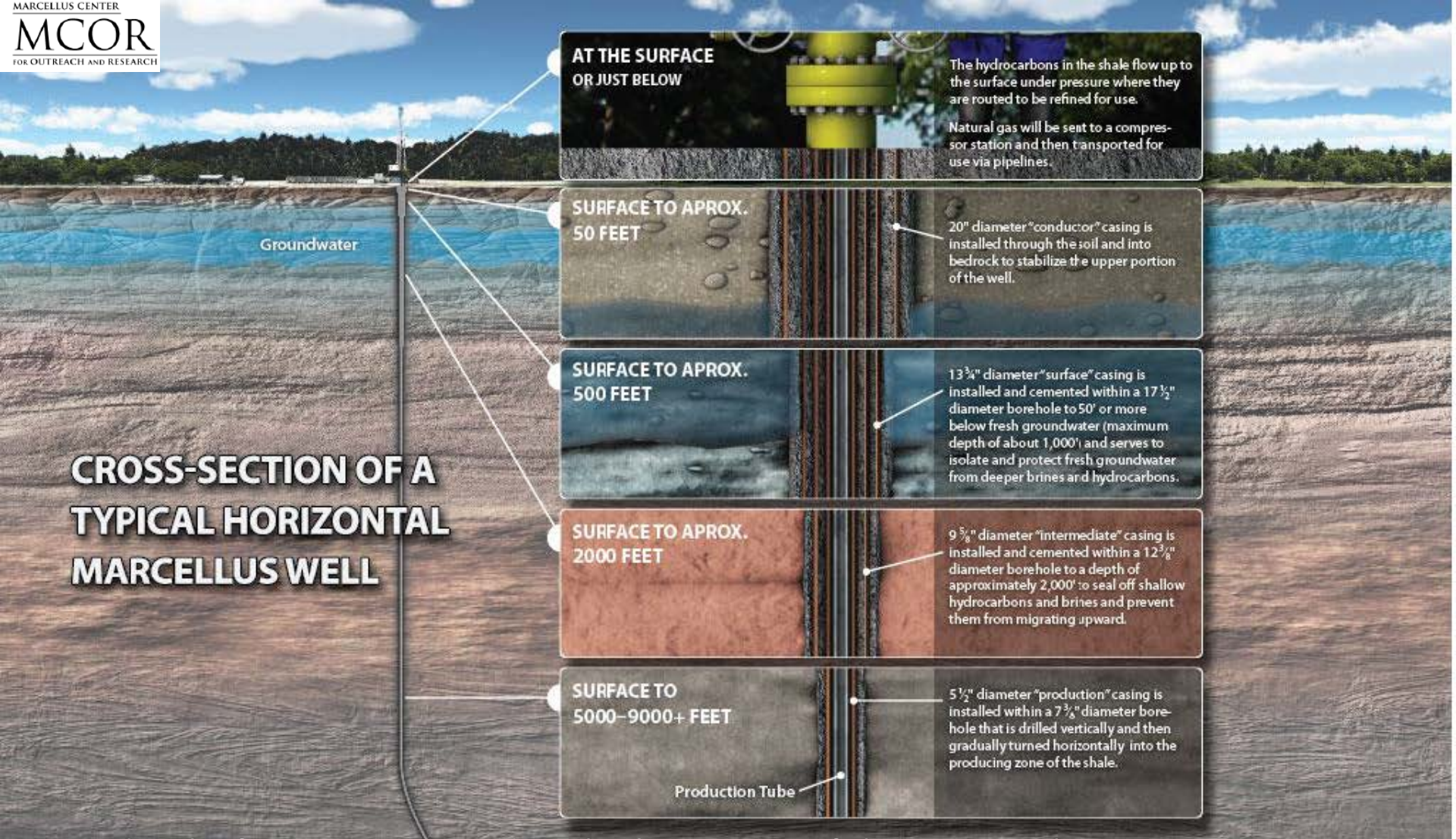
Hydraulic Fracturing

- Hydraulic fracturing is the process of injecting fluids into the rock mass under high pressure
- Propping agents are introduced to maintain the fractures open upon fluid withdrawal.
- The economical extraction of shale gas more than doubles the projected production potential of natural gas, from 125 years to over 250 years.



Shale production is projected to increase from 23% of total US gas production in 2010 to 49% by 2035 - International Energy Agency (IEA).

