

The Magic of Petroleum



ENVIR 100

Nov 5, 2008

<https://courses.washington.edu/.../PetroleumGe>

The Prize

- In 1970, several major US oil companies paid the government millions of dollars for oil-drilling rights off the coast of Oregon and Washington
- They drilled three holes, then abandoned the operation, losing millions of dollars

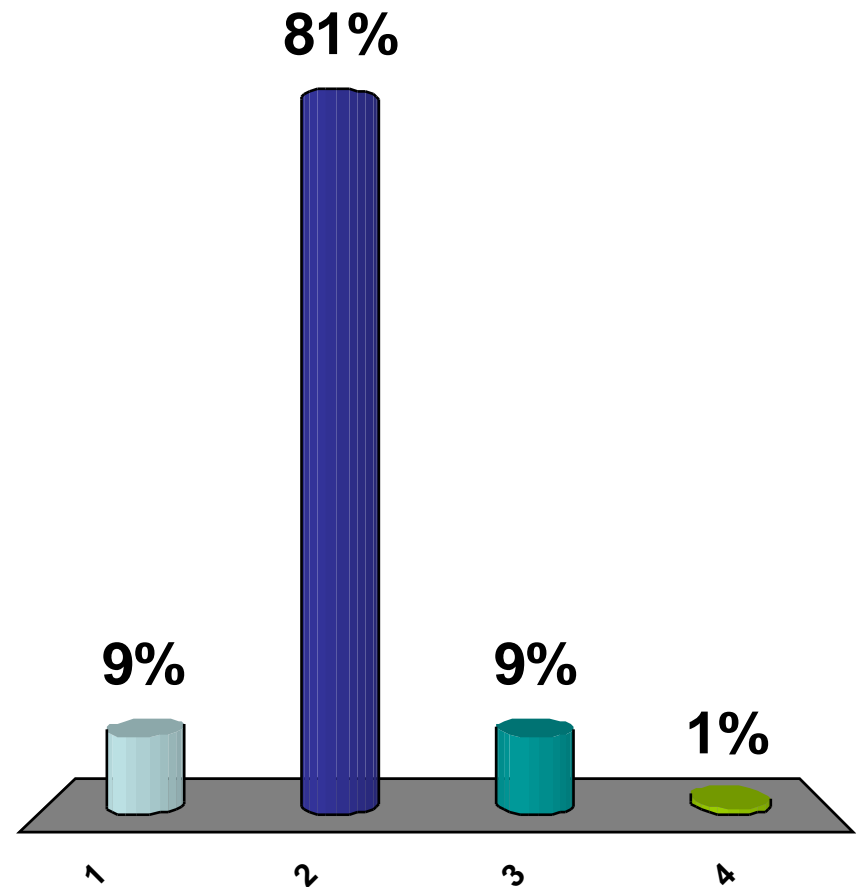


What went wrong?

- They forgot the story about the Texas county that produced oil after 30 dry holes were drilled
- They did not listen to the economists telling them that the amount of oil discovered depends on the number of dollars spent on the search
- Environmentalists were better organized in Oregon and Washington than anywhere else
- There was really bad news in those three holes
- All/None of the above

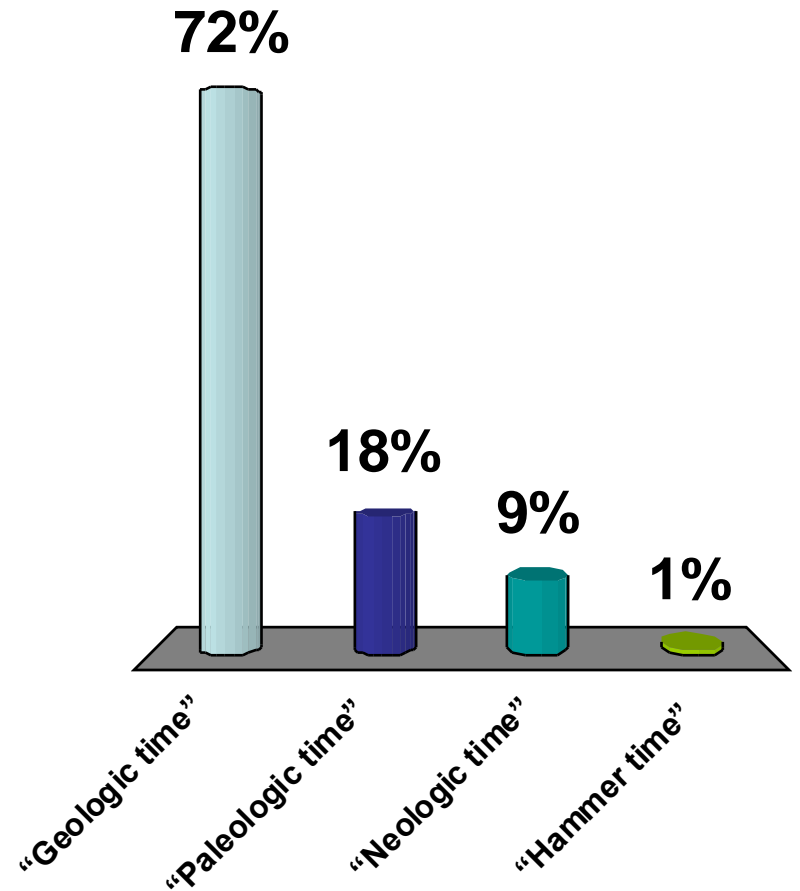
A key concept in the reading was...

1. Hubbert's folly
2. Hubbert's peak
3. Hubbert's equilibrium
4. Hubbert's squash



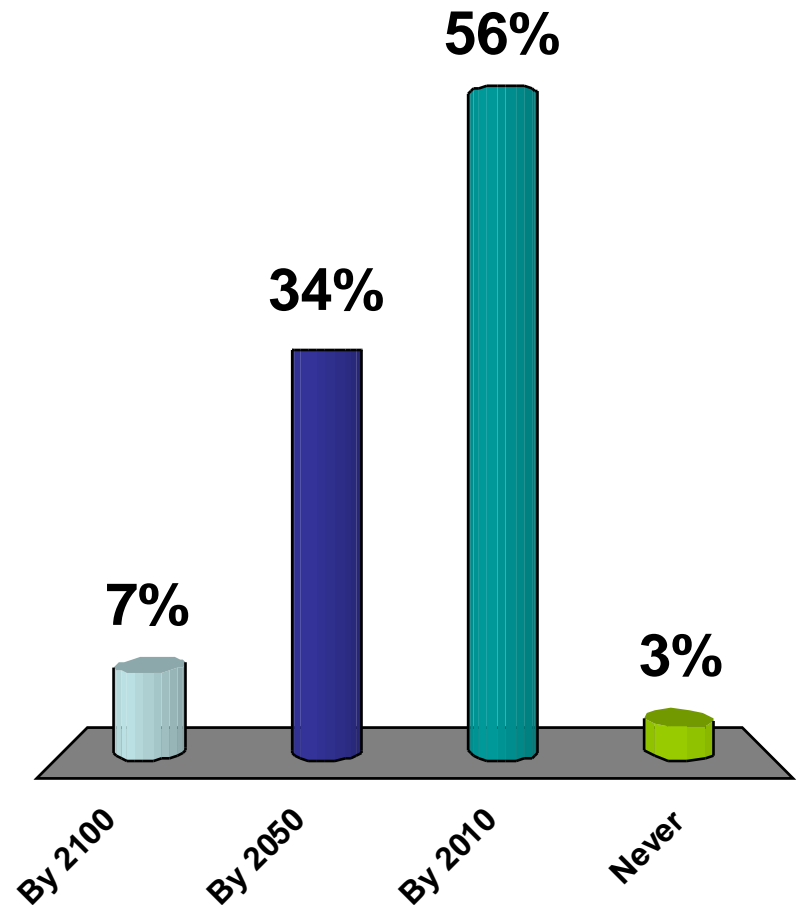
The time scale relevant for oil formation is know as

1. “Geologic time”
2. “Paleologic time”
3. “Neologic time”
4. “Hammer time”



The author of the article argues that world oil production will decline

1. By 2100
2. By 2050
3. By 2010
4. Never



The Magic of Petroleum

Outline

I. Where does petroleum come from?

II. Petroleum - A Strategic Natural Resource

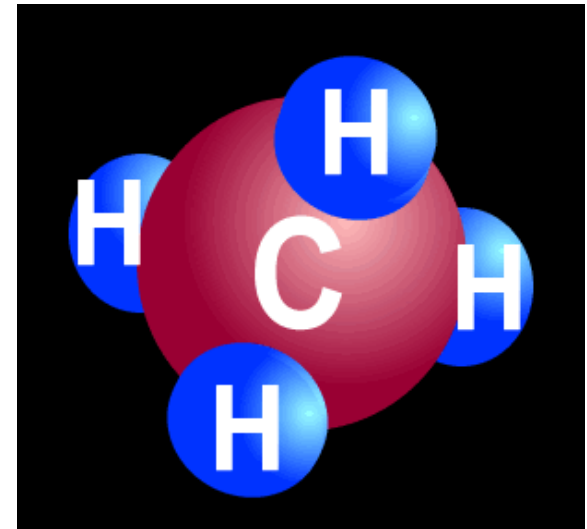
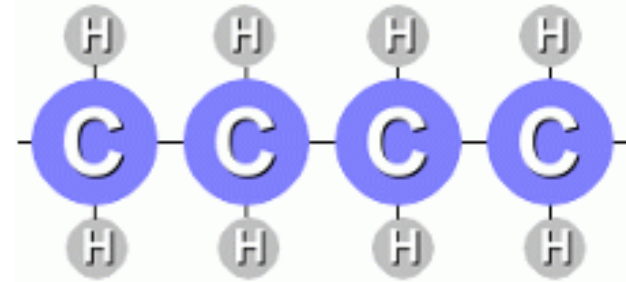


I. Where does petroleum come from?



What is petroleum?

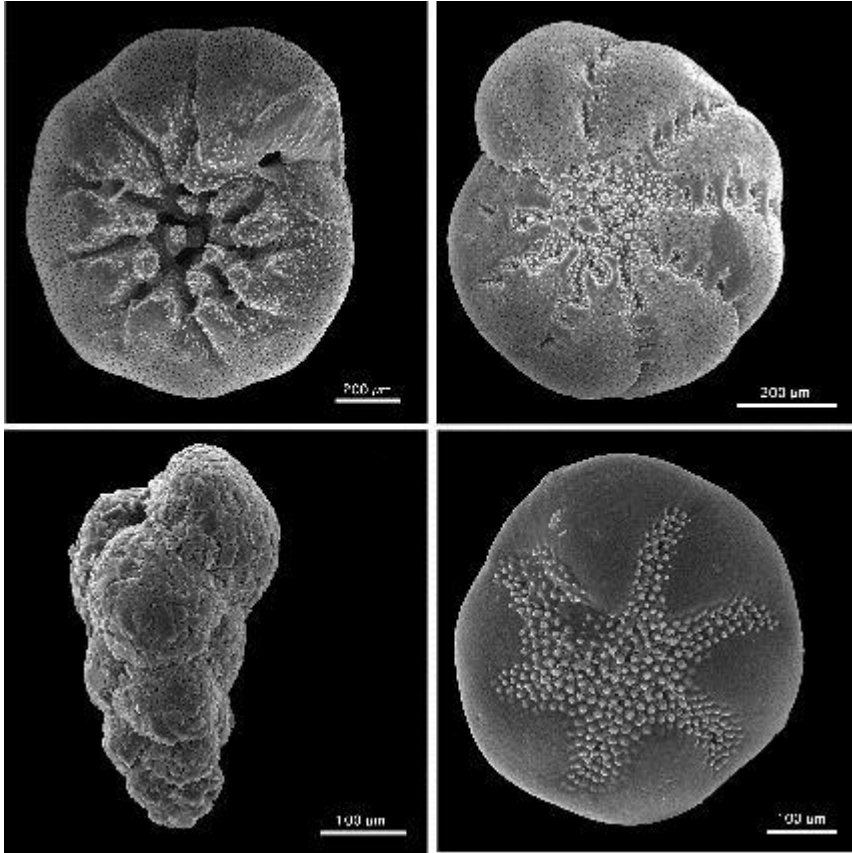
- **Petroleum:** A general term for all naturally occurring hydrocarbons (hydrogen + carbon)
- **Solid Hydrocarbons:** Asphalt
- **Liquid Hydrocarbons:** Crude oil
- **Gas Hydrocarbons:** Natural Gas: methane, butane, propane, etc.



The simplest hydrocarbon is Methane (CH₄)

1. Source Rocks

Organic Matter



- Sedimentary rocks rich in organic matter
 - 0.5 - 2% by weight
- Most commonly microscopic marine material, but it can be land based material
- Organic material cannot decay too much
 - It has to keep its carbon

1. Source Rocks

Modern Sedimentary Basins

- Gulf of Mexico
- Parts of the Mediterranean and Black Sea



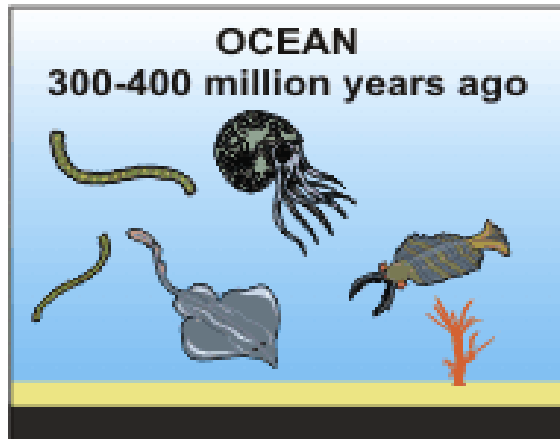
The Mediterranean Basin



2. Transform organic matter

Add heat and pressure by burying it (**Maturation**)

PETROLEUM & NATURAL GAS FORMATION



Tiny sea plants and animals died and were buried on the ocean floor. Over time, they were covered by layers of silt and sand.

