An Overview of Hydraulic Fracturing

Presented on behalf of the
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Weyburn, SK

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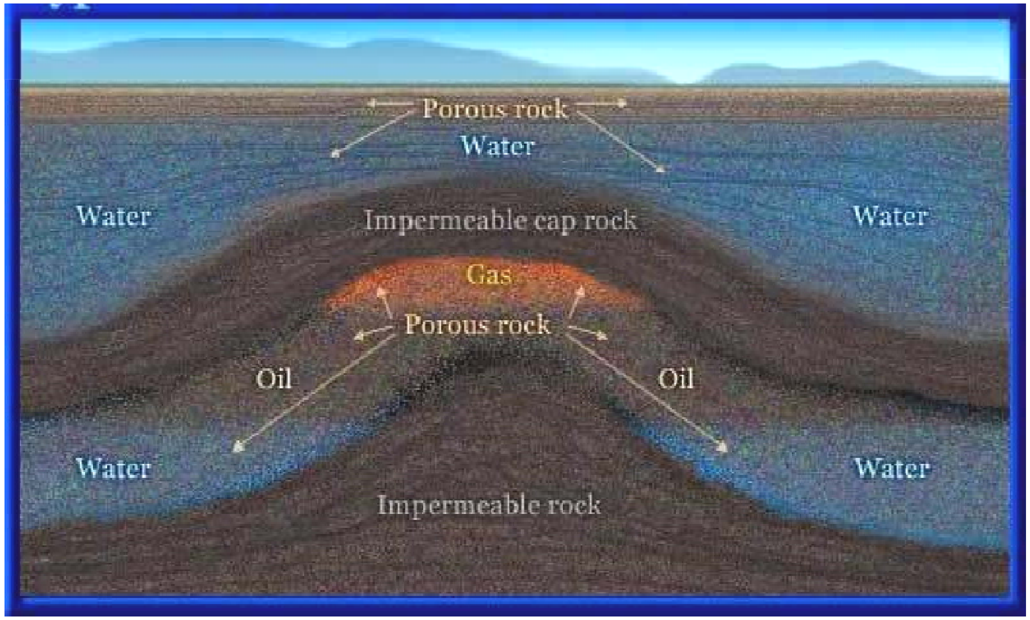
Presentation Overview

- What is an oil reservoir?
- Brief history of hydraulic fracturing.
- What is hydraulic fracturing?
- What are the components of fracture fluids?
- The facts behind hydraulic fracturing concerns and possible risks.



http://www.planetseed.com/node/15250

Terminology

Hydraulic fracturing

- Hydrofracking
- Fracking
- Fraccing
- Fracing (frac'ing)
- Frac jobs
- Fracture stimulation
- Well stimulation

How Do Oil/Gas Reservoirs Form?

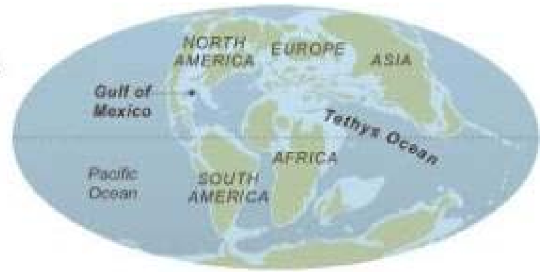
- Reservoir: A subsurface "pool" of hydrocarbons contained within porous or fractured subsurface rocks.
  - Not an actual cavern or void space.
- The hydrocarbons (oil/gas) originally began as organic matter (plankton, plants, animal remains, etc…) that was buried and compressed by other layers of sediment.
- After burial, the pressure and temperature increase, essentially "cooking" the plant and animal matter into oil and gas.
- The oil and gas often migrate away from the organic-rich source rock and accumulate in underground "traps."

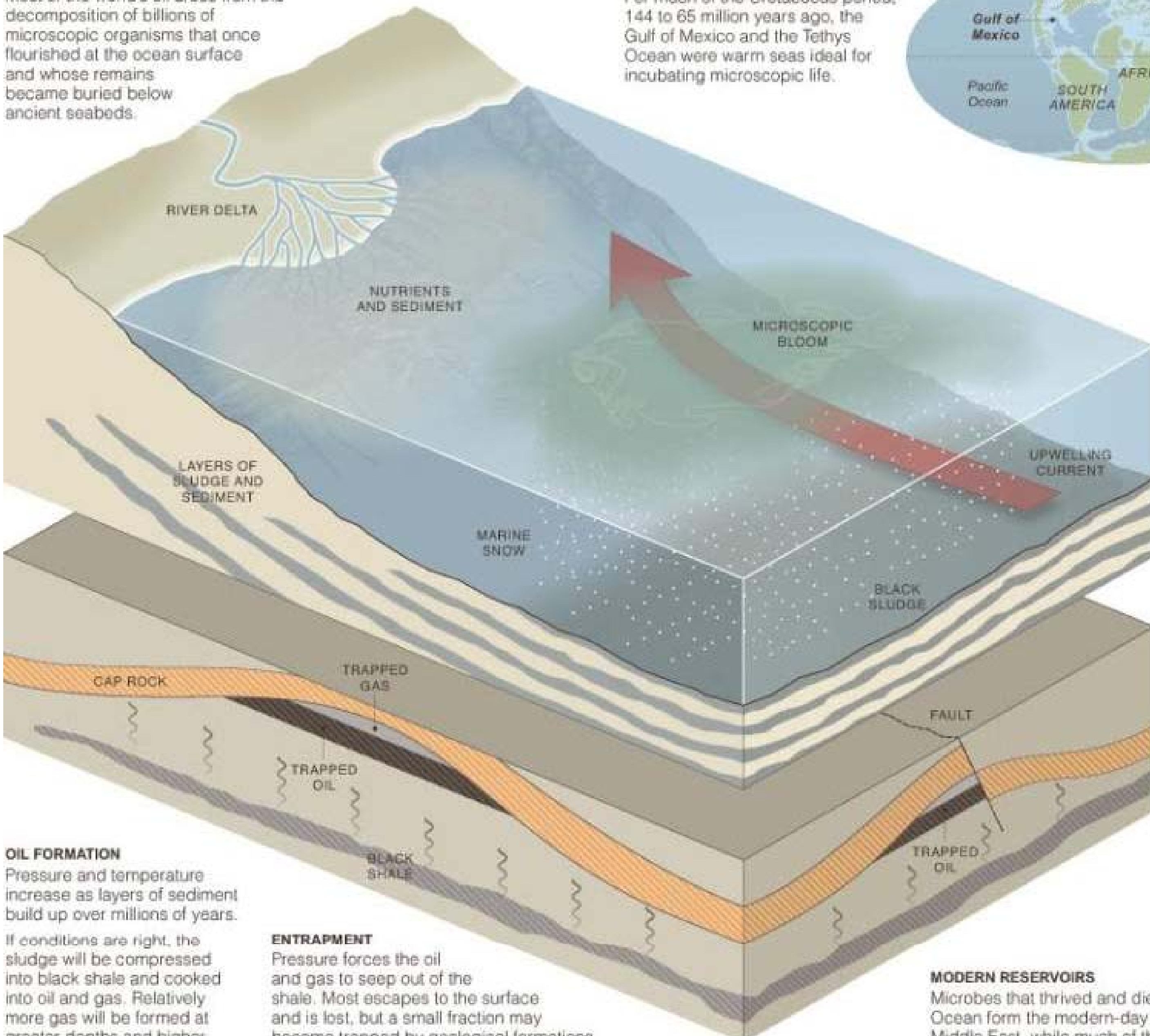
From Microbes to Crude

Most of the world's oil arose from the decomposition of billions of microscopic organisms that once flourished at the ocean surface and whose remains became buried below ancient seabeds.

ANCIENT SEAS

For much of the Cretaceous period, 144 to 65 million years ago, the Gulf of Mexico and the Tethys Ocean were warm seas ideal for incubating microscopic life.





BLACK SLUDGE

Oil production begins when nutrients from rivers or upwelling currents encourage microbes to thrive in warm surface waters.

If the "marine snow" of debris and dead microbes falling from the surface outpaces decay on the seabed, the microbes will accumulate into a thick biologic sludge.

Sediment covering the sludge prevents further decay.

