Peak Oil: Myth or Not. Does the Free Market Trump Mother Nature?

- How the late M. King Hubbert applied geology, conservation of mass, and exponential growth to energy resources.
- What are coming consequences?

Question for public discourse: How does scientific analysis become controversial and a subject of widespread skepticism?

Modified after a presentation to PHYS 3333

"The Scientific Method: Debunking Pseudoscience"

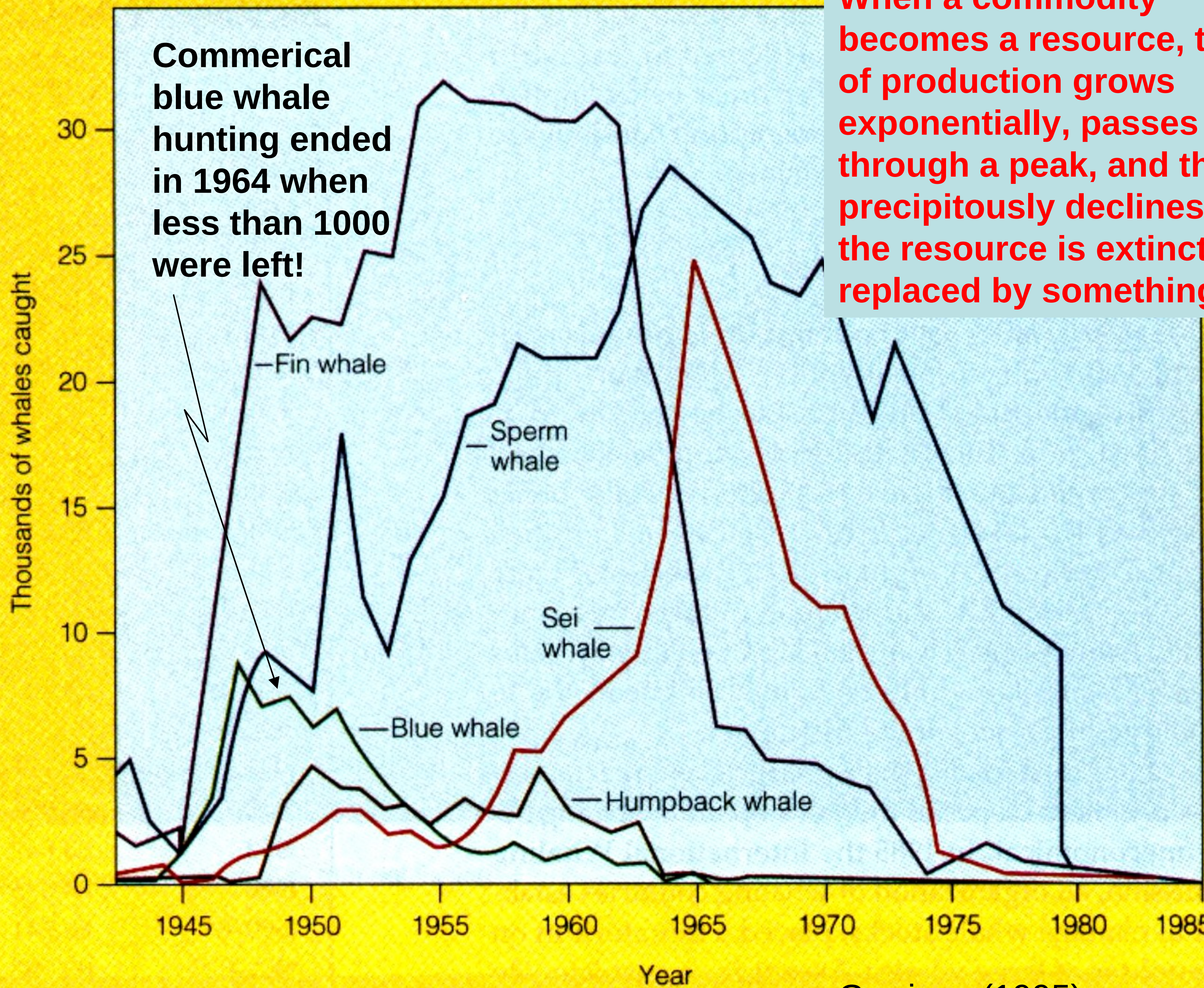
R.T. Gregory 11/05/2007

Non-renewable Resources

- A resource is a natural substance that can be exploited for a profit.
- Resources whose natural replenishment rates are slower than their rates of exploitation are considered to be non-renewable.
- Minerals (ore deposits), coal, oil and gas are produced by geologic processes and thus are finite and cannot be replenished on human timescales.

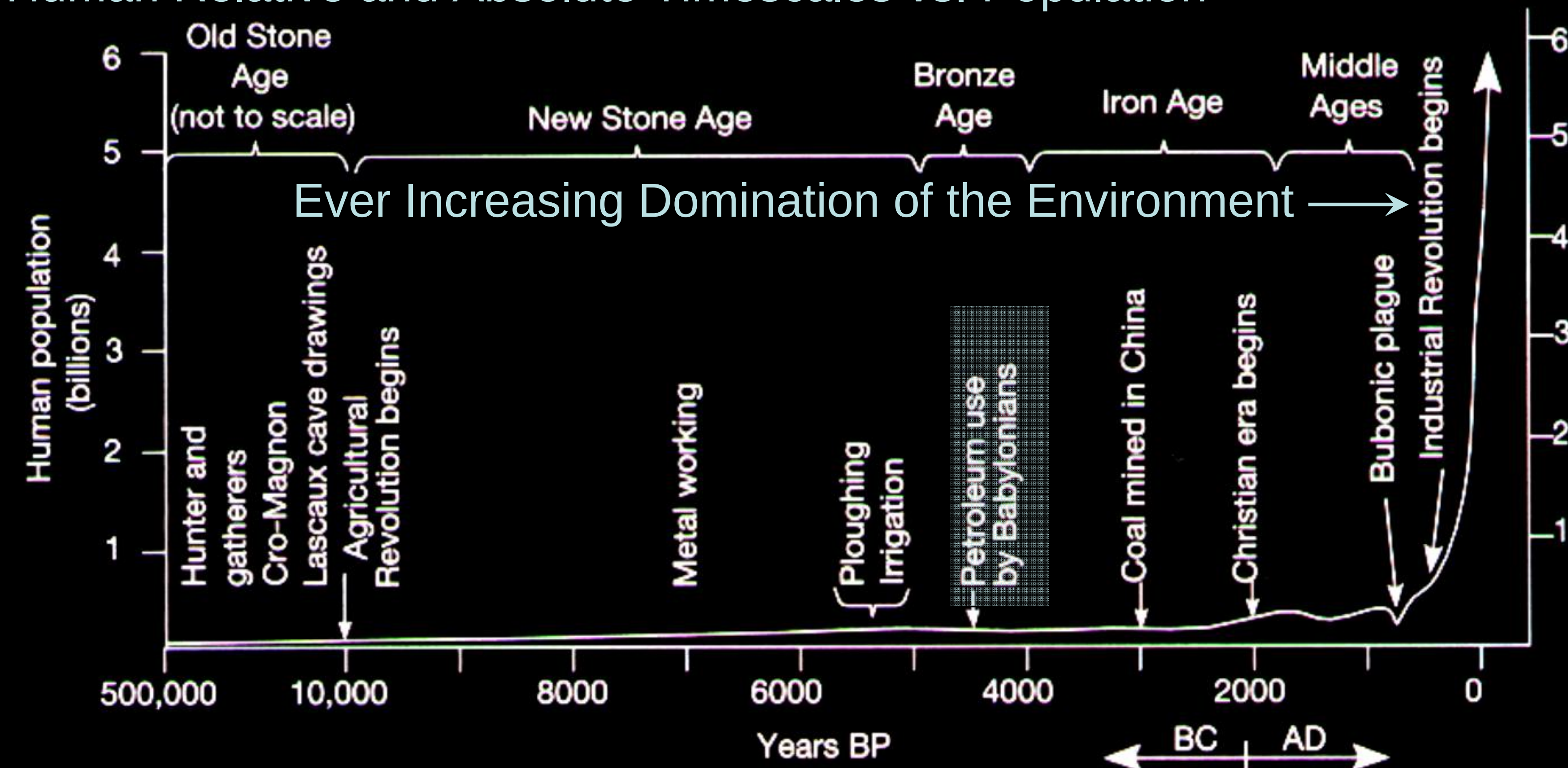
Naturally-occurring hydrocarbons are sourced from the burial of surface-derived organic matter. A *very small* fraction of the biosphere is buried each year.

When a commodity becomes a resource, the rate of production grows exponentially, passes through a peak, and then precipitously declines until the resource is extinct or replaced by something else.