3. Carrier beds

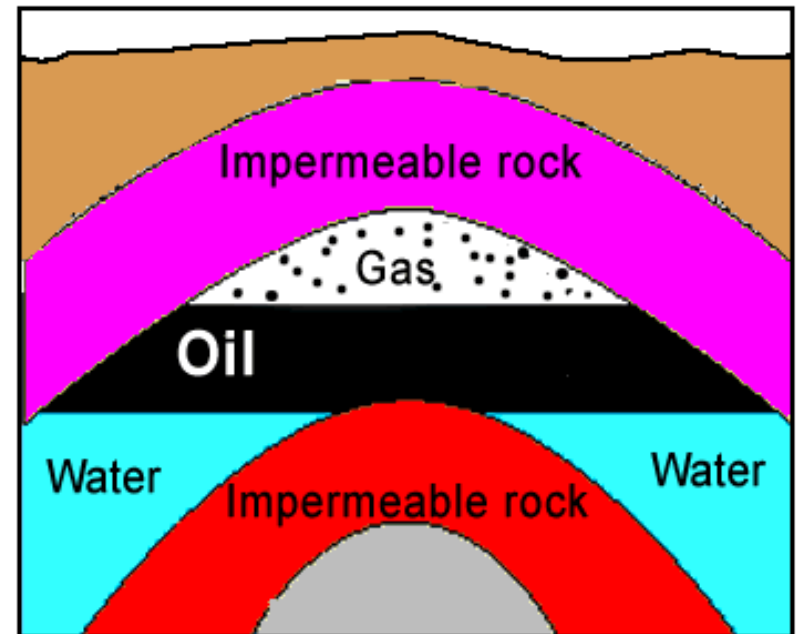
Oil on the move

- Oil is less dense than water and will rise through the fluid system of the surrounding rock
- **Carrier beds** are rock layers that allow fluids to pass through them
 - Ex: Sandstone
- If petroleum stays buried, it can become post-mature



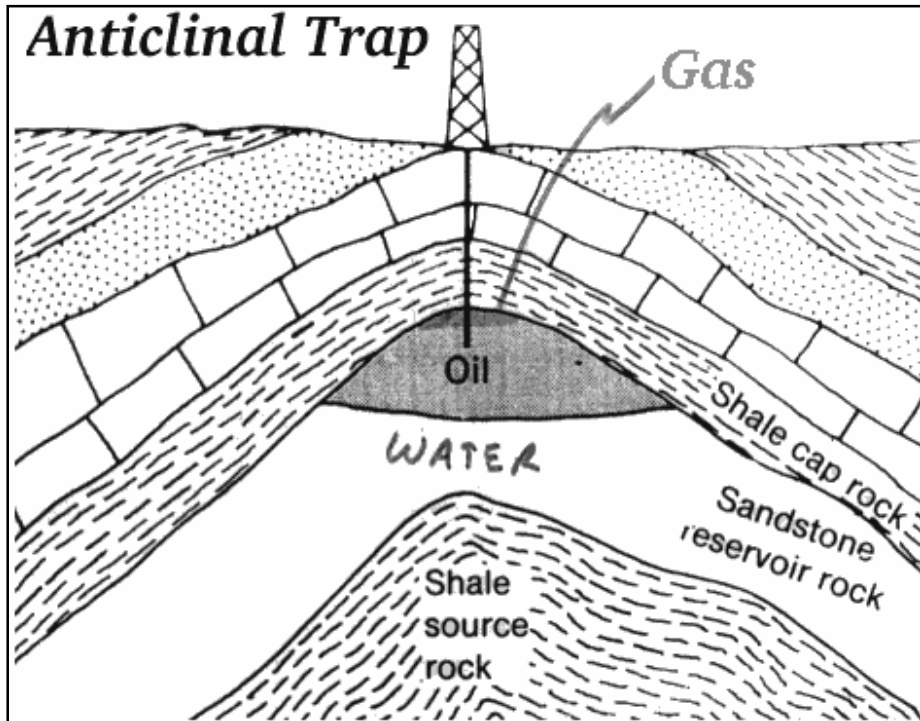
4. Traps

- If nothing stops oil from rising, it will reach surface
 - Ex: The La Brea tar pits
- **Traps** can be rocks that do not allow fluids to pass through them, or folds and faults in the rock can trap petroleum



5. Reservoir rocks

The oil needs to be trapped in a good place



- A good reservoir rock is:
 - **Porous:** holes
 - **Permeable:** holes are connected
 - so that its fluids can be **produced** (removed from them)

6. Proper timing

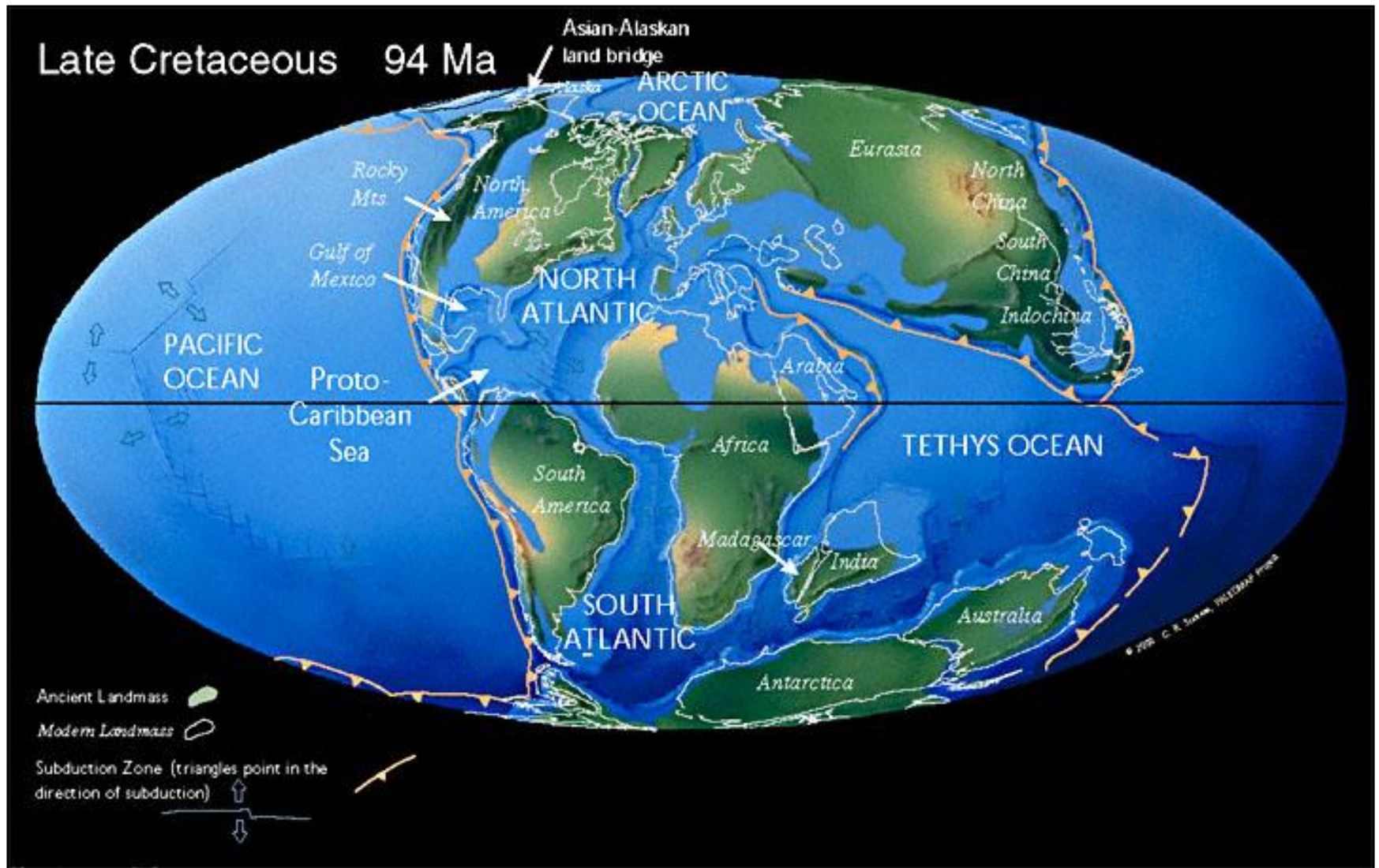
- Timing between accumulation of organic material, petroleum maturation, migration, and trap formation is vital



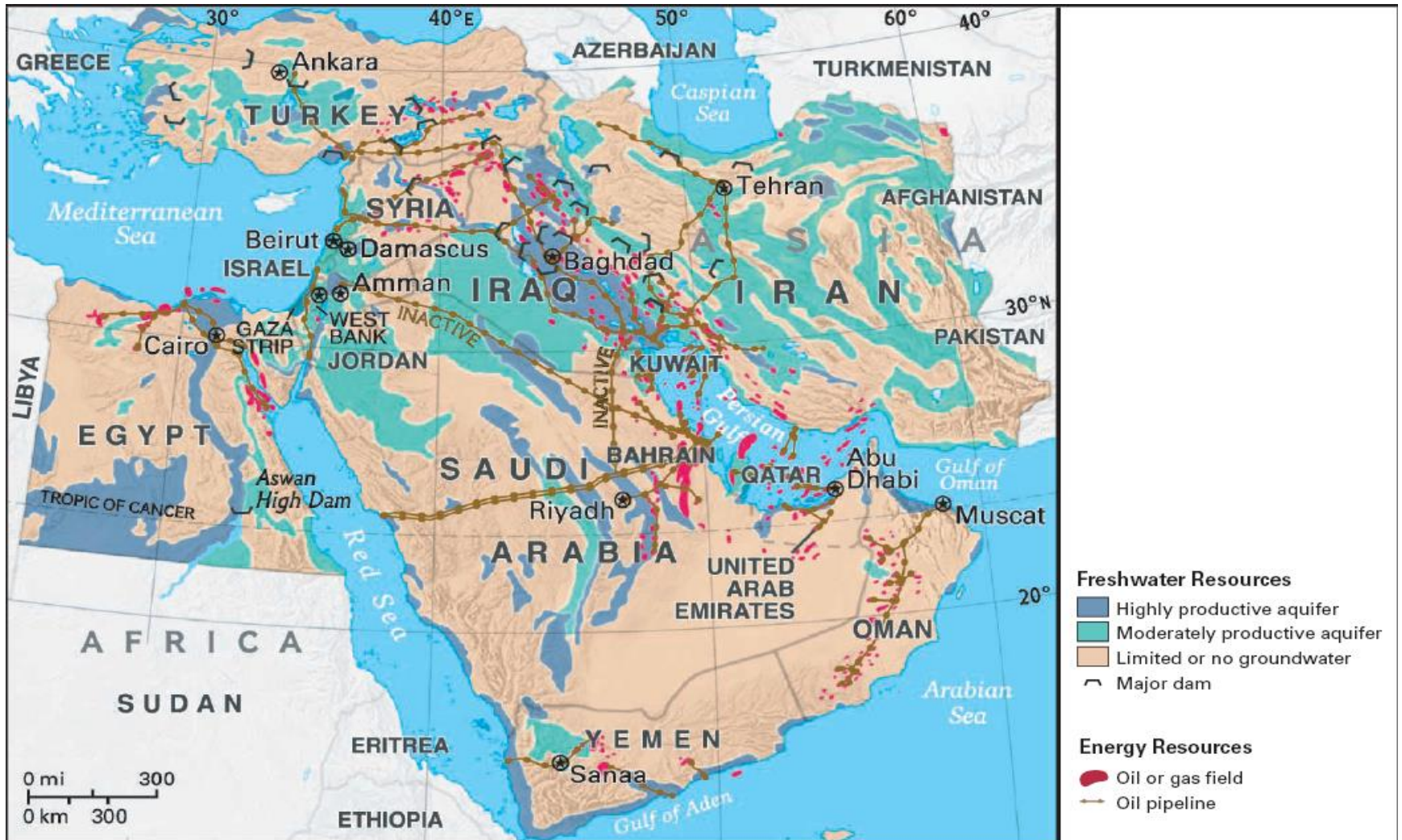
Review: Where does petroleum come from?

1. **Source rocks** rich in organic matter
2. Transform the organic material with heat and pressure to into petroleum (**Maturation**)
3. **Carrier beds** that allow the generated petroleum to move
4. **Traps** that keep the petroleum below ground
5. Adequate **reservoir beds** from which the petroleum can be extracted
6. Proper **timing** of events 1-5

Why is there oil in Texas?



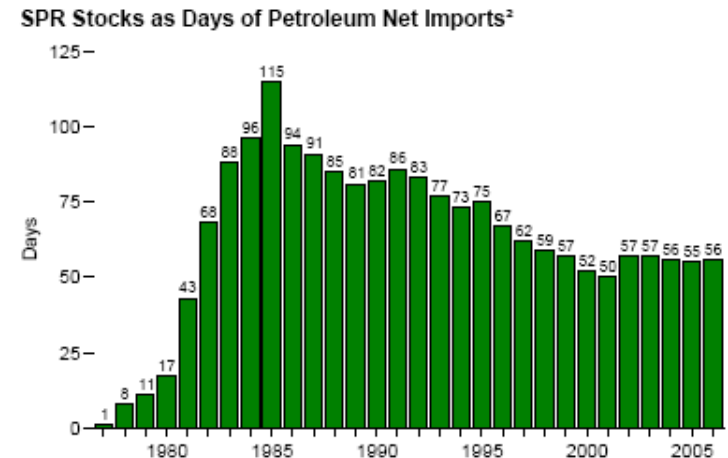
II. A Strategic Natural Resource



Strategic Natural Resource

- A) a resource that supports military power in a vital way
- B) a resource to which states would be willing to fight to protect their access to

Figure 5.17 Strategic Petroleum Reserve, 1977-2006



¹ Imported by SPR and imported by others for SPR.

² Derived by dividing end-of-year SPR stocks by annual average daily net imports of all petroleum.