OIL FORMATION

Pressure and temperature increase as layers of sediment build up over millions of years.

If conditions are right, the sludge will be compressed into black shale and cooked into oil and gas. Relatively more gas will be formed at greater depths and higher temperatures.

ENTRAPMENT

Pressure forces the oil and gas to seep out of the shale. Most escapes to the surface and is lost, but a small fraction may become trapped by geological formations above the shale.

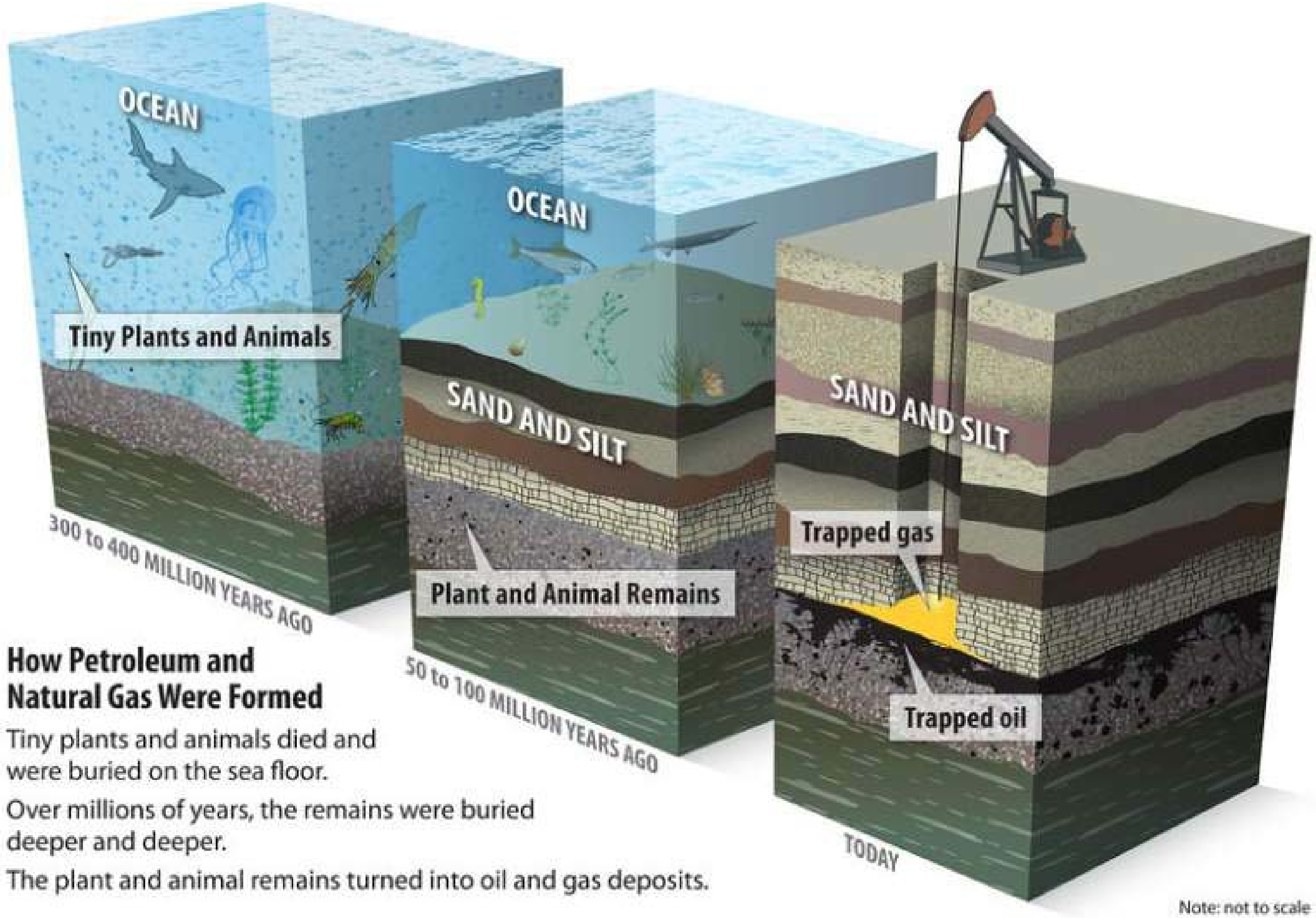
MODERN RESERVOIRS

Microbes that thrived and died in the ancient Tethys Ocean form the modern-day oil deposits of the Middle East, while much of the oil trapped below the ancient Gulf of Mexico remains under the seafloor.

Sources: "Vanished Ocean" by Dorrik Stow; "Understanding Earth" by John Grotzinger, et al.; Ron Blakey, Northern Arizona University Geology