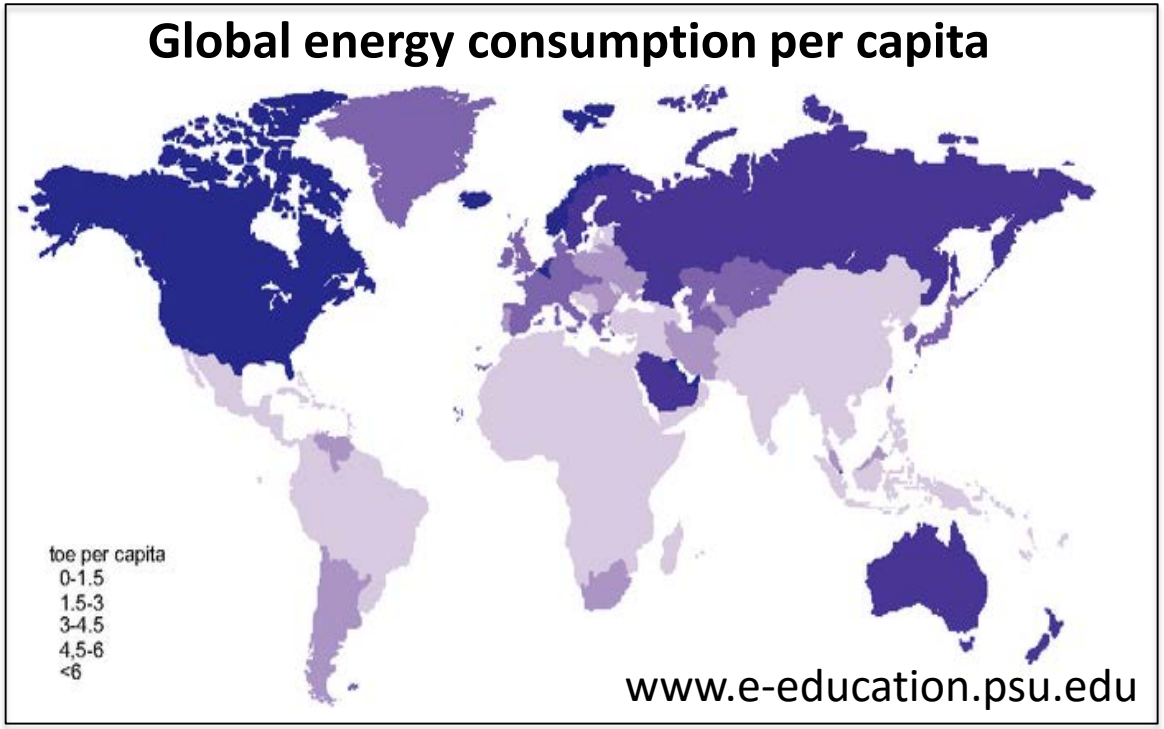
[Gregory et al., Elements, 2011]



- Hydraulic fracturing started at the beginning of the twentieth century in Kentucky's Devonian shale.
- It was based on explosives until the 40's.
- Lately, the technique of horizontal drilling created a revolution in unconventional oil and gas exploitation.

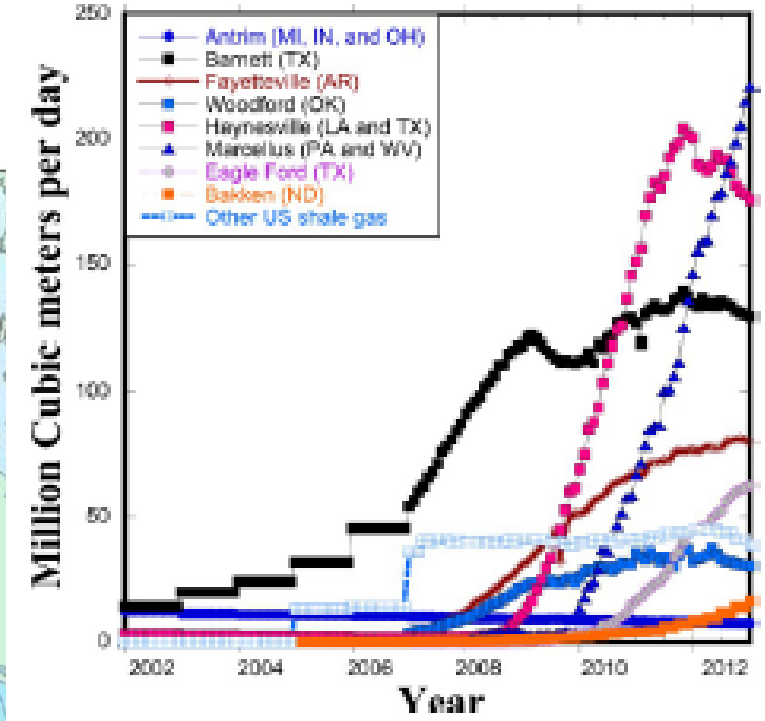
What are the reserves, energy needs and economic impacts?

