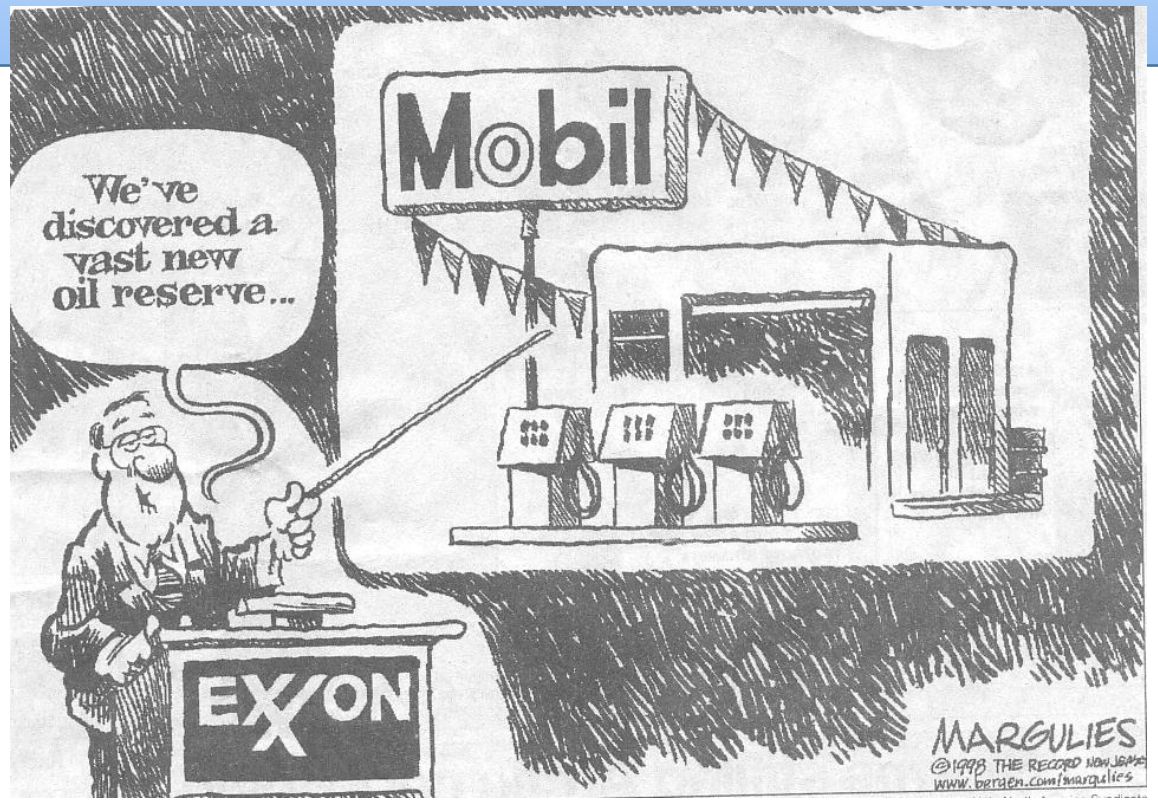
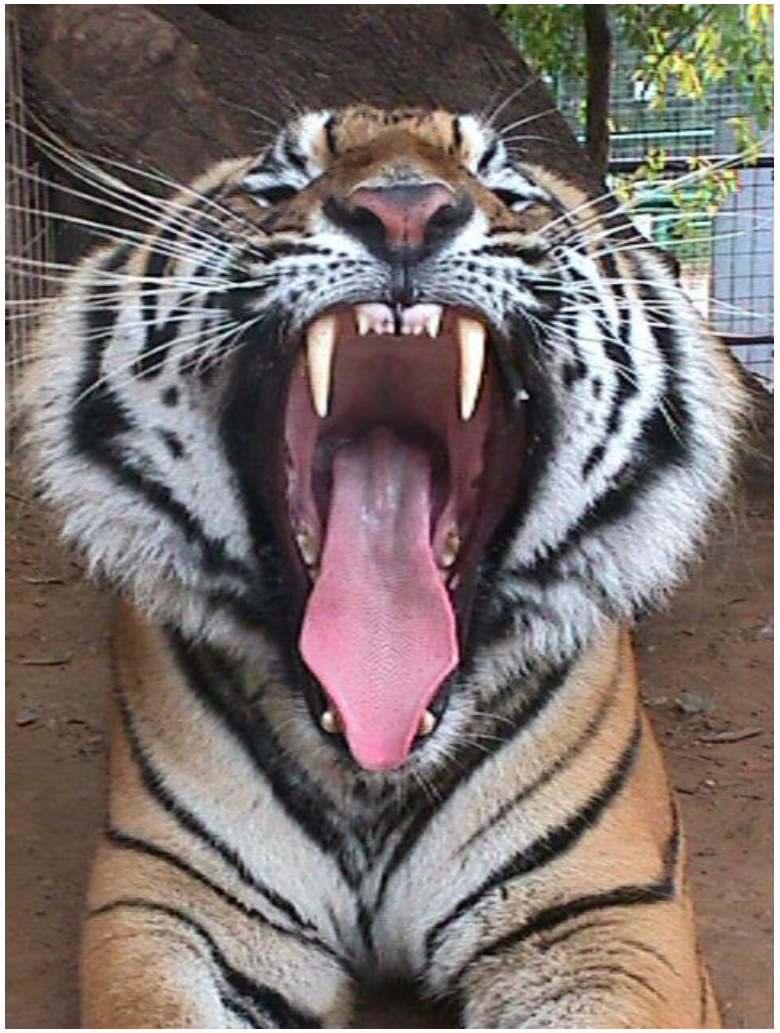
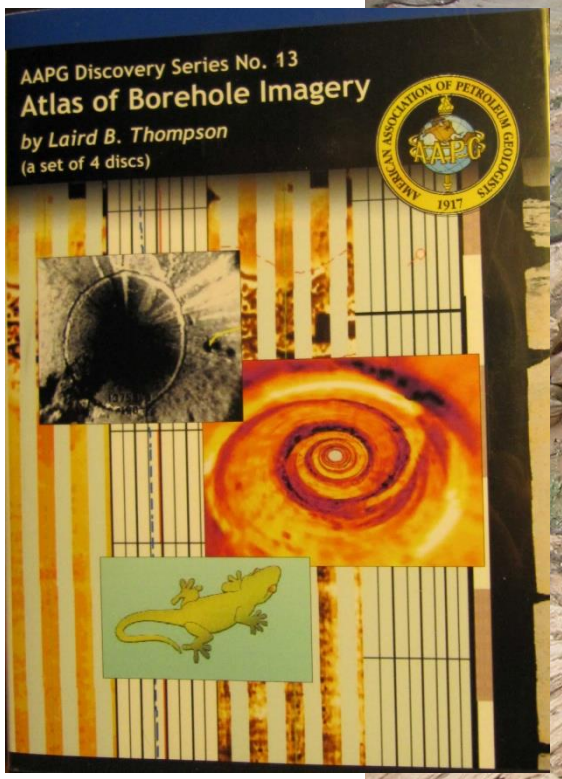
What the Frac is Going on?

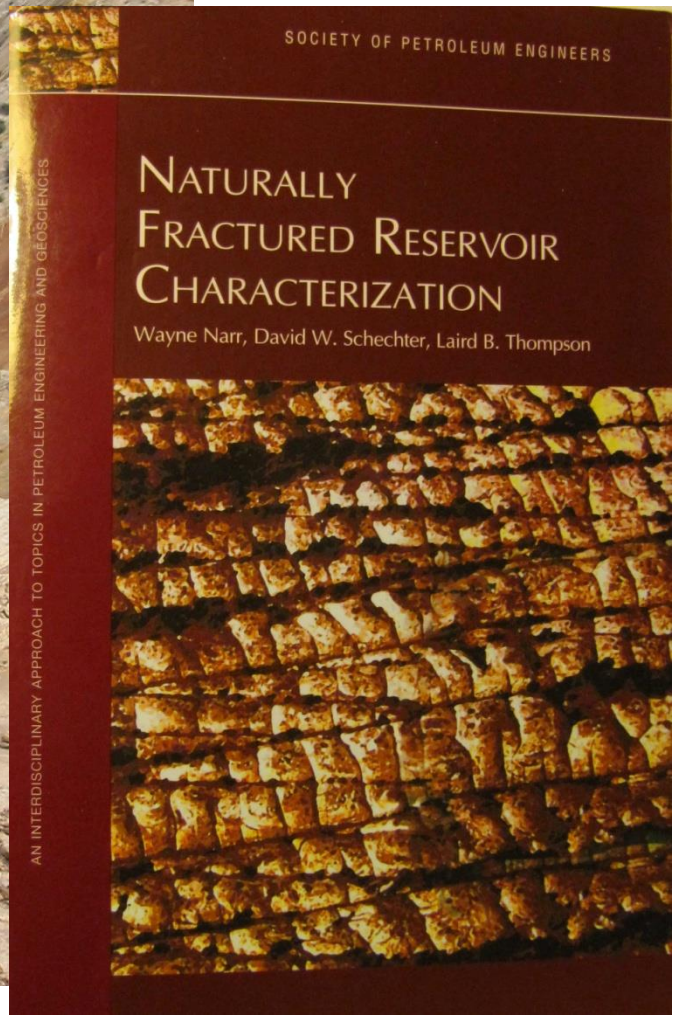
A Brief Introduction





A Brief Introduction





Talk Outline

Why do we frac?

What is a frac?

How does it work?

What are the problems?

What are the solutions?

How is Oil Formed?

New data show that
Coal and oil formed
in a flood
5000 years ago.

The Composition of Oil

Chemical Composition of Petroleum

Petroleum, also known as crude oil, is a very complex mixture consisting of **paraffin**, **naphthene** (cycloparaffin), and **aromatic hydrocarbons** as well as nitrogen-, oxygen-, sulfur- containing compounds and traces of a variety of metal-containing compounds, and inorganic compounds.

Saturated alkanes: (n-alkane and i-alkane)
General formula C_nH_{2n+2}

Naphthenes or Cycloparaffins (saturated cyclic hydrocarbons i.e. cyclohexane)
General formula C_nH_{2n} for one ring compounds

Alkenes or Olefins – unsaturated aliphatic hydrocarbon (i.e. ethylene or propylene)

Aromatics hydrocarbon (cyclic and polyunsaturated hydrocarbons containing conjugated double bonds)

Alkylaromatics have very high octane # - content in gasoline is limited by environmental regulations – health effects due to high toxicity.

Polyaromatic Hydrocarbons – aromatics containing more than 1 ring

Heteroatom compounds

Sulfur compounds might be present in inorganic and organic forms – it is difficult to relase the Sulfur

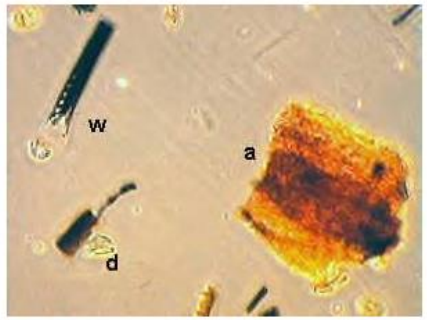
Oxygen compounds are responsible for petroleum acidity in particular.

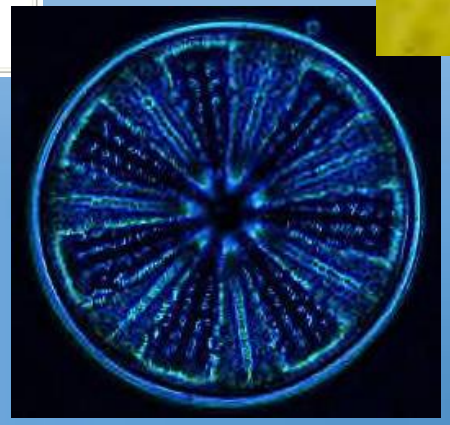
Nitrogen compounds

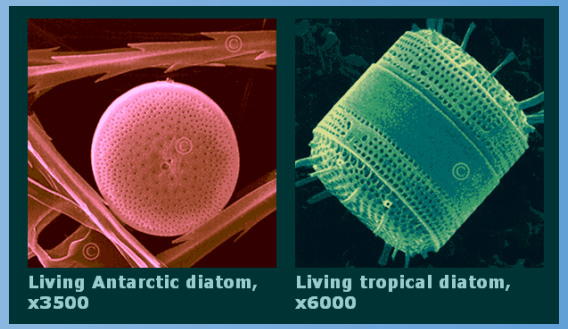
Metal Compounds

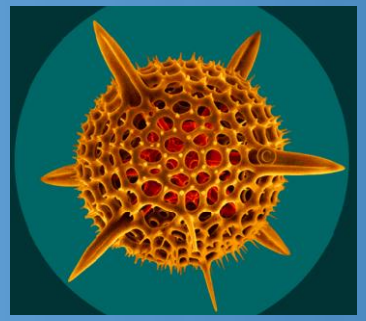
Porphyrins contain Ni, V, or Fe

How is Oil Formed?