JONATHAN CORUM/THE NEW YORK TIMES

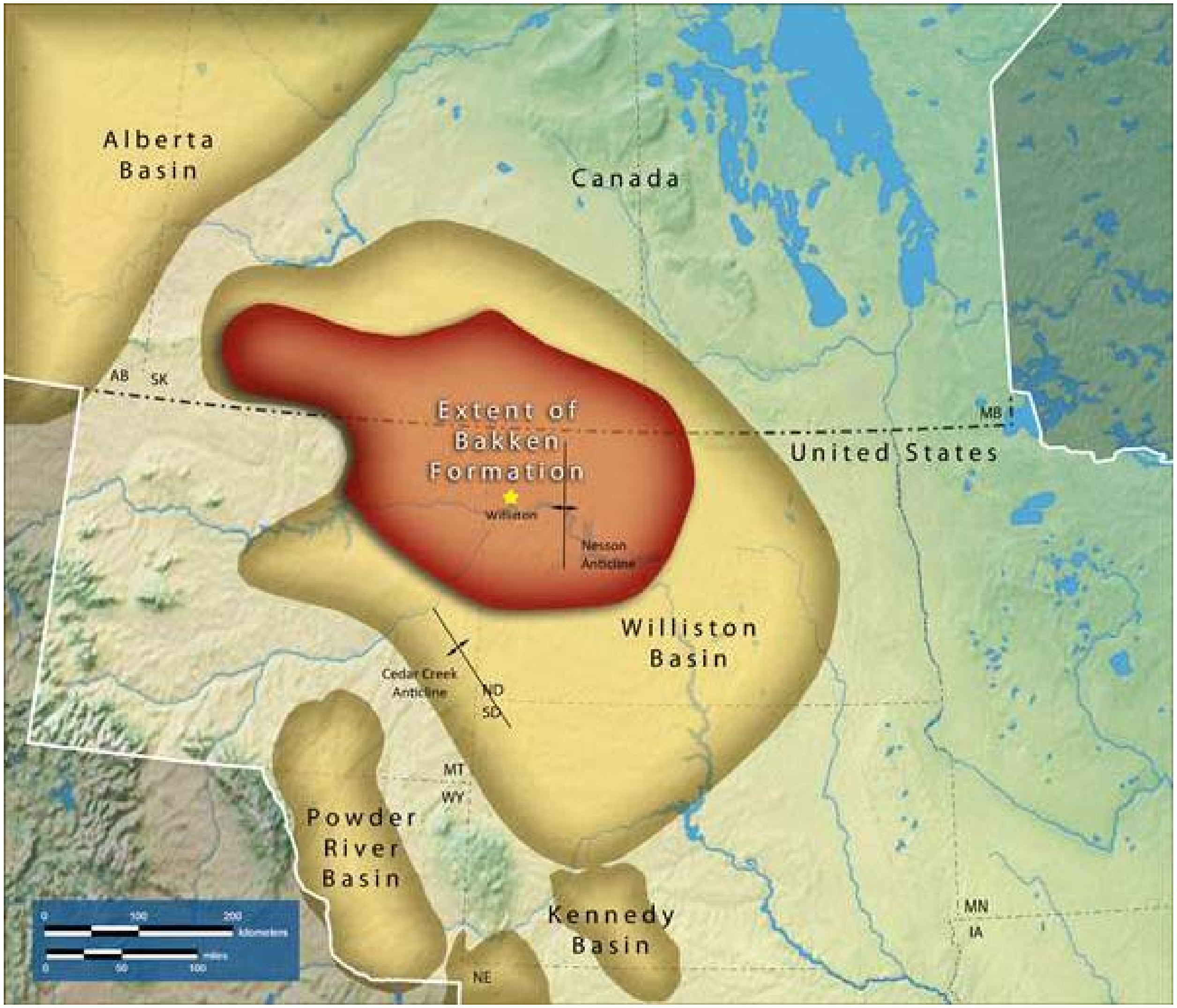
Hydrocarbon Formation



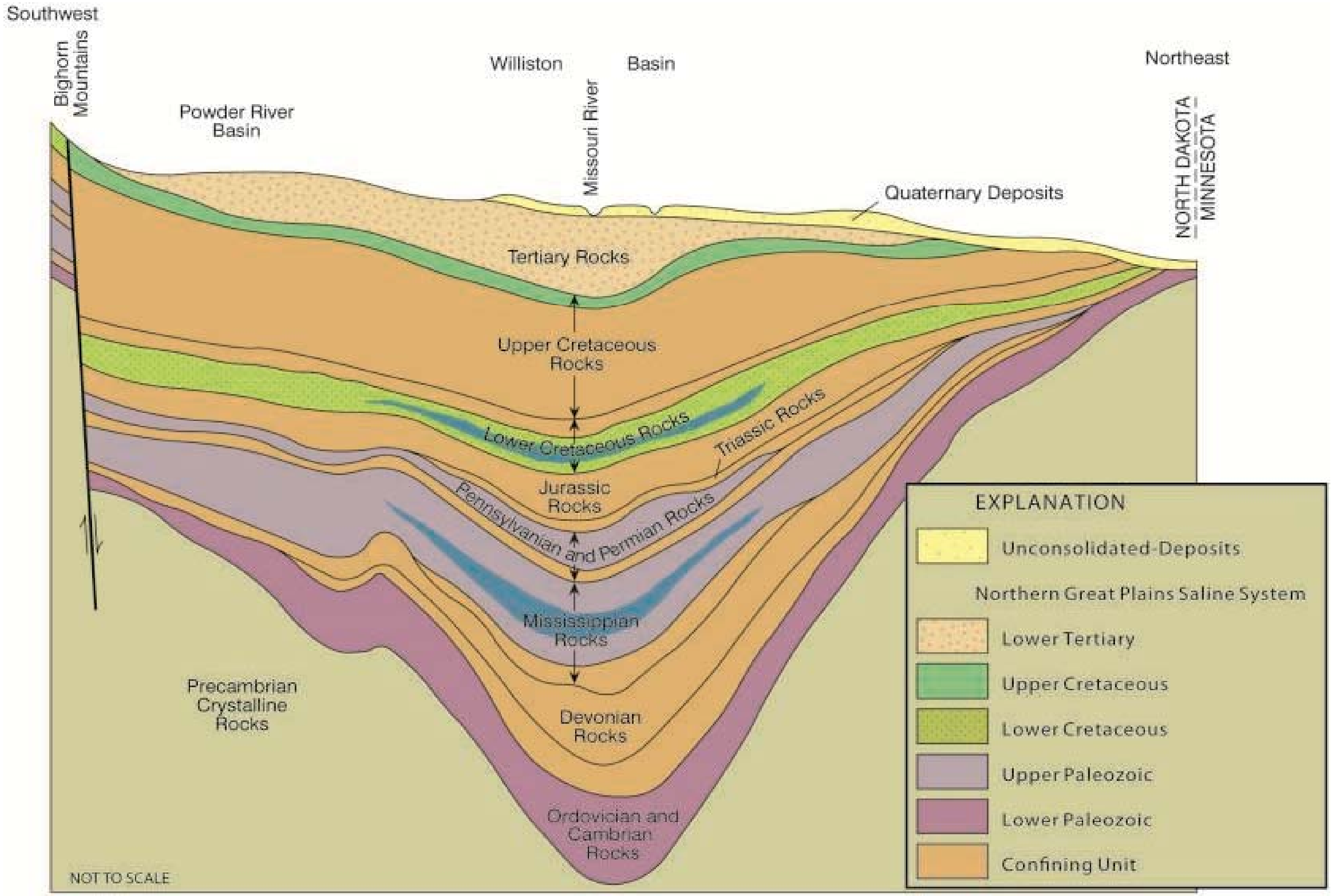
http://need-media.smugmug.com/Graphics/Graphics/i-n5JP5Fd/0/L/oilNaturalGasFormationPrimary-L.jpg

Sedimentary Basins of North America

Williston Basin

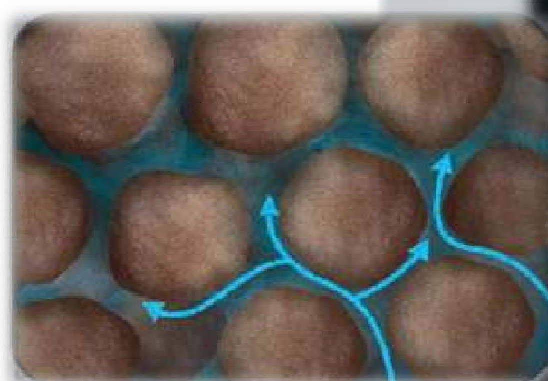


Williston Basin Cross Section



Porosity and Permeability

- The amount of oil in a reservoir and industry's ability to remove it are determined by the porosity and permeability of the reservoir rock.
- Porosity is the percentage of pore volume or void space within rock.
- Permeability determines how well fluids move through a rock.
  - Depends on how many pore spaces are in a rock and whether or not the pores are connected.



Permeability

- Rocks that transmit fluids readily, such as sandstones, are permeable and have many (relatively) large, well-connected pores.

- Impermeable rocks tend to be finer-grained such as shales and siltstones, with smaller, fewer, or less interconnected pores.

Historical Oil/Gas Extraction

- Historically, oil and gas reservoirs were in rocks that had relatively high permeability and/or porosity – "low hanging fruit."
- With advances in horizontal drilling and hydraulic fracturing, industry is now able to economically extract oil and gas from unconventional reservoirs, meaning rocks that have low porosity and permeability.

Source: Energy Information Administration based on data from various published studies.
Updated: March 21, 2011

Brief Explanation of Hydraulic Fracturing

- A technique used to extract oil and gas from very “tight” rocks (low permeability) in the subsurface.
- To produce oil and gas from these reservoirs, a mixture of water, proppant, and, to a lesser degree, chemical additives, is injected into the reservoir at high pressures to create fractures in the rock.
- These fractures create a pathway for hydrocarbons to move through the reservoir to be extracted.

History of Hydraulic Fracturing

- The first experimental fracturing operation was conducted in 1947 by Stanolind Oil in the Hugoton Field (gas-producing limestone) located in southwestern Kansas (Montgomery and Smith, 2010).
  - Utilized 1000 gallons of napalm (gelled gasoline) and sand from the Arkansas River.

History of Hydraulic Fracturing (continued)

- In 1949, an exclusive license for the hydraulic fracturing process was granted to the Halliburton Oil Well Cementing Company.
- On March 17, 1949, Halliburton performed the first two commercial hydraulic fracturing treatments in Stephens County, Oklahoma, and Archer County, Texas (Montgomery and Smith, 2010).