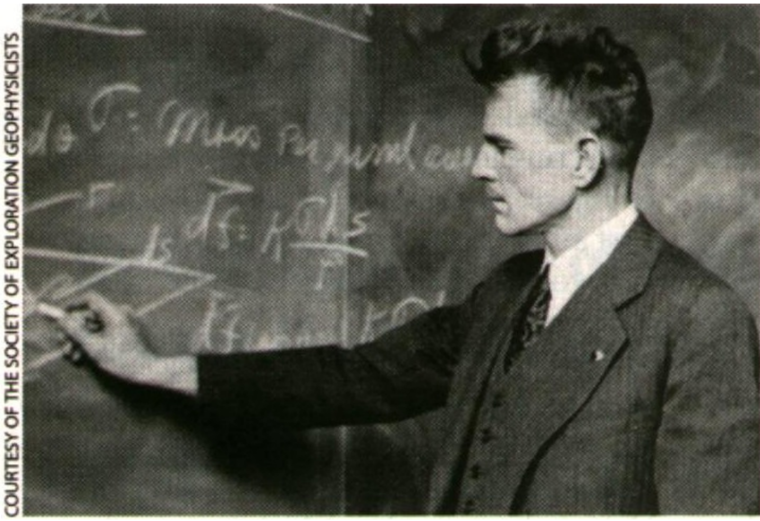
Garrison (1995)

Human Relative and Absolute Timescales vs. Population



Human Population	Date	Time Required
1 billion	1850	all of human history
2 billion	1930	80 years
4 billion	1975	45 years
8 billion (projected)	2020	44 years

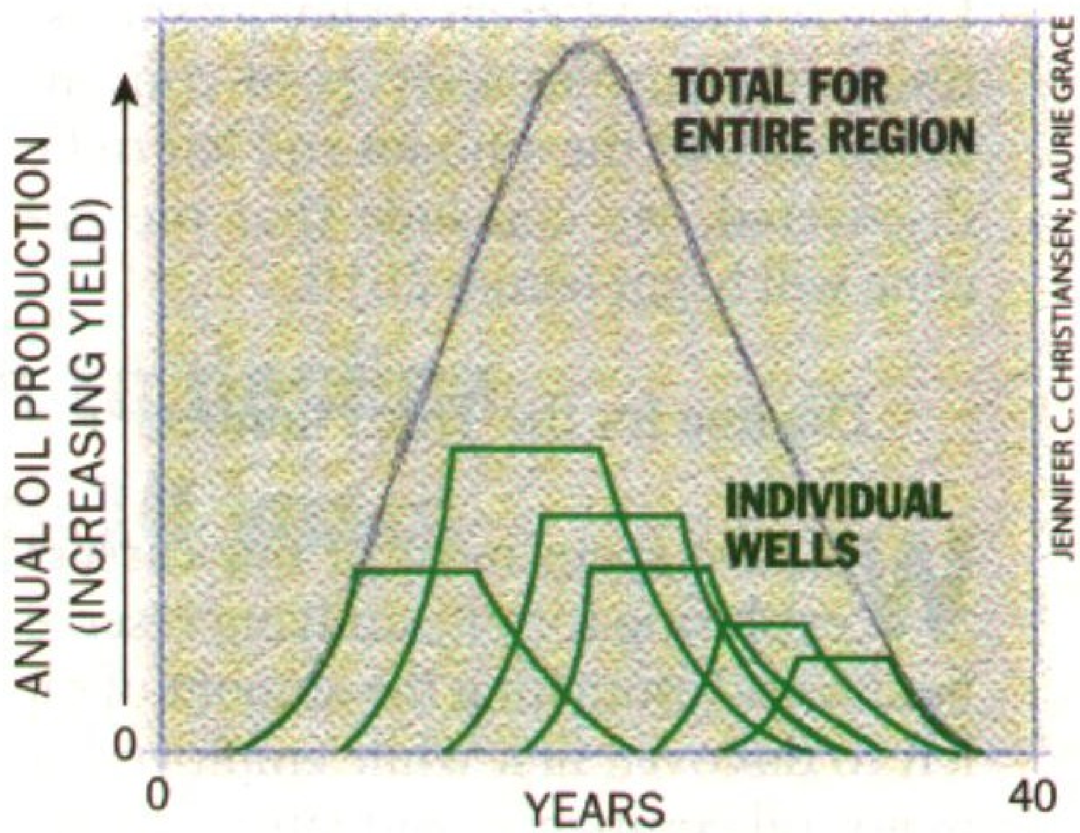
Mackenzie (1998)



M. King Hubbert applied principles derived from mining geology concerning the life cycle of a non-renewable resource to petroleum geology and scaled the analysis up to continents and the globe.

Campbell & Lherrere (1998)

FLOW OF OIL starts to fall from any large region when about half the crude is gone. Adding the output of fields of various sizes and ages (*green curves at right*) usually yields a bell-shaped production curve for the region as a whole. M. King Hubbert (*left*), a geologist with Shell Oil, exploited this fact in 1956 to predict correctly that oil from the lower 48 American states would peak around 1969.



M.K. Hubbert, 1976,
Bull. Assoc. Engr. Geol.

The history of mining for metal

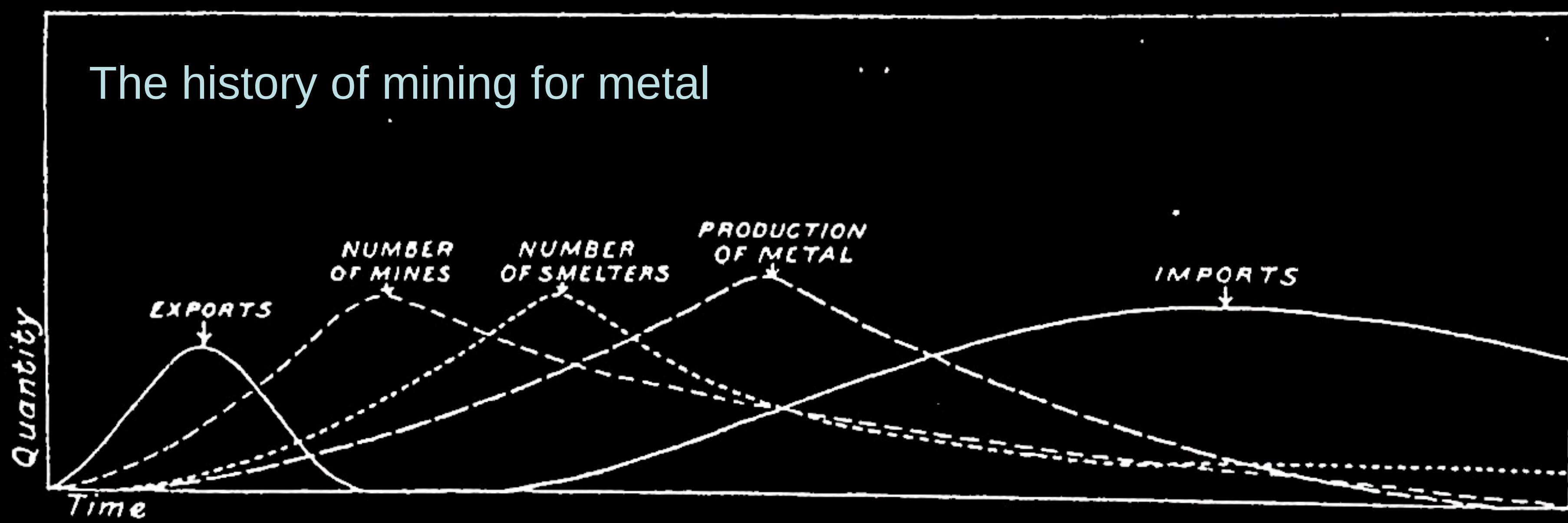


FIGURE 11. Figure 7 from D. F. Hewett's paper, "Cycles in Metal Production" (1929)

Foster Hewett's, "Lifecycle of a Non-renewable Resource."

Ore deposits are chemical systems that obey "Conservation of Mass."