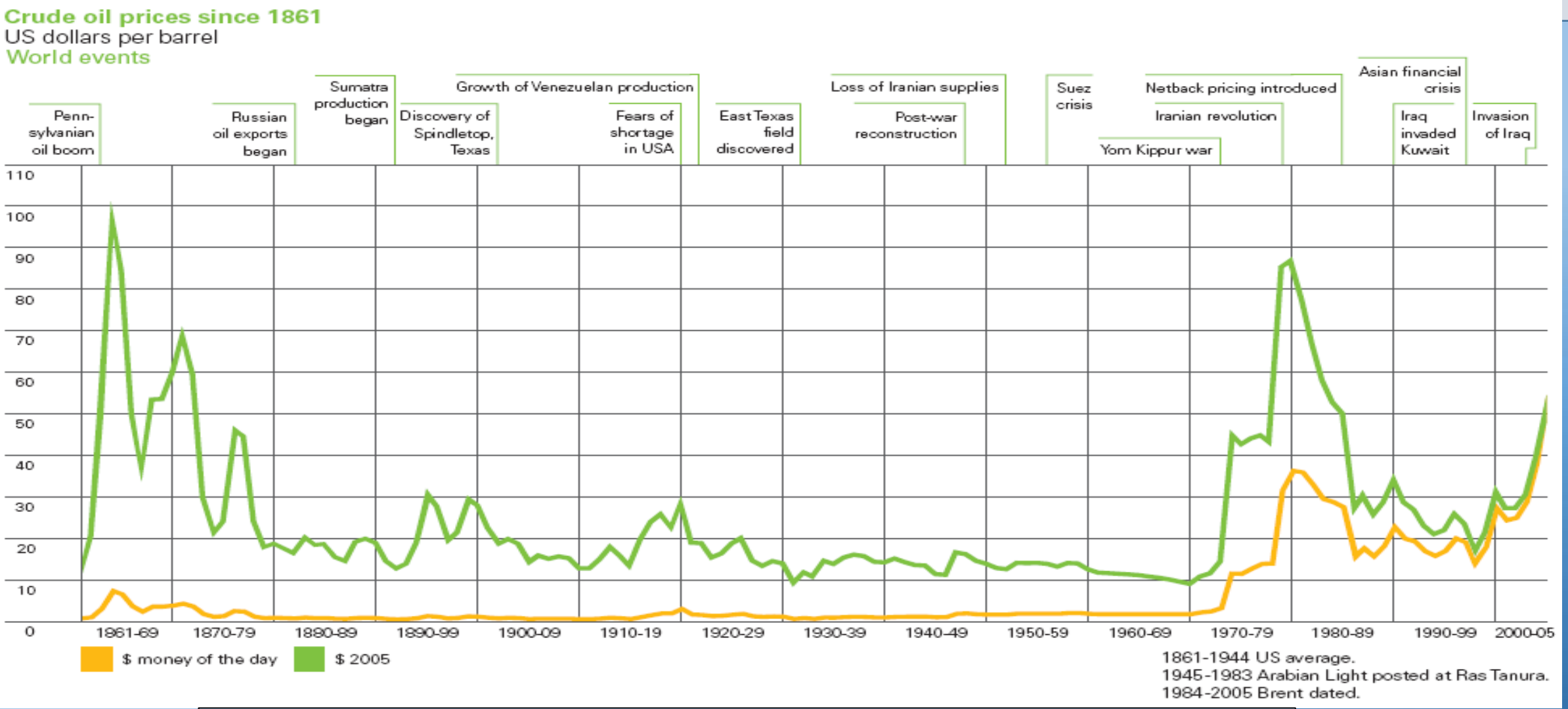






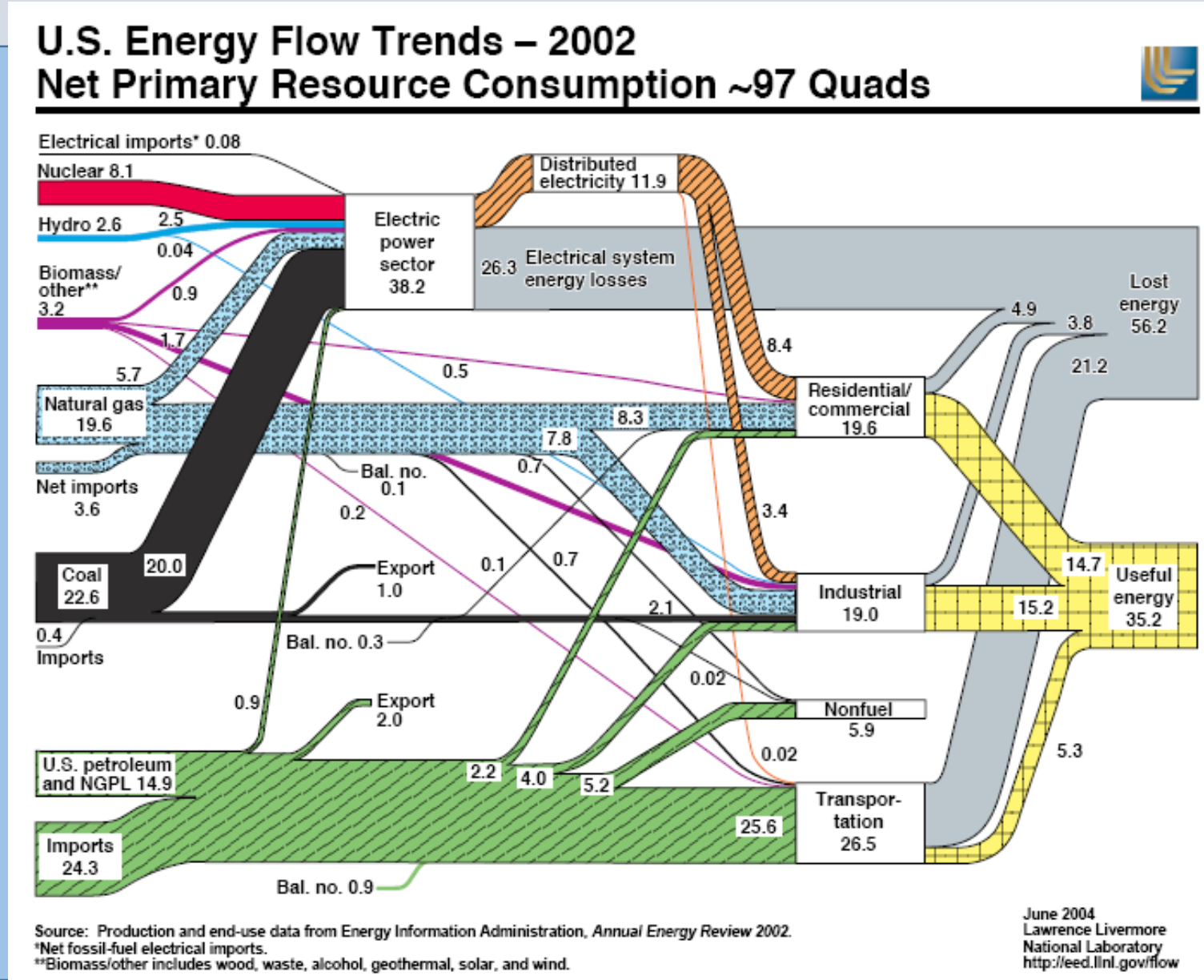


Why do we frac?



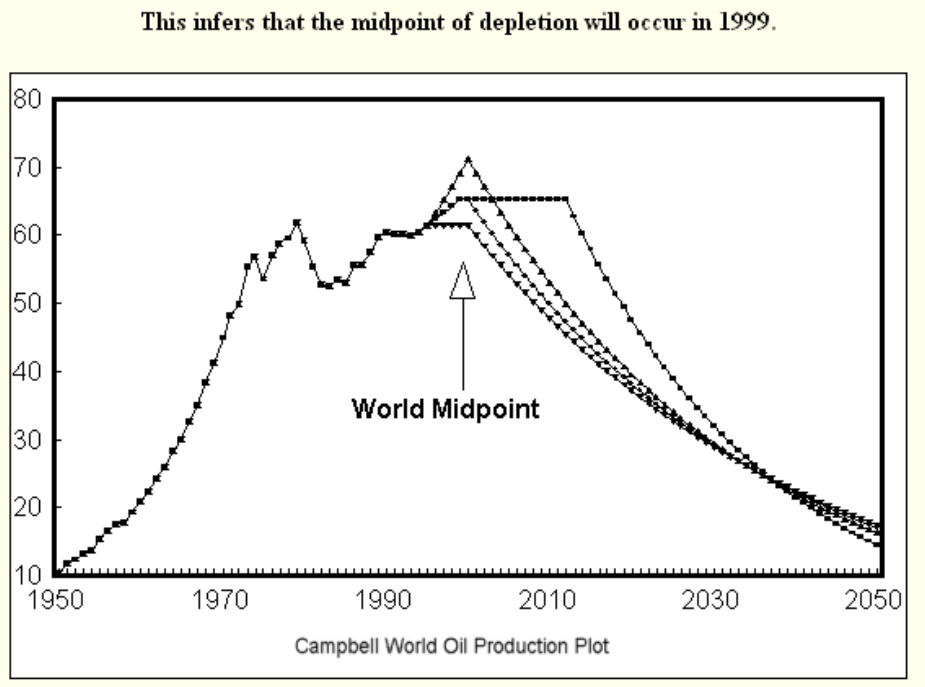
The reason that we are an oil-based economy is that until the 1970s, it was dirt cheap and readily available. As a result all our infrastructure was built on that premise.

Why do we frac?

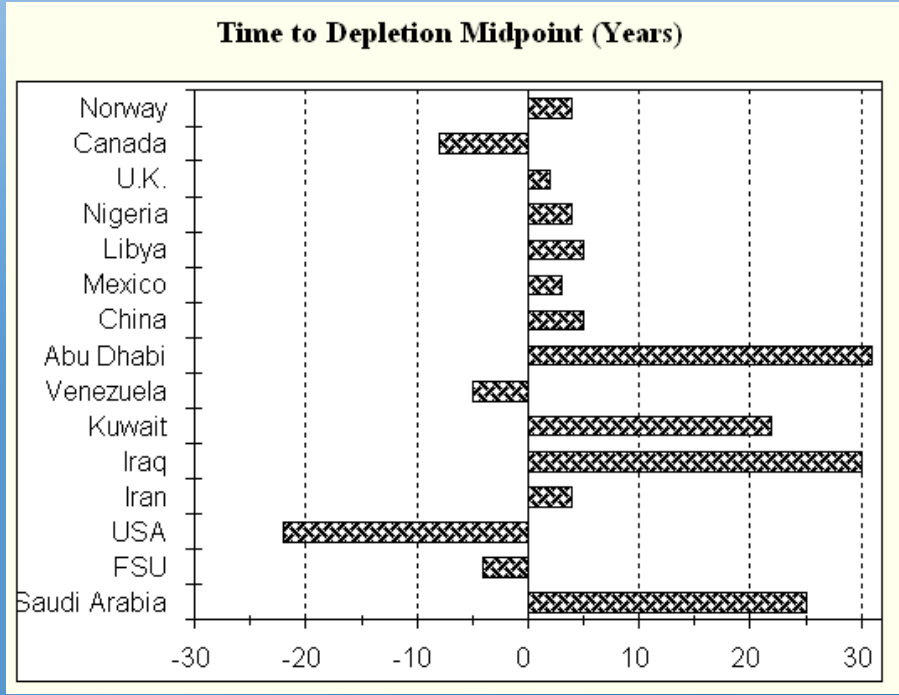


Because energy was cheap and readily available, our energy usage is extremely inefficient. Conservation in many ways can have a significant impact on this.

Oil – How Much is Left?

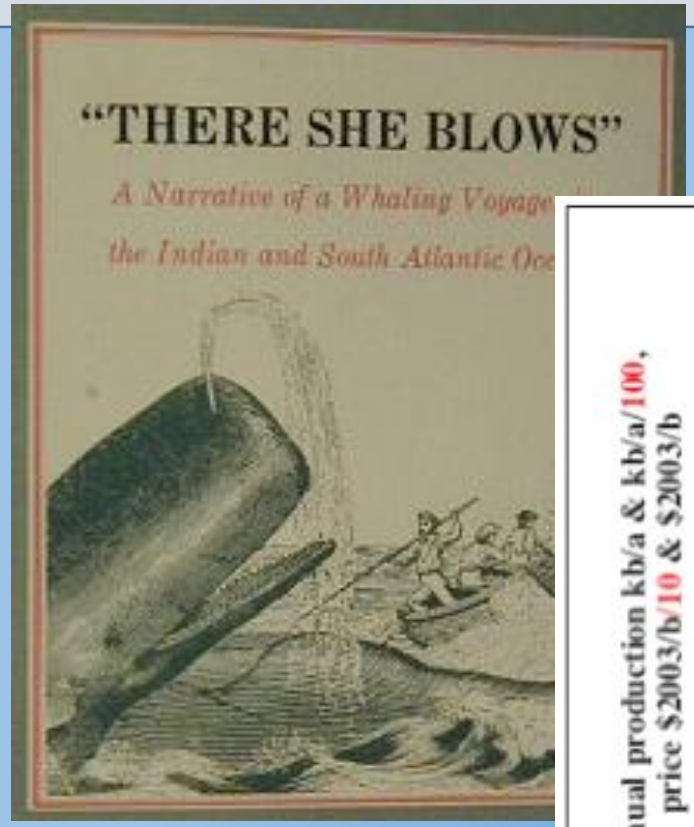


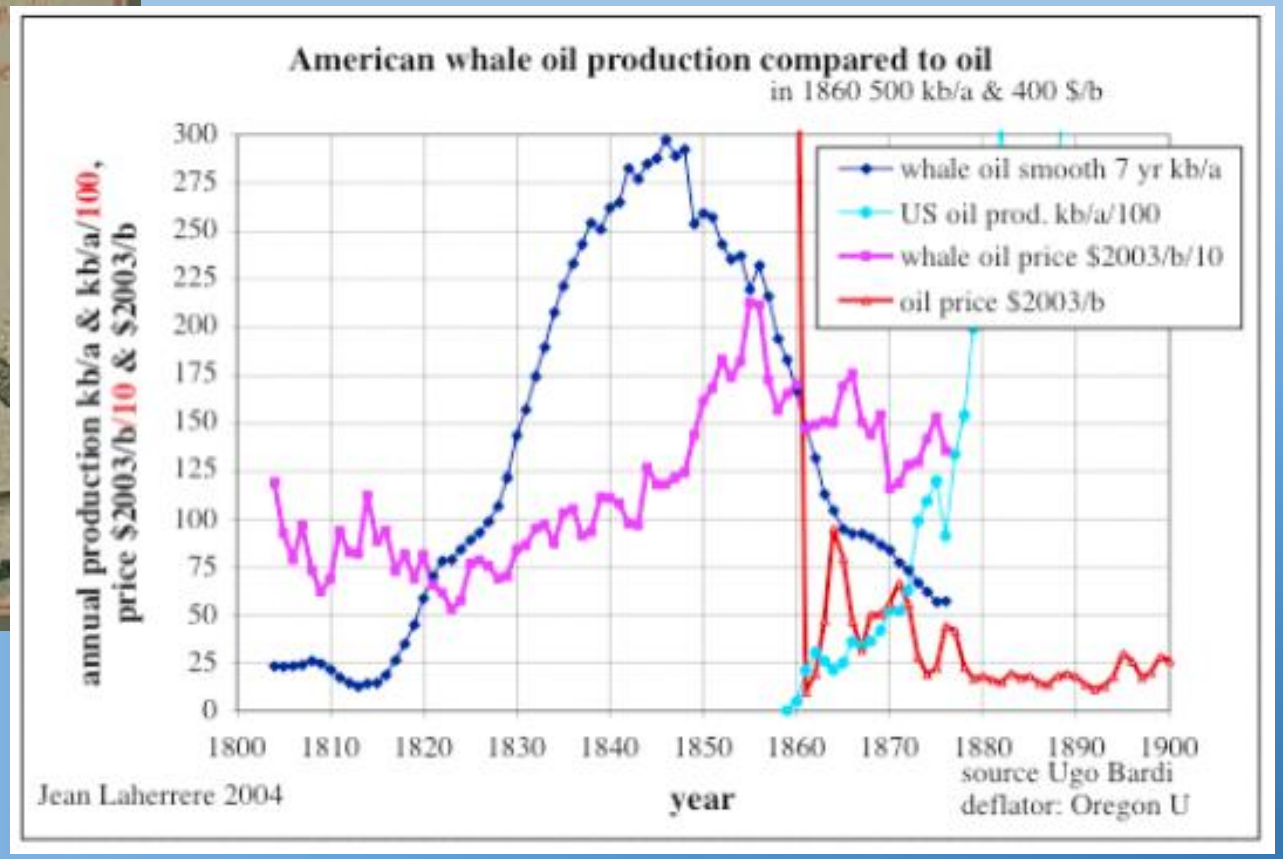
Peak Oil Prediction
Hubbert Peak.com



Peak oil is a fact, although there is disagreement on when we will (or have) hit it.
Being a limited, non-renewable resource means that this is a fact but the changing price of oil keeps moving the bar.