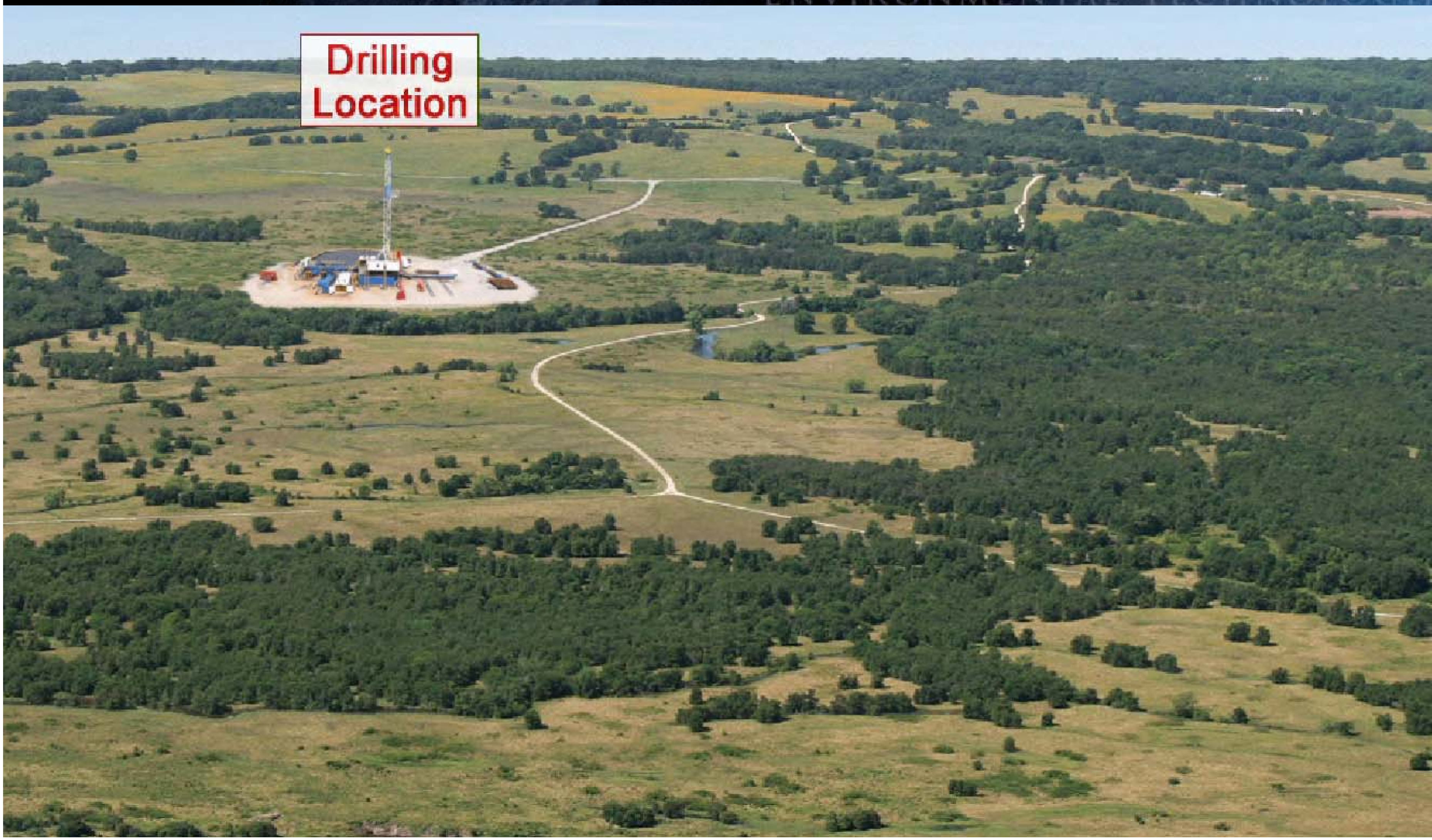
Early Hydraulic Fracturing Operations

Vintage 1950s remotely controlled fracture pumper powered by surplus WWII Allison aircraft engines (Montgomery and Smith, 2010).

Times Have Changed

http://www.cuadrillaresources.com/what-we-do/hydraulic-fracturing/history/

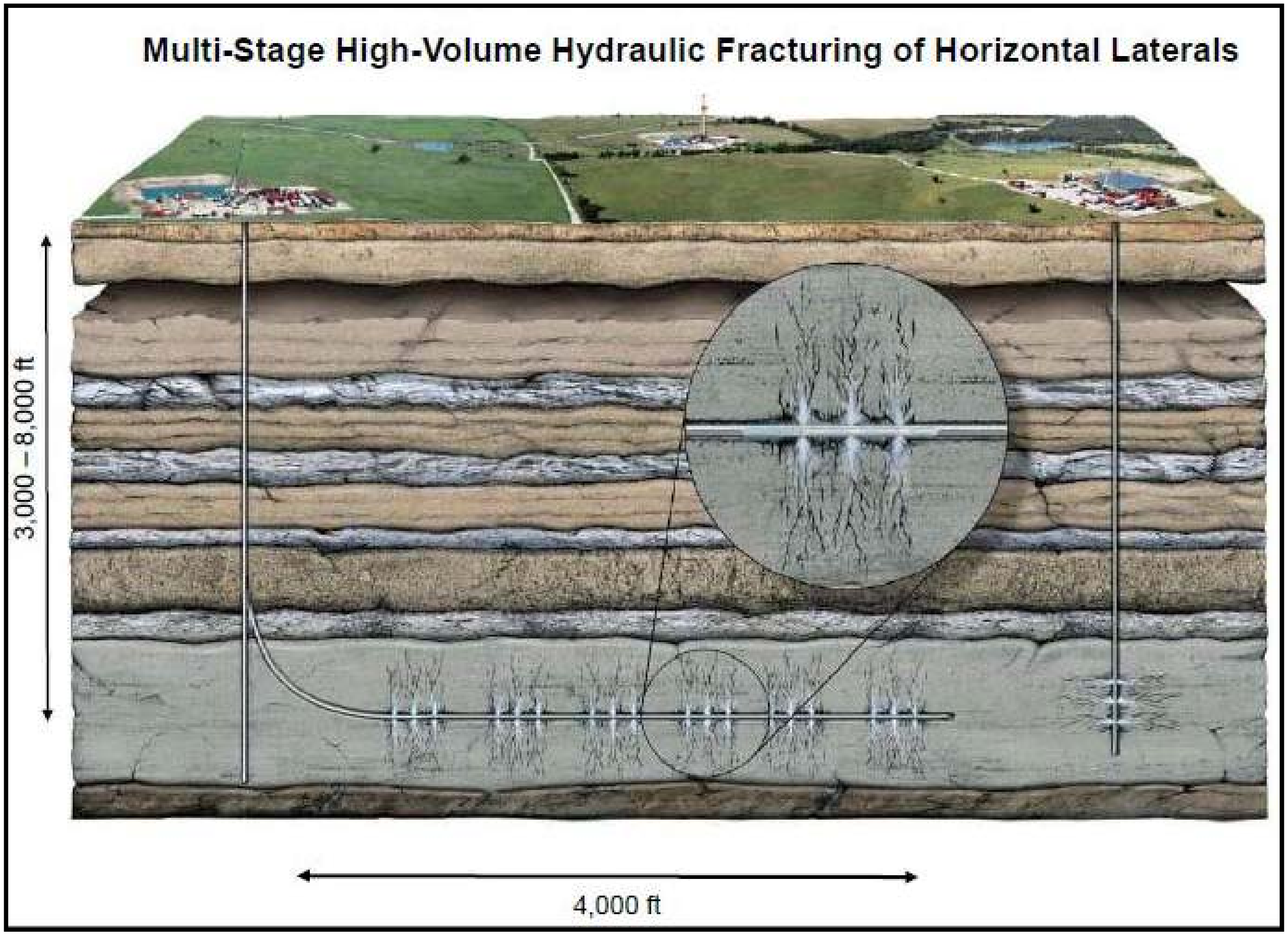

HALLIBURTON
BAKER


Drilling Location

Where Is Hydraulic Fracturing at Today?

- Over 2.5 million hydraulic fracture treatments have been conducted globally.
- Over 1.0 million wells have been hydraulically fractured in the United States.
- Vertical drilling and hydraulic fracturing have shifted to horizontal drilling and fracturing.
- Hydraulic fracturing has evolved from a single stage operation to multiple stages (40 plus).
- Lateral lengths (in the Bakken) can extend for 10,000 feet.