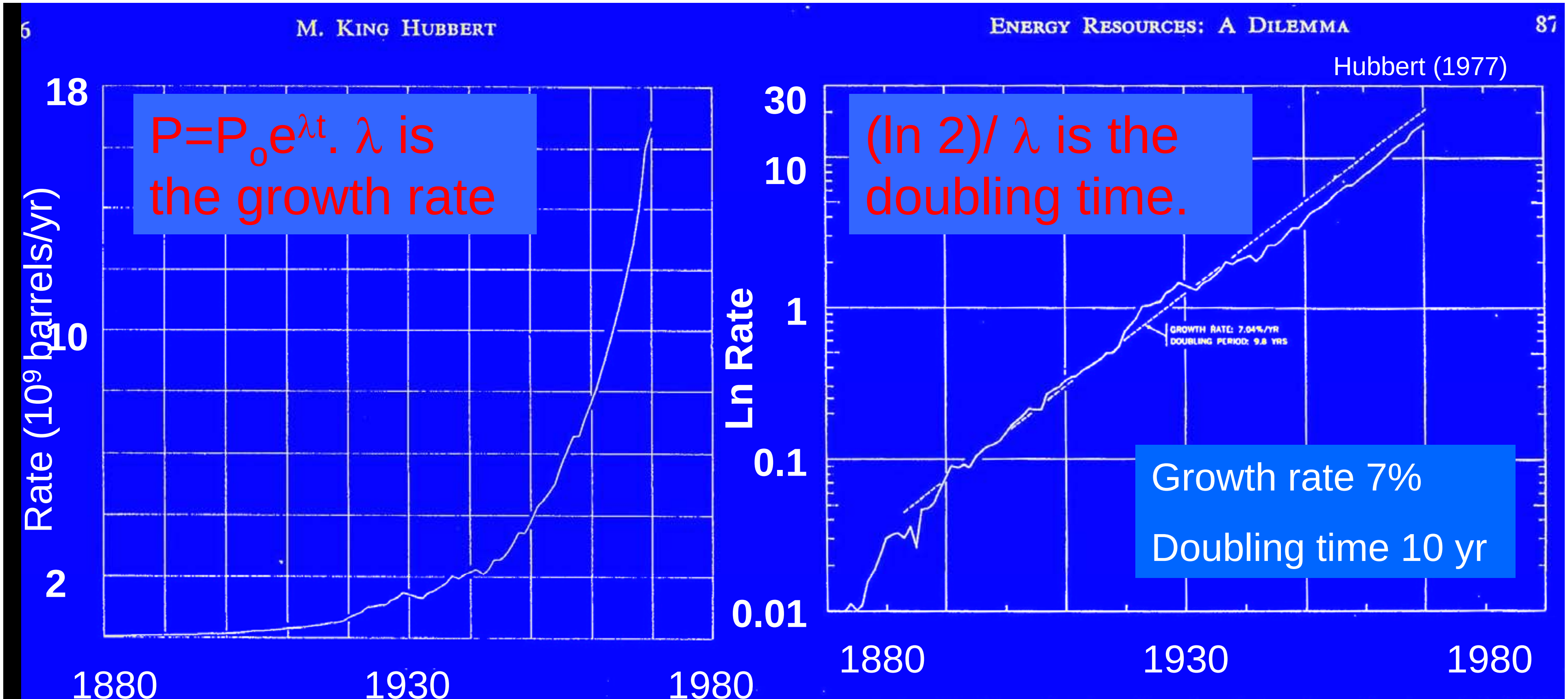


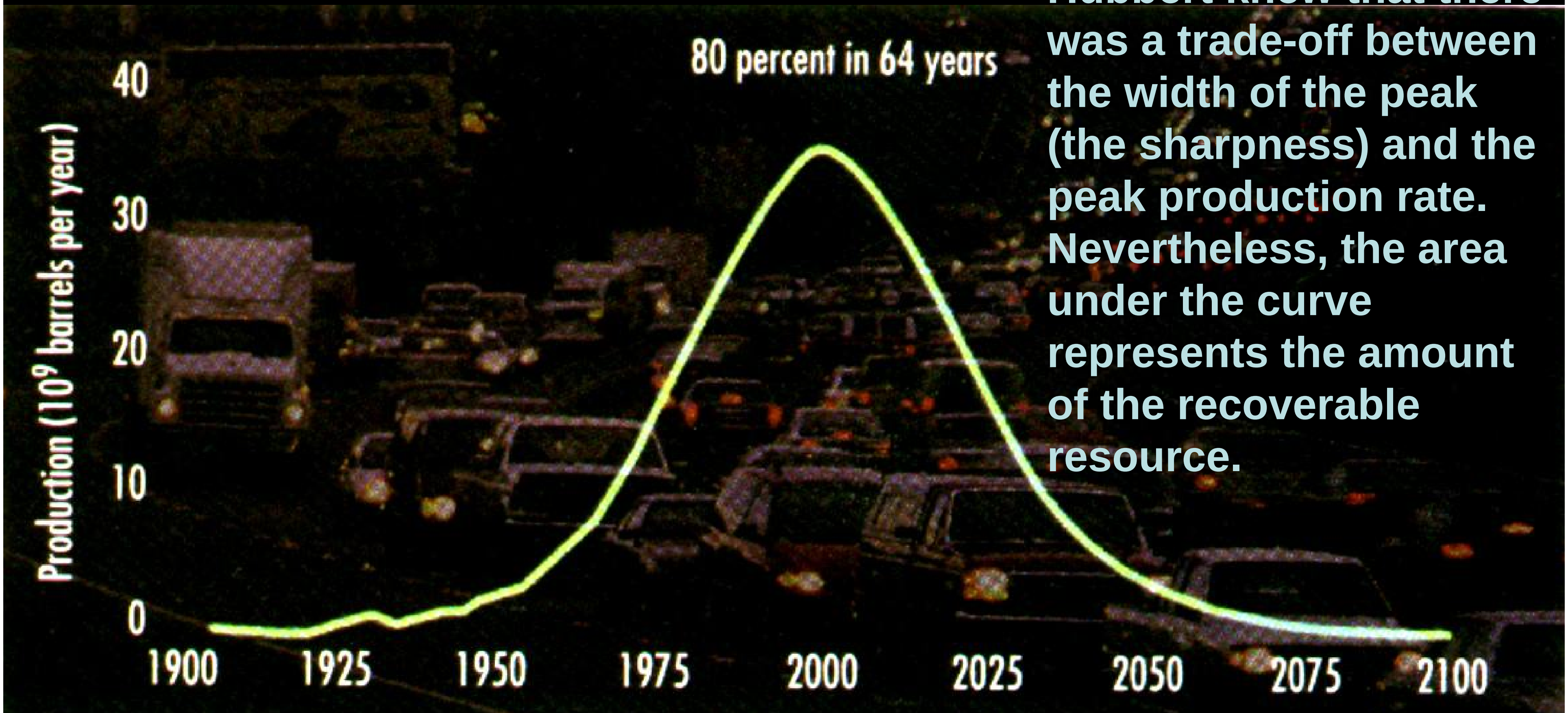
FIGURE 4. World production of crude oil (Hubbert, 1974, fig. 5)

FIGURE 5. World production of crude oil (semilogarithmic scale) (Hubbert, 1974, fig. 6)

M. King Hubbert plotted world production figures (the rate versus the time) and demonstrated that, on a semilog plot, a linear relationship exists between time and rate of production. This implies exponential growth.

The rate X time= amount. ∴ The area under the curve on the left is the amount. For a non-renewable resource the amount is finite.

Hubbert’s (1974) prediction as reproduced by *the Economist*



Hubbert knew that there was a trade-off between the width of the peak (the sharpness) and the peak production rate. Nevertheless, the area under the curve represents the amount of the recoverable resource.

The shape of the peak depends on the doubling time for consumption; the area under the curve must be the amount of the finite resource.

Increasing Q_∞ to ~3300 X 10^9, the current US Geological Survey estimate, only shifts the peak of production a decade or so & adds ~ 5 squares beneath the curve!