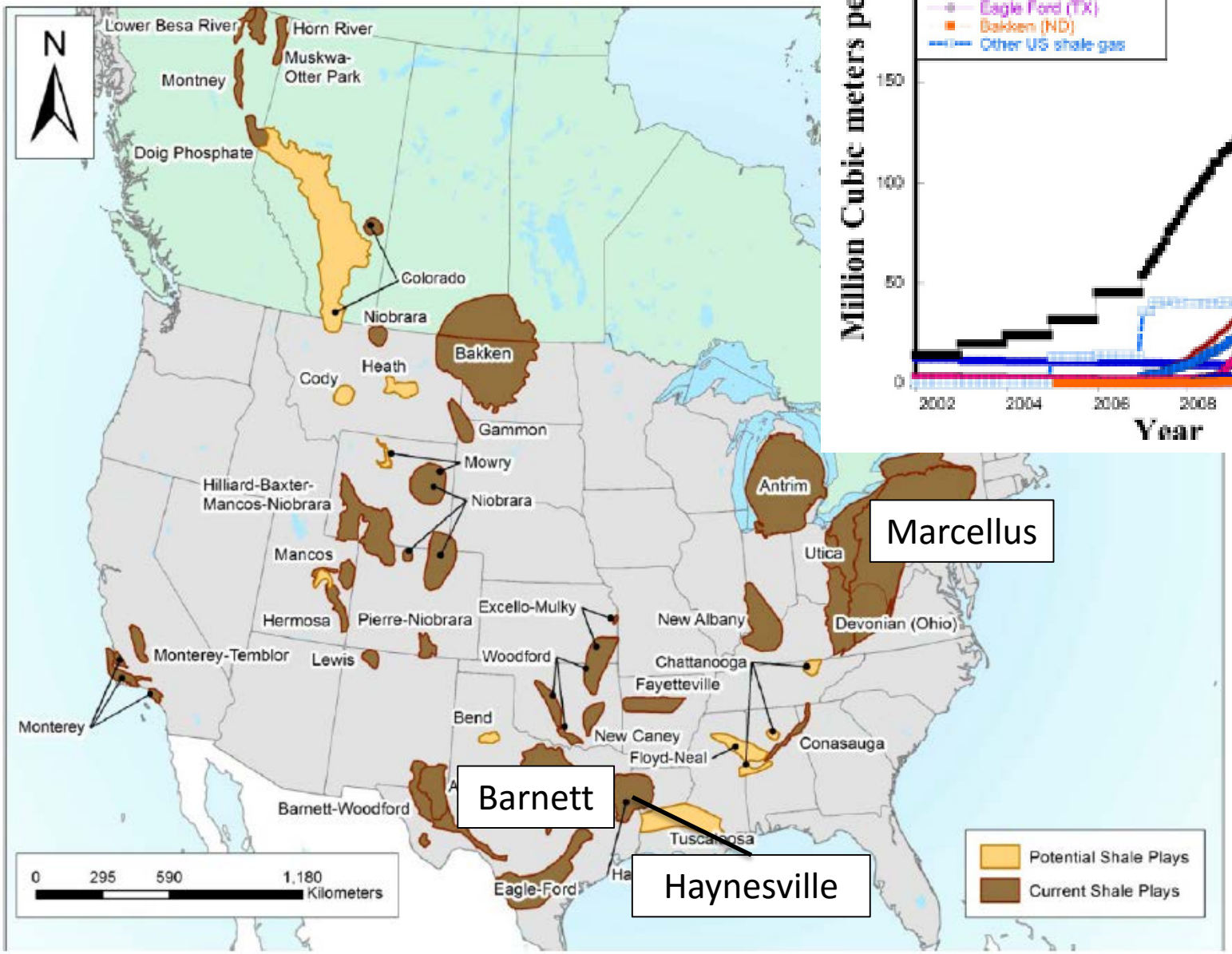
- At present, 85% of the energy power consumed in the world is produced by fossil fuel combustion.
- The United States produce about 20% of the natural gas consumed worldwide, which represents 4% of the world's current energy demand.



- In the past twenty years, the production of shale gas from wells in the United States raised from less than 2% to more than 40% of U.S. gas production.

Shale in the U.S





[Vengosh et al., Env. Sc. & Technology, 2014]

A Few Terms

Hazard

Risk

Uncertainty

Acceptable Risk

Acceptable Risk

What are the risks? → Which risks are acceptable?

descriptive normative

What level of risk may we reasonably expect people to put up with?

Acceptable Risk

Benefit

Equity

Consent

Environmental Justice

Equity and Consent regarding:

- Exposure to Risk
- Protection from Risk
- Access to Benefits
- Inclusion in Decisions