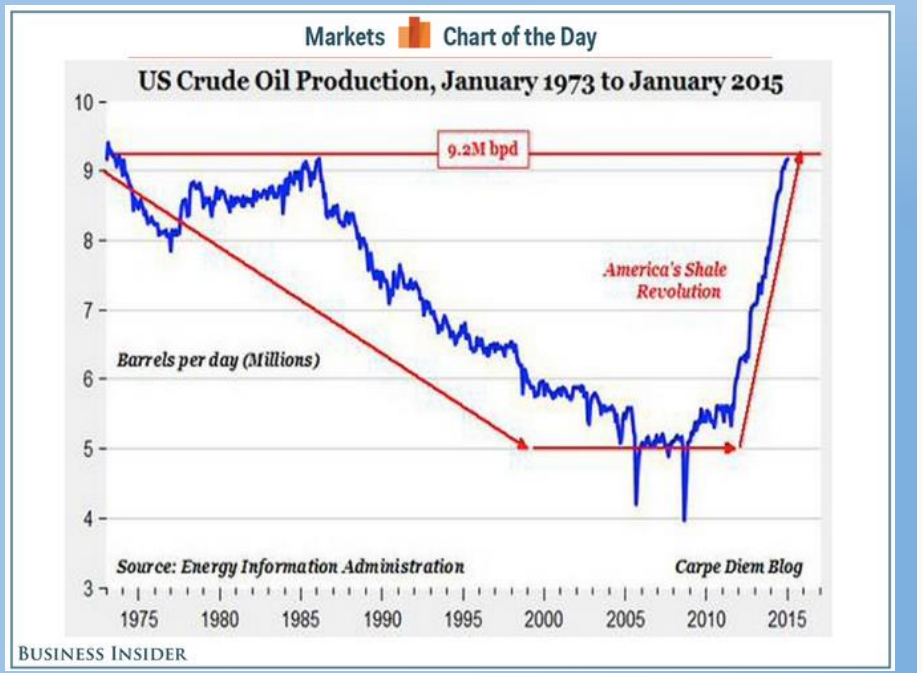
Limited Natural Resource Facts

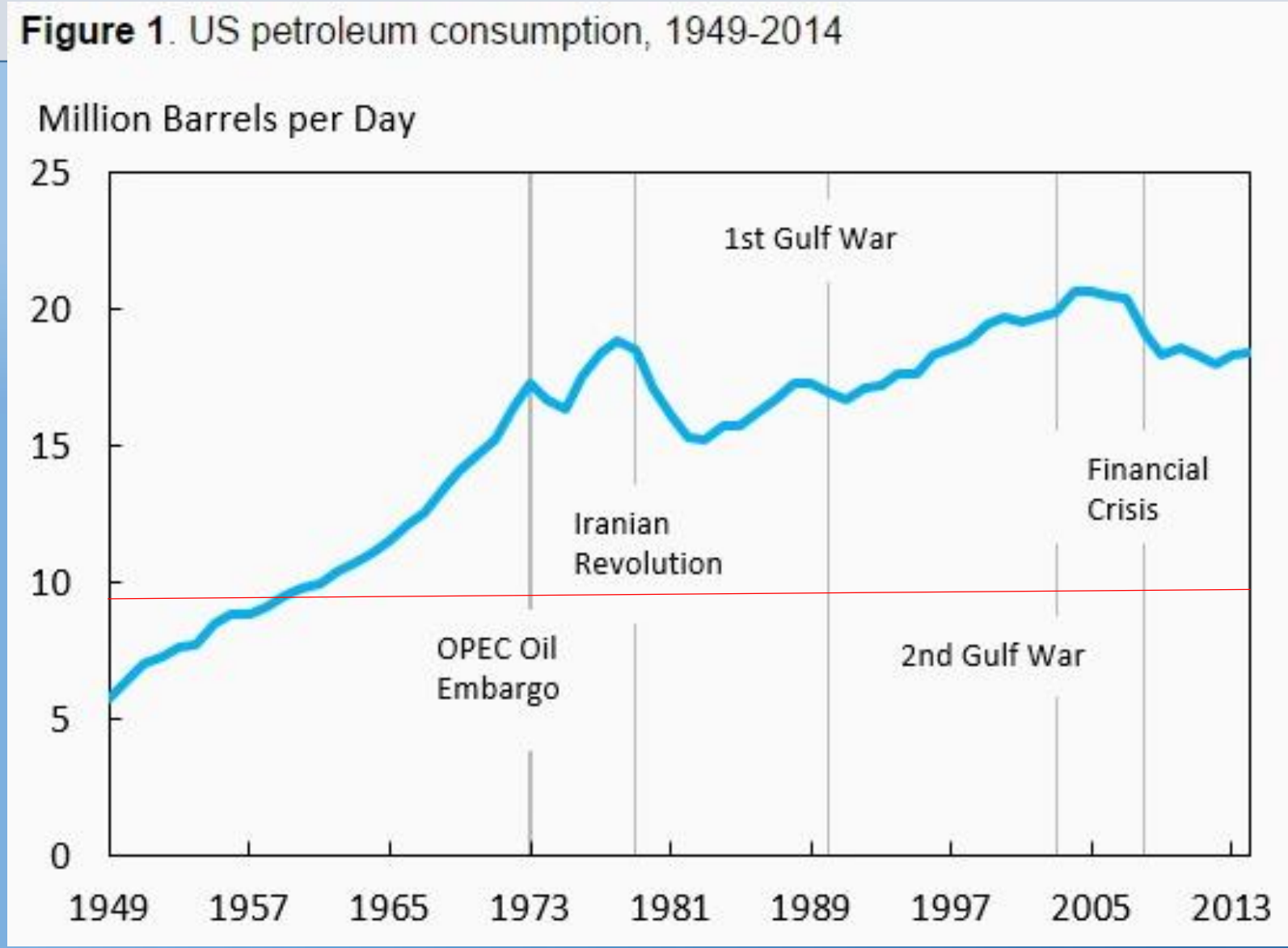




If you rely on non-renewable energy, you get a normal distribution curve of its' availability.

Shale Oil Helps, Right?





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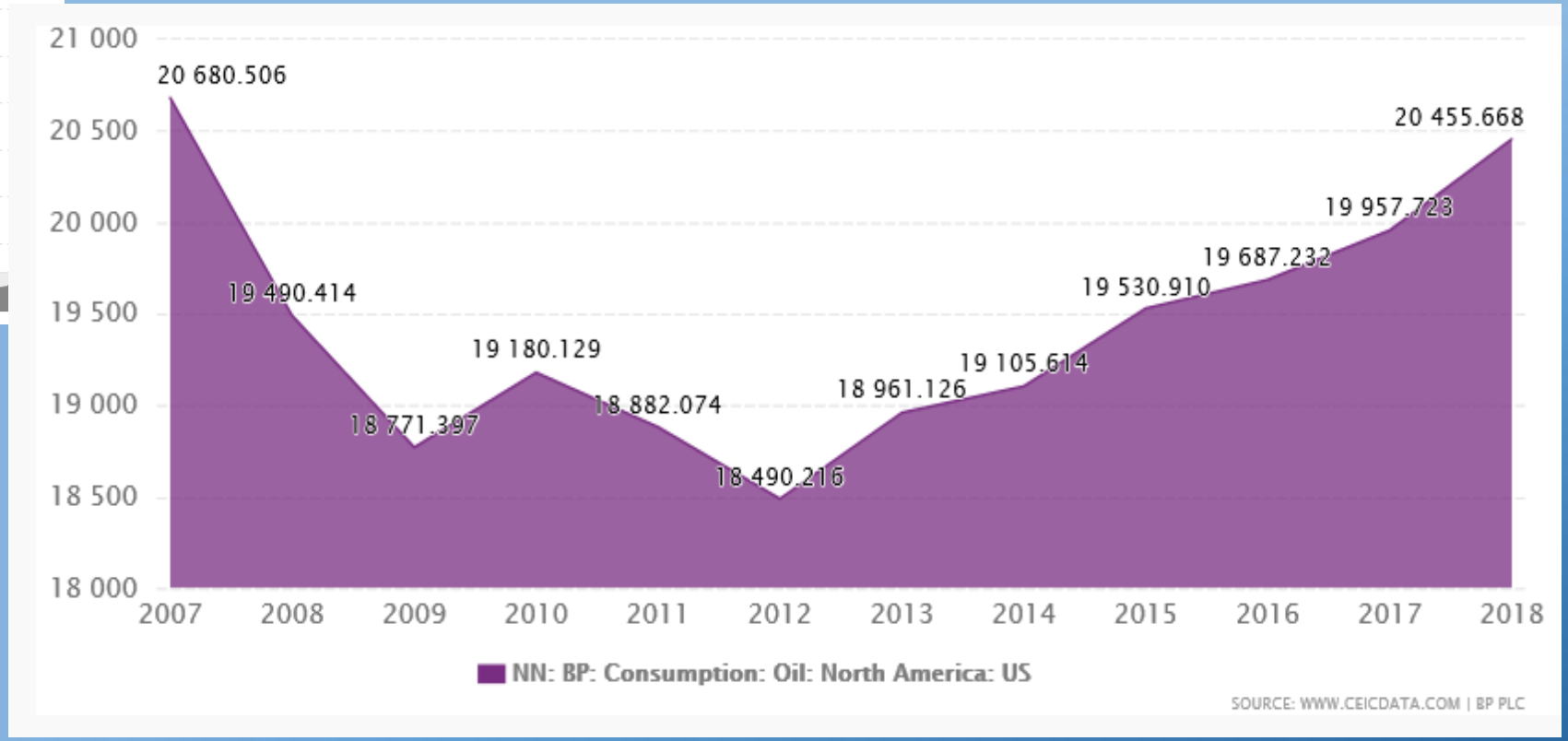
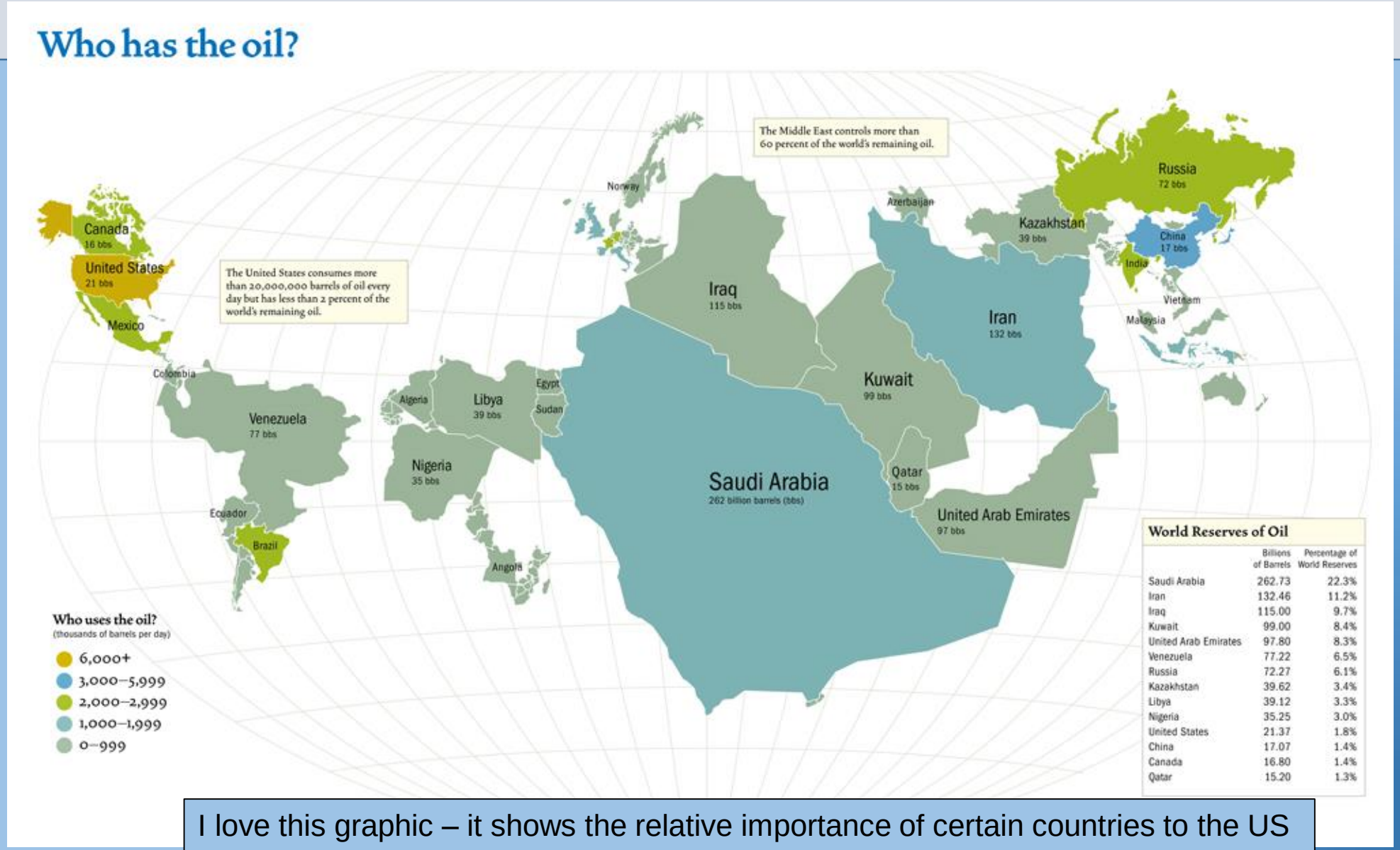


Oil – Who Has It?