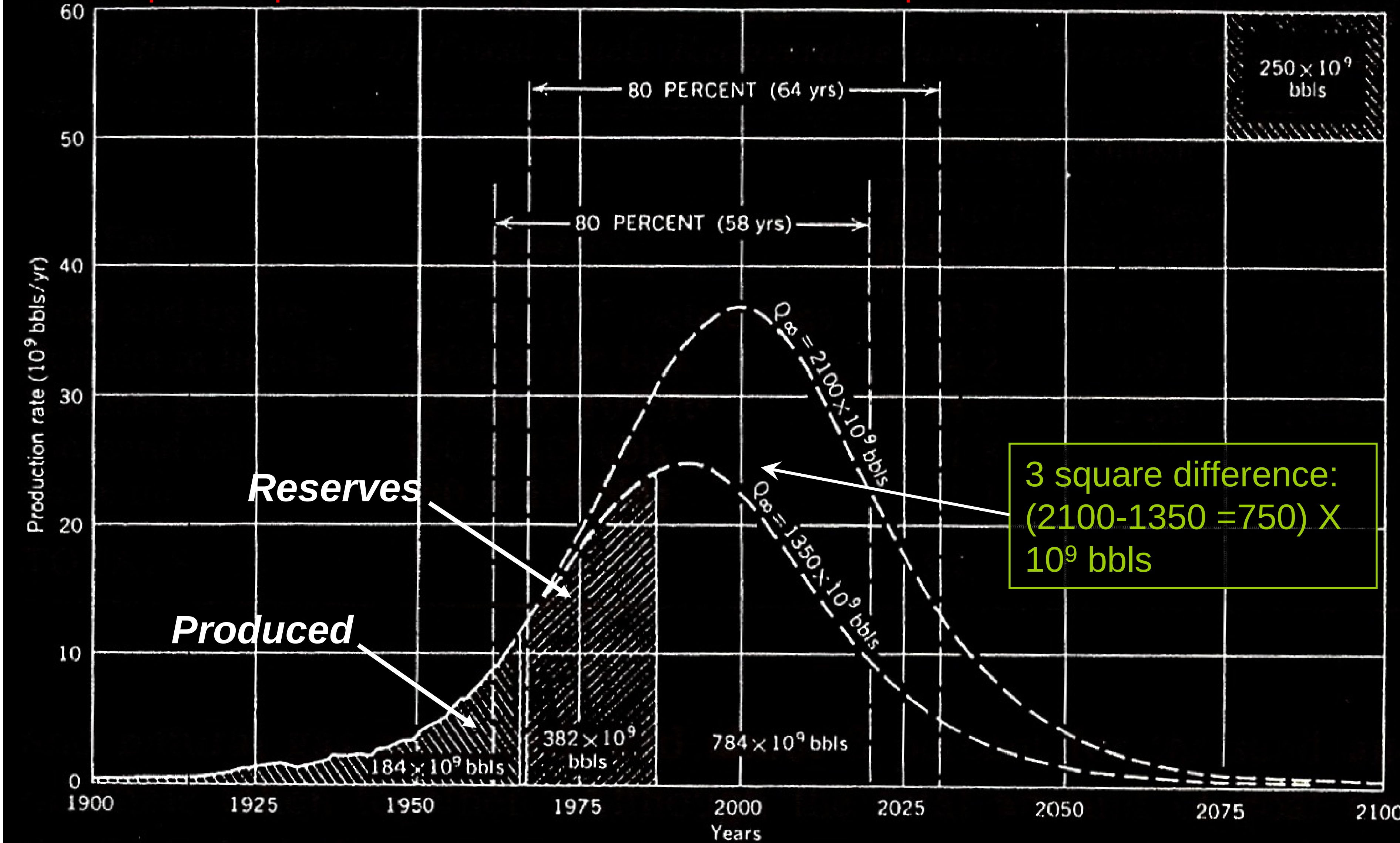
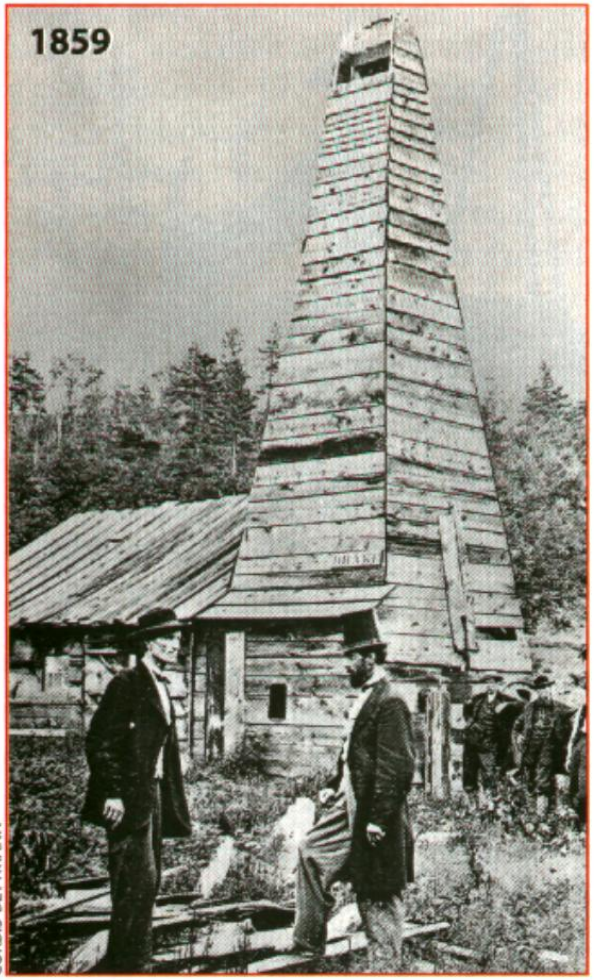


FIGURE 25. Complete cycle of world crude-oil production for two values of Q_∞ (Hubbert, 1969, fig. 8.23)



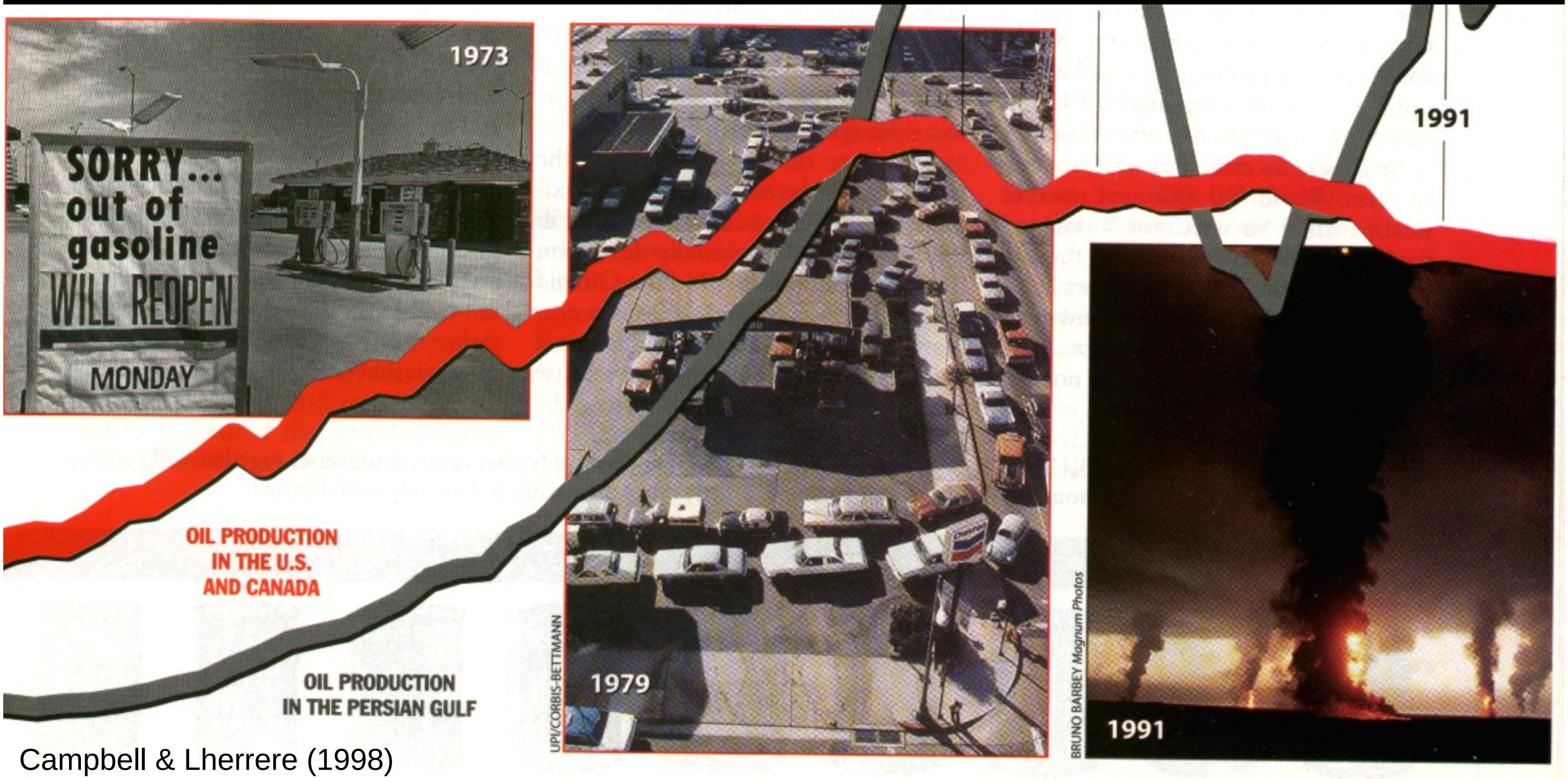
CORBIS-BETTMANN

HISTORY OF OIL PRODUCTION, from the first commercial American well in Titusville, Pa. (*left*), to derricks bristling above the Los Angeles basin (*below*), began with steady growth in the U.S. (*red line*). But domestic production began to decline after 1970, and restrictions in the flow of Middle Eastern oil in 1973 and 1979 led to inflation and shortages (*near* and *center right*). More recently, the Persian Gulf War, with its burning oil fields (*far right*), reminded the industrial world of its dependence on Middle Eastern oil production (*gray line*).

CORBIS-BETTMANN

Campbell & Lherrere (1998)

The time from the first commercial oil well (1859) to the peak of domestic U.S. production was only about 110 years. The "Age of Oil" will last ~200 years!