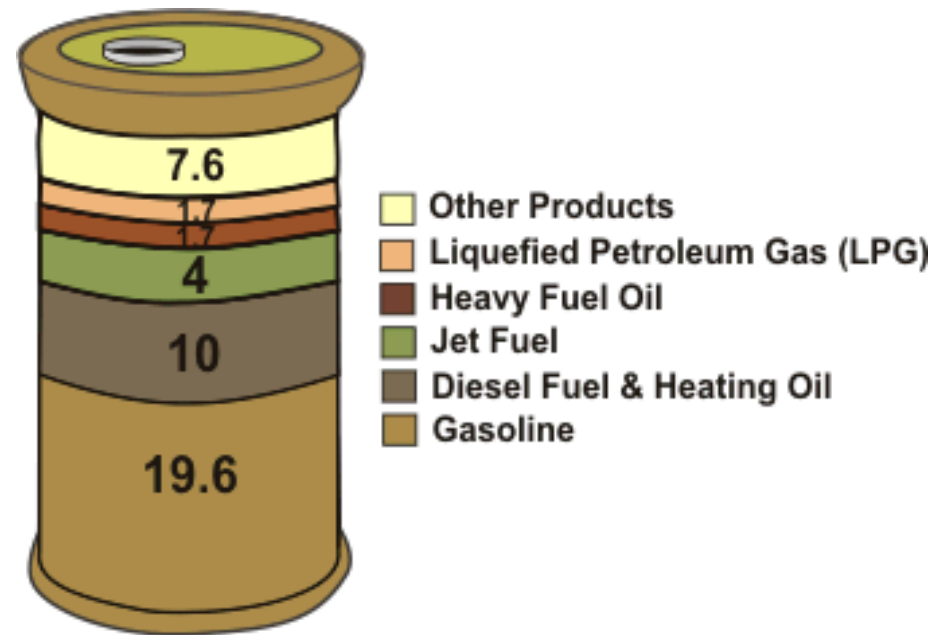
World Wars

- World War One
 - Churchill switches British navy to diesel
- World War Two
 - Japanese oil embargo
- Carter Doctrine, 1980



What do we get from oil?

- 1 barrel = 42 gallons of crude oil
- 83% becomes fuel
 - Gasoline, diesel, jet fuel, heating oil, and liquefied petroleum gas (propane and butane)
- 17% other
 - Solvents, fertilizers, pesticides, plastics

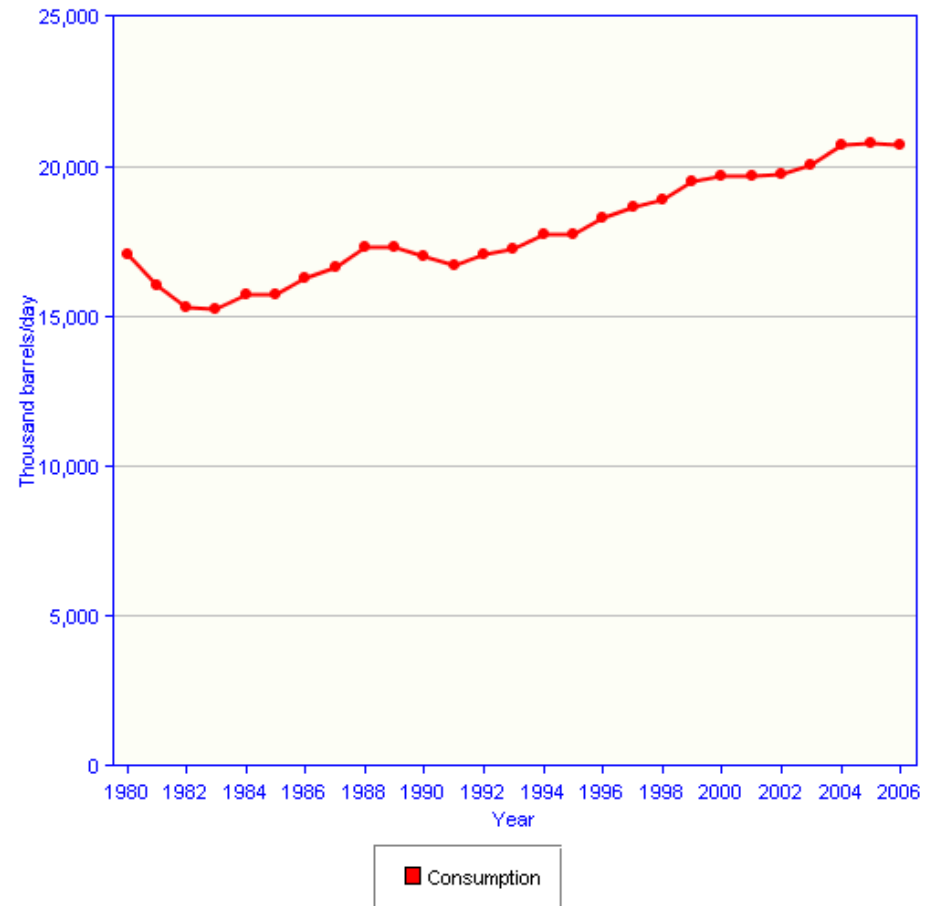


* These add up to 44.6 gallons because volume is increased during the refining process.

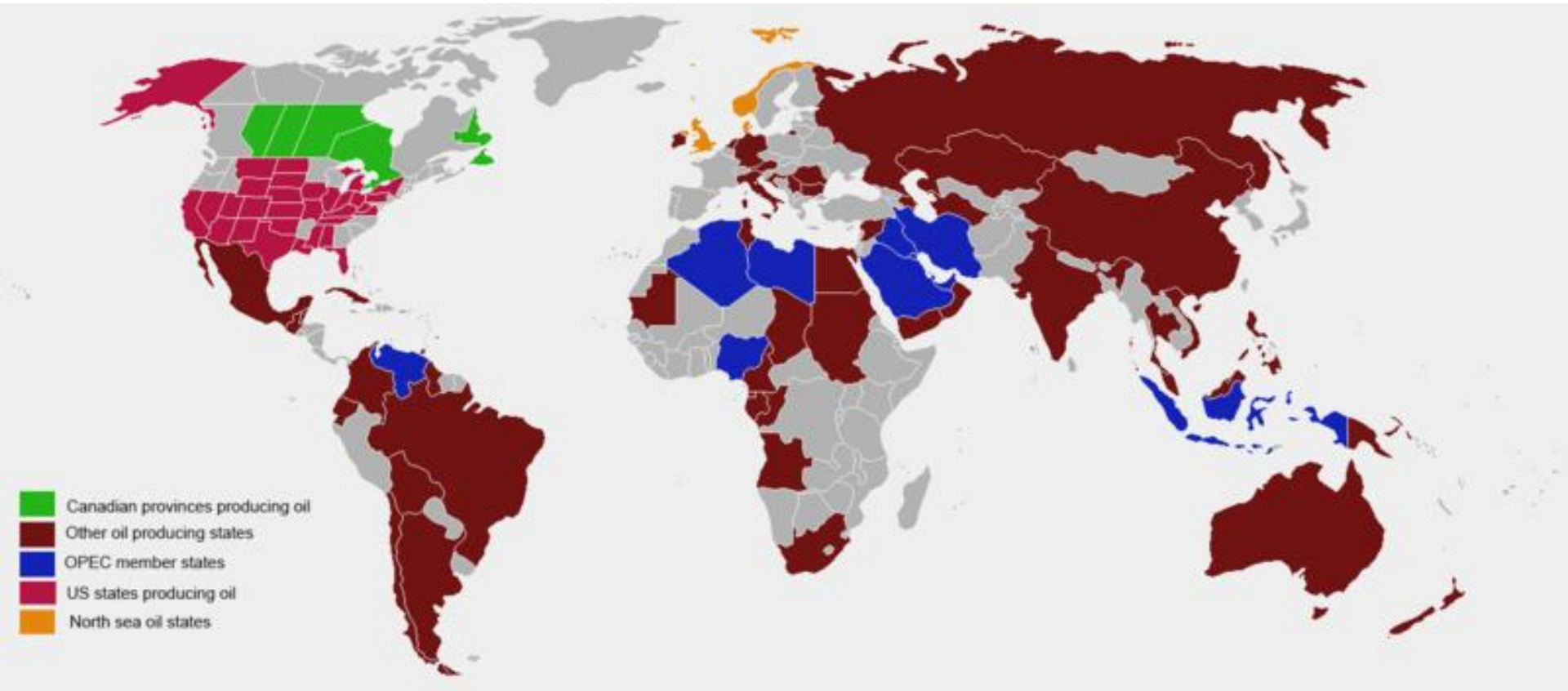
How much oil do we use?

- US consumes 20,680,000 barrels of oil each day (2007)
- US motor gasoline consumption 9,286,000 *b/d* (390 million gallons/day) (2007)
- World consumes 83,607,000 *b/d* (2005)

US oil consumption 1980-2006

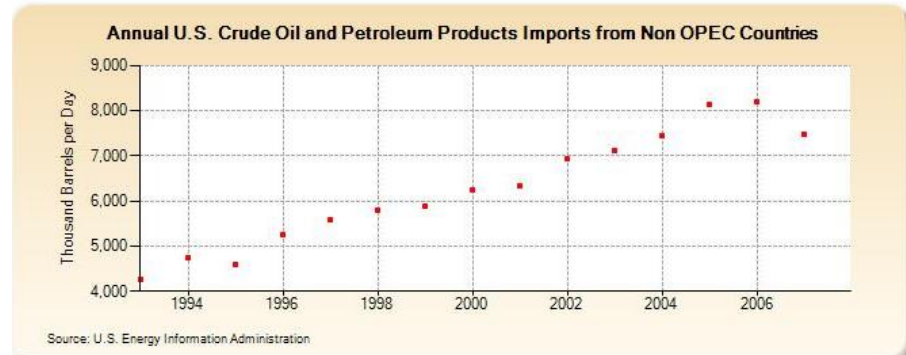
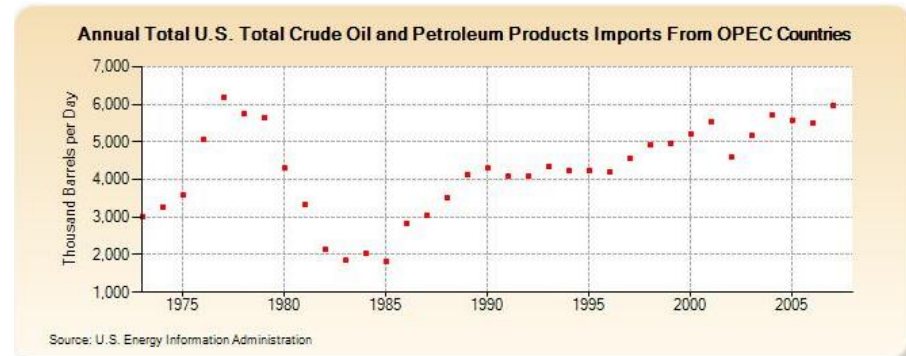
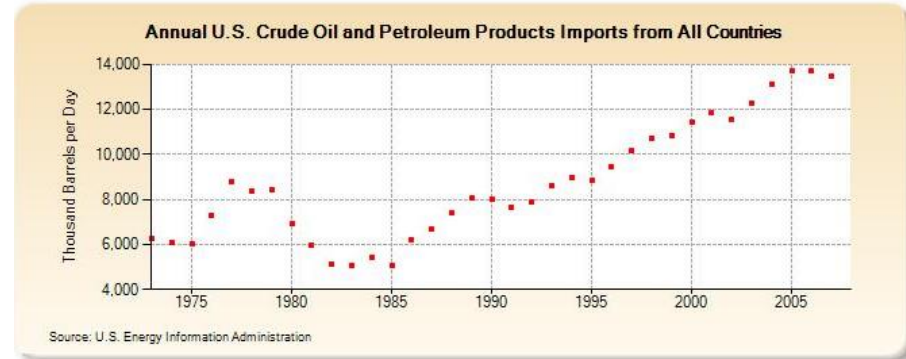


Where do we get our oil from?