Horizontal vs. Vertical Drilling



http://ny.water.usgs.gov/projectsummaries/CP30/Marcellus_Presentation_Williams.pdf

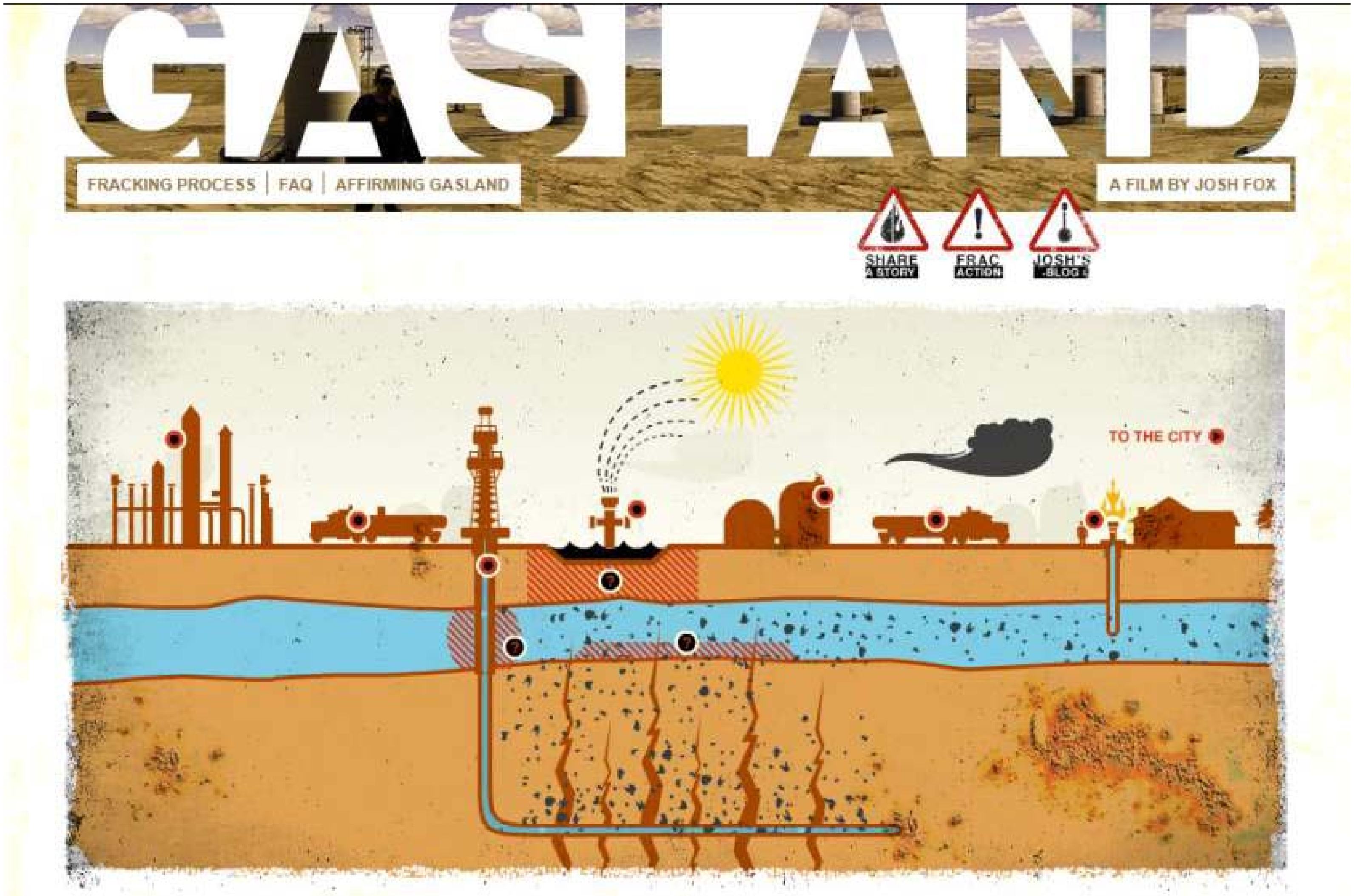
Common Issues in the Media

- Water availability, especially in arid and semiarid areas.
- Public perception of how much water is needed for hydraulic fracturing.
- Concerns over water quality and hydraulic fracture flowback disposal.
- Potential impacts of hydraulic fracturing on underground supplies of drinking water.
  - Precautions are taken to protect groundwater supplies when a well is drilled and subsequently fractured.
  - Hydraulic fracturing has been successfully employed for over 60 years.

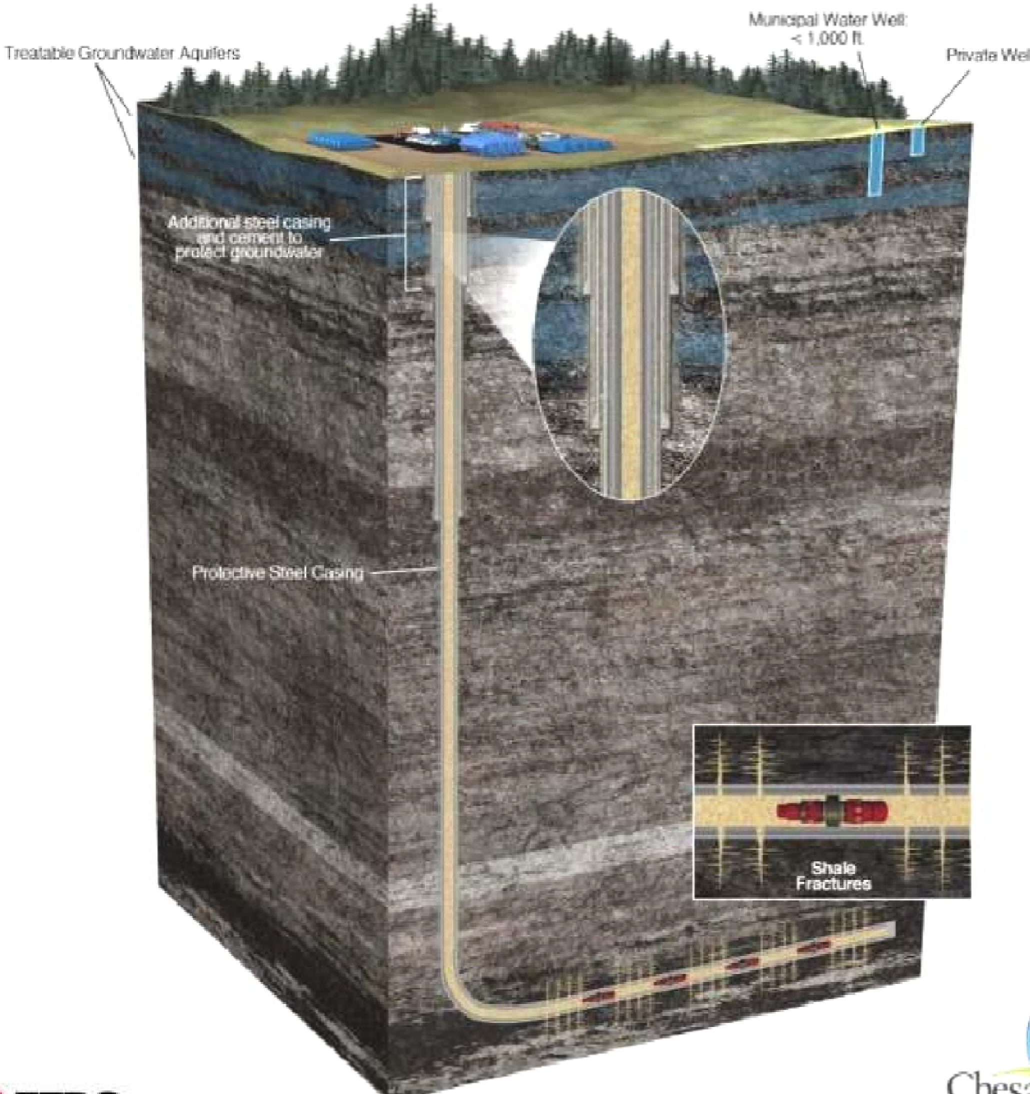
EPA’s Hydraulic Fracturing Study

- Congress directed the U.S. Environmental Protection Agency (EPA) to study the relationship between hydraulic fracturing and drinking water.
- Primary goal is to evaluate the potential impact of hydraulic fracturing on surface and subsurface drinking water supplies.
- A Scientific Advisory Board (SAB) was formed to advise the study.
  - Of the 23 members, only four are not affiliated with a university.