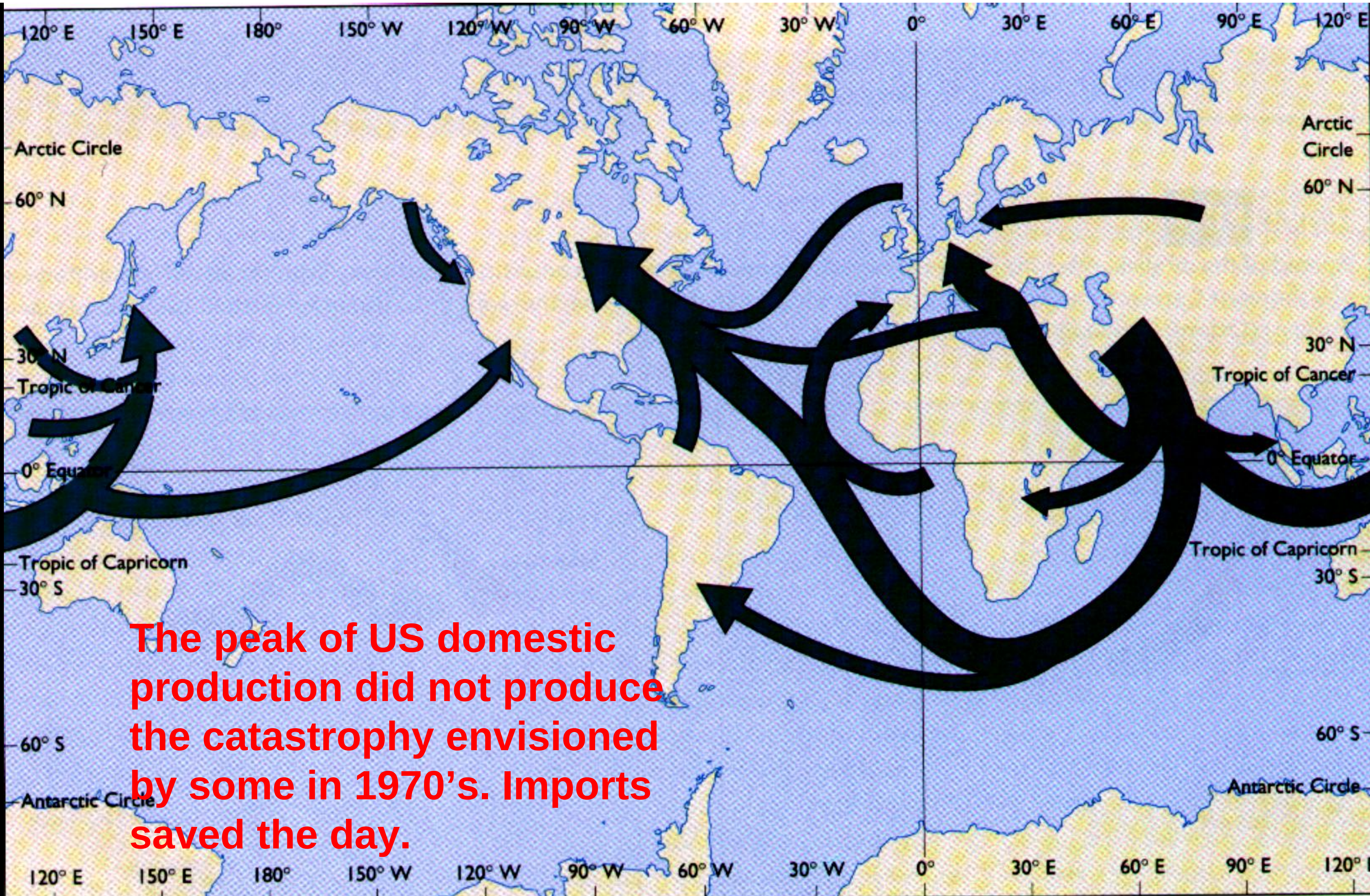


Campbell & Lherrere (1998)

Disruptions to Oil Supply:

Arab Oil Embargoes of 1973 &1979

Burning Kuwait Oil Fields (1st Gulf War)



The peak of US domestic production did not produce the catastrophy envisioned by some in 1970's. Imports saved the day.

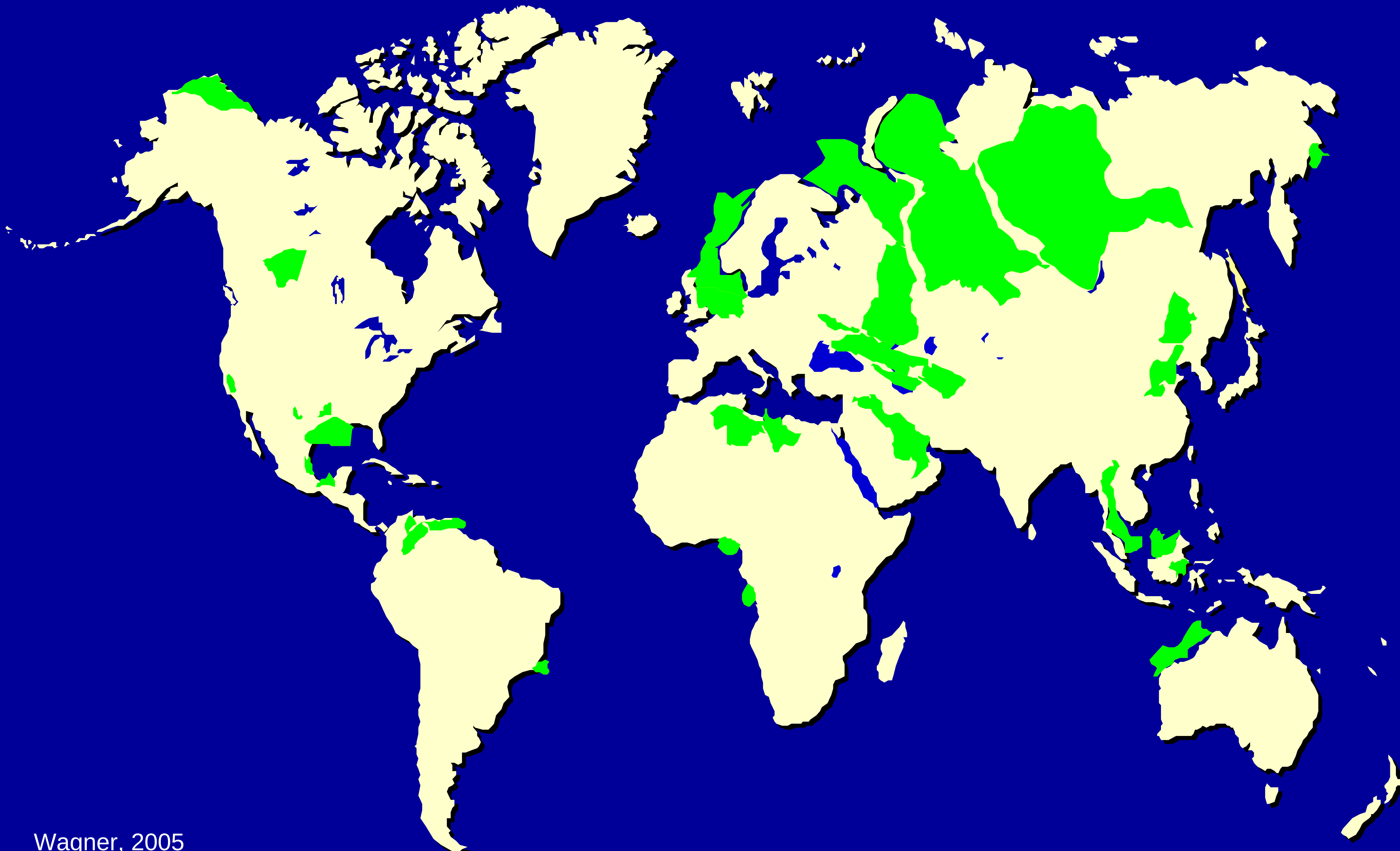
FIGURE **15-2**

Transport routes of crude oil. The thickness of the arrows indicates the relative volume of petroleum transported across the oceans. Note how dependent are the industrialized nations on Mid-East oil resources. [Adapted from R. B. Clark, *Marine Pollution* (Oxford: Claredon Press, 1989).]

Pinet (2003)

Largest Hydrocarbon Basins

by Ultimate Potential



Wagner, 2005

Global Giant Oil and Gas Fields

Wagner, 2005

Naturally-occurring hydrocarbons are sourced from the burial of surface-derived organic matter.

Geology allows us to estimate the amount.

Oil is essentially "canned" energy originally derived from the Sun.