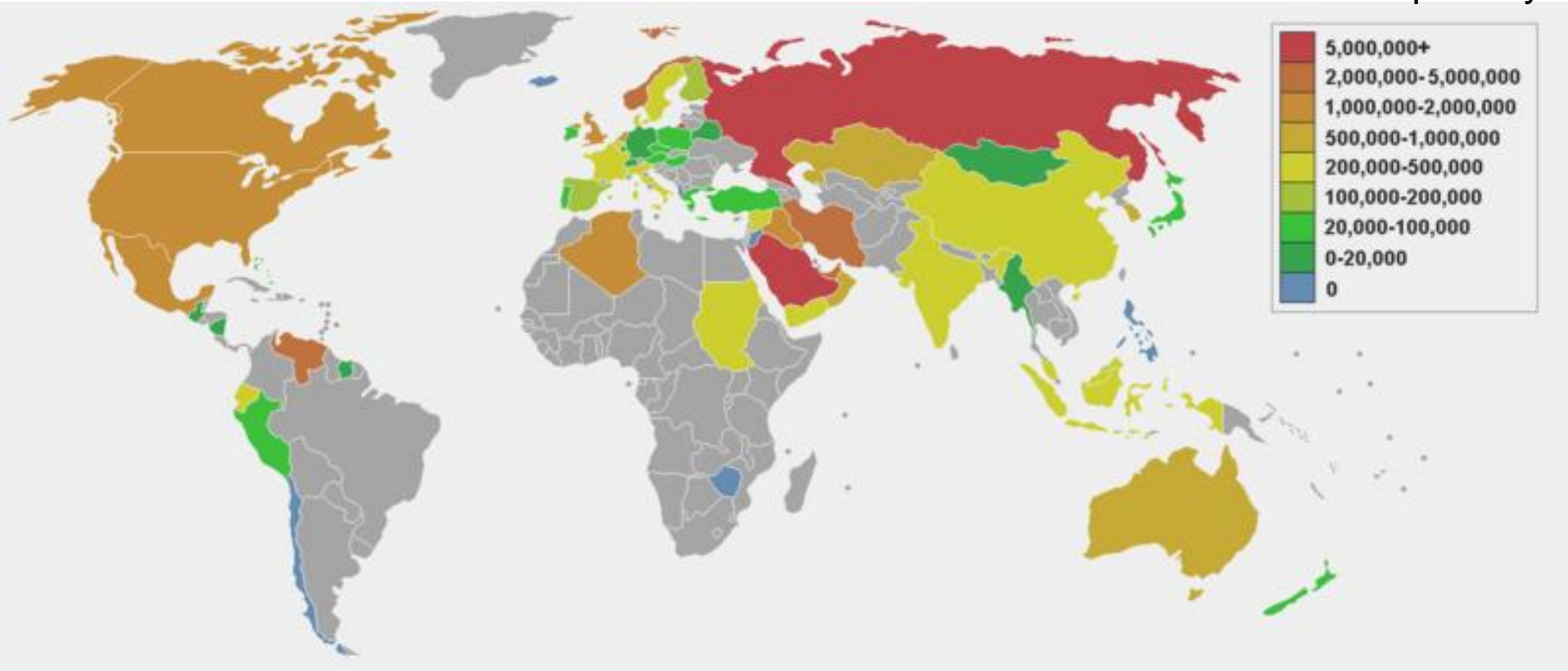
2007 US Imports by Country

Rank	Country	Mb/d
1	Canada	2.5
2	Mexico	1.5
3	<u>Saudi Arabia</u>	1.5
4	<u>Venezuela</u>	1.4
5	<u>Nigeria</u>	1.1
6	<u>Algeria</u>	0.67
7	<u>Iraq</u>	0.48
8	<u>Angola</u>	0.51
9	Russia	0.41
Total	All Countries	13.5
	Non-OPEC	8.1
	OPEC	5.98



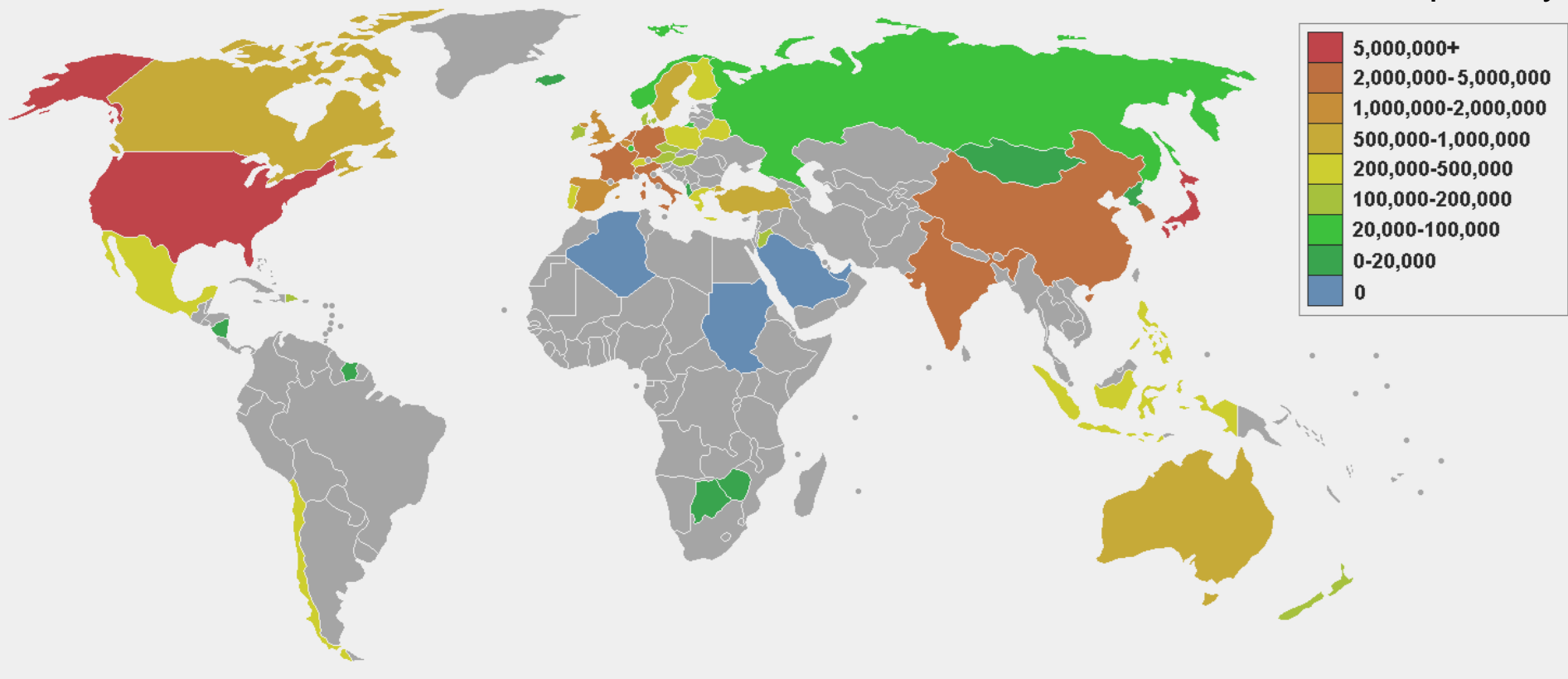
Oil exports by country

Barrels per day



Oil imports by country

Barrels per day



Who Produces the World's Oil?

Top World Oil Producers, 2005* <i>(OPEC members in <u>underlined italics</u>)</i>		
Rank	Country	Total Oil Production** (million barrels/day)
1	<u>Saudi Arabia</u>	11.1
2	Russia	9.5
3	United States	8.2
4	<u>Iran</u>	4.2
5	Mexico	3.8
6	China	3.8
7	Canada	3.1
8	Norway	3.0
9	<u>United Arab Emirates</u>	2.8
10	<u>Venezuela</u>	2.8
11	<u>Kuwait</u>	2.7
12	<u>Nigeria</u>	2.6
13	<u>Algeria</u>	2.1
14	Brazil	2.0

**Table includes all countries total oil production exceeding 2 million barrels per day in 2005. **Total Oil Production includes crude oil, natural gas liquids, condensate, refinery gain, and other liquids.*

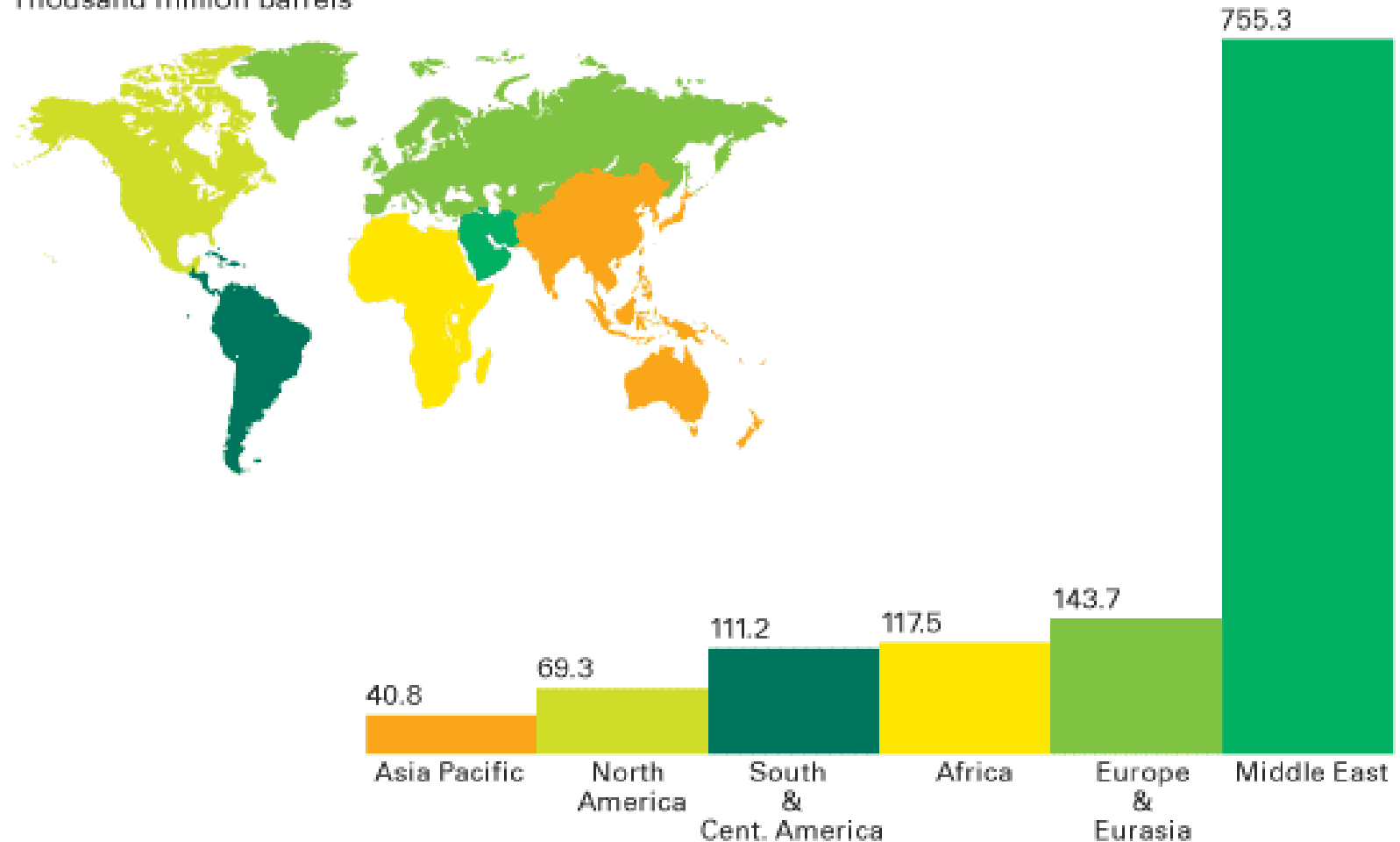
US Energy
Information
Administration

How much oil is there?

Oil Reserves: Year-end 2007		
Region	Billions of Barrels	Percentage
North America	69.3	5.6%
Latin America	111.2	9.0%
Europe and Eurasia	143.7	11.6%
Middle East	755.3	61.0%
Africa	117.5	9.5%
Asia and Pacific	40.8	3.3%
Global	1237.9	100%

Oil Reserves: Year-end 2007

Proved reserves at end 2007
Thousand million barrels



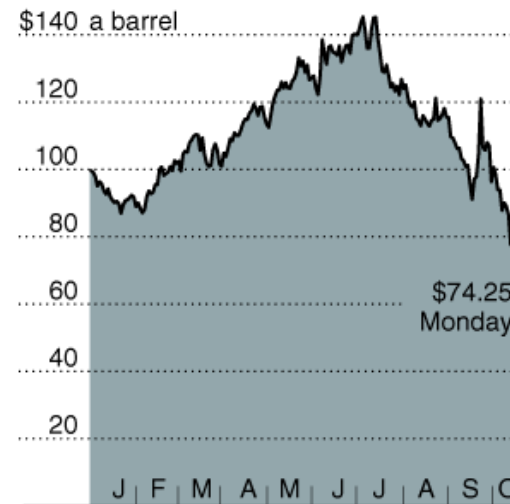
Reserves vs. Resources

- **Reserves** are natural resources that have already been discovered and can be produced for profit today
- **Resources** are deposits that we know of (or believe to exist), but are not producible at a profit today
- Example: *oil reserves* ~1.2 trillion barrels, *oil resources* ~2 trillion barrels

A Problem for Oil Producers

A slide in oil prices has caused problems for oil producers that were banking on higher prices. For example, Venezuela's 2009 budget was based on \$60-a-barrel oil and Russia's was pegged to roughly \$70.