Spread of Public Misconceptions



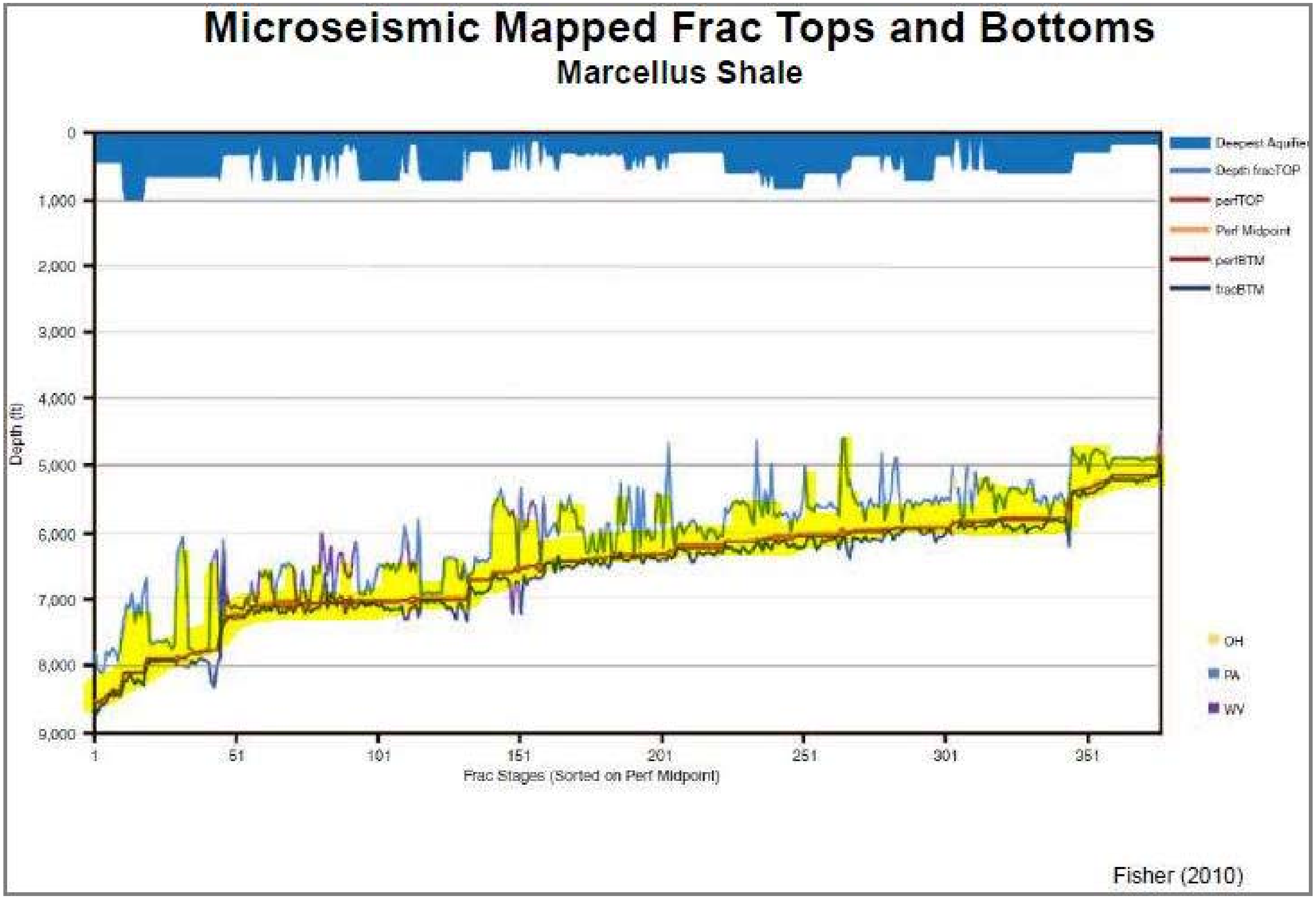
Groundwater Protection



How deep is 7700 feet?

- More than **six Empire State Buildings** stacked end to end
- **1½ times deeper** than the deepest part of the **Grand Canyon**
- More than **25 football fields** laid out goal line to goal line

Fracture Propagation



http://ny.water.usgs.gov/projectsummaries/CP30/Marcellus_Presentation_Williams.pdf

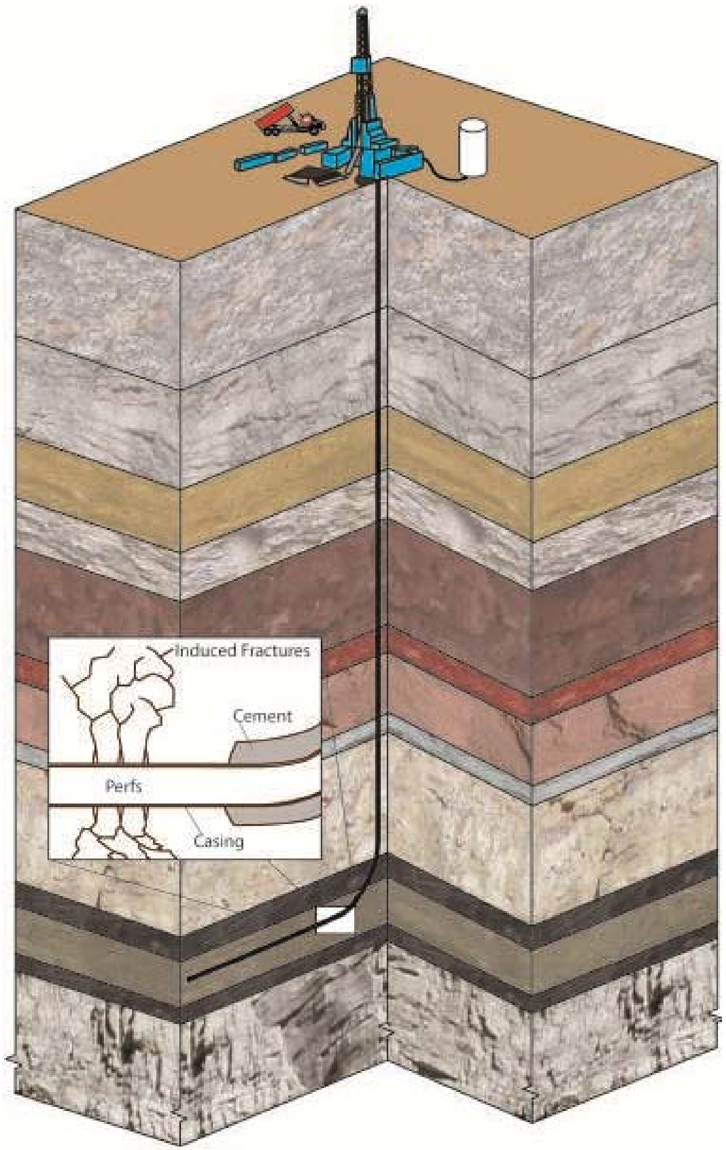
Regulation of Oil and Gas Drilling and Production

- Each oil and gas producing state and/or province has regulations in place to project drinking water supplies and other natural resources.
- There are regulations in place for:
  - permitting
  - well construction
  - hydraulic fracturing
  - temporary abandonment
  - well plugging
  - tanks and pits
  - waste handling and spills.

http://www.drillingahead.com/photo/crown-drilling-rig-reserve-pit

Water Needs for Hydraulic Fracturing

- Requires anywhere from ~ 3 to 5 million gallons of water per well.
- The water is mixed with various additives prior to injection.
- A percentage of the water returns to the surface (flowback) and is recovered and disposed of (or recycled).
  - Typically contains dissolved solids (salts), suspended solids, residual hydrocarbons, and hydraulic fracturing constituents.



How Much Water Is 4 million gallons?

- The approximate amount of water used to irrigate a 1-square-mile section of land for **one day** in western North Dakota.
- **1%** of the average daily water withdrawal for once-through cooling at a 400-MW coal-fired power plant.
- About 1/5 of the average daily water use in Regina, SK.

http://localism.com/sk/regina

Water Hauling and Tank Storage

- Water is transported to well sites in 7500- to 8000-gallon tanker trucks.
- Water is stored on-site in 21,000-gallon tanks.

