Outline 16:
The Mesozoic World:
Formation of Oil Deposits
(with a side trip to the Devonian Marcellus Shale)
The first commercial oil well was drilled by “Colonel” Edwin Drake in Titusville, Pennsylvania, in 1859.
Los Angeles in the 1920s
Are we running out of oil, or not? What happened between these years?

2004

PLUNGING OIL PRICES

BRENT CRUDE PRICES HAVE FALLEN BY NEARLY 60% SINCE MIDDLE OF JUNE 2014

$/Barrel

$ 115.06 on June 19, 2014

$ 48.90 on Jan. 9, 2015 intra-day

$ 50.11 on Jan 9, 2015
Horizontal Drilling and Hydrofracking

We will come back to this.
Facts about Oil Deposits

• 70% are Mesozoic in age
• 20% are Cenozoic in age
• 10% are Paleozoic in age
• What’s so special about the Mesozoic?
Facts about Oil Deposits

• The majority of the world’s oil reserves are in the Middle East around the Persian Gulf.

• What’s so special about the Persian Gulf area?
Conventional Oil Reserves

Less than 10% of the population of USA

Less than 1% of the population of USA
If India or China consumed at the same rate as the U.S., that would use the total available world oil supply!
Oil Reserves:
1 trillion barrels (2007)

- Saudi Arabia 20%
- Iran 10%
- Iraq 9%
- Kuwait 8%
- UAE 7%
- Other 1%
- Middle East 55%

- Asia/Australia 8%
- South America 7%
- Africa 7%
- Russia 5%
- Europe 1%
- USA 2%
- Canada/Mexico 15%

(USA consumes 25% of world oil)
Alberta Tar Sands – a major source of oil at high prices for the Keystone Pipeline
Major U.S. Oil Suppliers, 2010
(We import 55% of our oil)

- Canada, 28%
- Mexico, 13%
- Nigeria, 11%
- Saudi Arabia, 10%
- Venezuela, 9%
- Algeria, 6%
- Russia, 4%

Source: U.S. Energy Information Administration.
How long will the reserves last?

Current annual worldwide consumption is 25 billion barrels (BB) per year. Divide that into the 2007 reserves:

\[
\frac{1,000,000,000,000 \text{ barrels}}{25,000,000,000 \text{ barrels/yr}} = 40 \text{ years}!!!
\]

This assumes no increased consumption and no new discoveries.
How much oil is undiscovered?

• Hard to know, but scientific estimates in 1996 suggest that 2/3 of commercial oil have already been found. Estimates in 2000 suggest only ½ has been found.

• The remaining oil will be harder to find and will require the abilities of talented geologists.

• Horizontal drilling is a game changer. Previous estimates are being revised upwards.
Reserves calculated to be 1.6 Trillion barrels in 2013

**World Oil Reserves (2013)**

- **Middle East**
  - 802.16 BBL
  - 49%
- **North America**
  - 213.90 BBL
  - 13%
- **Central & South America**
  - 325.93 BBL
  - 20%
- **Asia & Oceania**
  - 45.36 BBL
  - 3%
- **Europe**
  - 12.02 BBL
  - 1%
- **Africa**
  - 127.74 BBL
  - 8%
- **Eurasia**
  - 118.89 BBL
  - 7%
Is Oil Production near its Peak? Probably not.

Figure 40: Oil production world summary

- WEO2006
- Middle East
- Africa
- Latin America
- South Asia
- East Asia
- China
- Transition Economies
- OECD Pacific
- OECD Europe
- OECD North America

Projected Need

WEO 2006
Geologic Mapping and Sampling

- Gravity
- Magnetics
- Seismic Reflection
- Geologic Mapping
Geologic Data Analysis
Largest Hydrocarbon Basins
by Ultimate Potential
Origin of Fossil Fuels

Coal
  Plants

Natural Gas
  Marine Algae

Oil
The Origin of Petroleum

Organic-rich Source Rock → Thermally Matured Organic Matter → Oil
Source Rock for Petroleum

Organic-Rich

Thin Laminae

Measured Values

- Total Organic Carbon: 3.39
- Hydrogen Index: 378
- In-Place Petroleum $S_1$: 2.24
- Pyrolytically Generated Petroleum $S_2$: 12.80

LOMPOC Quarry Sample
Monterey Formation, CA
Production of Oil and Gas

1. Need source materials: marine plankton
2. Burial of source materials to “cook” it.
3. Reservoir rock: porous sandstone or limestone (reefs)
4. Seal for reservoir: shale or salt
5. Trap: a structural trap or a facies trap.
Hydrocarbon Trap Types

Anticline
Pinchout
Unconformity
Fault
Salt Dome
Anticlinal Theory
Petroleum Accumulates in Structural Closure
Production of Oil and Gas

- Maximum burial depths:
  - oil: 25,000 ft (5 miles)
  - gas: 35,000 ft (7 miles)

- Drilling technology is limited to 35,000 ft, which is the effective limit of fluid hydrocarbons.
Exploring for Petroleum: Collecting Seismic Reflection Data
Geology of a continental shelf revealed by seismic reflection data. Folded layers trap oil and gas.
Other examples of seismic lines showing traps for oil and gas deposits.
3 D Seismic Imaging off the SE coast of Brazil. Major oil discovery in 2010.
3D Seismic Imaging of the Marcellus Shale in Pennsylvania
Horizontal production wells from directional drilling. Common practice today, even in WV

We continue to set new industry benchmarks in drilling and completions.