Price of oil, 2008

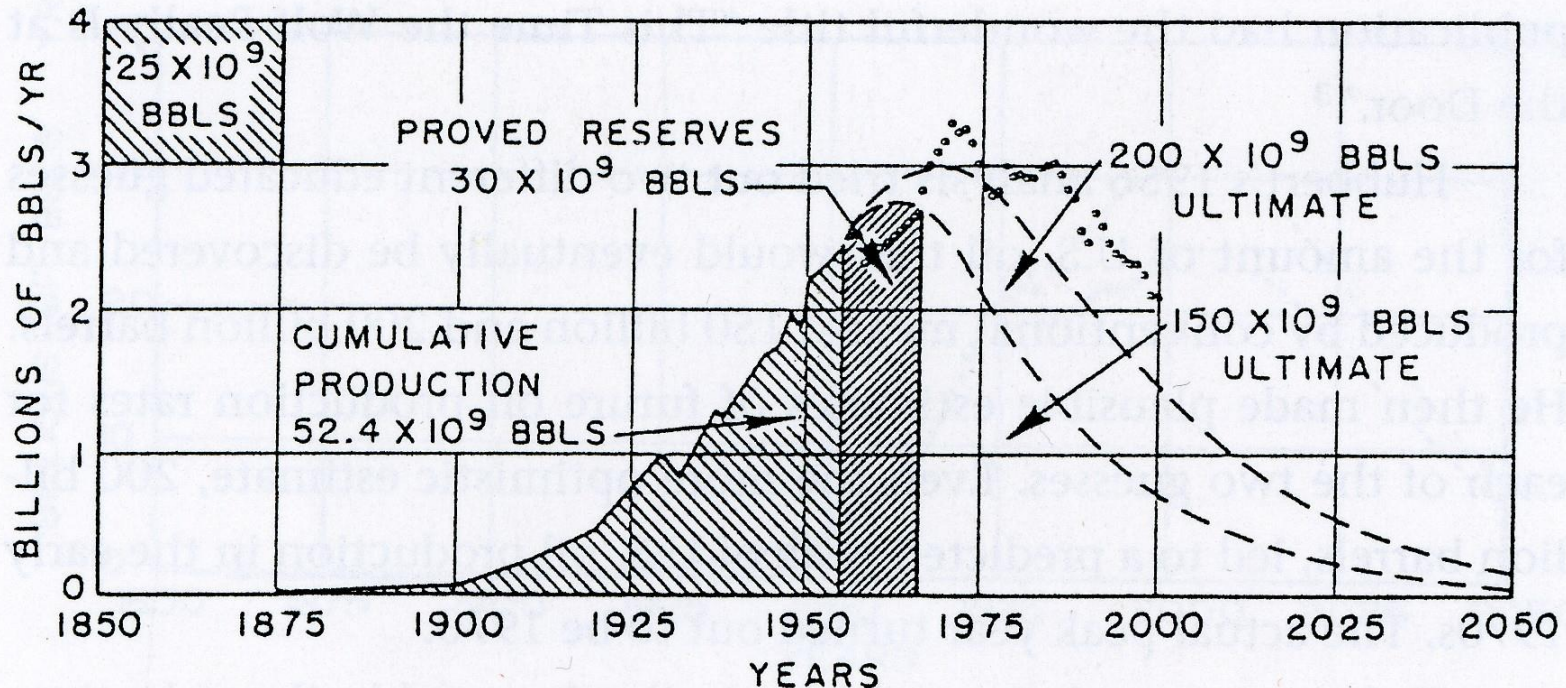


Source: Bloomberg

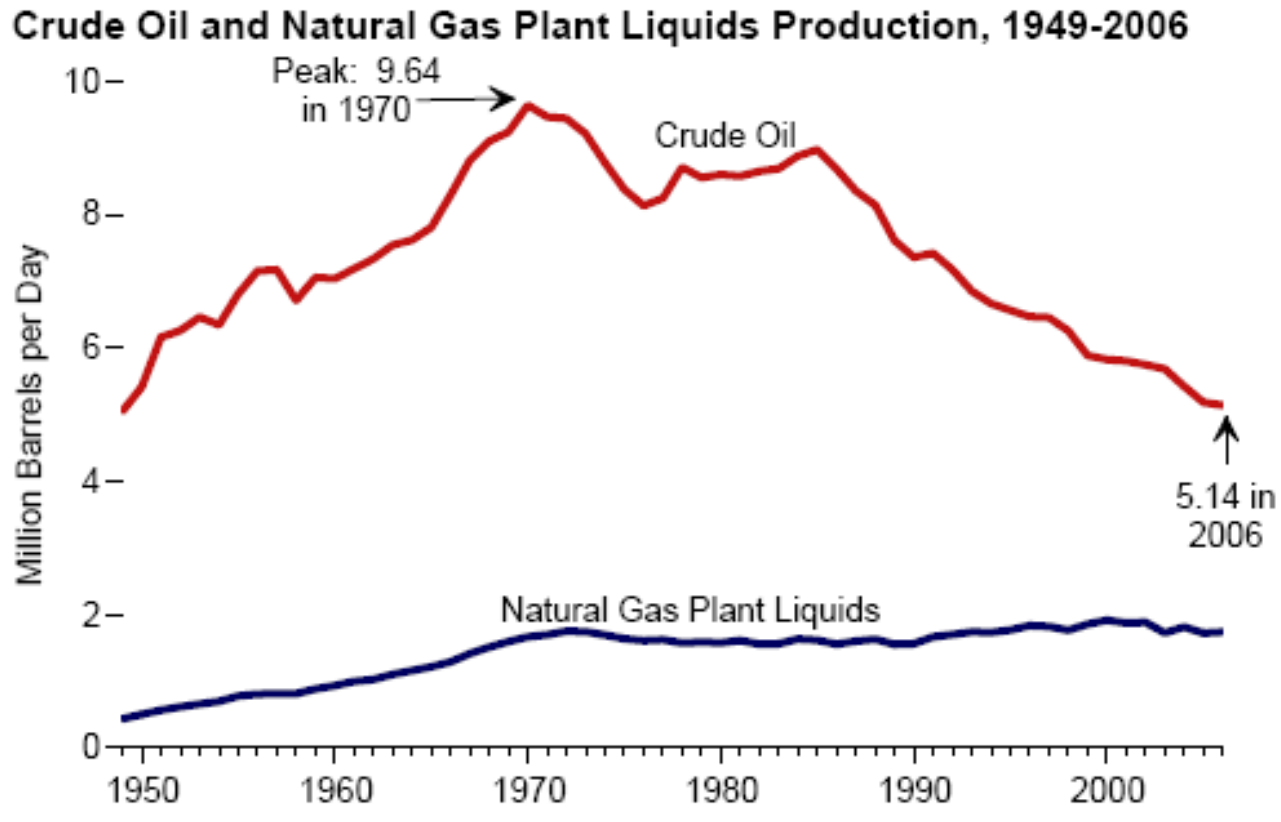
Are We Running Out of Oil?

Marion King Hubbert (1903-1989)

- Shell geophysicist
- Hubbert's Peak and Curve



US Peak Crude Oil Production

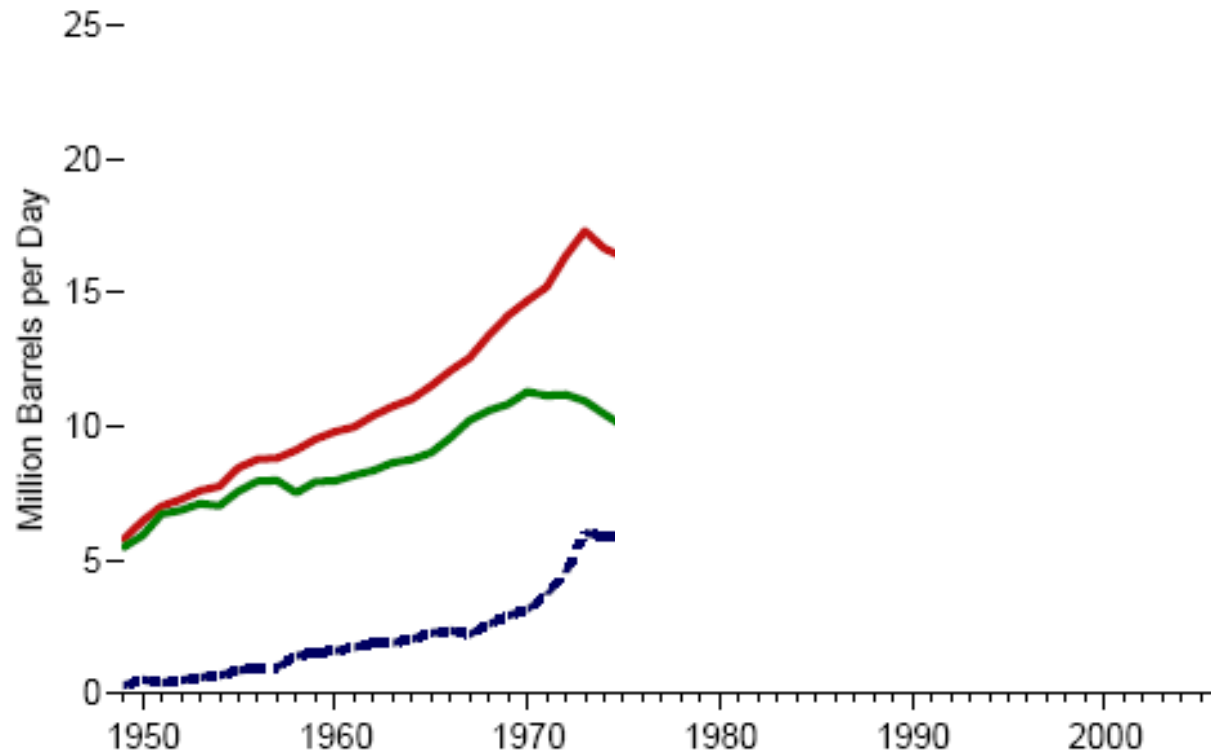


¹ Petroleum products supplied is used as an approximation for consumption.

² Crude oil and natural gas plant liquids production.

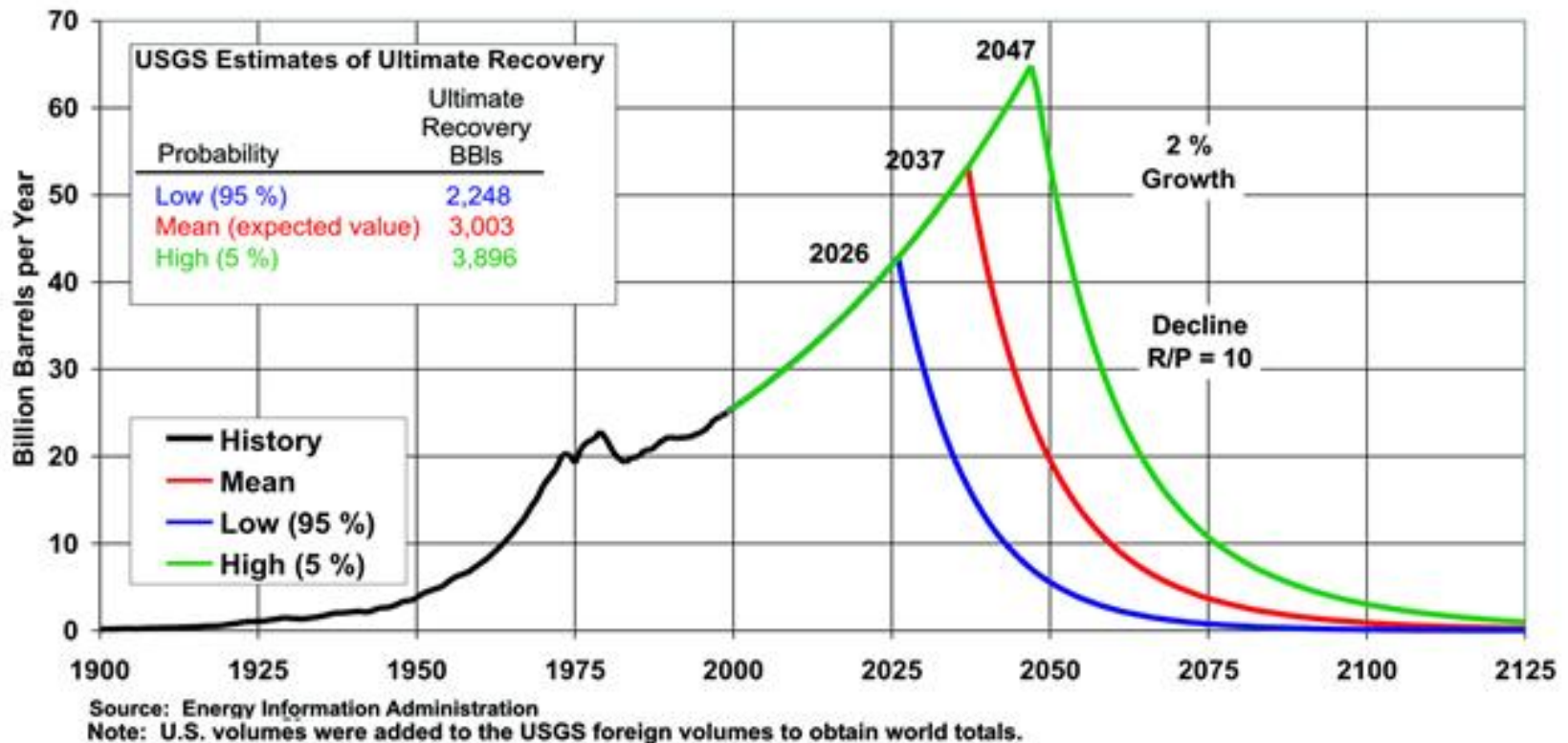
Does consumption follow Hubbert's curve?

Overview, 1949-2006

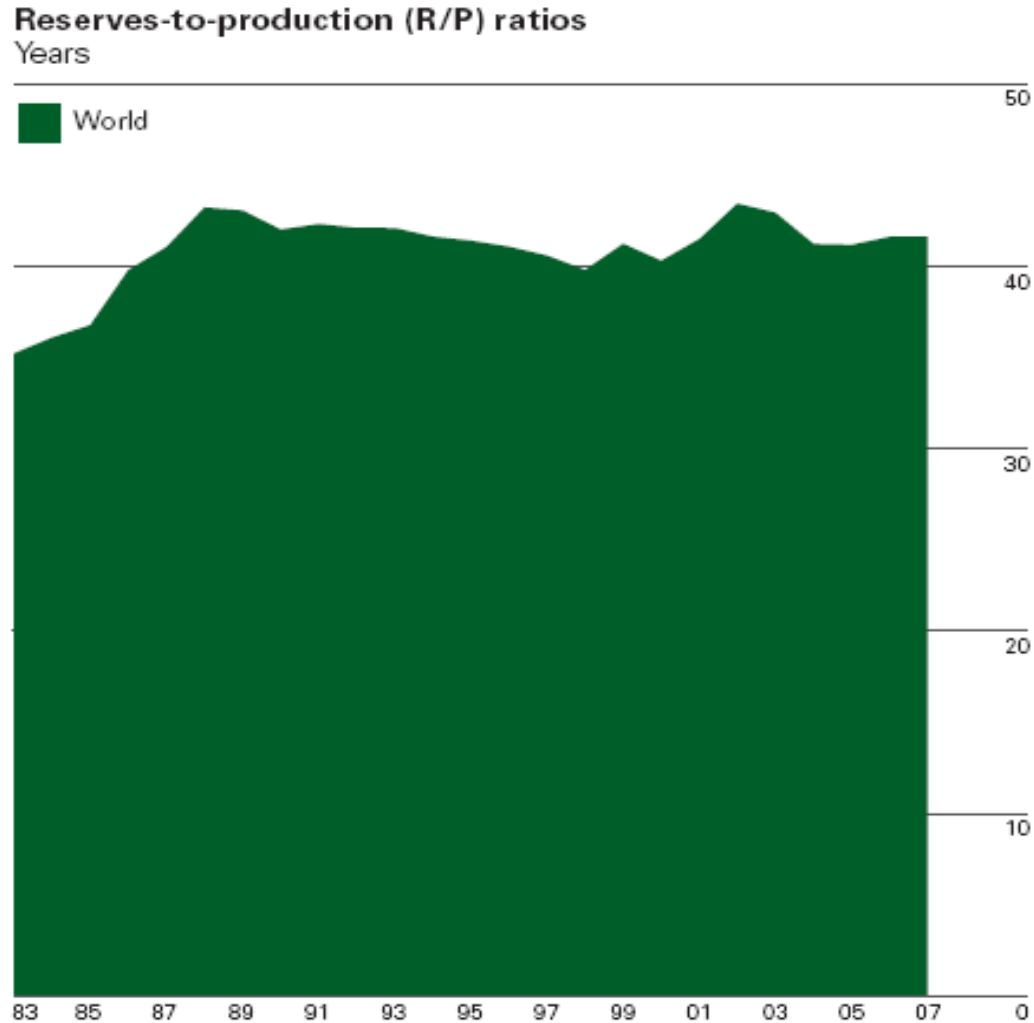


US Energy Information Administration Predictions

Figure 2. Annual Production Scenarios with 2 Percent Growth Rates and Different Resource Levels (Decline R/P=10)