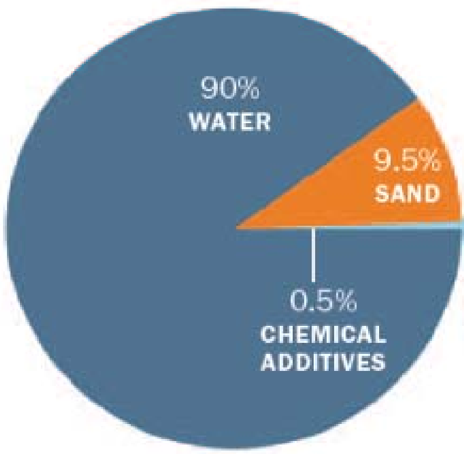


Common Hydraulic Fracturing Fluid Constituents

- Freshwater → Usually high quality, but that is changing.
- Proppant → Typically sand or ceramic beads that help keep the fractures open following fracturing (approximately 3 to 5 million pounds of proppant used per operation).
- Biocides → Reduce the risk of well souring from microbes.
- Friction-reducing agents ("slick water") → Surfactants that promote fluid flow.
- Polymers → Form gels to keep proppants in suspension.
- Scale inhibitors → Reduce scale formation in pipes.
- Weak acids → Help dissolve minerals that cement pore spaces.

What Are Fracturing Fluids?

Typical Shale Fracturing Mixture Makeup



Typical Chemical Additives Used in Frac Water

Compound	Purpose	Common application
Acids	Helps dissolve minerals and initiate fissure in rock (pre-fracture)	Swimming pool cleaner
Sodium Chloride	Allows a delayed breakdown of the gel polymer chains	Table salt
Polyacrylamide	Minimizes the friction between fluid and pipe	Water treatment, soil conditioner
Ethylene Glycol	Prevents scale deposits in the pipe	Automotive anti-freeze, deicing agent, household cleaners
Borate Salts	Maintains fluid viscosity as temperature increases	Laundry detergent, hand soap, cosmetics
Sodium/Potassium Carbonate	Maintains effectiveness of other components, such as crosslinkers	Washing soda, detergent, soap, water softener, glass, ceramics
Glutaraldehyde	Eliminates bacteria in the water	Disinfectant, sterilization of medical and dental equipment
Guar Gum	Thickens the water to suspend the sand	Thickener in cosmetics, baked goods, ice cream, toothpaste, sauces
Citric Acid	Prevents precipitation of metal oxides	Food additive; food and beverages; lemon juice
Isopropanol	Used to increase the viscosity of the fracture fluid	Glass cleaner, antiperspirant, hair coloring

Source: DOE, GWPC: Modern Gas Shale Development in the United States: A Primer (2009).

Slide Courtesy of S. Baumgartner, Marathon Oil

Hydraulic Fracturing Fluid Chemical Disclosure

- Increasing public pressure to disclose information on fracturing fluid chemistry.
  - EPA is encouraging voluntary public disclosure.
  - No federal rules yet, but some states require disclosure (Wyoming, Alaska, Pennsylvania, Colorado, Texas).
- The Ground Water Protection Council and the Interstate Oil and Gas Compact Commission have developed a chemical registry Web site.
  - Voluntary disclosure of fracture fluid chemical information.
  - 25 companies have contributed so far, many of which are major oil producers.

Frac Focus Chemical Disclosure Registry

Options for Flowback Disposal

- Underground injection
- Discharge to a commercial industrial treatment facility
- Discharge to a municipal wastewater treatment plant
- Discharge to surface water bodies (usually following treatment)
- Reuse
  - Blending with freshwater
  - Recycling

Photo: VWS Oil and Gas

Multiwell Pads

- Horizontal drilling allows for placement of several wells at one location.
- Benefits:
  - Reduced surface impacts (fewer well pads, pipelines, roads, etc…)
  - Increased drilling efficiency (rigs move tens of feet, rather than miles, to drill the next well)
  - Reduced truck traffic
  - Allows for more efficient oil and gas production

Multiwell Pad Example

Continental's ECO-Pad concept is being employed in the Bakken.

- Reduced surface impact by as much as 75%
- Significant time and cost savings (10% cost savings for a four-well pad)

Photos: Continental Resources

What Are the Risks of Groundwater or Surface Contamination?

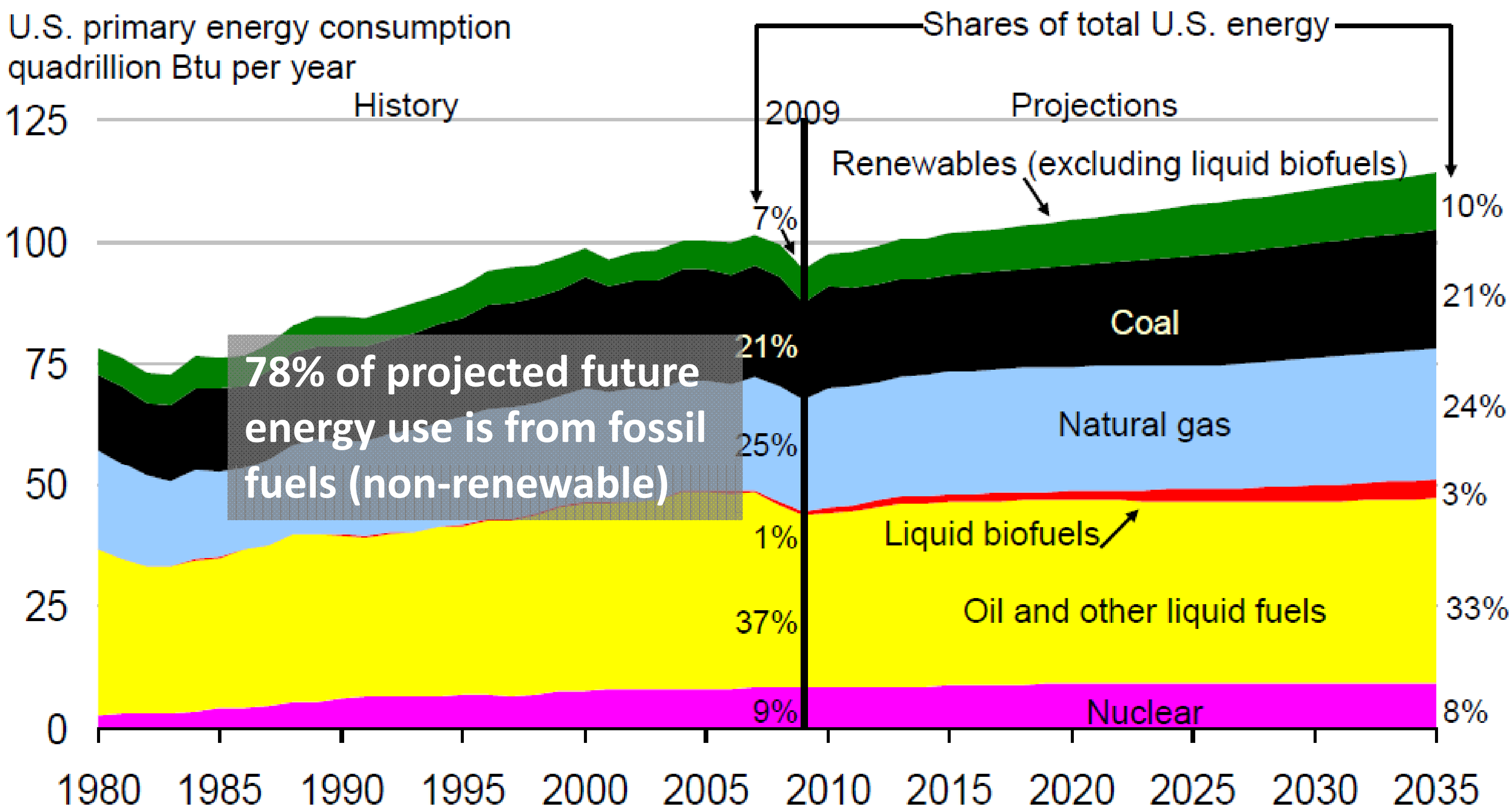
- The risk of groundwater contamination from hydraulic fracturing is approximately equal to dying from falling out of bed.
- The risk of a hydraulic fracturing fluid spill, even in concentrated form, is less than the risk of spills from the delivery of gasoline and diesel fuel at the neighborhood convenience store.

Does Hydraulic Fracturing Cause Earthquakes?