Local Control

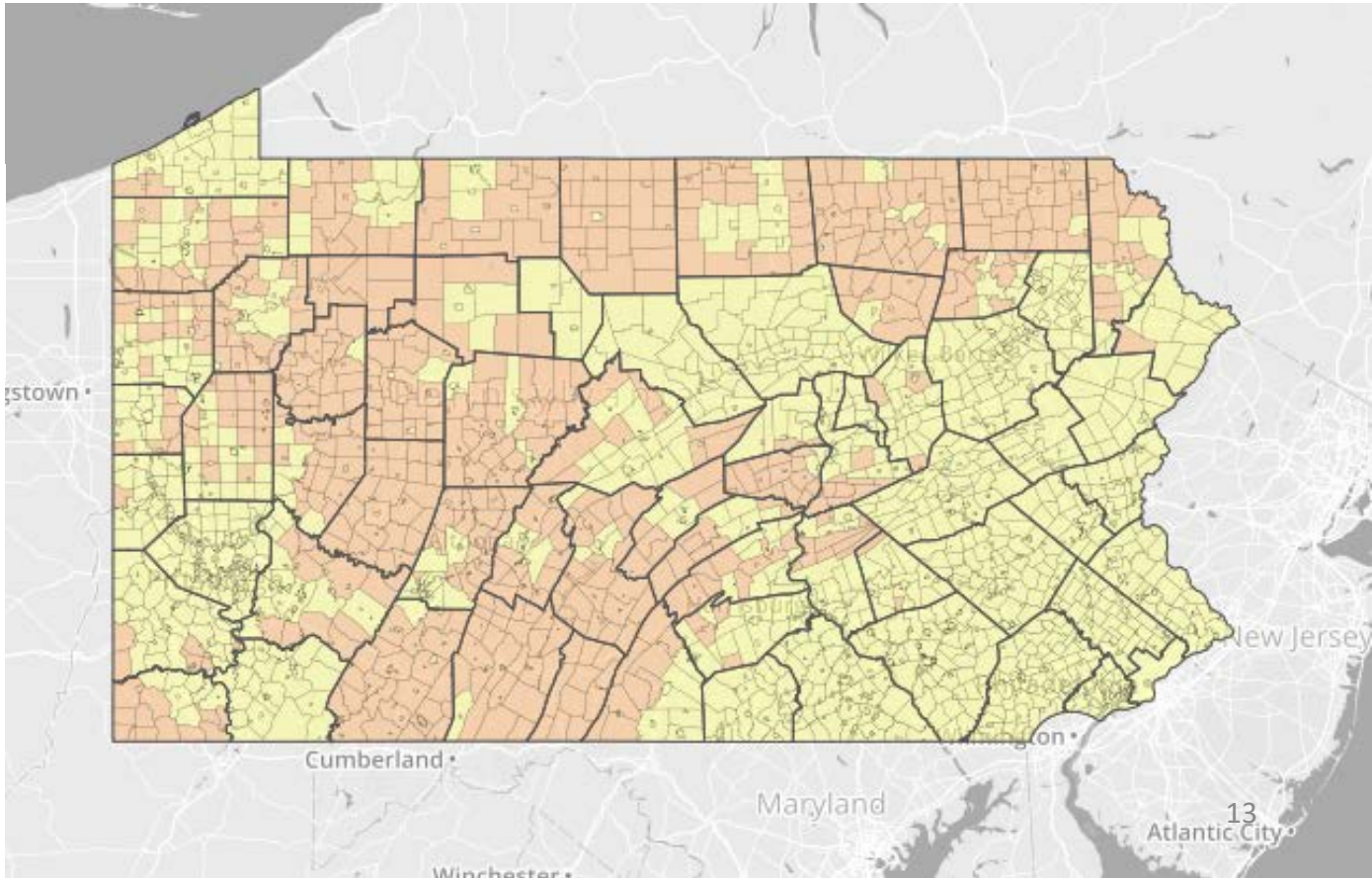
- Zoning laws do not allow drilling
- Each municipality must vote on if the residents want to allow drilling or not.

Read the related story.

By Katie Colaneri and Casey Thomas – February 11, 2014

Municipality with zoning

Municipality without zoning



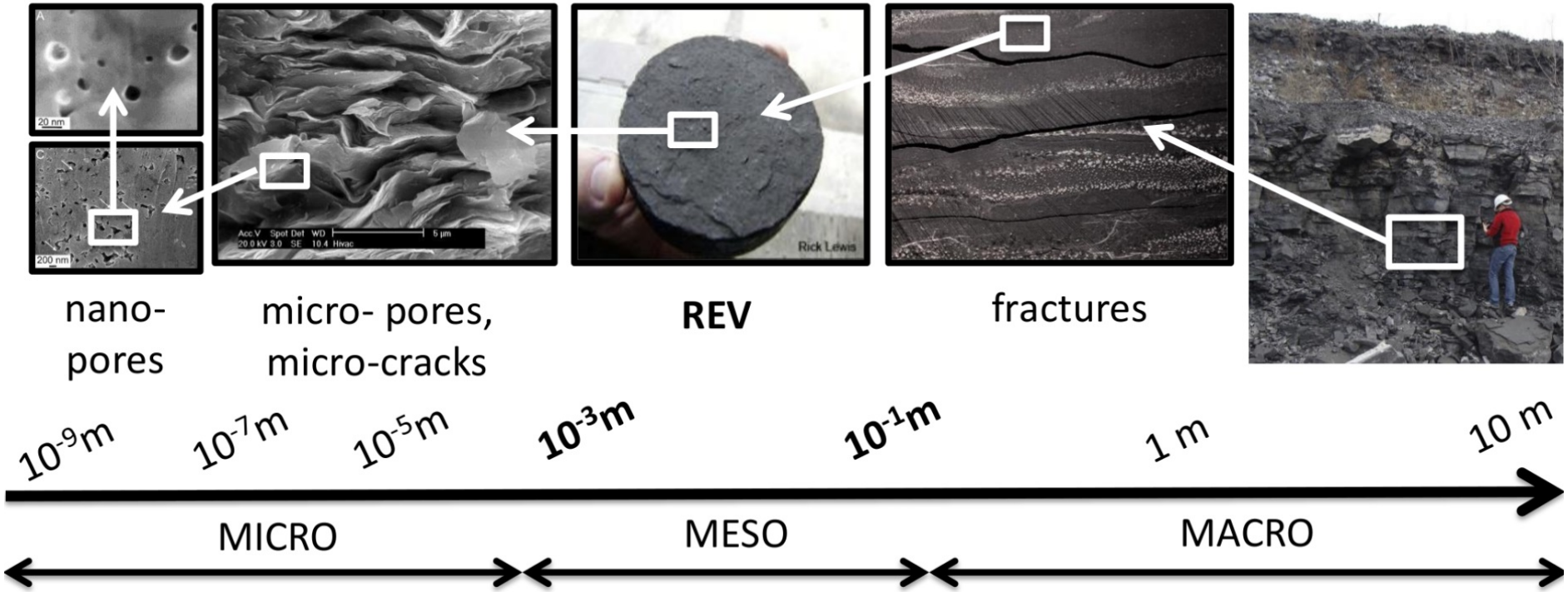
You may be asking:

What does all this have to do with me?