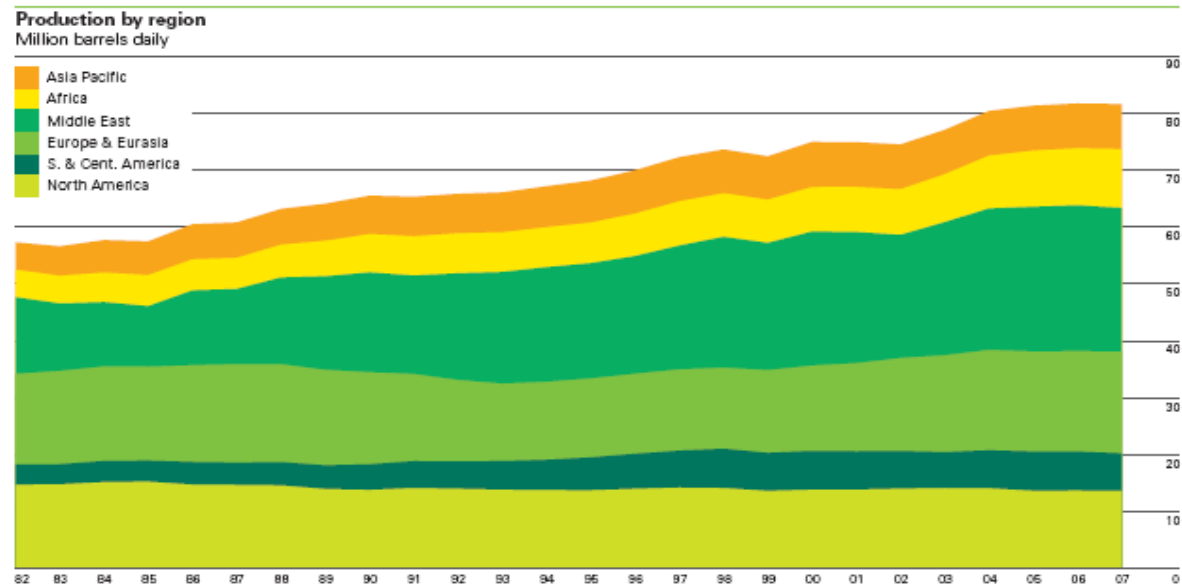
Reserve to Production Ratios



Questions?