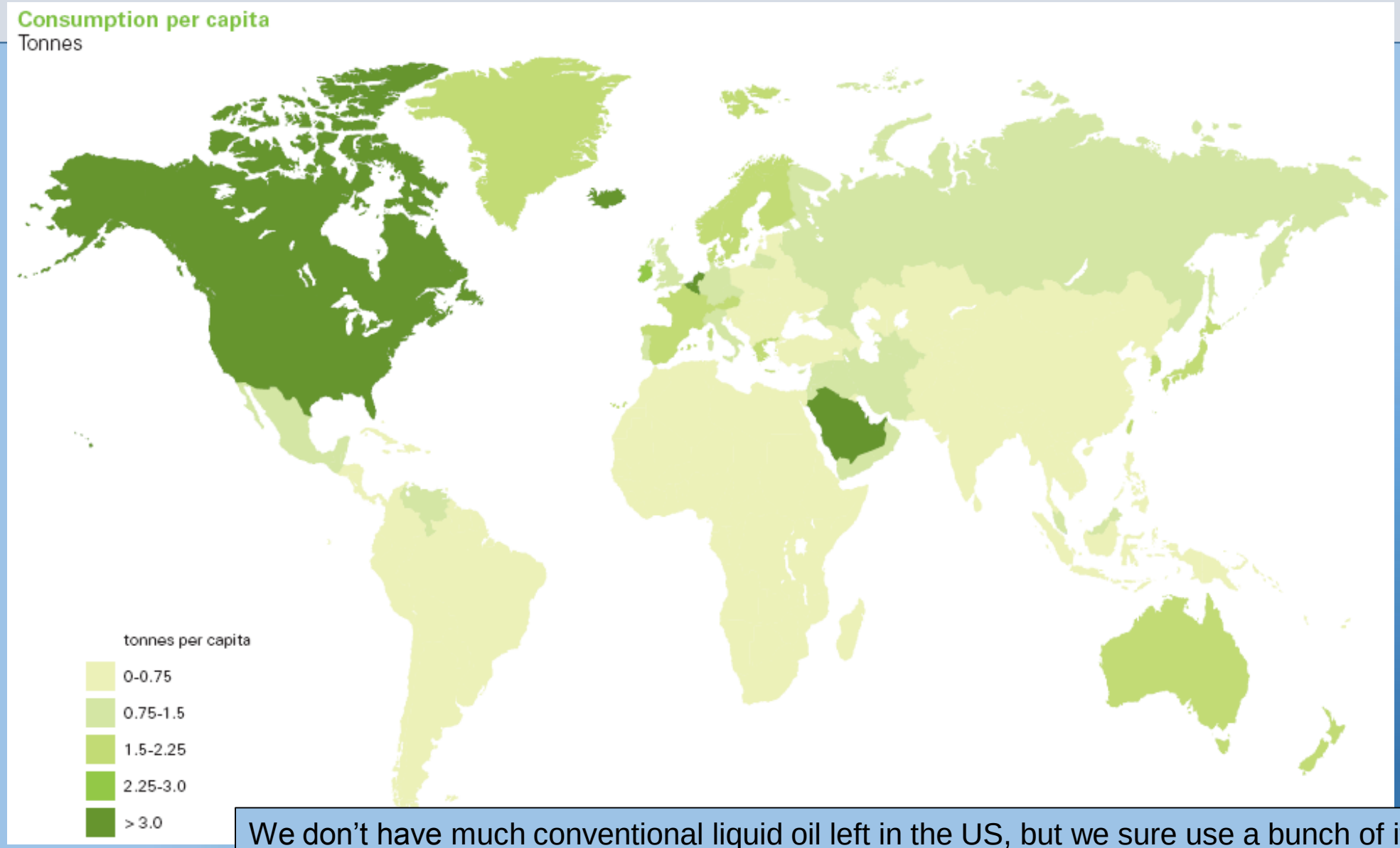


World Reserves of Oil

	Billions of Barrels	Percentage of World Reserves
Saudi Arabia	262.73	22.3%
Iran	132.46	11.2%
Iraq	115.00	9.7%
Kuwait	99.00	8.4%
United Arab Emirates	97.80	8.3%
Venezuela	77.22	6.5%
Russia	72.27	6.1%
Kazakhstan	39.62	3.4%
Libya	39.12	3.3%
Nigeria	35.25	3.0%
United States	21.37	1.8%
China	17.07	1.4%
Canada	16.80	1.4%
Qatar	15.20	1.3%

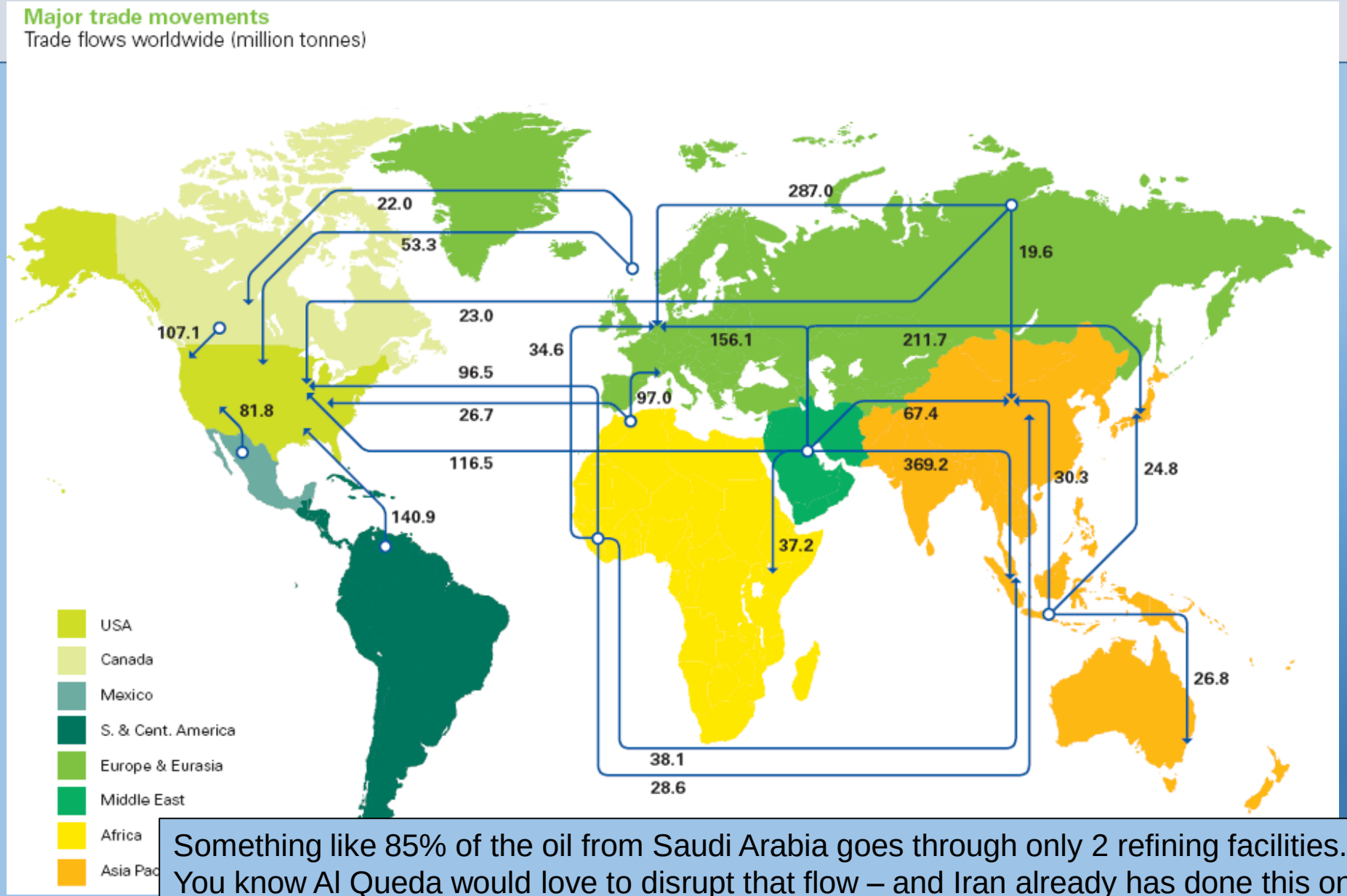
I love this graphic – it shows the relative importance of certain countries to the US so long as we are dependent on liquid hydrocarbons.

Oil – Who Uses it?



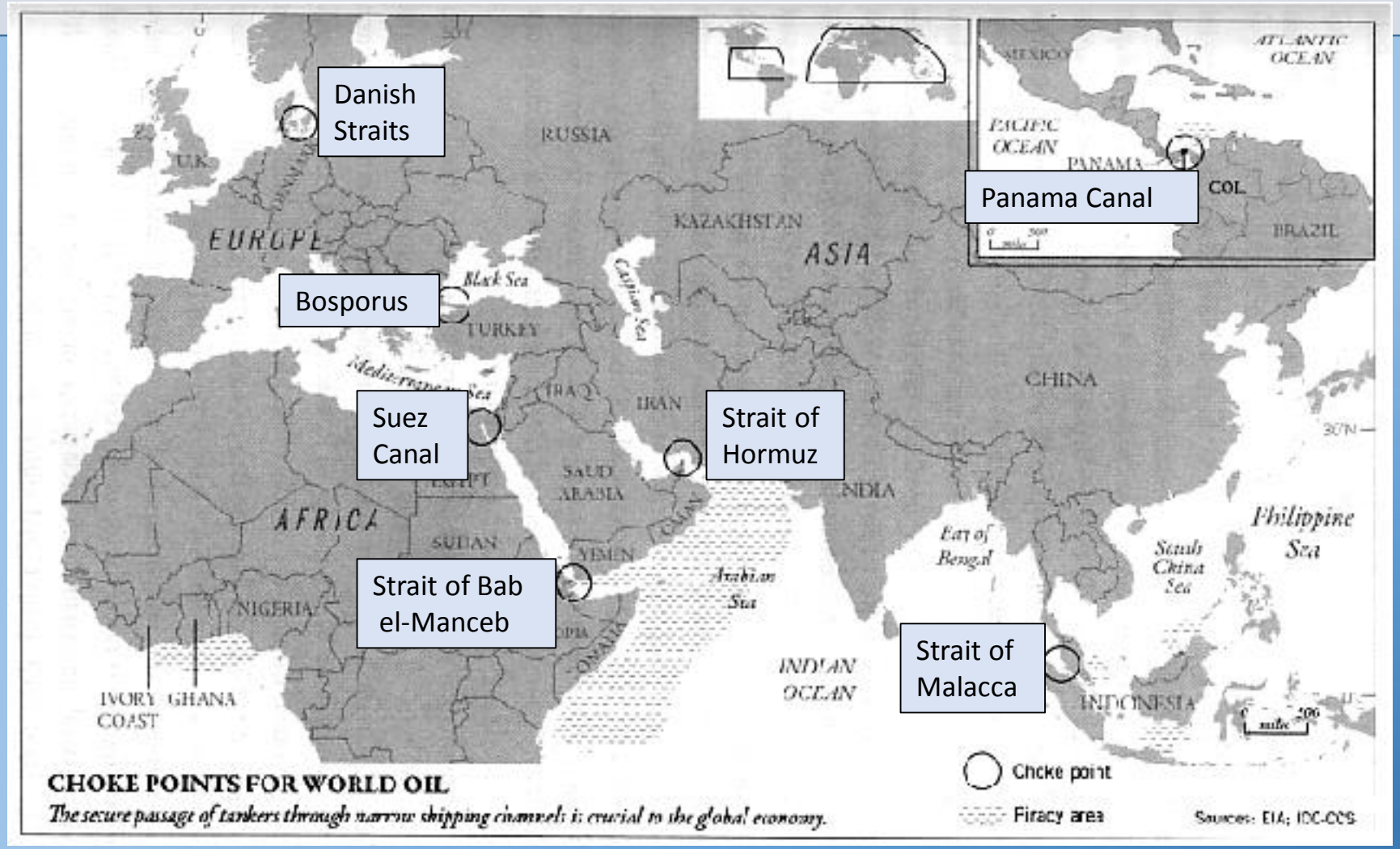
We don’t have much conventional liquid oil left in the US, but we sure use a bunch of it!

Oil – Who Controls it?



Something like 85% of the oil from Saudi Arabia goes through only 2 refining facilities.
You know Al Queda would love to disrupt that flow – and Iran already has done this once.

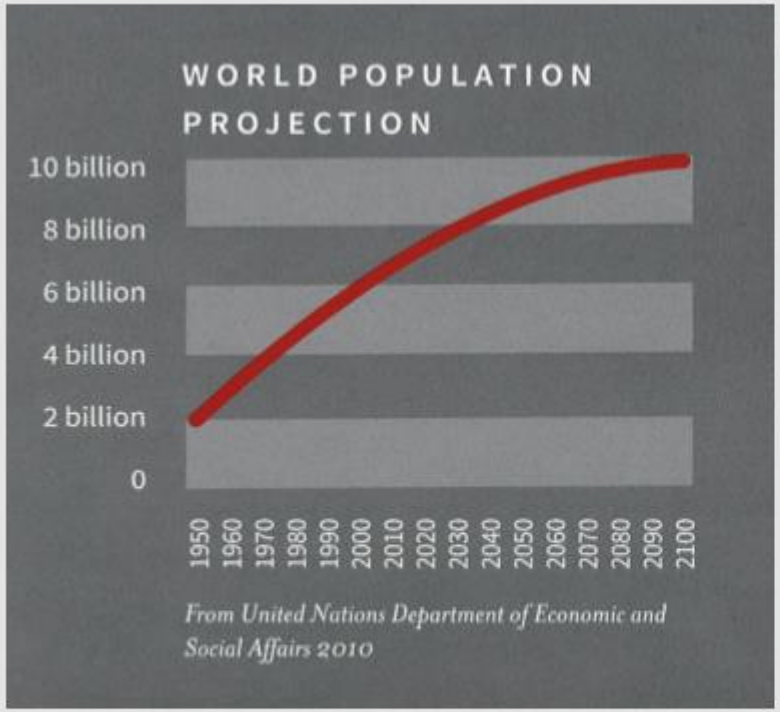
Oil – Who Controls it?



The price of oil depends on supply, demand and stability of availability. These Choke Points are areas of concern for the US, China and others.