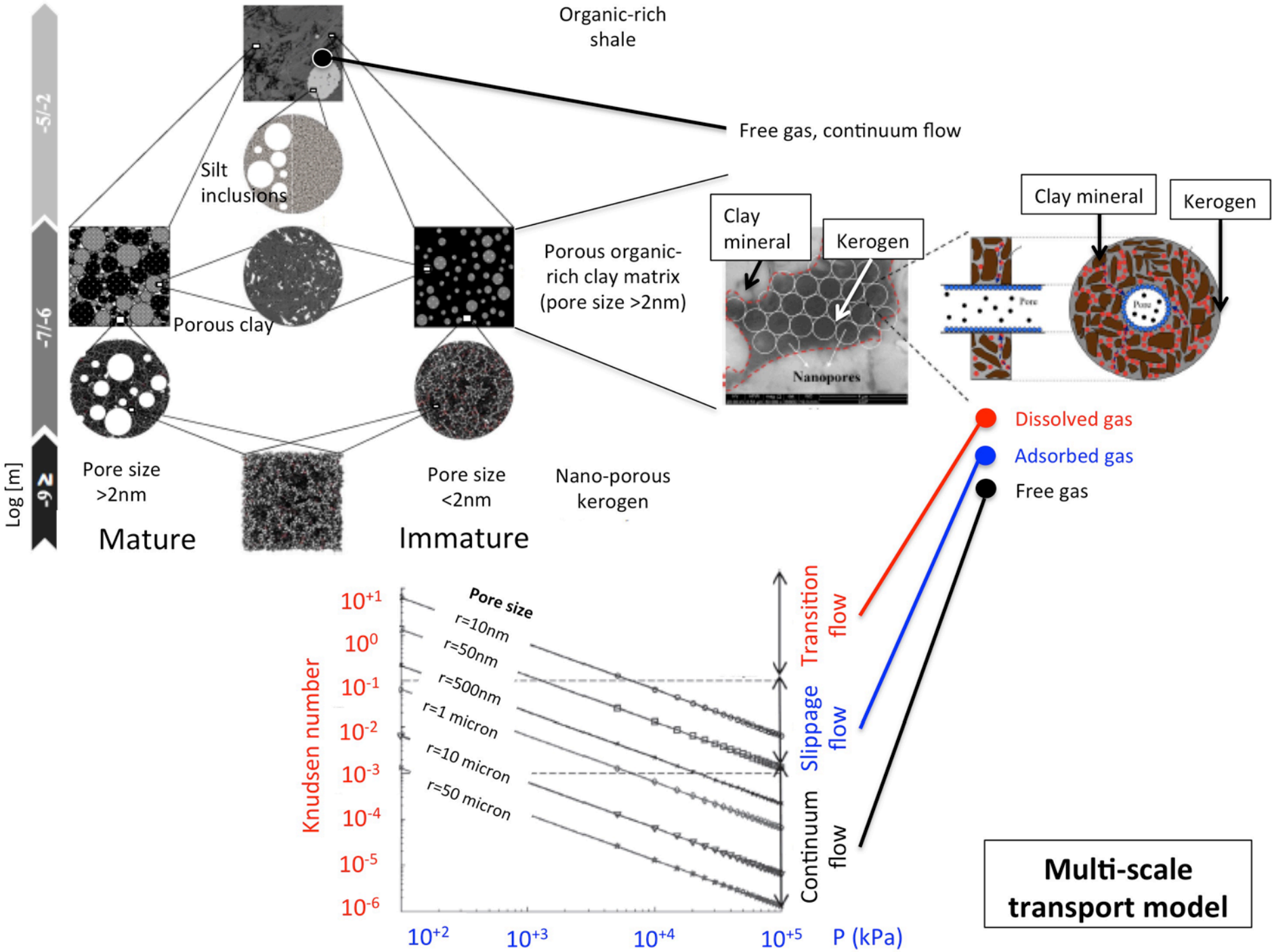
In the Lab

What is Shale?

- One third of U.S. natural gas is extracted from shale.
- Shale is a structured rock, containing clay flakes forming porous floccules of up to tens of micrometers.



[Xu, 2014]


Organic-rich shale
Free gas, continuum flow
Silt inclusions
Porous clay
Porous organic-rich clay matrix (pore size >2nm)
Clay mineral
Kerogen
Nanopores
Pore
Dissolved gas
Adsorbed gas
Free gas
Pore size >2nm
Pore size <2nm
Nano-porous kerogen
Mature
Immature
Log [m]
-5/-2
-7/-6
-9/-8
Knudsen number
Pore size
r=10nm
r=50nm
r=500nm
r=1 micron
r=10 micron
r=50 micron
Transition flow
Slippage flow
Continuum flow
P (kPa)
Multi-scale transport model

In the Field

Economic Impacts for PA

- **$19.5 billion to the state's labor income annually**
- 339,000 jobs, or **4.7% of employment in PA**
- **No Property tax increase** in Washington county for the past 5 years
- State Impact fees have generated **over $630 million over the past 3 years** and are given as grants to help communities

Water Consumption

- 8000 to 100 000 m3 (2– 13 million gallons) per unconventional well (3 to 38 olympic swimming pools)

Alternatives:

- As of 2012, companies were recycling 14% of the fracking water used, up from 1% in 2010. Recycling the water can cost up to 80% less than using an injection well.
- Other options include use of gels instead of fresh water-based fluids.