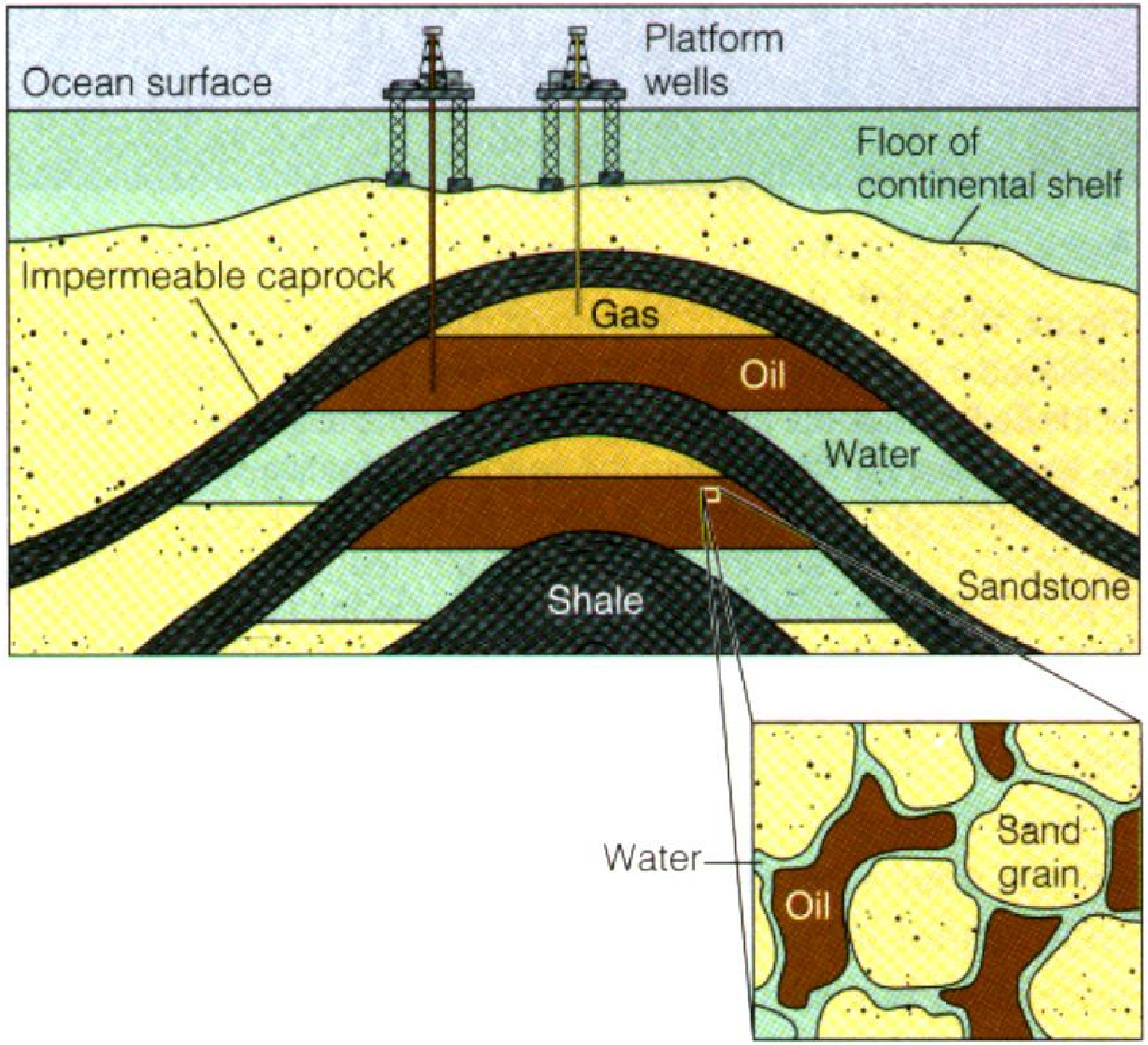


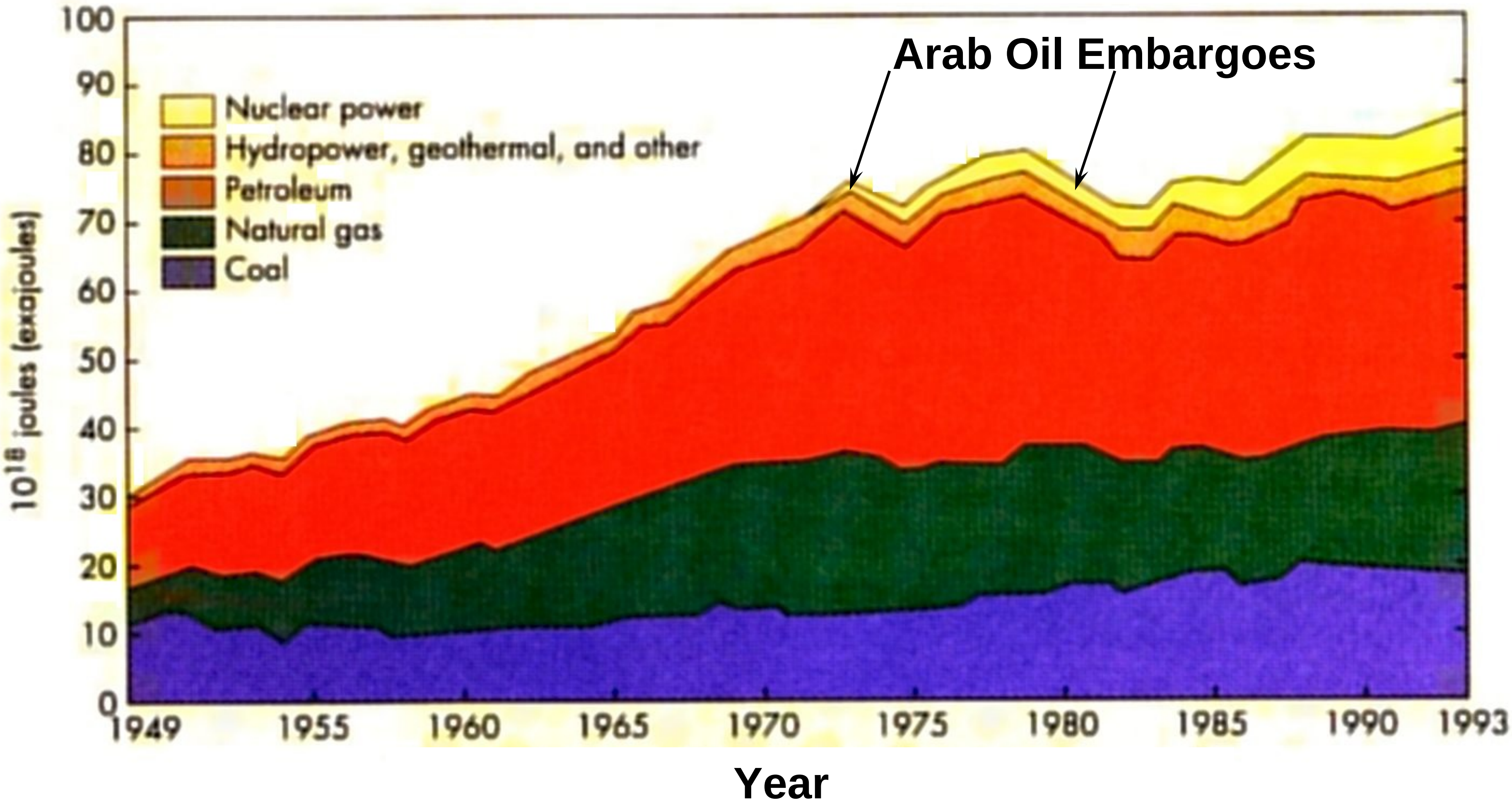
Figure 15.2 Oil and natural gas are often found together beneath a dome of impermeable caprock. Oil and gas are not found in great hollow reservoirs, but within pore spaces in rock.

Garrison (1995)

Some Energy Terms

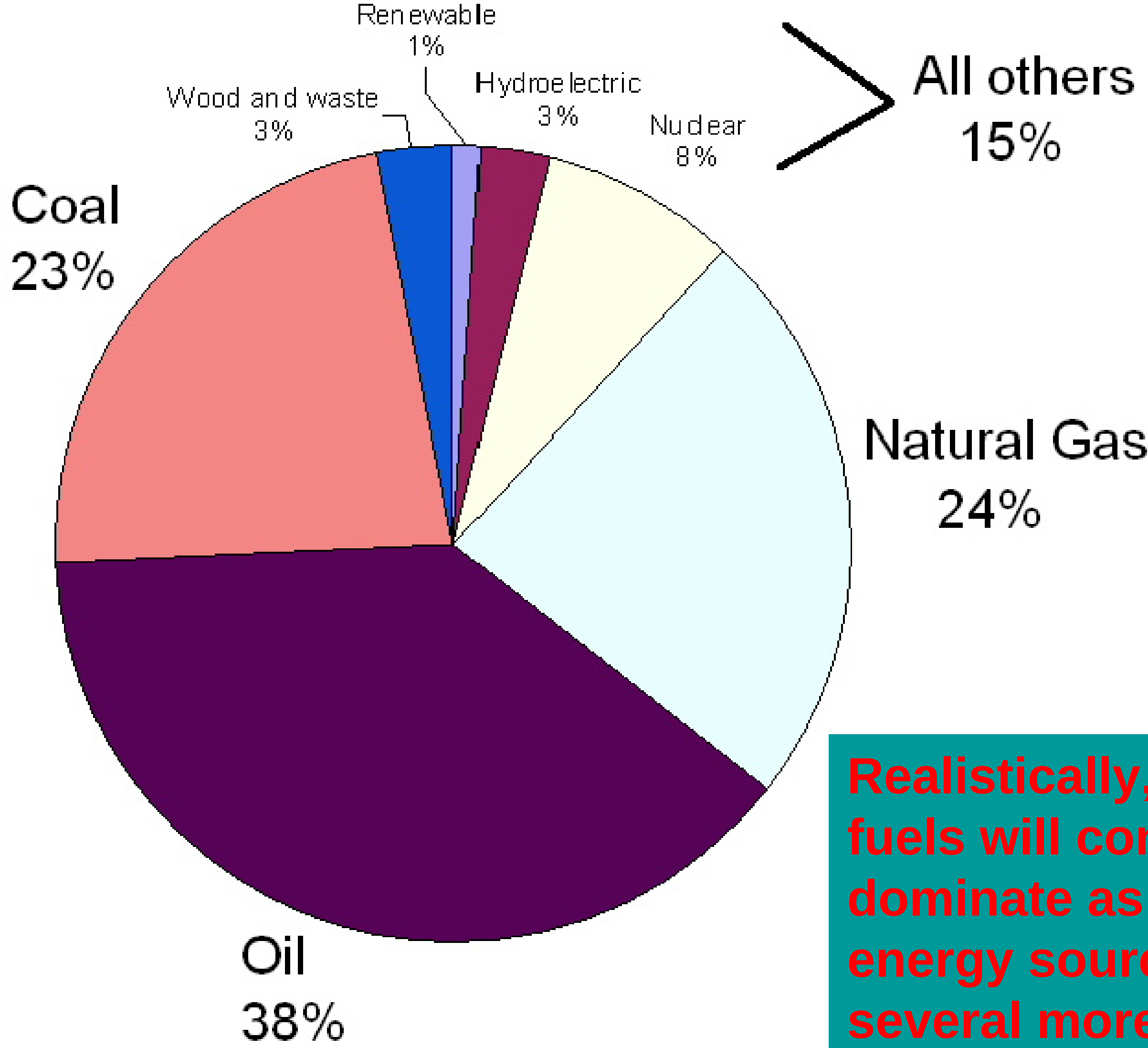
- A barrel of oil upon combustion delivers about 6 gigajoules energy.
- A joule/sec is a watt.
- Humans use about 30 billion barrels of oil per year for an energy use at a rate of 6 terawatts.
- The Sun delivers approximately 1300 W/m^2 compared to the geothermal output of ~60 milliwatts per meter square.
- The Earth puts out about 30 terawatts. 30,000 gigajoules per sec from geothermal energy.