Limited Natural Resource Facts

The World in 2050

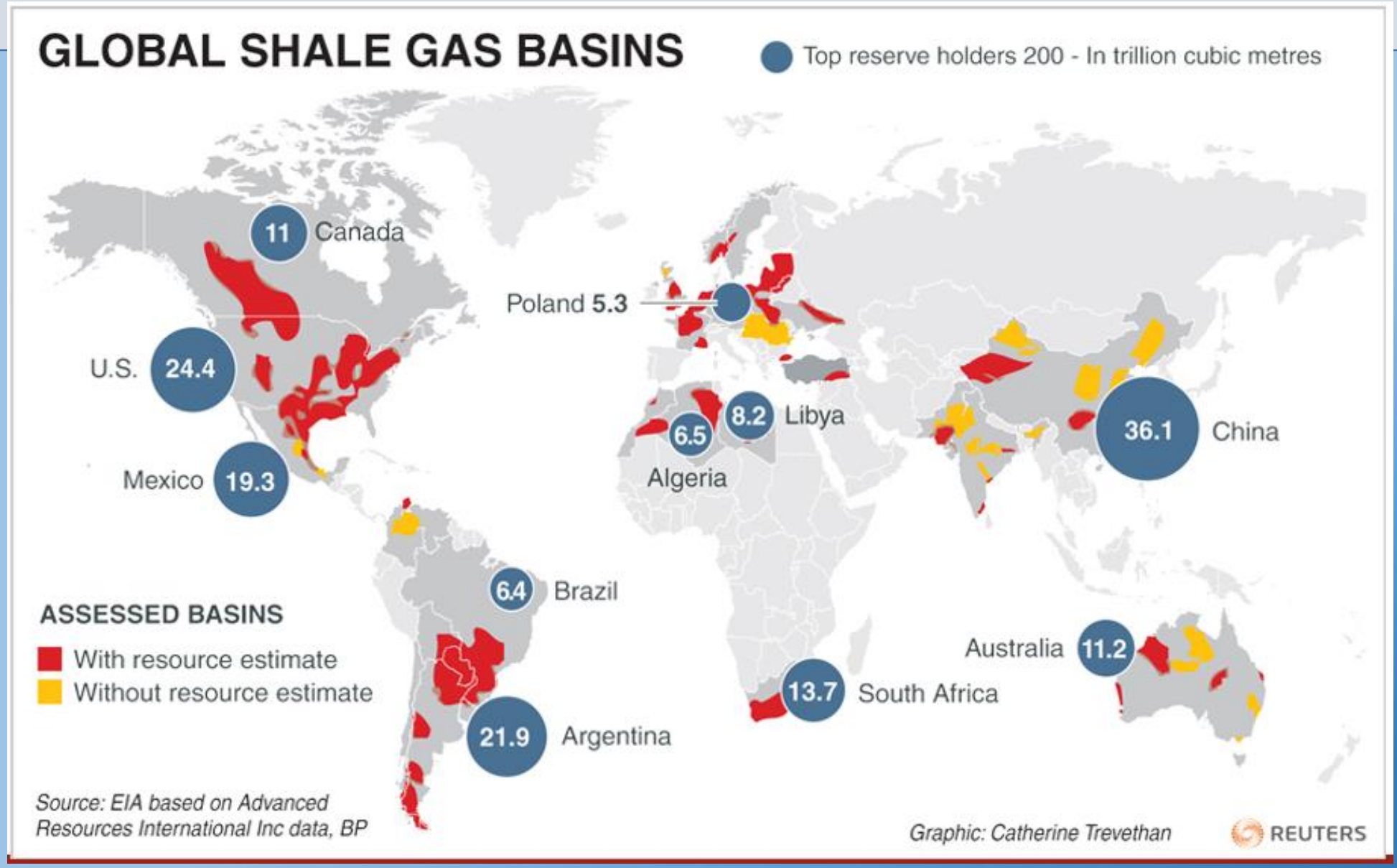


~ 9 Billion People

How Will We Provide Twice As Much Accessible, Affordable, and Secure Energy While Protecting the Planet?

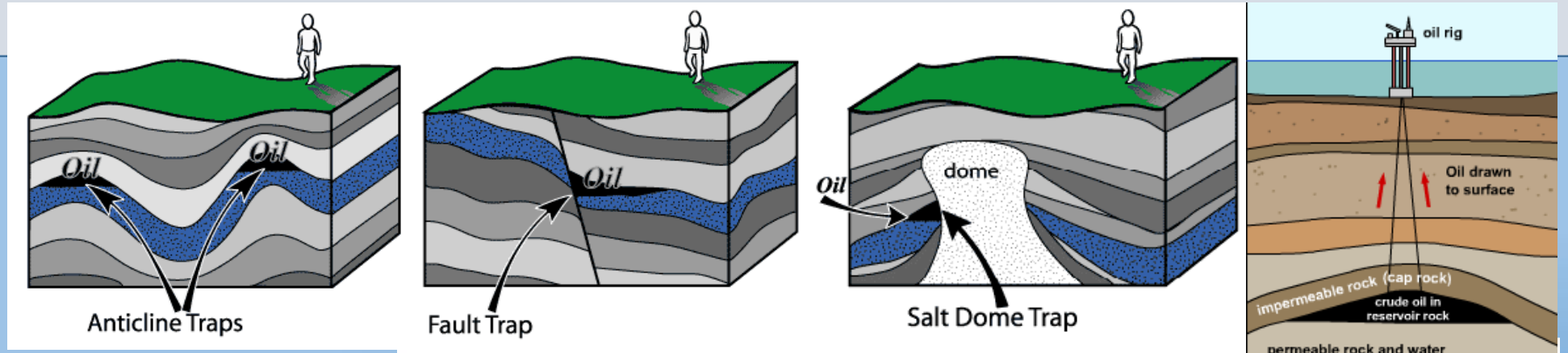
Zoback, 2018

Natural Gas Resources



200 years of supply at current usage levels.

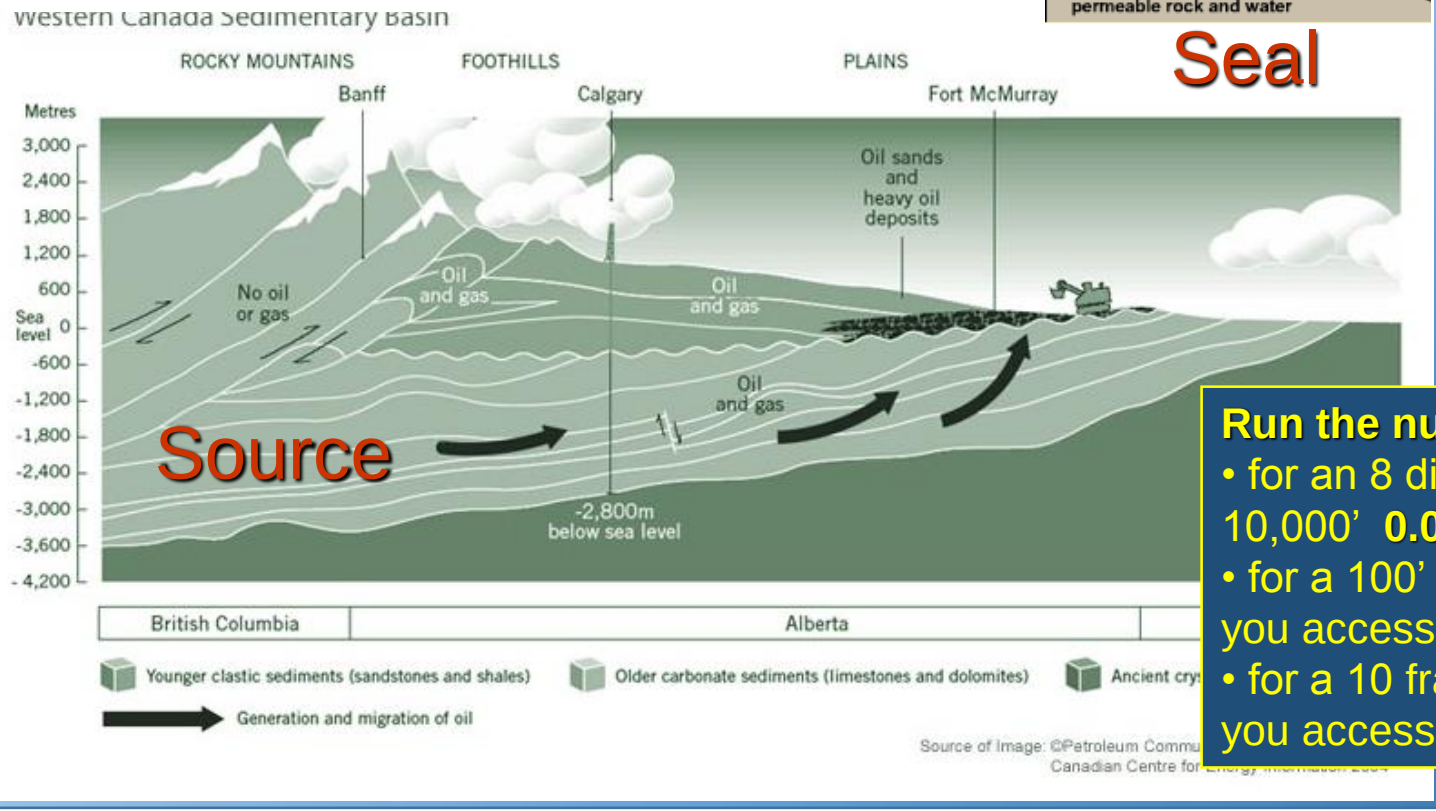
Where is Oil & Gas Found?



Trap

Seal

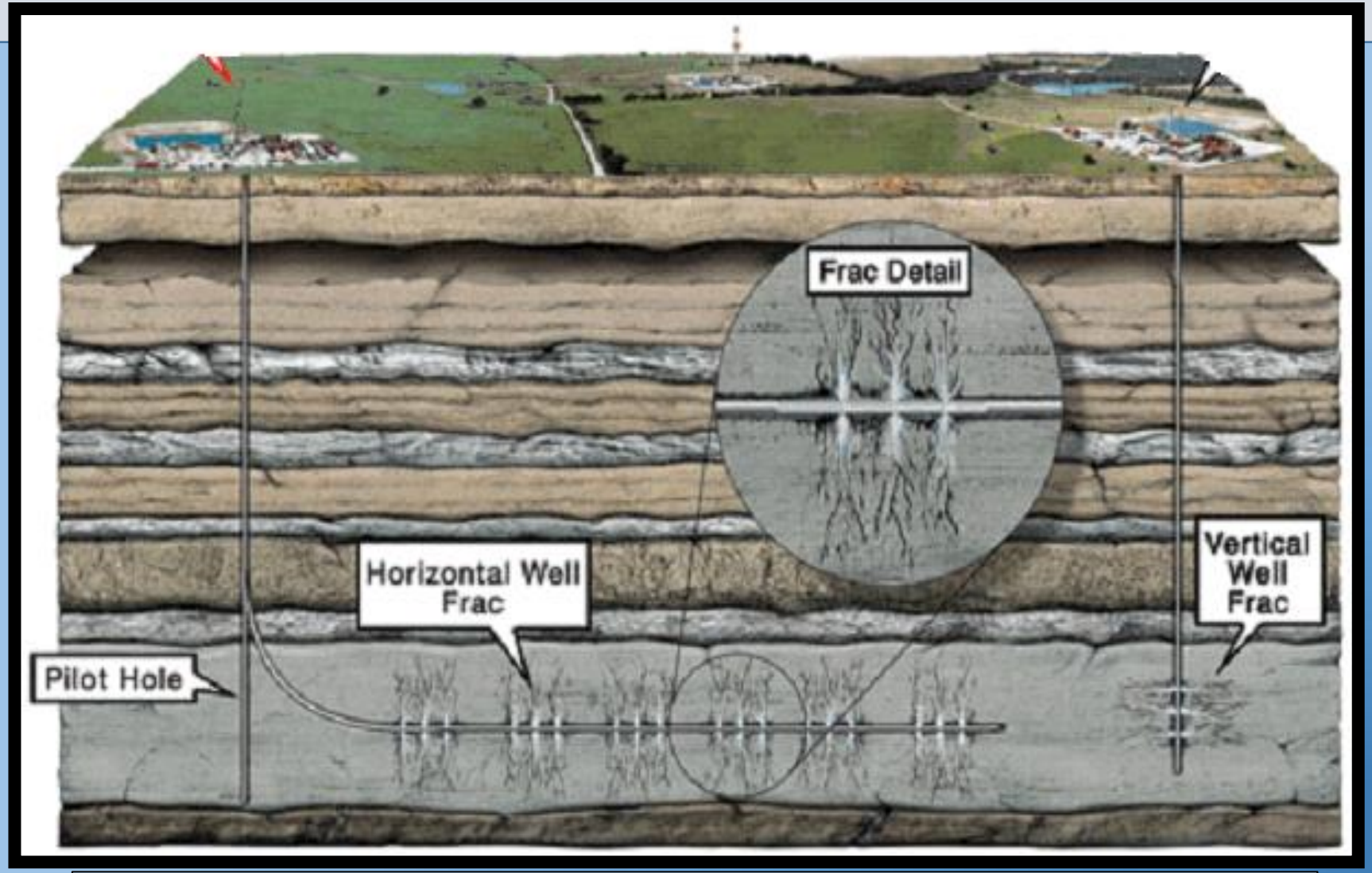
Source rock = shale gas resource. BUT permeability is extremely low, so it won't flow at commercial rates. The answer is to frac it.



Run the numbers:

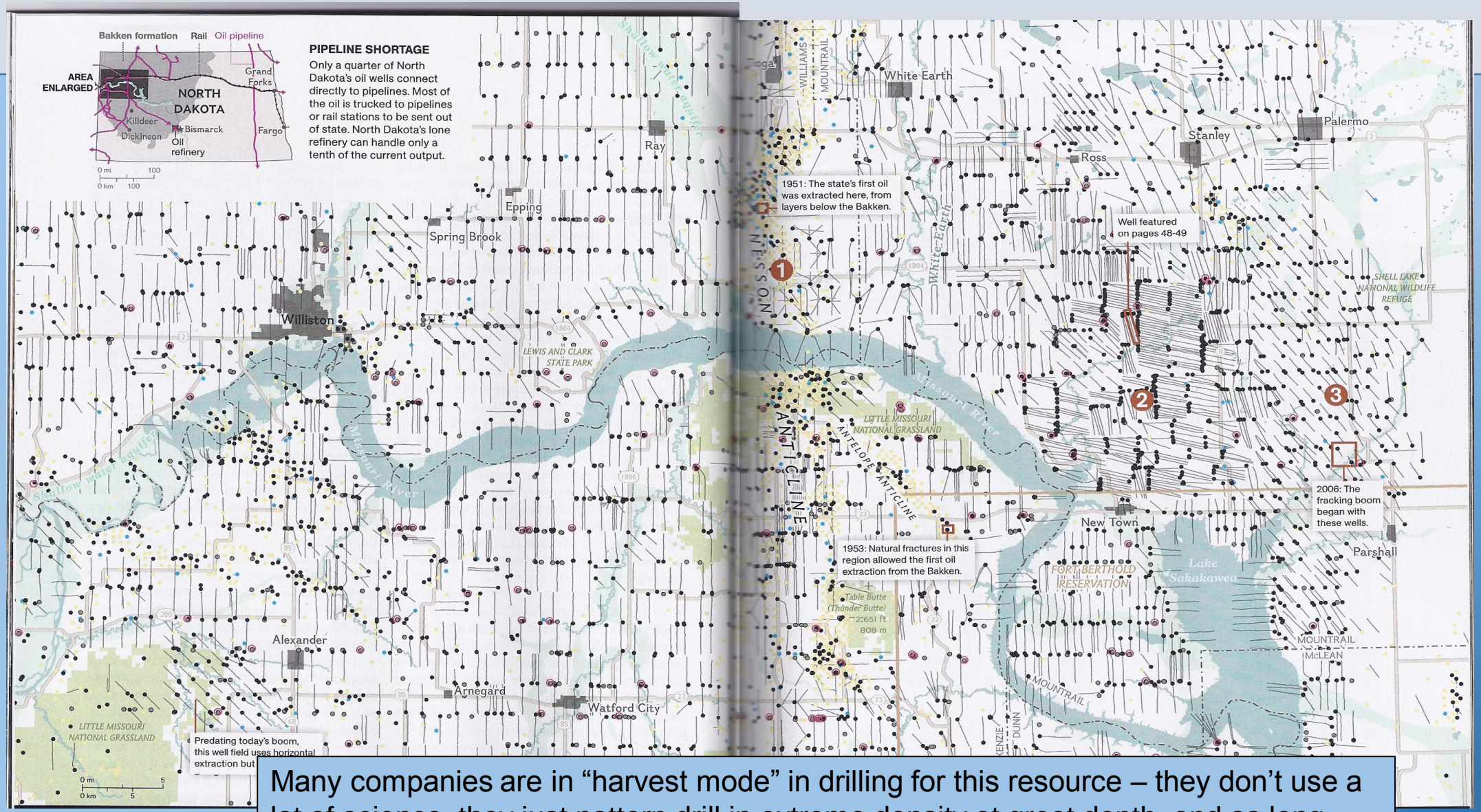
- for an 8 diameter" vertical well at 10,000' **0.0013Mscfg** is accessed
- for a 100' long frac you access **500x**
- for a 10 fracs in one well, you access **5,000x**

Shale Gas – How to Recover it at Commercial Rates?