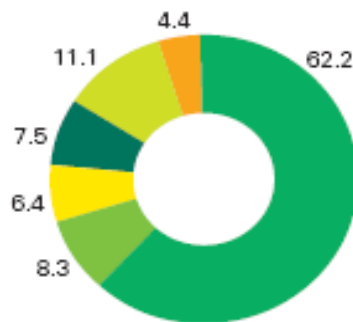
Oil Production by Region



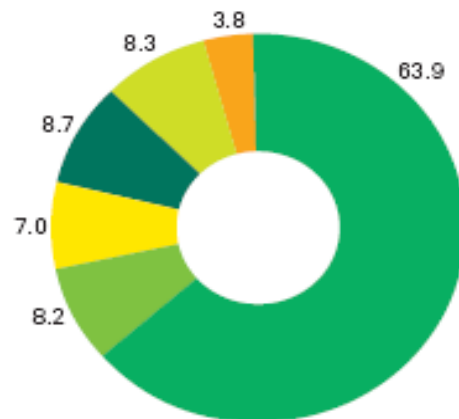
Distribution of Reserves

Distribution of proved reserves in 1987, 1997 and 2007

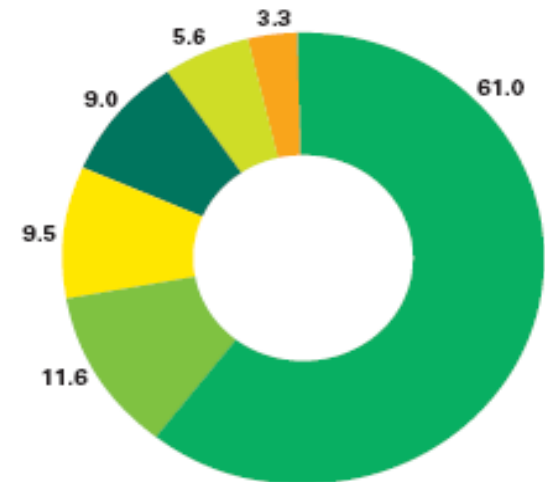
Percentage



1987
Total 910.2 thousand million barrels

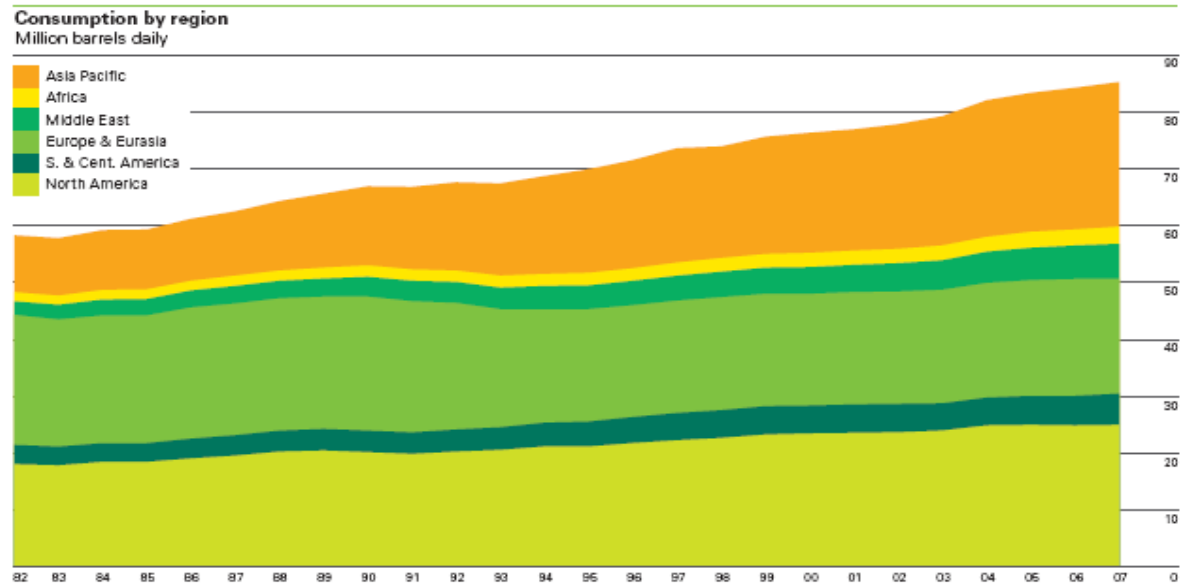


1997
Total 1069.3 thousand million barrels

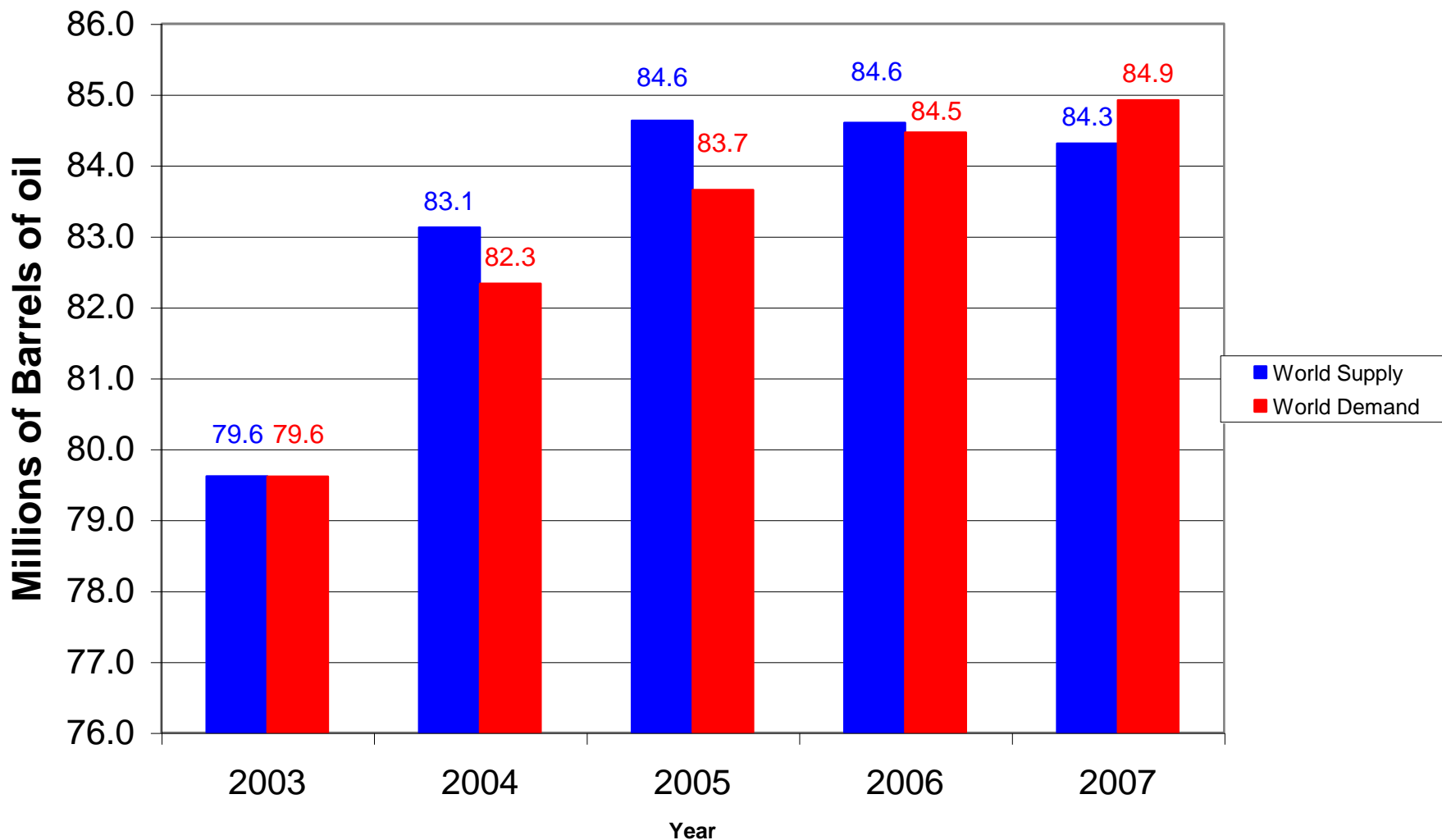


2007
Total 1237.9 thousand million barrels

Oil Consumption

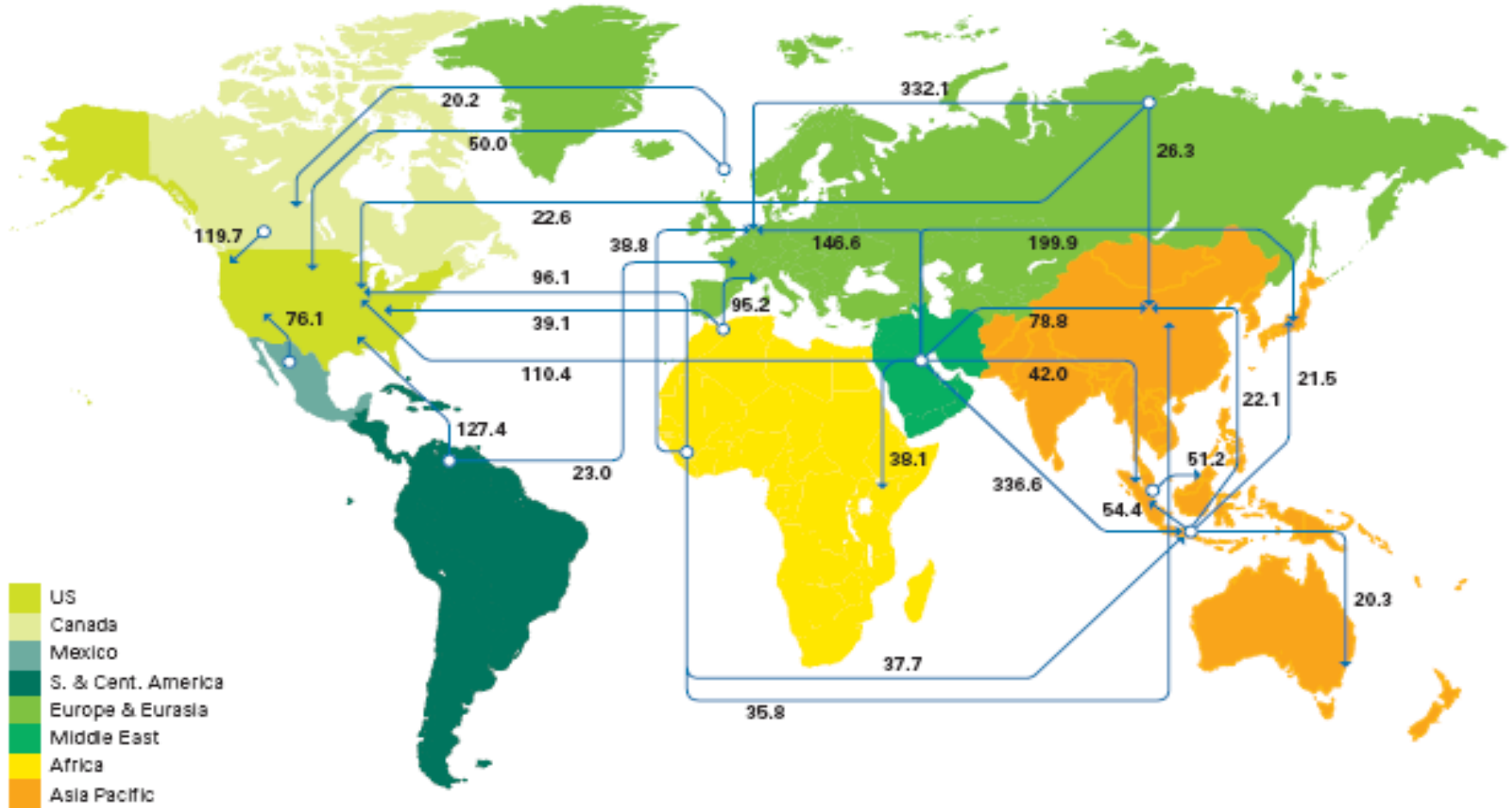


World Supply and Demand



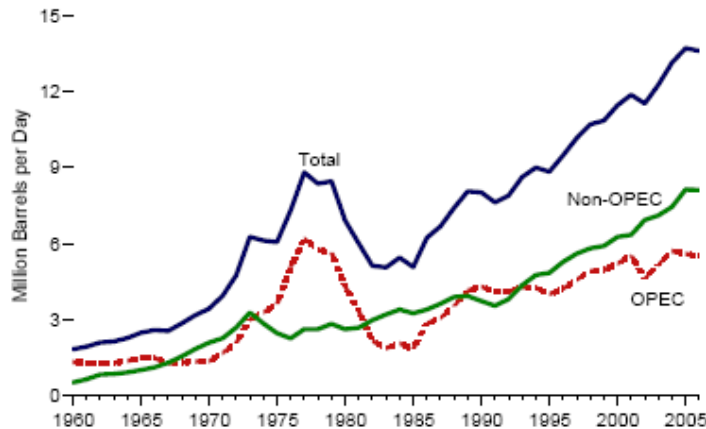
Global Oil Flows

Major trade movements 2007
Trade flows worldwide (million tonnes)

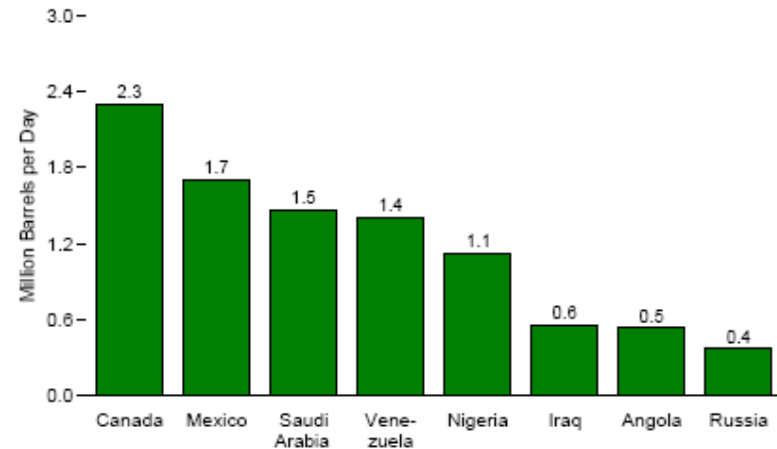


Petroleum Imports by Country of Origin

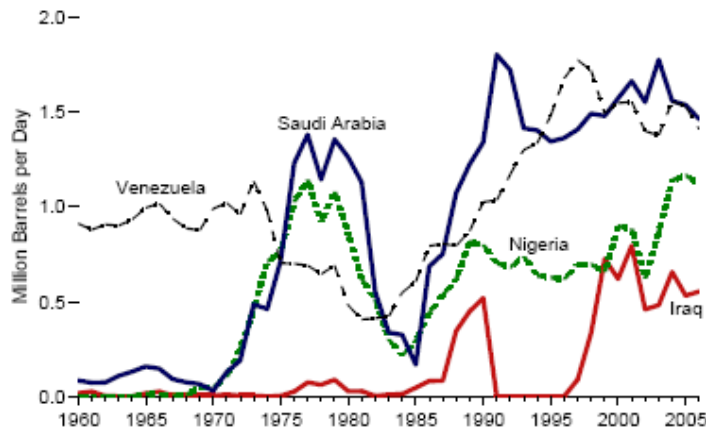
Total, OPEC, and Non-OPEC, 1960-2006



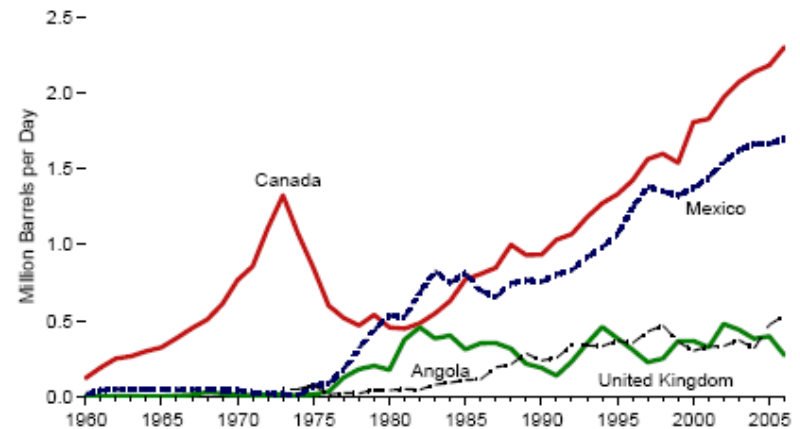
Selected Countries, 2006



Selected OPEC Countries, 1960-2006



Selected Non-OPEC Countries, 1960-2006

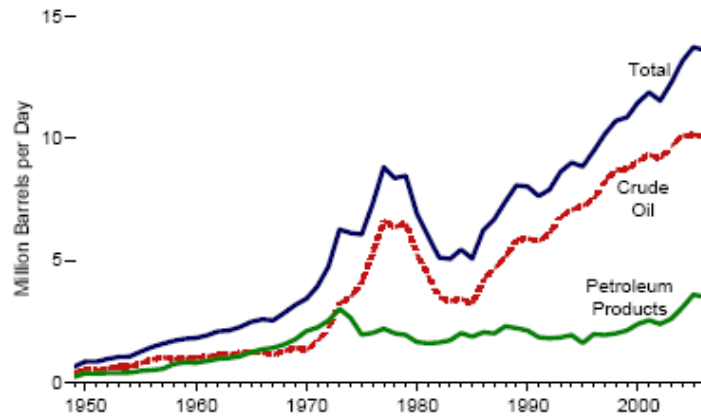


Notes: • OPEC=Organization of the Petroleum Exporting Countries. • Because vertical scales differ, graphs should not be compared.

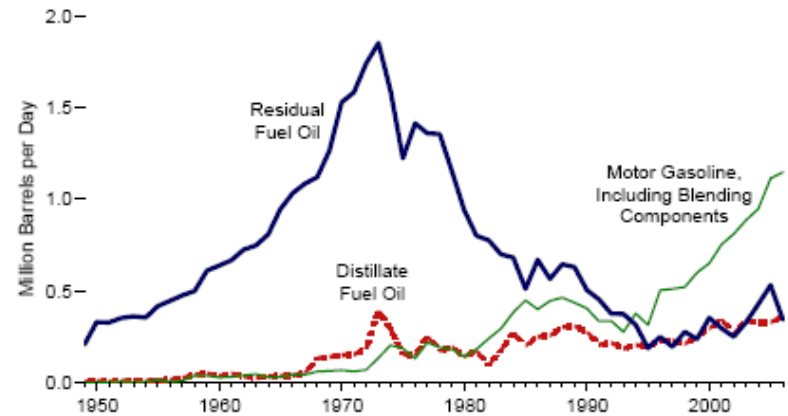
Source: Table 5.4

Petroleum Imports by Type

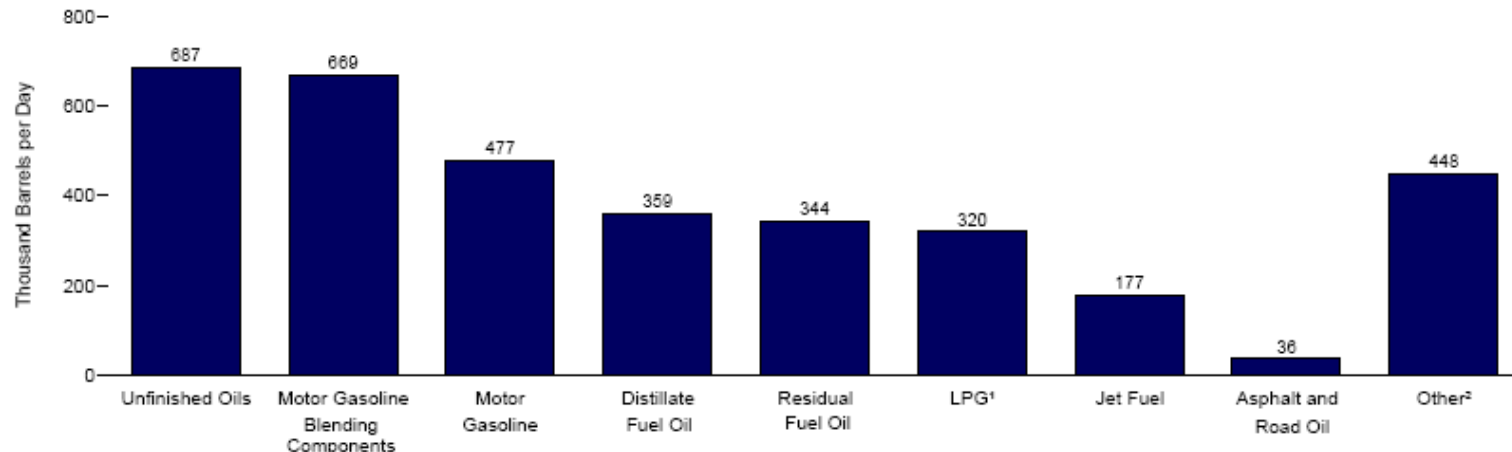
Total, 1949-2006



By Selected Product, 1949-2006



By Product, 2006

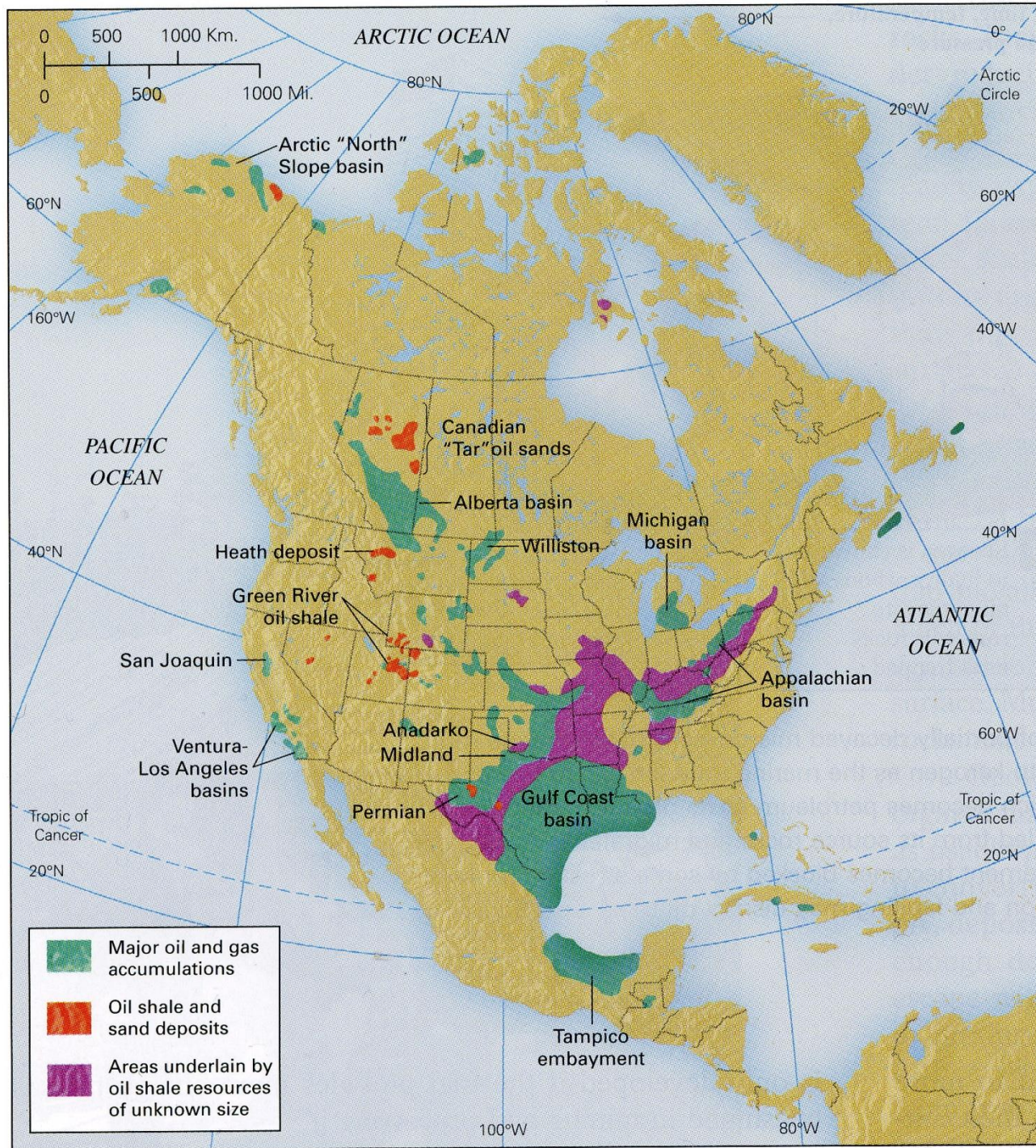


¹ Liquefied petroleum gases.