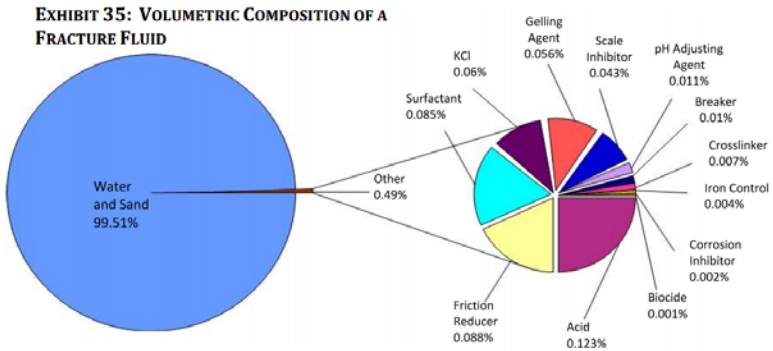
Water Pollution

- **Groundwater contamination** by salts or dissolved constituents and stray gases

- **Surface water contamination** from spills, leaks and disposal of untreated wastewater, HF fluids and backflow fluids

Water Pollution

Constituent	Composition (% by vol)	Example	Purpose
Water and sand	99.50	Sand suspension	"Proppant" sand grains hold microfractures open
Acid	0.123	Hydrochloric or muriatic acid	Dissolves minerals and initiates cracks in the rock
Friction reducer	0.088	Polyacrylamide or mineral oil	Minimizes friction between the fluid and the pipe
Surfactant	0.085	Isopropanol	Increases the viscosity of the fracture fluid
Salt	0.06	Potassium chloride	Creates a brine carrier fluid
Scale inhibitor	0.043	Ethylene glycol	Prevents scale deposits in pipes
pH-adjusting agent	0.011	Sodium or potassium carbonate	Maintains effectiveness of chemical additives
Iron control	0.004	Citric acid	Prevents precipitation of metal oxides
Corrosion inhibitor	0.002	n,n-dimethyl formamide	Prevents pipe corrosion
Biocide	0.001	Glutaraldehyde	Minimizes growth of bacteria that produce corrosive and toxic by-products



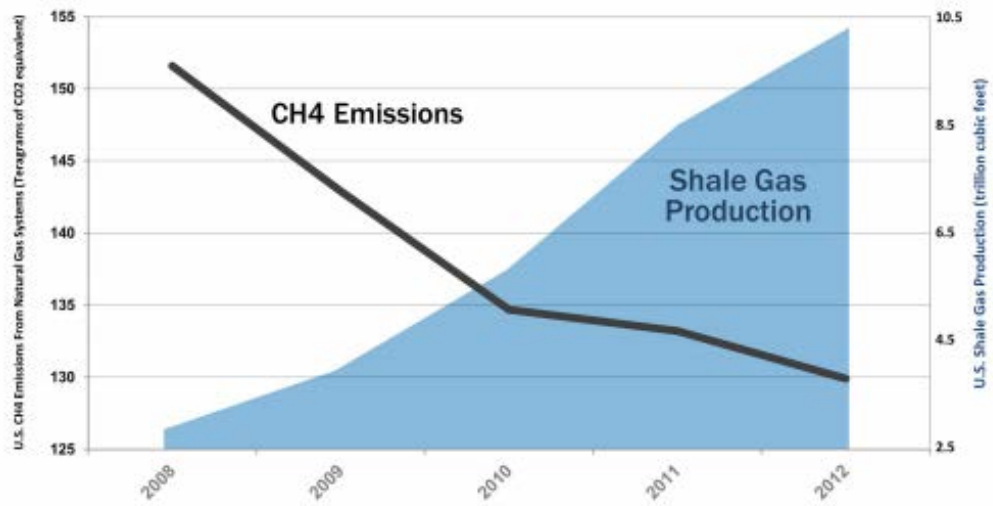
Gregory et al., Elements, 2011

Air Pollution

"Natural gas plays a key role in our nation's clean energy future."

EPA, 2014

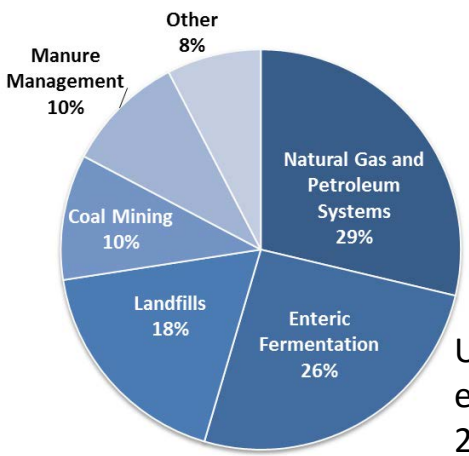
- Methane emissions have decreased 16.9% since 1990
- Green House Gas emissions reduce by ½ as power plants switch from coal to natural gas



