What the Frac is Going on?
A Brief Introduction

We've discovered a vast new oil reserve...
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\textsubscript{n}H\textsubscript{2n+2}

Naphthenes or Cycloparaffins (saturated cyclic hydrocarbons i.e. cyclohexane)
General formula C\textsubscript{n}H\textsubscript{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.
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.
If you rely on non-renewable energy, you get a normal distribution curve of its availability.
Shale Oil Helps, Right?

**Figure 1. US petroleum consumption, 1949-2014**

- **US Crude Oil Production, January 1973 to January 2015**
  - **Source:** Energy Information Administration
  - **Chart of the Day**

- **Barrels per day (Millions)**

- **Key Events:**
  - 1st Gulf War
  - Financial Crisis
  - Iranian Revolution
  - OPEC Oil Embargo
  - 2nd Gulf War

- **Source:** Carpe Diem Blog
Shale Oil Helps, Right?
I love this graphic – it shows the relative importance of certain countries to the US so long as we are dependent on liquid hydrocarbons.
We don’t have much conventional liquid oil left in the US, but we sure use a bunch of 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.
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

WORLD POPULATION PROJECTION

10 billion
8 billion
6 billion
4 billion
2 billion
0

1850 1900 1950 2000 2050 2020 2030 2040 2050 2060

From United Nations Department of Economic and Social Affairs 2010

~ 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.
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’ 0.0013Mscf is accessed
• for a 100’ long frac you access 500x
• for a 10 fracs in one well, you access 5,000x
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.
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. 3.25—Example calculation of height growth for a seven-layer model.*

=Gidley et al 1989, Fig 3.25, p. 73
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.

For the given velocity model, travel time is computed for each voxel recording-site pair.
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 ($\sigma_1 = \sigma_V = 60$ MPa [8700 psi]; $\sigma_2 = \sigma_H = 50$ MPa [7250 psi]; $\sigma_3 = \sigma_h = 40$ MPa [5800 psi]). Initial pore pressure is 30 MPa (4350 psi).
How Does a Frac Work?
So What Can Go Wrong?

1. Shallow microbial CH₄
2. Geologic migration of gas-rich brine
3. Exsolution of "in-situ" gases
4. Annulus-conducted gas
5. Faulty production casing
6. Migration from depth from hydraulic fracturing
7. Leakage from abandoned wells
So What Can Go Wrong?
So What Can Go Wrong?

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

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

Zoback, 2018
Solutions?

Thank you.

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