Exploitation of energy on a massive scale to conquer our environment has enabled our species to flourish.



In 1993, oil supplied about 30% or our energy needs. The peak of U.S. domestic production (~1970) and OPEC pricing drove recession and inflation.

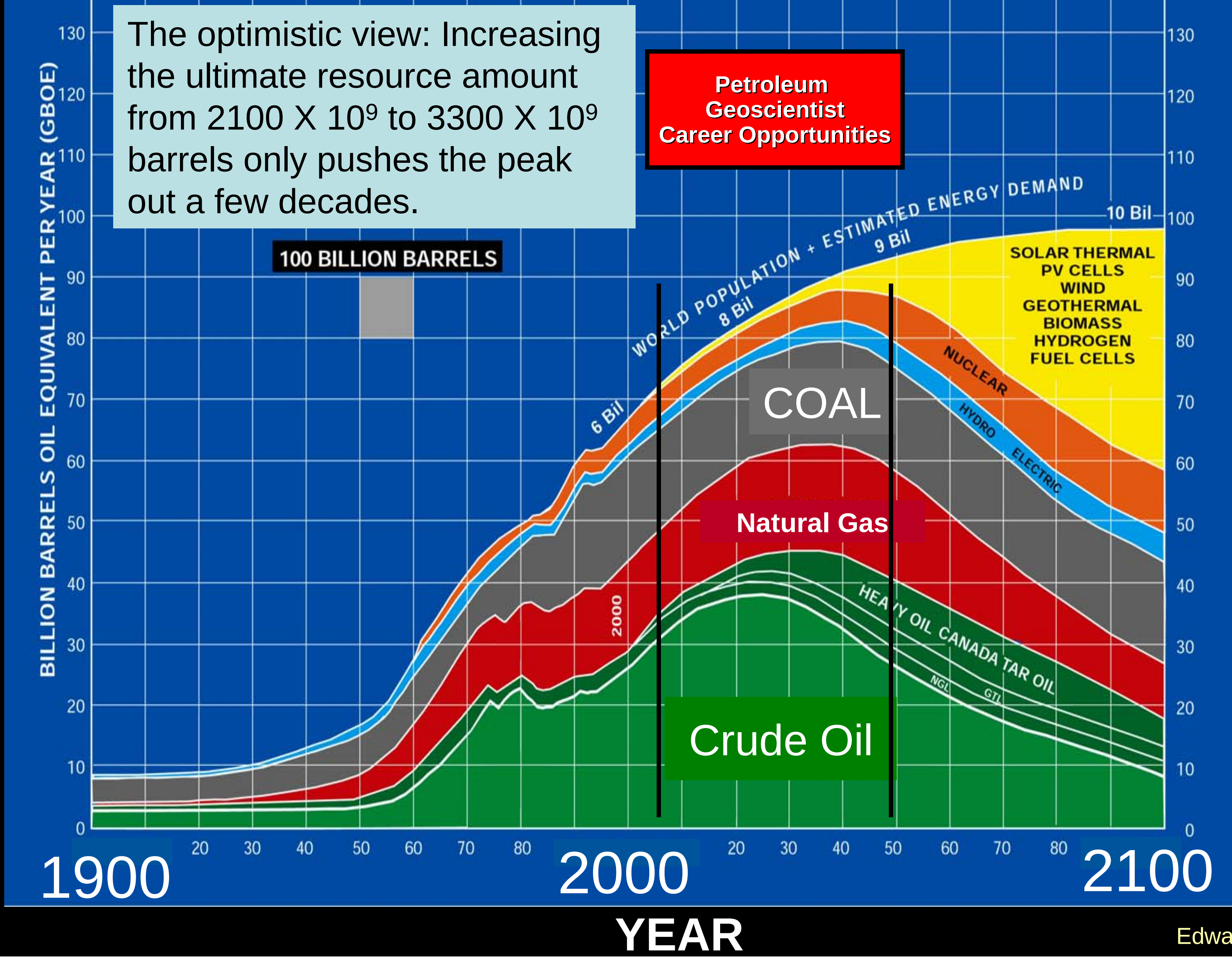
U.S. Energy Consumption: 2003



Our dependence on oil did not decrease, our imports did!

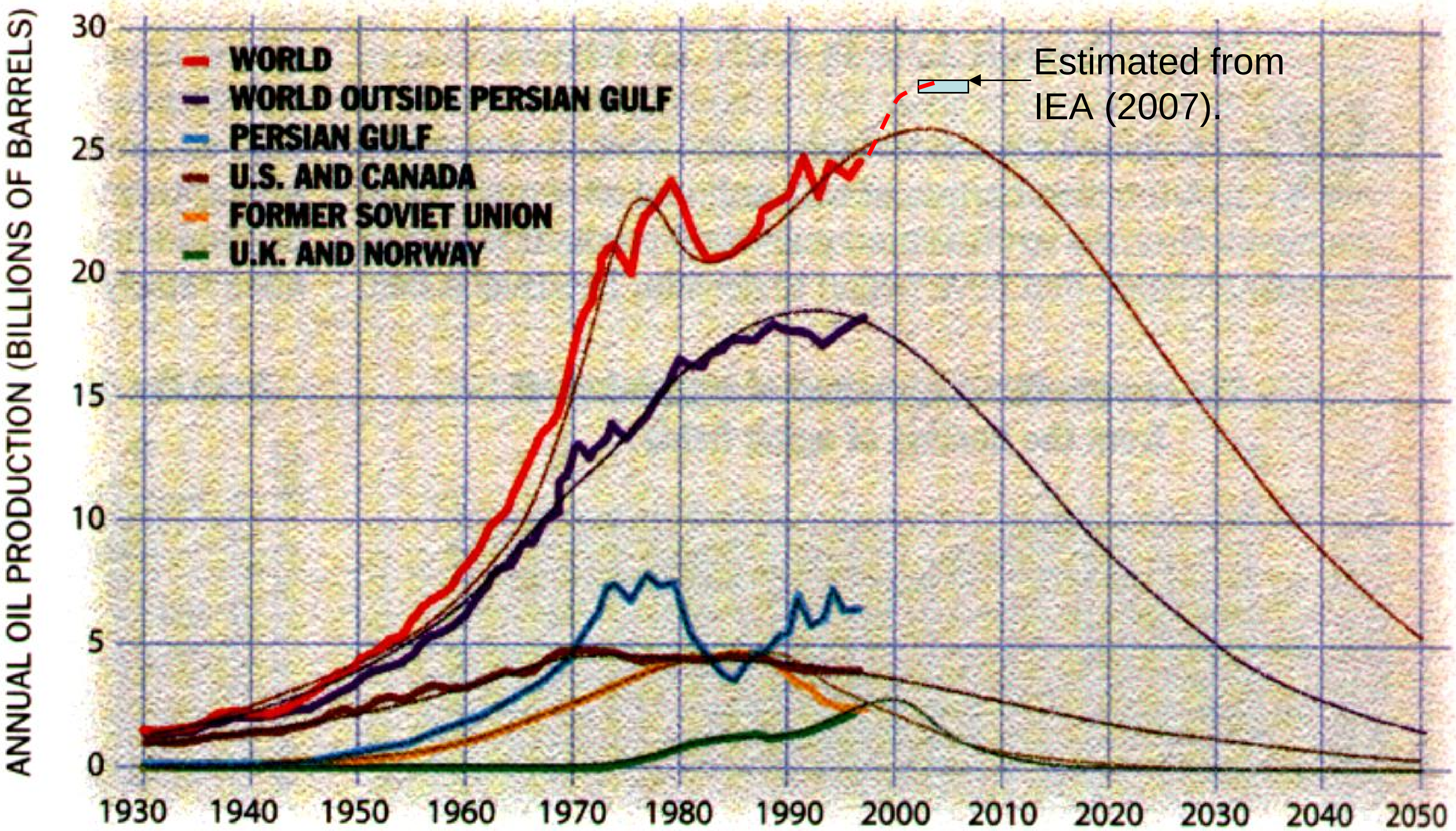
Realistically, fossil fuels will continue to dominate as an energy source for several more decades.