- Fracturing can result in “microseismic” events.
- The largest microseismic event ever recorded had a measured magnitude of about 0.8 on a normalized scale, which is approximately 2000 times less energy than a magnitude 3.0 earthquake. (Like a person jumping.)
- In most cases, microseismic energy ranges from 10,000 to 1,000,000 times less energy than a 3.0 magnitude quake.

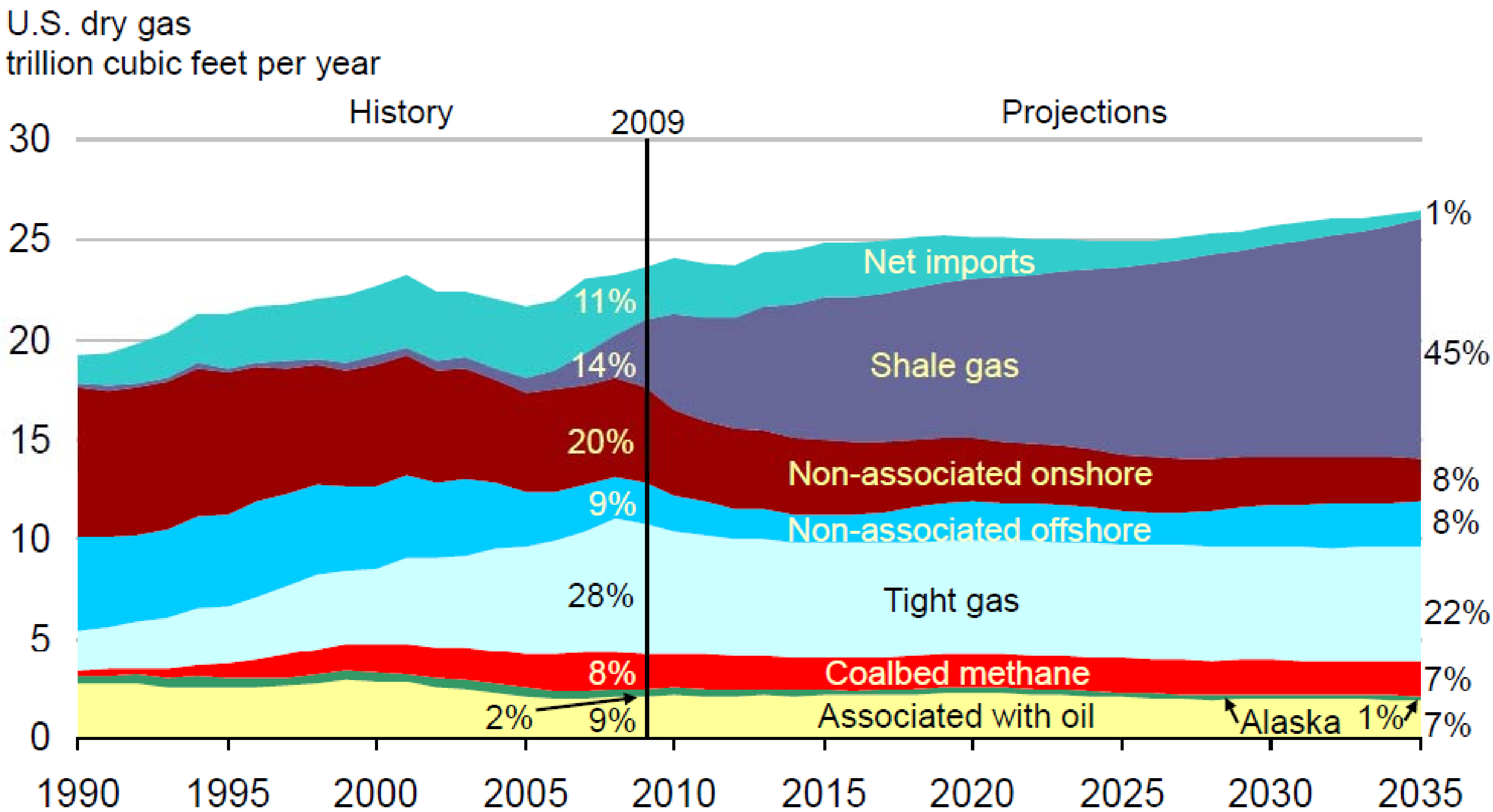
Source: www.energyfromshale.org

Projected U.S. Energy Use



Source: Energy Information Administration, 2011, http://www.eia.gov/neic/speeches/newell_12162010.pdf

Projected Domestic Gas Production



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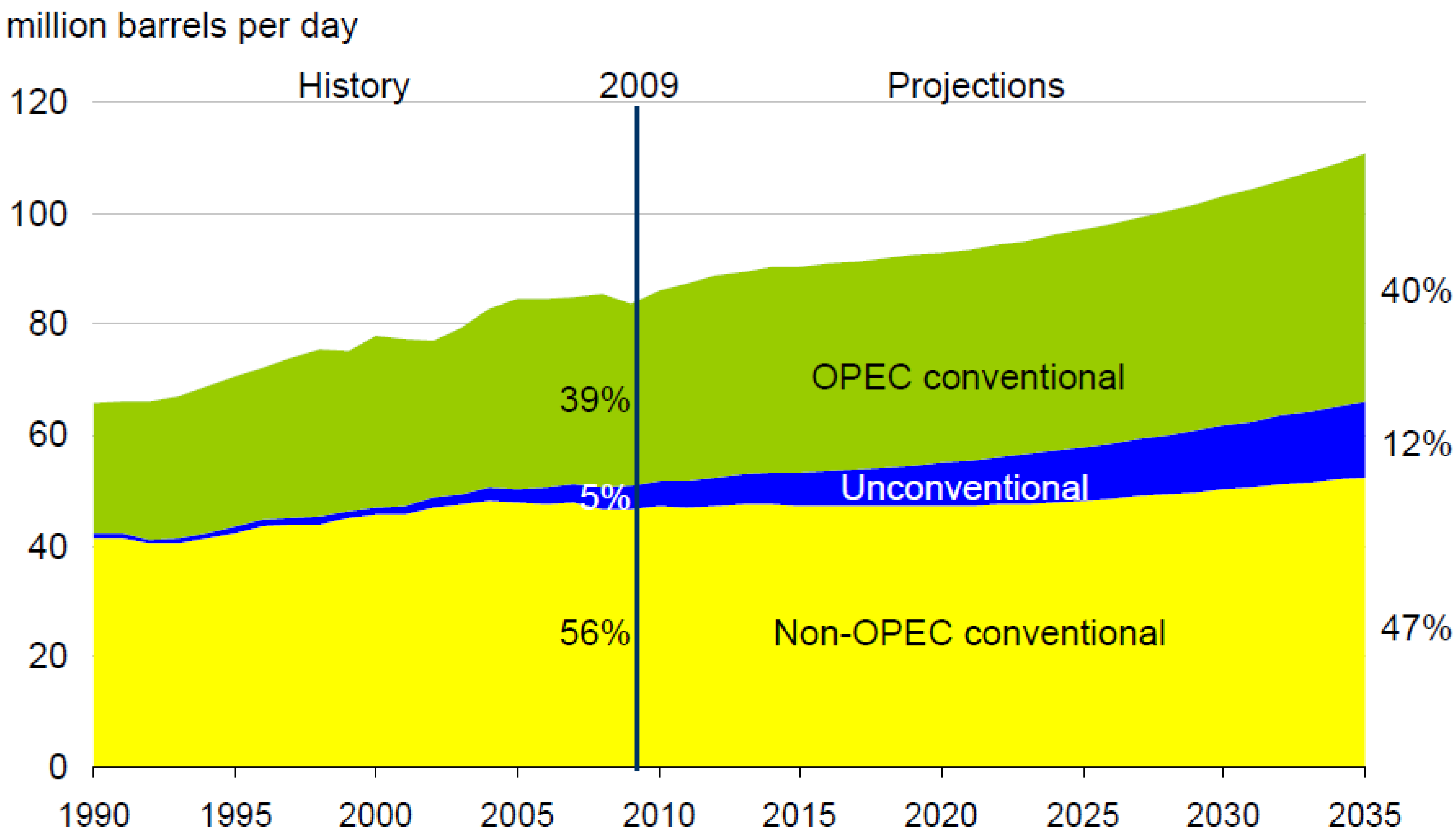
Global Liquids Production



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