Horizontal wells have multiple frac stages to open large volumes of rock. Some recent fracs have involved over 60 stages along more than 2 miles of distance.

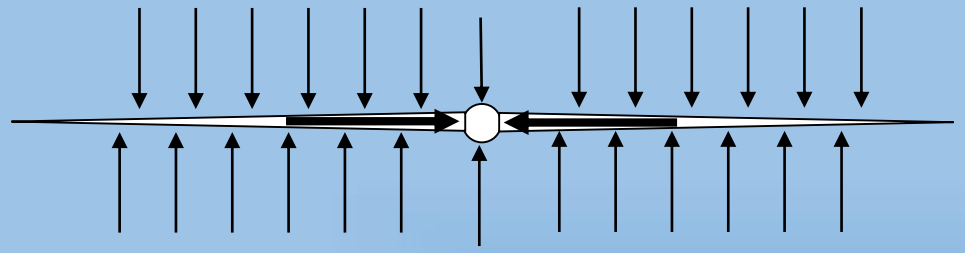
Let's Frac The Bakken



Many companies are in "harvest mode" in drilling for this resource – they don't use a lot of science, they just pattern drill in extreme density at great depth, and as long as they make money, this will be their business plan.

What is a frac job?

How Does a Frac Work?



Fractures turn radial flow into linear flow

Increase “effective wellbore size” to 5 to 10ft

Tap into existing natural fractures, enlarging drainage volume

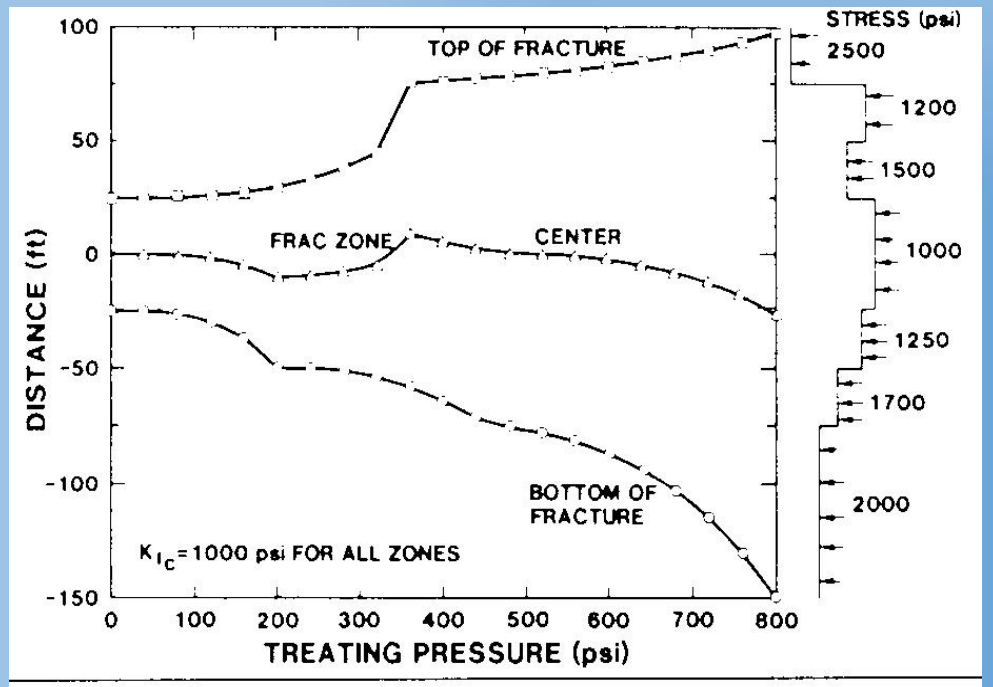


Fig. 3.20—Example calculation of height growth for a seven-layer model.

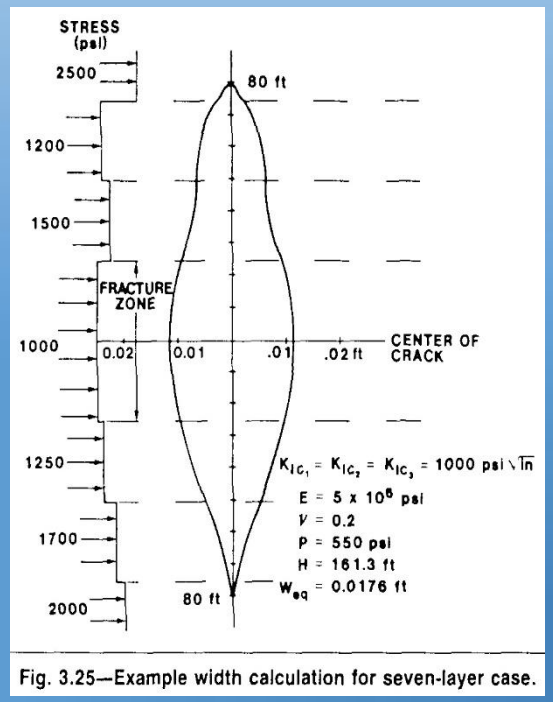
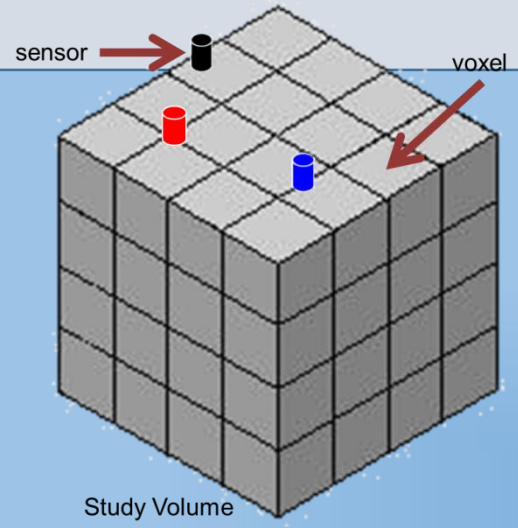


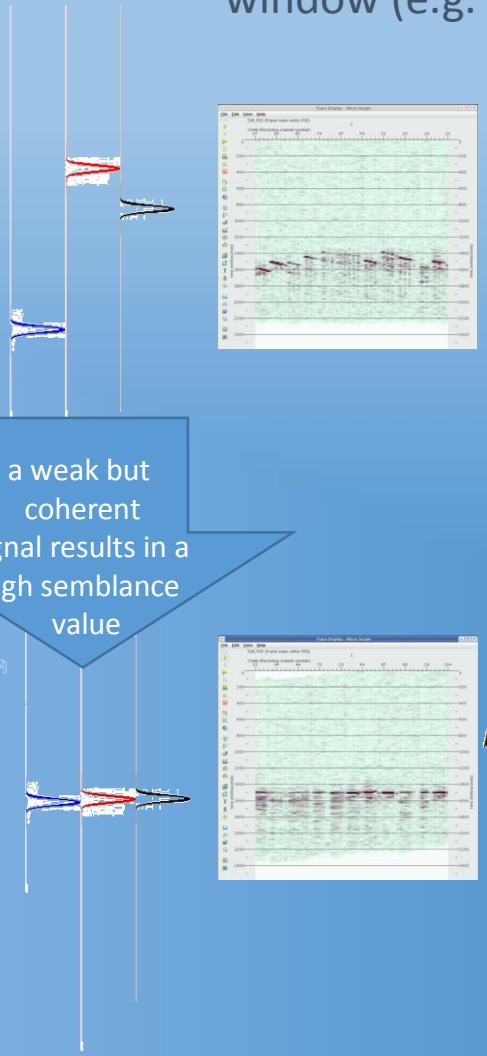
Fig. 3.25—Example width calculation for seven-layer case.

Gidley et al 1989, Fig 3.25, p. 73

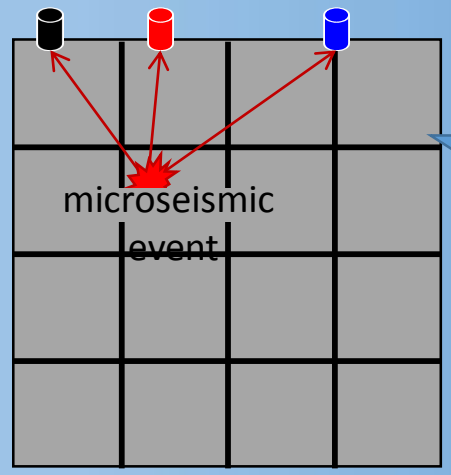
Imaging Fracs With Seismic Emission Tomography



Semblance (**S**) is a measure of the coherence of acoustic emission for each voxel, over a selected time window (e.g. 1 sec.).



For the time window (1 sec., sampled at 1000 sps) the data are stacked, a semblance value is computed for each voxel.

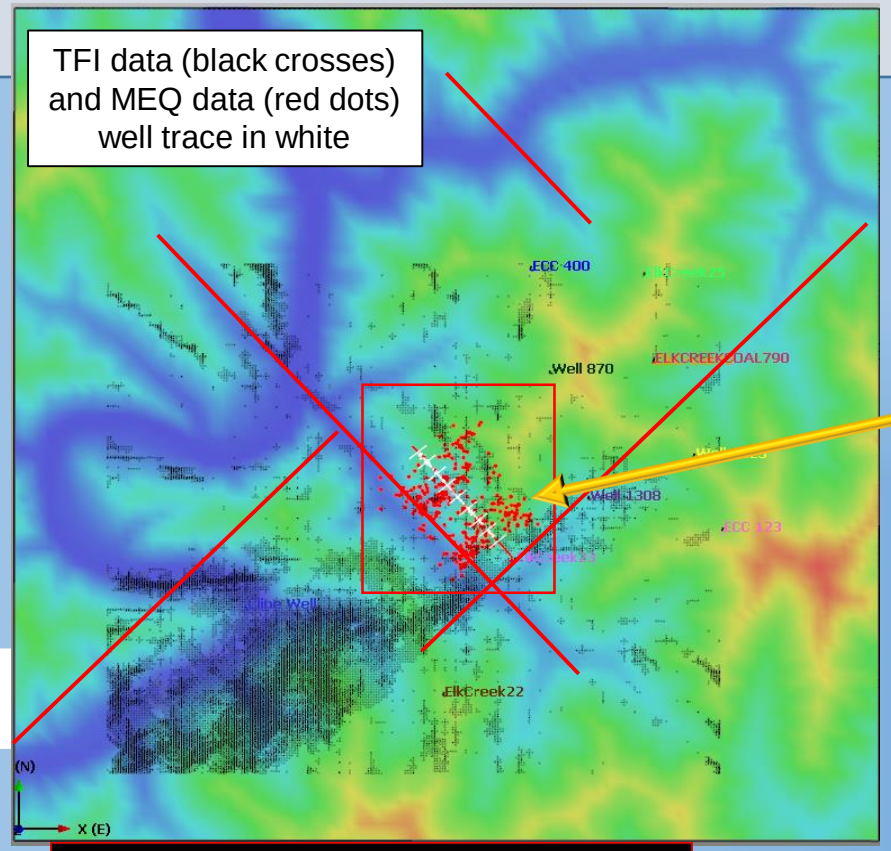


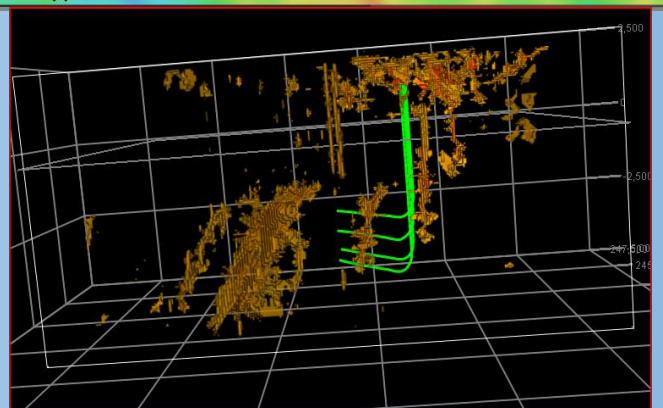
a weak but coherent signal results in a high semblance value

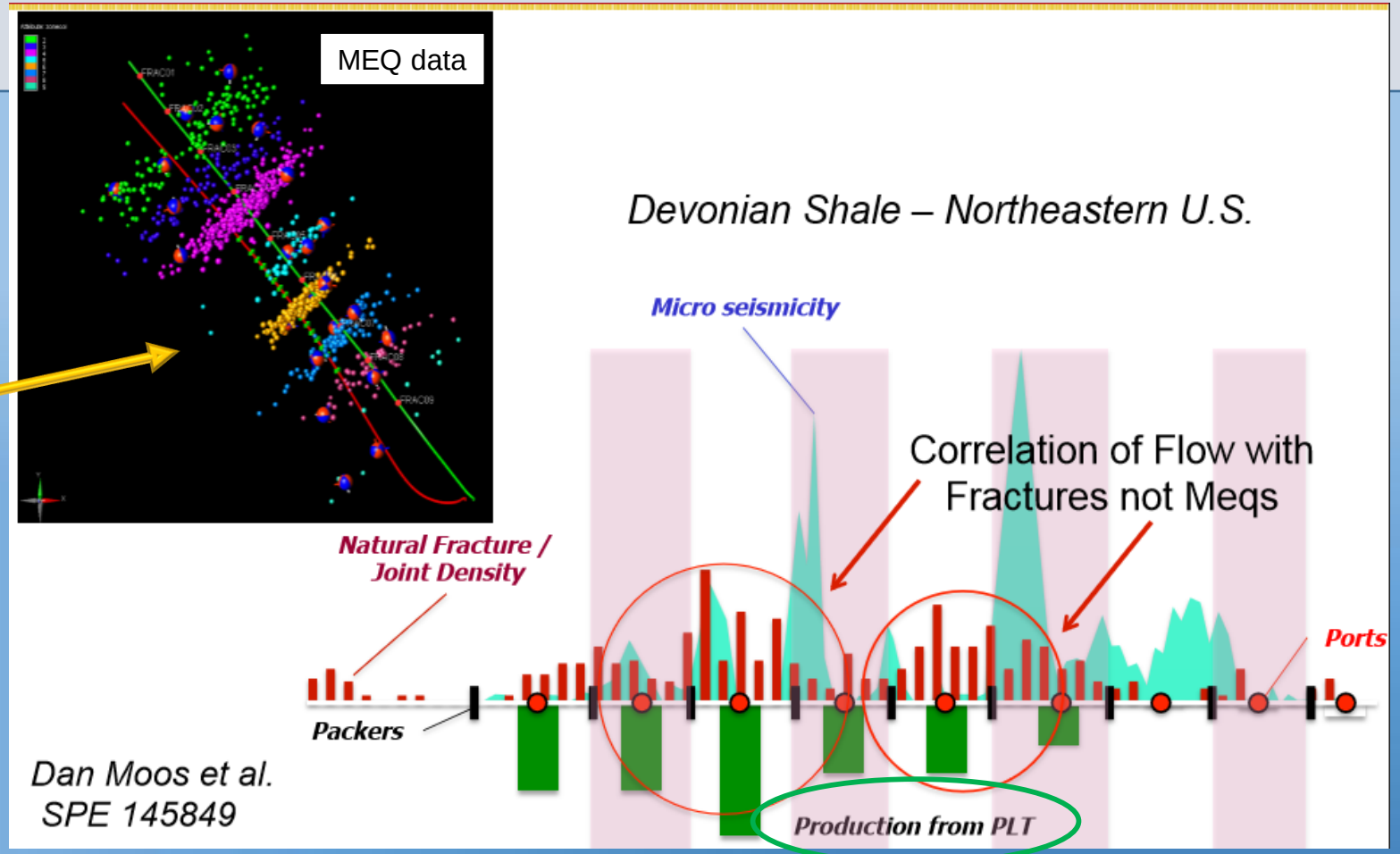
For the given velocity model, travel time is computed for each voxel recording-site pair.

$$S = \frac{\sum_{j=0}^{T}\left[\sum_{i=0}^{K} f_{ij}(\tau_i)\right]^2}{\sum_{j=0}^{T}\sum_{i=0}^{K} f_{ij}^2(\tau_i)}$$

Imaging Fracs With Seismic Emission Tomography







The cited paper corroborates the observed TFI™ data as resulting from permeable fracture systems and that it is the total trace signal, not hypocenter microseismic signals, that images the reservoir permeability.

