Origin of Petroleum

- Long standing debate:
  Where does rock oil come from?

- Organic or Inorganic?
  Organic = a product of life (biogenic)

Yet ....

- Hugoton Gas Field (Kansas)
  Contains up to 2% Helium!
  360 billion cubic feet produced so far

- Where does the He come from?

Arguments for biogenic origin

- 99.9% of oil deposits are in sedimentary basins
- 99% in rocks younger than 400 million years
- Bituminous shales can be heated up to produce oil
- Analogous to coal (which contains plant fossils)
- Crude oil contains many biomarkers
- $^{13}$C/$^{12}$C is typical of biological activity (enriched in $^{12}$C)
Titan, Moon of Jupiter

Huygens Probe Jan. 14, 2005

- A sea of hydrocarbons
- Atmosphere is Nitrogen, methane and ethane
- Volcanoes vent methane

Huygens probe landing on Titan

- Carried a Gas Chromatograph spectrometer which could detect $^{12}\text{C}$ and $^{13}\text{C}$
- Isotopic composition of Titan hydrocarbons is not biogenic

Soviet Geologists (1950s) and Thomas Gold (1992)

- Natural gas is emitted by the earth
- Gas feeds bacteria in deep reservoirs
- Bacteria make oil

- 21,000 ft deep well drilled in Sweden into the Sinjan impact structure in 1985 failed.
- (Not widely accepted ideas!)

What are trees made of?

- Natural gas is emitted by the earth
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Photosynthesis

- The most important reaction on the planet (for us)

\[
\text{CO}_2 \uparrow + \text{H}_2\text{O} \rightarrow [\text{CH}_2\text{O}]_n + \text{O}_2 \uparrow
\]

Carbon Cycle

- The most important reaction on the planet (for us)

\[
\text{CO}_2 \uparrow + \text{H}_2\text{O} \rightarrow [\text{CH}_2\text{O}]_n + \text{O}_2 \uparrow
\]
### Carbon Storage

- 24% Organic C (reduced) in sediments
- 76% Inorganic C (oxidized) in Limestones
- 0.04% Dissolved in the Ocean
- 0.005% Atmosphere and life
- 0.01% in Coal and Oil
- 0.005% in oil reservoirs

### Atmospheric CO₂ concentration

- 399 ppm (2014)

Mauna Loa

*Ice Core record from Antarctica (Etheridge et al., 1989)*

### Global Mean Temperature Change

L. McCarthy, NASA, 2007

### Greenhouse Effect

Greenhouse gases: Water vapor, CO₂, Methane, N₂O, Ozone …

### Arctic Sea Ice - Sept. 2012- Record Minimum

30 year average

### Arctic Sea Ice Loss Models vs. Observation
Factors required to make a conventional oil deposit

- A Sedimentary Basin with:
  - Source rock - rich in organic matter
  - Burial heating ⇒ maturation
  - Reservoir rock - porous and permeable
  - Migration Path - source to trap
  - Trap -
    - structural trap
    - stratigraphic trap
  - Correct Timing
  - Preservation

Key Element: Source Rocks

- Black organic-rich marine shales
- Organic matter is preserved in low-oxygen water
- Restricted marine basins and zones were water rises from the deep

Unconventional Petroleum Systems

- Gas Shales - Drill into the mature source rock and hydro fracture it (no trap or reservoir needed)
- Coal Bed Methane - Drill into a coal seam (source rock) and pump the water out to lower the pressure
- Tar Sands - Mine the tar-saturated sandstone and remove the oil with heat and solvents
- Oil Shale - Mine the immature source rock and cook it
- Gas hydrates - ???
**Is there a lot of oil left to discover?**

- **Reserves**: Oil that is proven to be there and can be extracted economically using current technology

- **Resource**: Oil that it thought to exist based on geological concepts

**Our role**

It is our job to convert Resources into Reserves and to Produce those reserves in a responsible manner.

**Take home ideas**

- Most Petroleum produced is of biogenic origin
- The Carbon cycle is inefficient at producing petroleum
- Burning hydrocarbons has profound implications for global climate
- Petroleum system requires: mature source rock, reservoir, and trap formed in the right order
- Unconventional systems may need only a source rock
- We can only produce oil that has been discovered

**Reading for Next Time**

- Chemistry of Petroleum
  Ch 2, pp. 13-16 and 26-33 Selley (2nd ed)