² Aviation gasoline and blending components, kerosene, lubricants, pentanes plus, petrochemical feedstocks, petroleum coke, special naphthas, waxes, other hydrocarbons and oxygenates, and miscellaneous products.

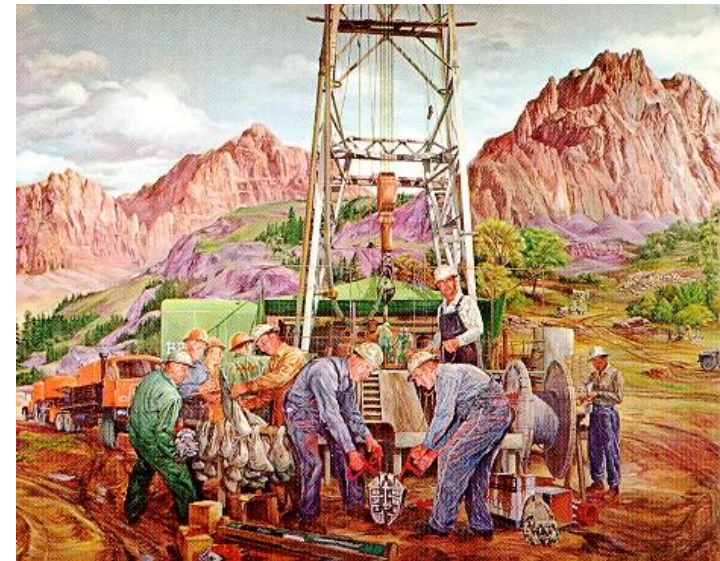
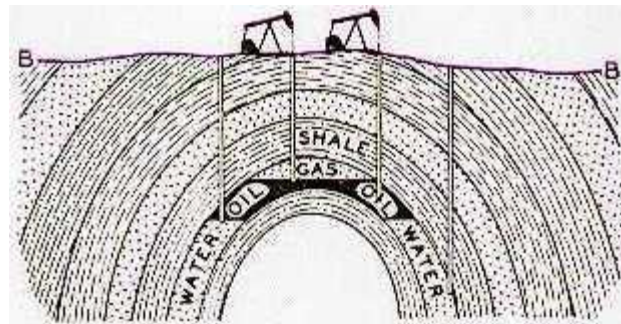
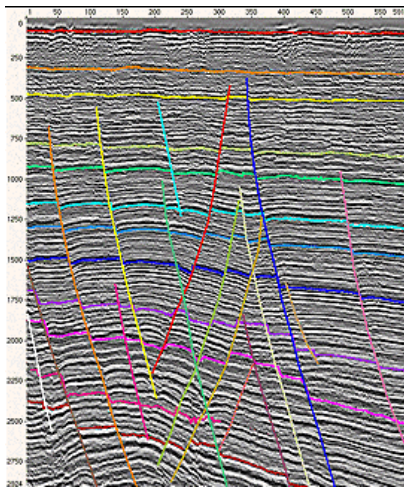
Note: Because vertical scales differ, graphs should not be compared.
Source: Table 5.3.

Where is there oil in North America?

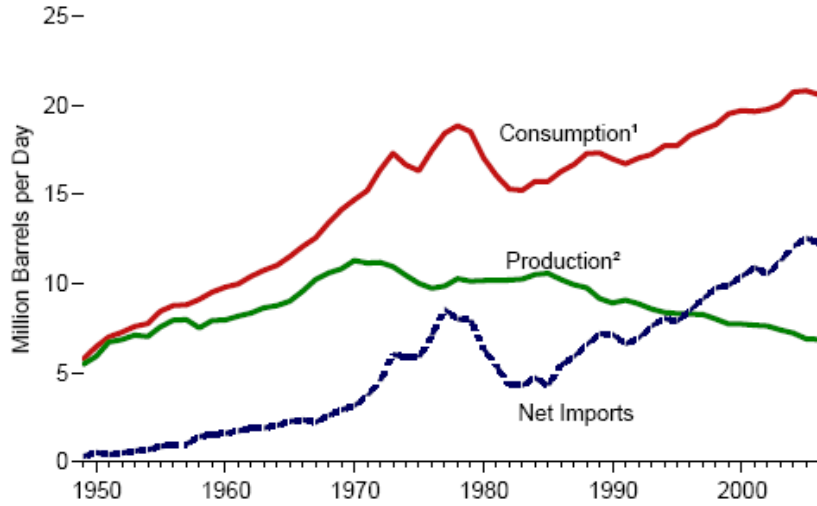


Petroleum Exploration

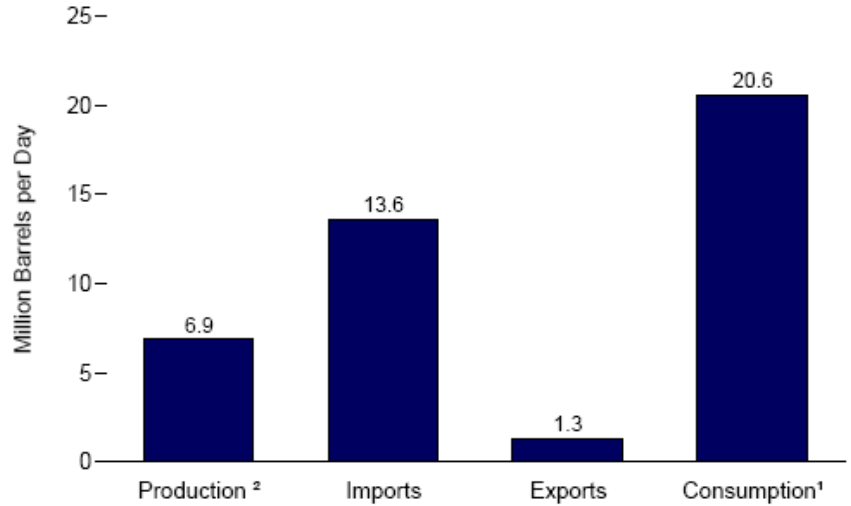
- Surface and subsurface geological studies
- Seismic surveys
- Gravity and magnetic surveys
- Horizontal magnetic gradient
- Helium content of soils



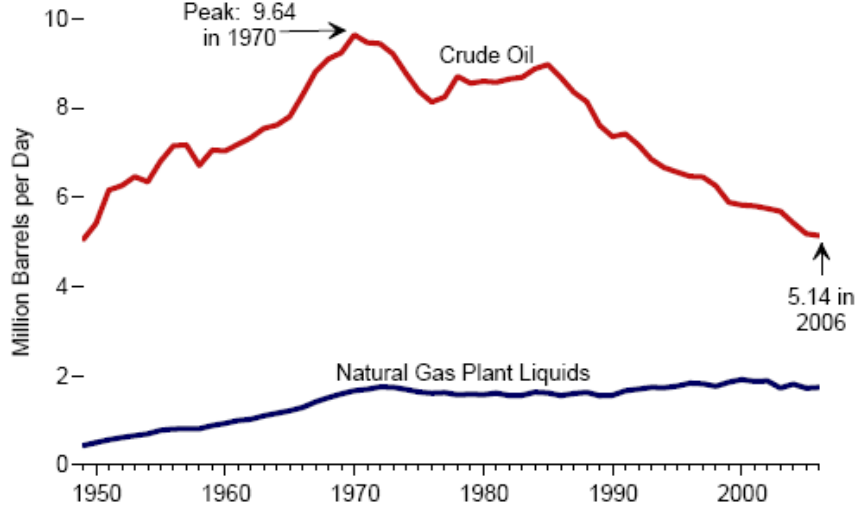
Overview, 1949-2006



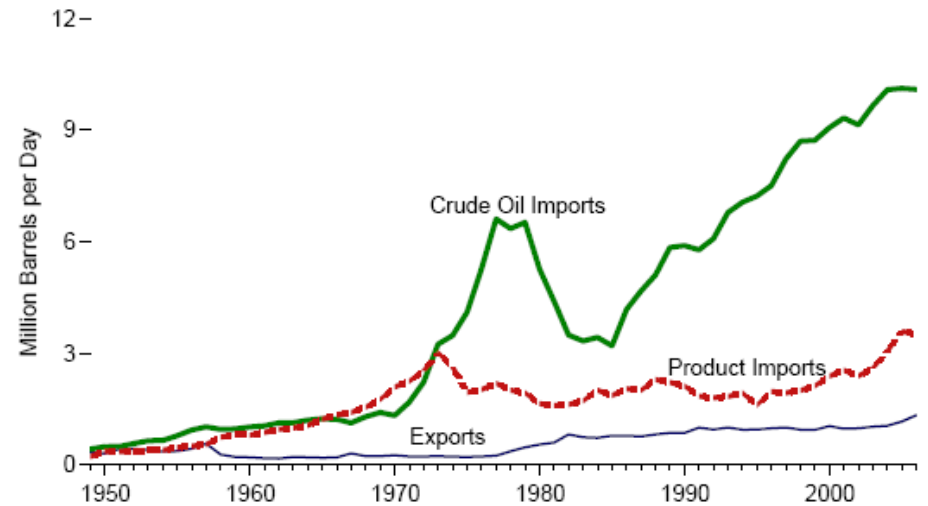
Overview, 2006



Crude Oil and Natural Gas Plant Liquids Production, 1949-2006



Trade, 1949-2006

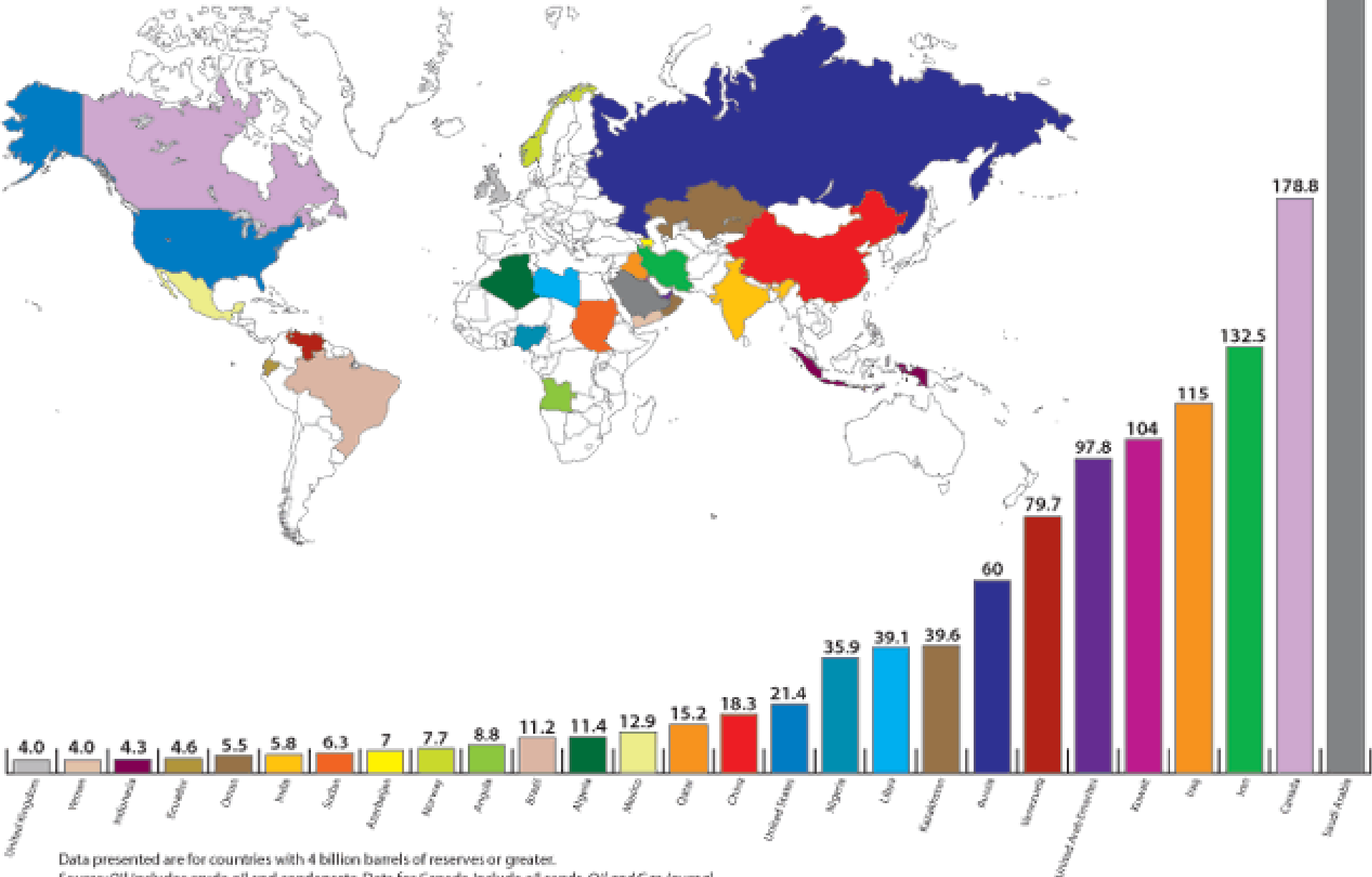


¹ Petroleum products supplied is used as an approximation for consumption.
² Crude oil and natural gas plant liquids production.

Note: Because vertical scales differ, graphs should not be compared.
 Sources: Tables 5.1 and 5.3.

Oil Reserves

(billion barrels)



Data presented are for countries with 4 billion barrels of reserves or greater.
 Source: OIL includes crude oil and condensate. Data for Canada include oil sands. *Oil and Gas Journal*,
 December 19, 2005. Data for the United States are from the Energy Information Agency, November 2005.