How Does a Frac Work?

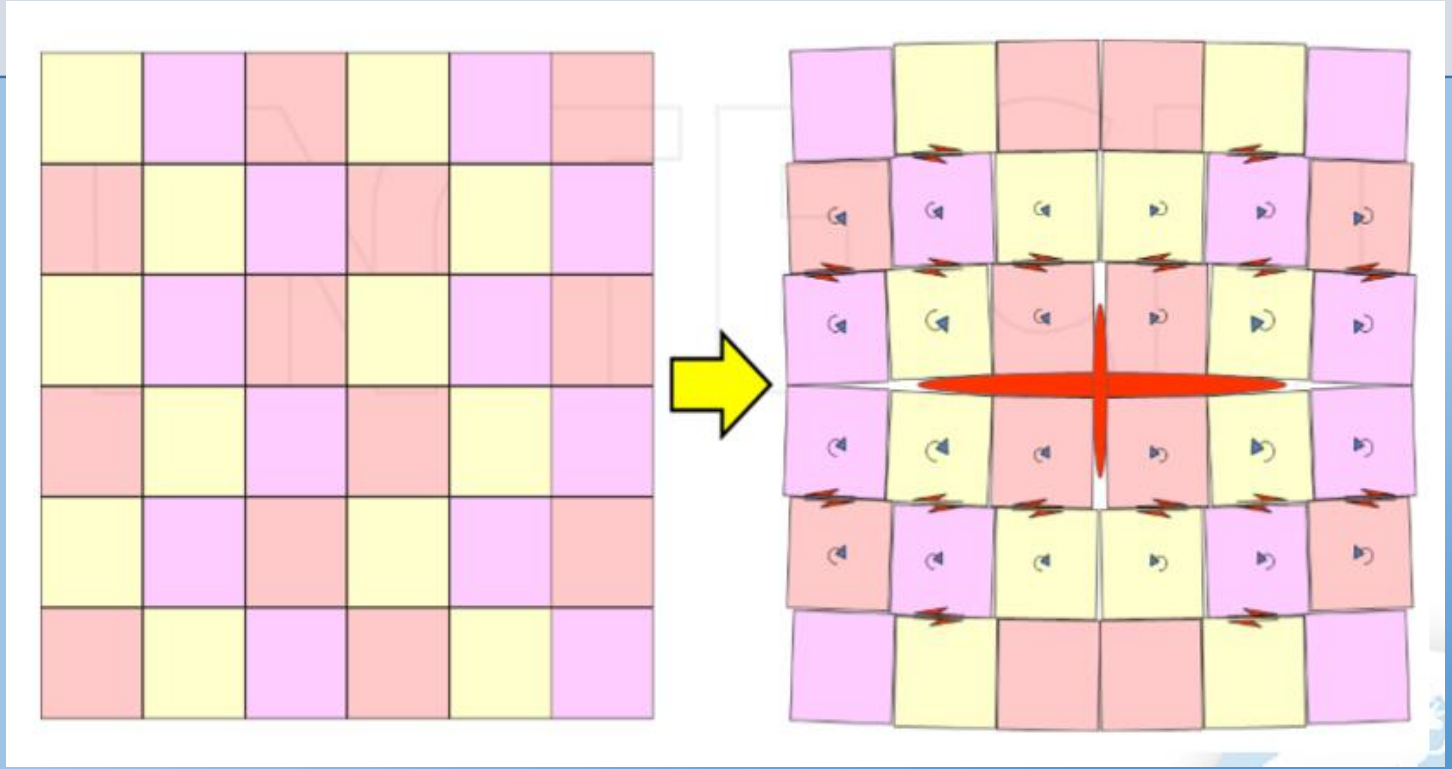
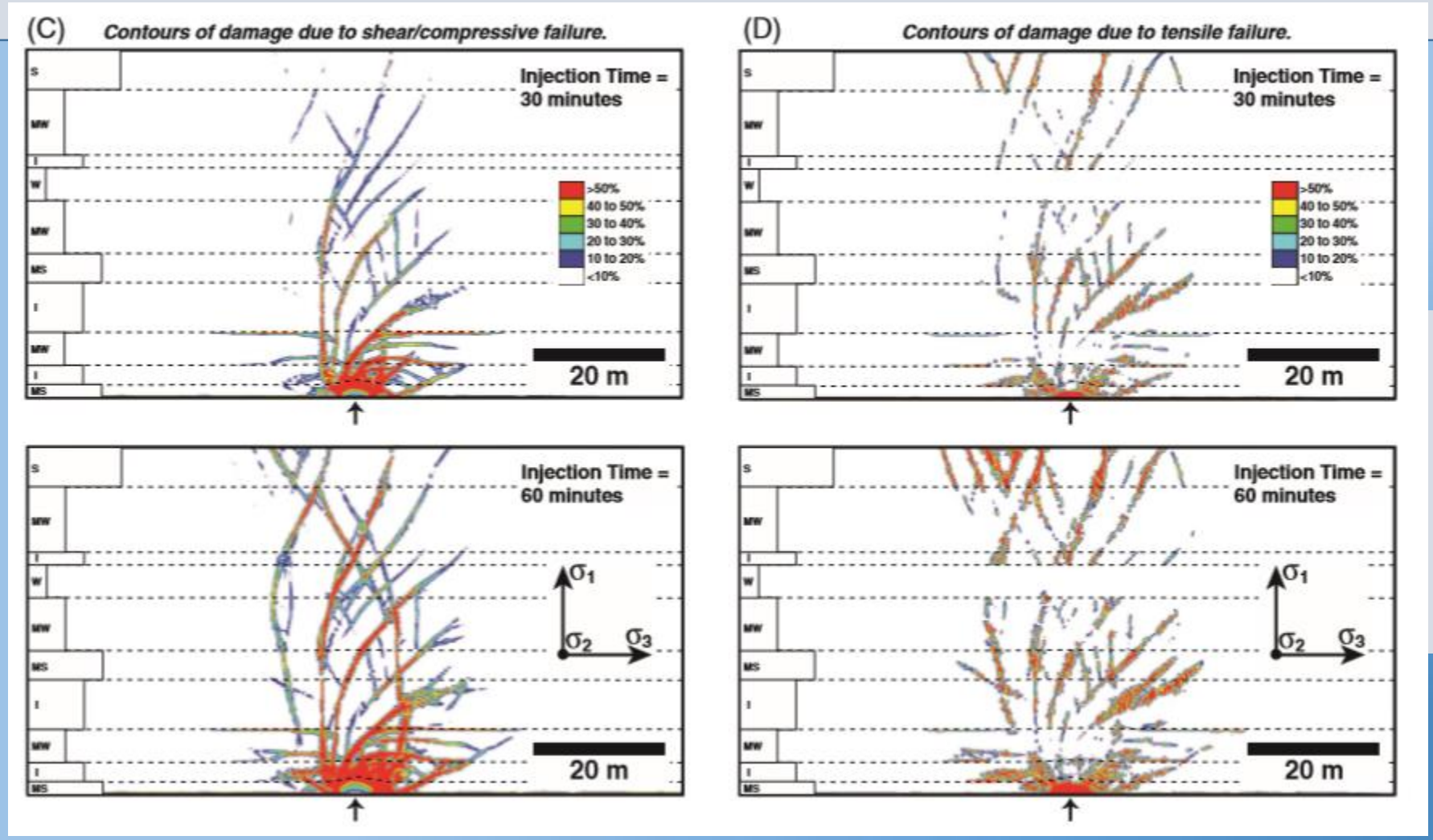


Figure 1. Frac pressure and fluid injection generate a complex pattern of failure as shown by van der Baan et al, 2013. This graphic is taken from Figure 6 of that publication.

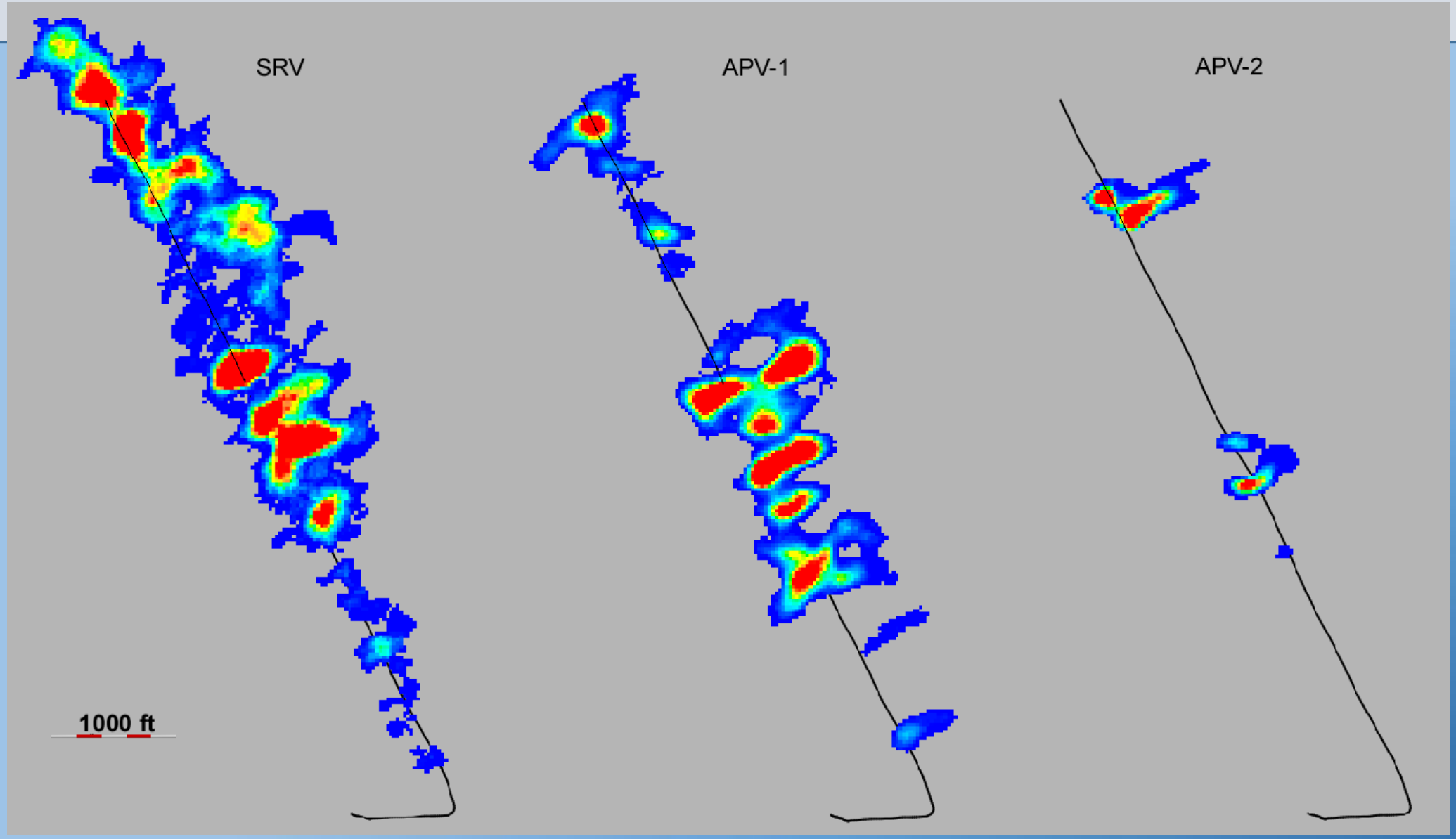
The emplacement of fluid and proppant inflates the formation. This in turn generates a sphere of strain energy that moves away from the stimulation point, changes the stress as it moves, and thus generates more shear failure in the fluid system at distance from the stimulation.

How Does a Frac Work?