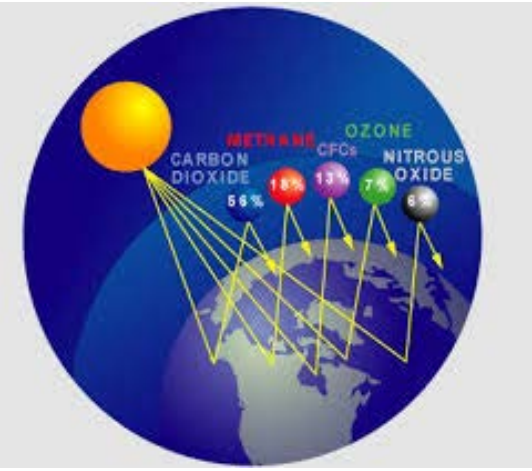
SOURCE: EIA, EPA

Air Pollution

- Methane is a very potent greenhouse gas that, according to the latest IPCC report, is ~ 84 times as potent as CO2 over a 20 year time frame and ~ 36 times as potent over 100 years.
- Because of the methane problem, the US EPA came out with proposed rules for new and modified sources in the oil and gas sector this past fall.
- Natural gas development from shale offers no climate advantage and, at current rates of leakage during production and transmission, may actually be worse than coal from a lifecycle perspective.



U.S. methane emissions, 1990-2013 (EPA)



Induced Micro-seismicity

- Felt seismic events (M>2) officially correlated with hydraulic fracturing for shale gas development: Blackpool, England, 2011 (NRC, 2013); Prague, Oklahoma, 2011 (USGS, 2014; Sumy et al., 2014)

- Other possible earthquake sequences may be associated with hydraulic fracturing in Oklahoma.

- Reoccurring problem in induced seismicity studies: the seismic events are small, the regional networks are sparse, and the data quality is often too poor to fully confirm a causal link to fluid injection for energy development.

Induced Micro-seismicity

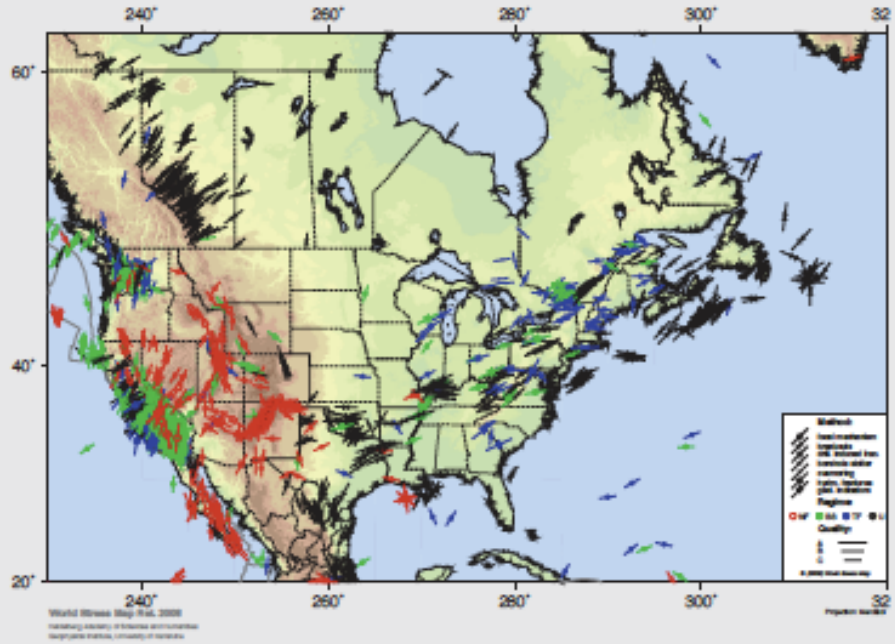


Figure 4 North America stress map. The stress map displays the orientations of the maximum horizontal compressive stress (σ_H). The length of the stress symbols represents the data quality, with A being the best quality. Quality A data are assumed to record the orientation of σ_H to within 10°-15°, quality B data to within 15°-20°, and quality C data to within 25°. As can be seen from this global dataset, stress measurements are absent in many parts of North America and the offshore regions. Because stress measurements are important in the consideration of induced seismicity, their measurement, particularly in areas where data are sparse, could usefully contribute to understanding the potential for induced seismicity related to energy development. The tectonic regimes are NF for normal faulting, SS for strike-slip faulting, TF for thrust faulting, and U for an unknown regime. Topographic relief is indicated by green (lower elevations) to brown (higher elevations) shading. SOURCE: Data used to plot this map were accessed from www.world-stress-map.org/ (see Heidbach et al., 2008).