Above - ExxonMobil is improving well production rates and reducing well-related problems using technologies validated by learnings in the laboratory and the field.

Right - ExxonMobil engineers use an integrated suite of technologies to drill and complete complex extended-reach wells.
Deep Gas Well: 8,000 ft in WV
Drilling the Devonian-age Marcellus Shale in the Appalachian Basin

See an Industry Video
http://www.youtube.com/watch?v=VY34PQUiwOQ

60 Minutes Story
https://www.youtube.com/watch?v=UuGrawkuA2s
Shale Gas is an Energy Game-Changer
Shale Gas is Displacing Coal for Generating Electricity

Source: Energy Information Administration, year 2011 data. / U.S. Environmental Protection Agency
https://www.eia.gov/
Black shale on outcrop

Extent of Devonian black shales

Marcellus Shale link
Marcellus Shale in West Virginia

With recent drilling it has come to the Survey's attention that Marcellus Shale may exist west of the current 0 thickness line. We will be examining data to determine what changes may be needed to the thickness map.

Explanations
1. Marcellus Wells
   A completed Marcellus well has one or more zones in the Marcellus that have been prepared for production—the well may or may not be producing currently, as permitted Marcellus wells are one with a Marcellus/Devonian shale or deeper target.

2. Onondaga
   The Onondaga Limestone and equivalent units underlie the Marcellus Shale. The top of the Onondaga and equivalents is approximately equal to the base of the Marcellus.

Legend
- Completed Marcellus Vertical Wells
- Completed Marcellus Deviated Wells
- Permitted Marcellus Wells

Marcellus Thickness (isopach)
- 0 ft. - 20 ft.
- 21 ft. - 40 ft.
- 41 ft. - 60 ft.
- 61 ft. - 80 ft.
- 81 ft. - 100 ft.
- Over 100 ft.
- Possible/Uncertain Marcellus
- Undetermined Thickness
- Marcellus Assumed to be Absent

Marcellus Thickness (isopach) Contours
- Thickness Contour (20 ft.)
- Possible/Uncertain Marcellus Shale Present

Onondaga Fold Axis
- Anticline
- Syncline
- Inferred Anticline
- Inferred Syncline

State Boundary
County Boundaries
Interstate Highways
U.S. Highways

West Virginia Geological and Economic Survey
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The Marcellus Shale
Since 2005, in Pennsylvania alone, more than 5,800 wells have been drilled into this mile-deep shale. At press time New York was debating an end to its drilling ban.
THE SHALE BOOM

The technology for pulling natural gas from deep shale, refined in the 1990s in Texas, has since spread to other “plays”—parts of a shale basin where large quantities of gas have been found. More than a third of U.S. gas now comes from shale.

Richest shale deposits
Recoverable gas, in trillion cubic feet (tcf)
Total for continental U.S. 542*

1. Marcellus 141
2. Haynesville 66
3. Eagle Ford 50
4. Barnett-Woodford 27
5. Woodford 24

Shale play (active or expected drilling)
Shale basin (potential gas resource)

ONE TCF CAN HEAT 15 MILLION HOMES FOR A YEAR.
*TOTAL INCLUDES “PROVED RESERVES” AND “UNPROVED RESOURCES.”

VIRGINIA W. MASON, NGM STAFF; ALEXANDER STEGMAIER, NG STAFF
SOURCES: U.S. EIA; FRACTRACKER; U.S. CENSUS BUREAU; STATISTICS CANADA
A drilling rig for a Marcellus gas well in the Appalachian Basin
Horizontal Drilling and Hydrofracking operations
Fractures in Marcellus black shale
What’s so special about the Mesozoic?

• The worldwide climate was tropical.
• Plankton were abundant in the ocean.
• Ocean bottoms were stagnant and anoxic, unlike today’s ocean.
• Black, organic-rich muds accumulated to form later source rocks.
Modern Ocean

Mesozoic Ocean

Low-oxygen layer

Cold water

Warm water

Figure 17-16
Earth System History, Second Edition
© 2005 W.H. Freeman and Company
Modern oceans are well ventilated unlike during the Cretaceous when there was no cold, oxygenated water to sink near the poles.
What’s so special about the Persian Gulf area?

• The Persian Gulf area was once on the edge of the Tethys Seaway.
• Tropical reefs were abundant.
• The Tethys was a particularly anoxic ocean.
• The closing of the Tethys produced numerous structural traps.
Reefs: Excellent reservoir rocks

Organic-rich mud accumulates in the Basin – source for oil and gas