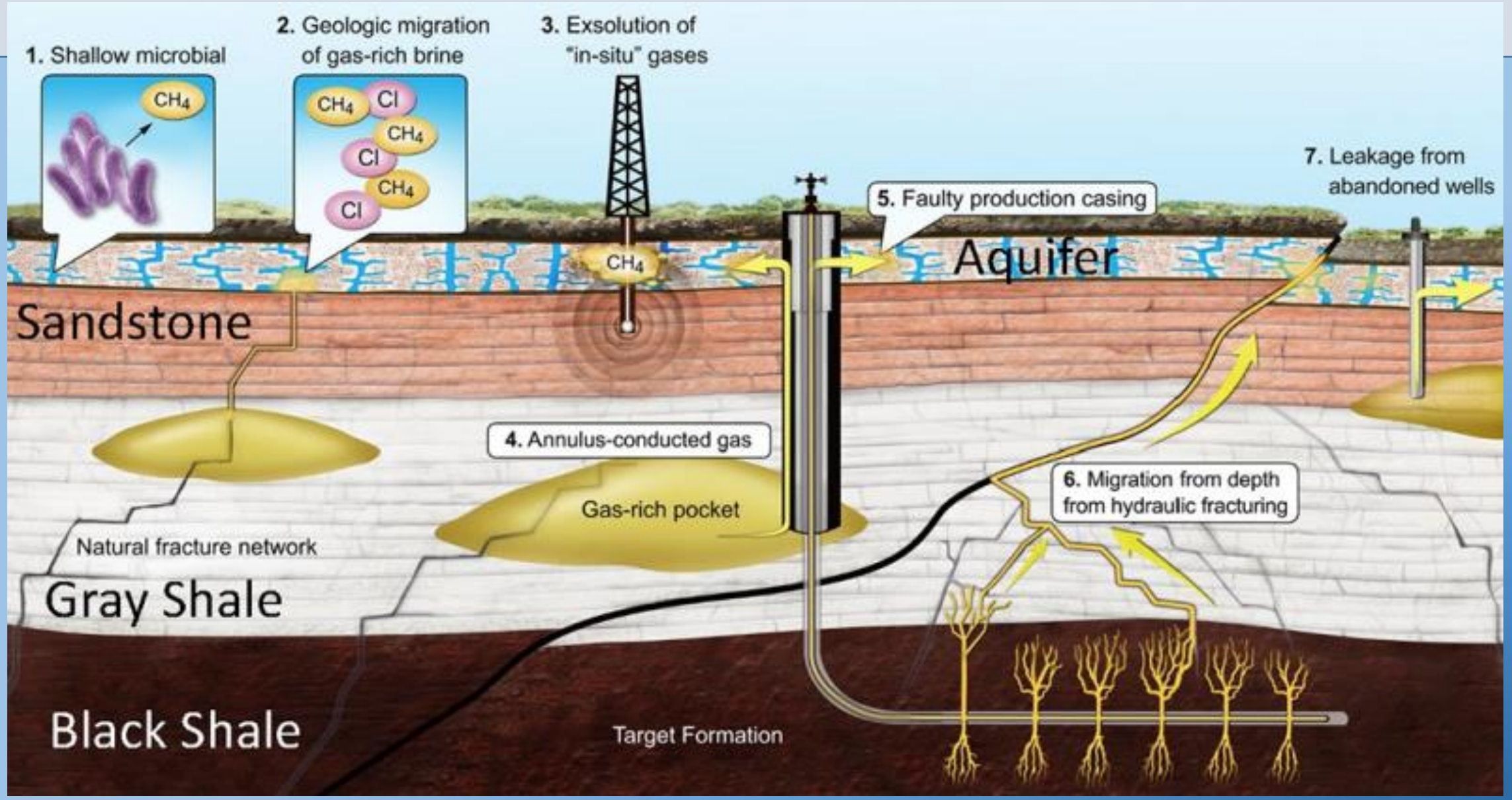


(C) compressive or shear failure and (D) tensile failure after 30 and 60 minutes of injection for model simulating an overburden depth of 3000 m (~9800 ft) with a normal-faulting stress regime (σ1 = σV = 60 MPa [8700 psi]; σ2 = σH = 50 MPa [7250 psi]; σ3 = σh = 40 MPa [5800 psi]). Initial pore pressure is 30 MPa (4350 psi).

How Does a Frac Work?



So What Can Go Wrong?



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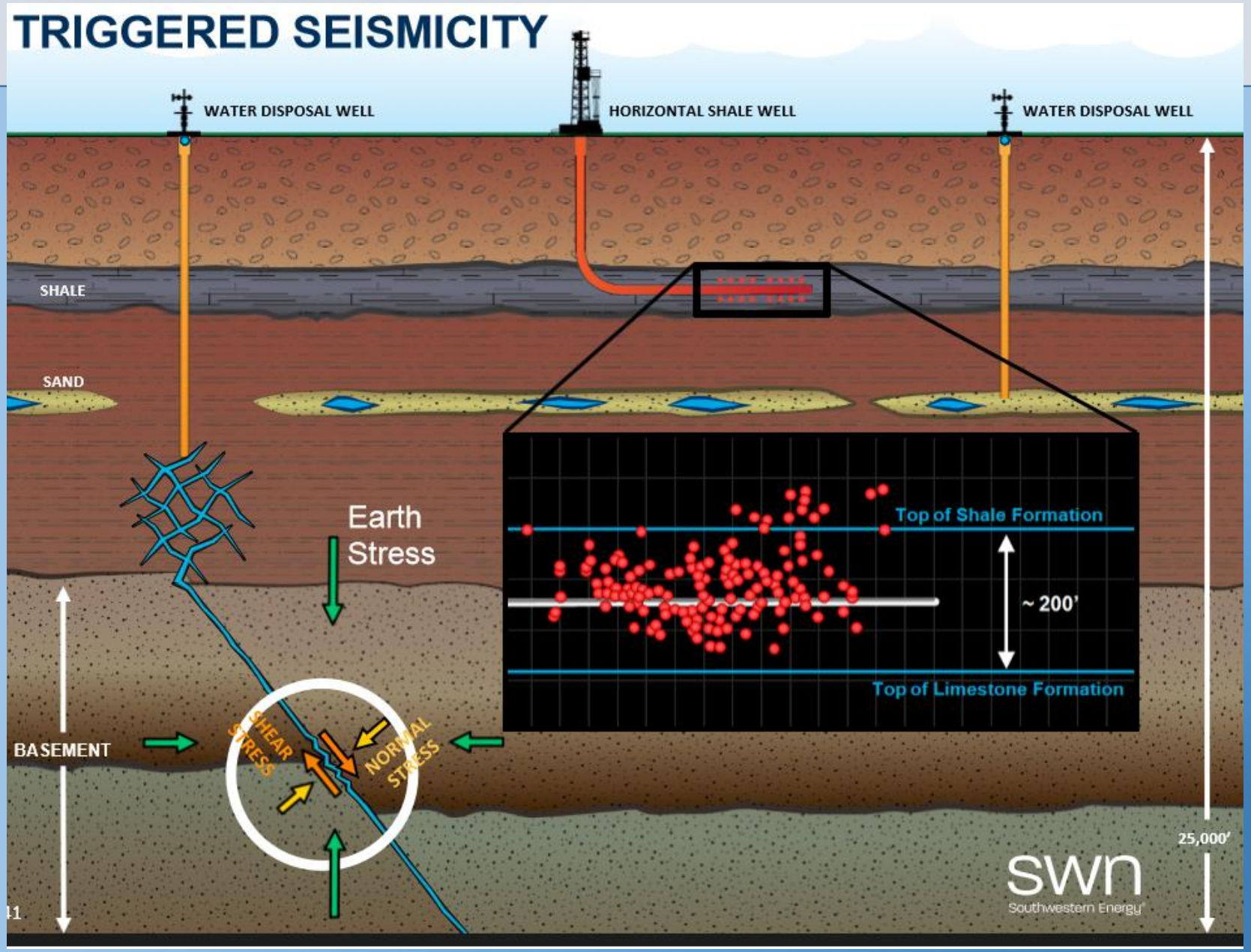

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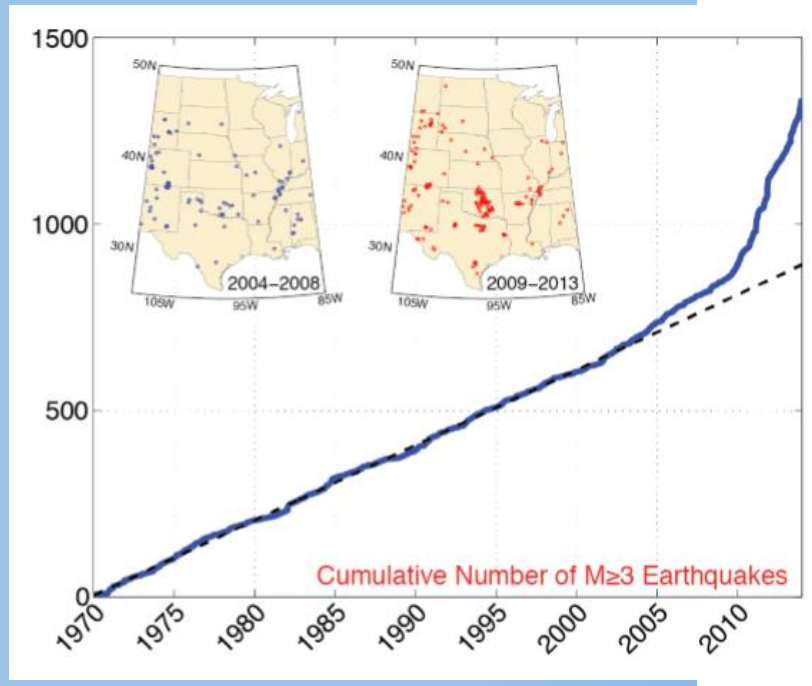
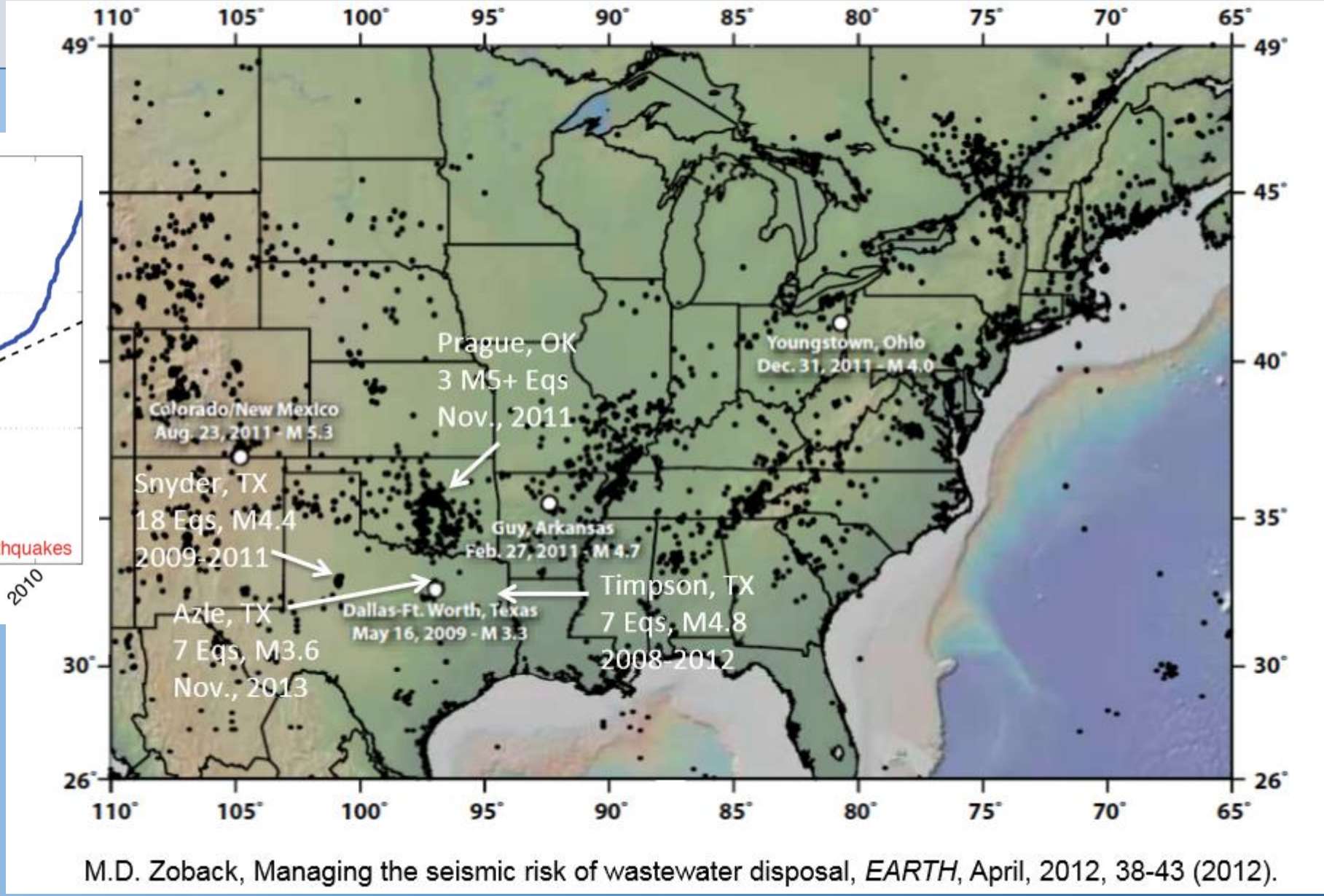




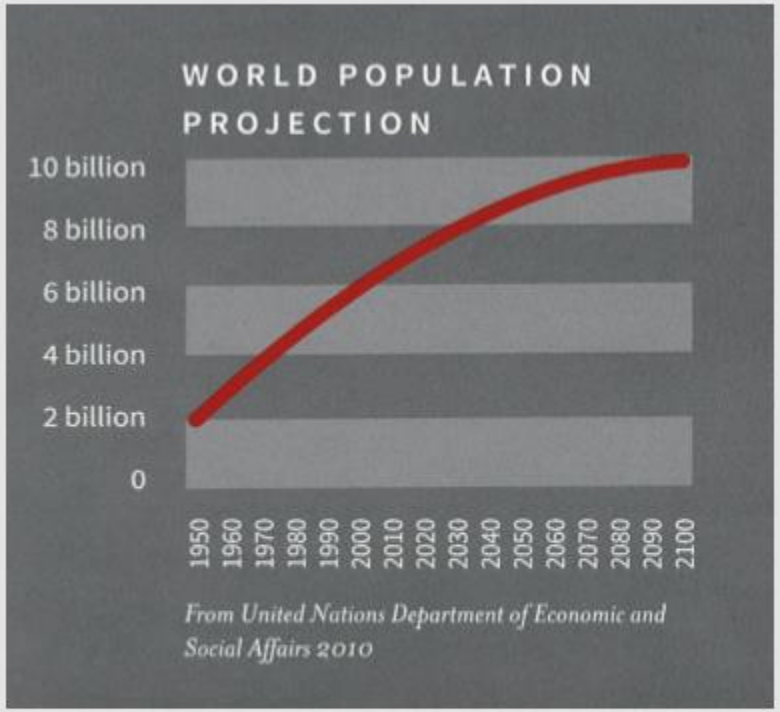
M.D. Zoback, Managing the seismic risk of wastewater disposal, *EARTH*, April, 2012, 38-43 (2012).

Solutions?

California Problems as of 2012

- Up $0.40 overnight!
- California has a closed market for gas
- Tesoro, BP (Arco) & Chevron control 54% of refining
- 27 refineries in 1980s, 14 today
- State “green” rules could result in 8 more closing
- Richmond refinery fire & power outage at ExM plant

The World in 2050



~ 9 Billion People

How Will We Provide Twice As Much Accessible, Affordable, and Secure Energy While Protecting the Planet?

Zoback, 2018

Solutions?

It's a complicated problem with LOTS of money involved.
Conserve energy & vote smart.