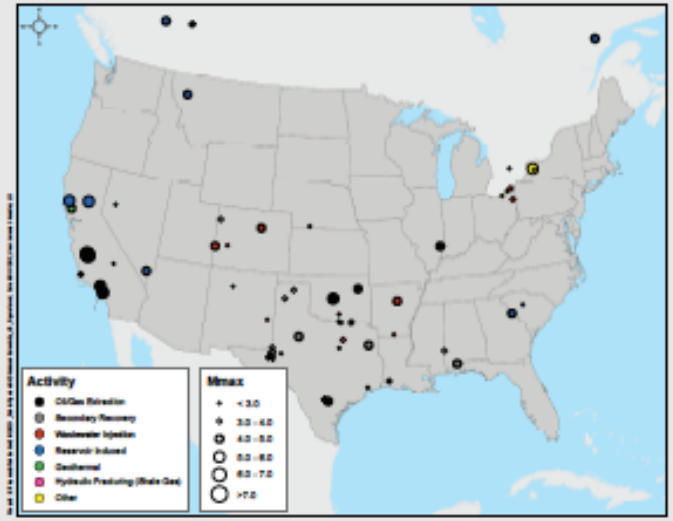
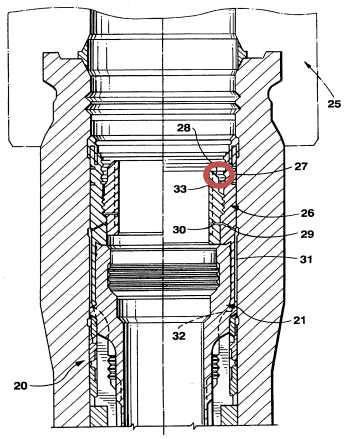


Figure 2 Locations of seismic events caused by or likely related to human activities within the coterminous United States and portions of Canada as documented in the technical literature.

Energy geotechnology vs. natural faults (NRC, 2013)

Explosions



- A failed gland nut (28) and lockscrew assembly caused the loss of well control
- The completion of the well was delayed due to weather
- Pressure of gas builds up
- Well is not sealed properly
- Lockpin releases gases

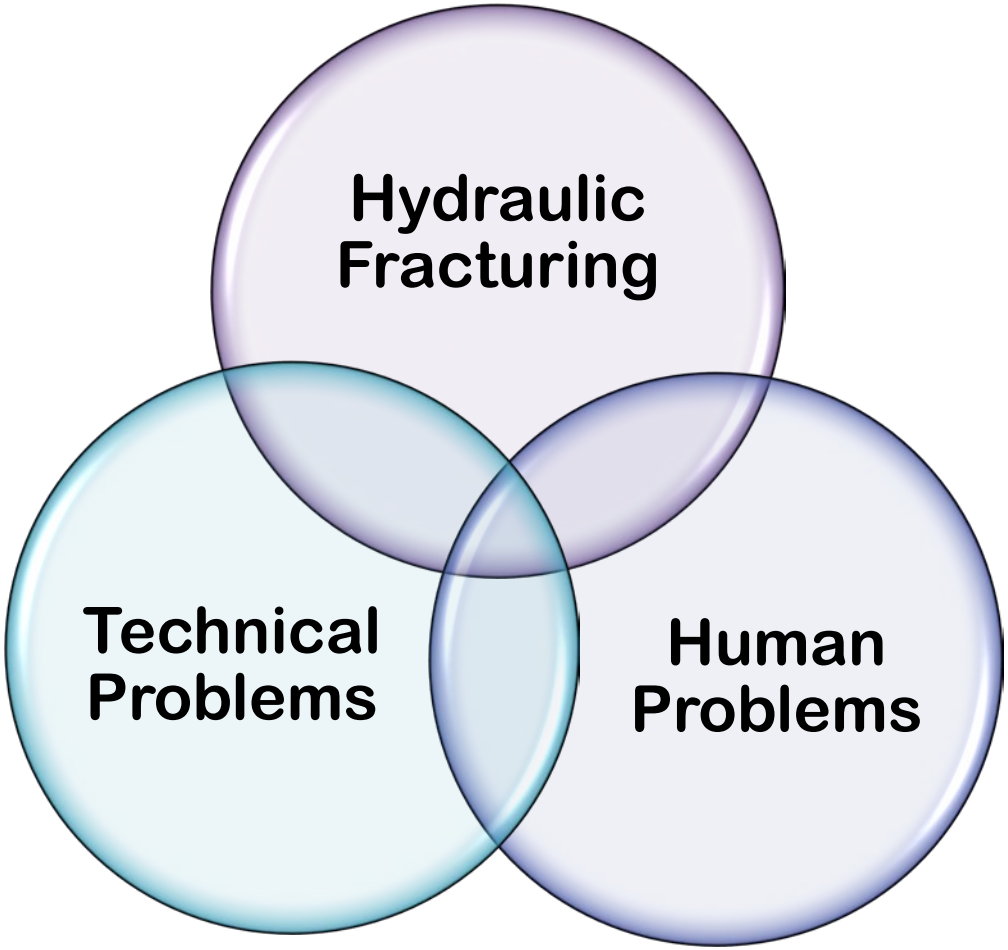
- Insufficient casing, BOP (blow out preventer), cement or wait on cement to prevent waste from conservation well.
- Failure to use casing of sufficient strength and other safety devices to prevent blowouts, explosions and fires.
- Failure to provide free and unrestricted access.

EPA recommendations put the responsibility to prevent future explosions on the well owners, inspectors, contractors and engineers associated with the well.

In the Forum

At its best:	At its worst:
Deliberation	Maneuvering
Argument	Manipulation
Consensus	Division

In the Forum



In the Forum

Challenges for Engineers:

Communication

Navigation

Trust

Modesty

In School

The Formation of Responsible Engineers

- Stand-Alone Courses
- Integration into Degree Programs
- Work Experience
- Events
- Campus Culture

What can you do now?