Estimates of 21st Century World Energy Supplies



Edwards 2001

Campbell & Lherrere (1998)

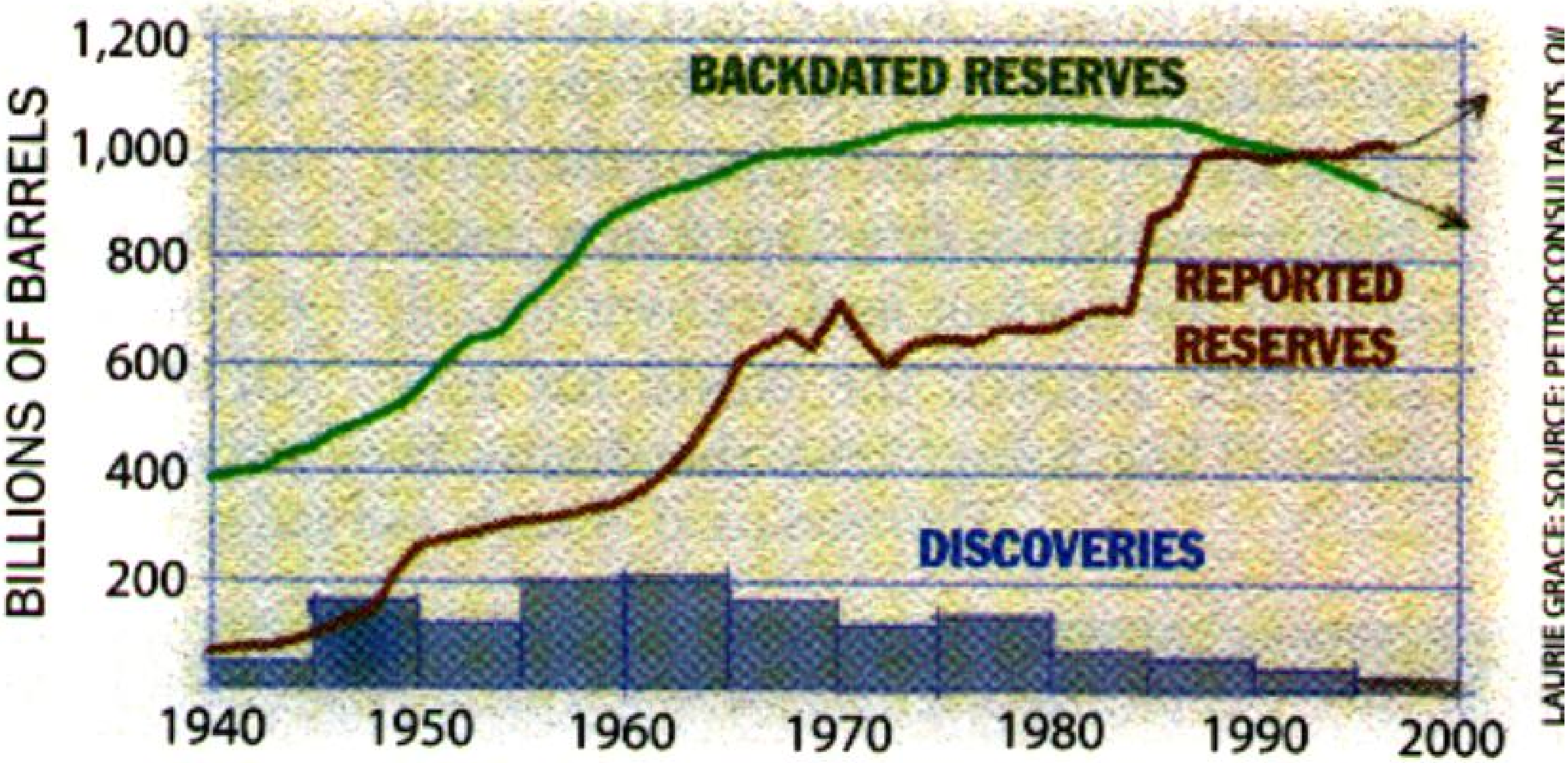


When global production and demand reaches 30 X 10^9 barrels/yr, watch out!

Global Exploration

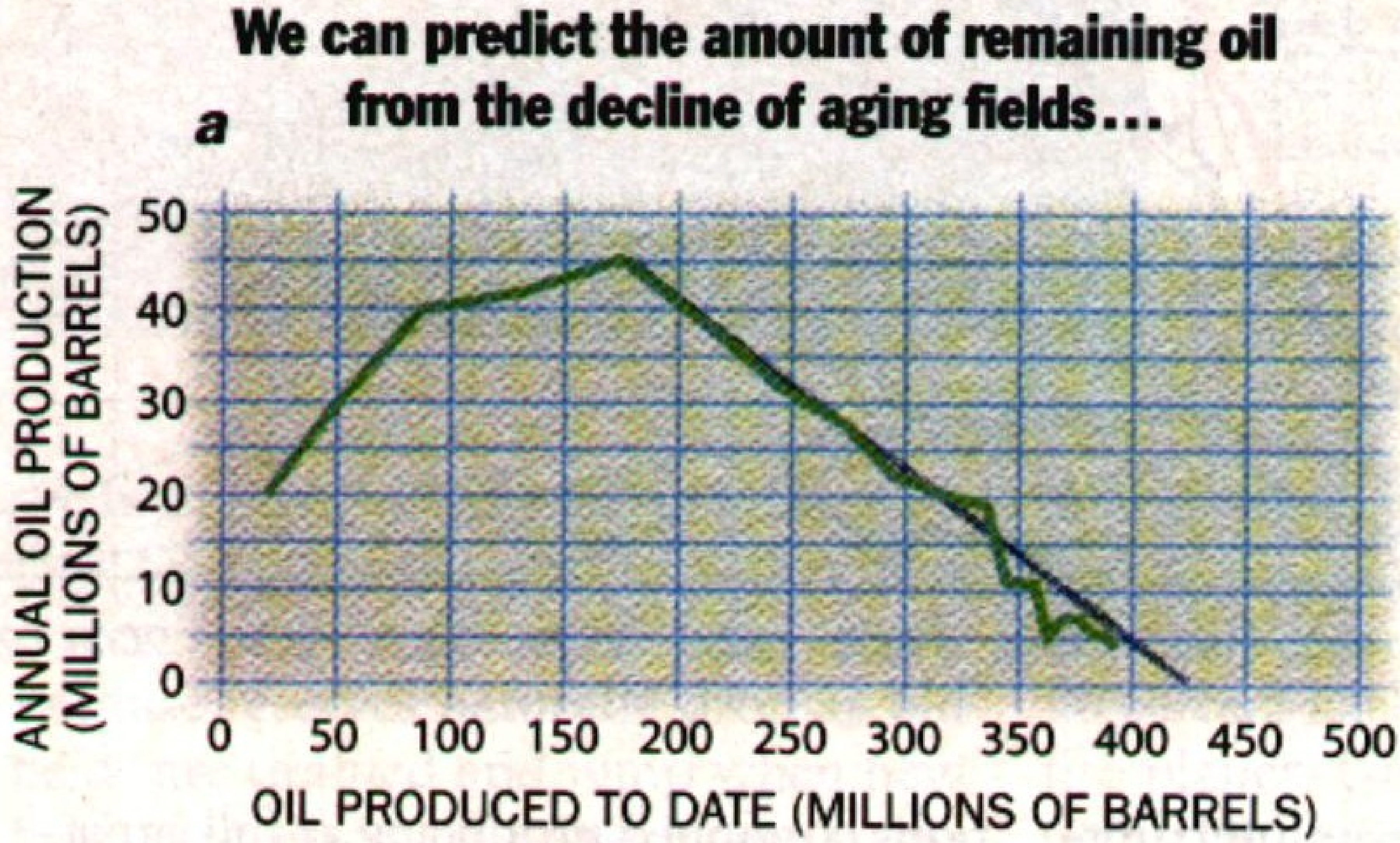
Opportunities for Future Growth

Wagner, 2005

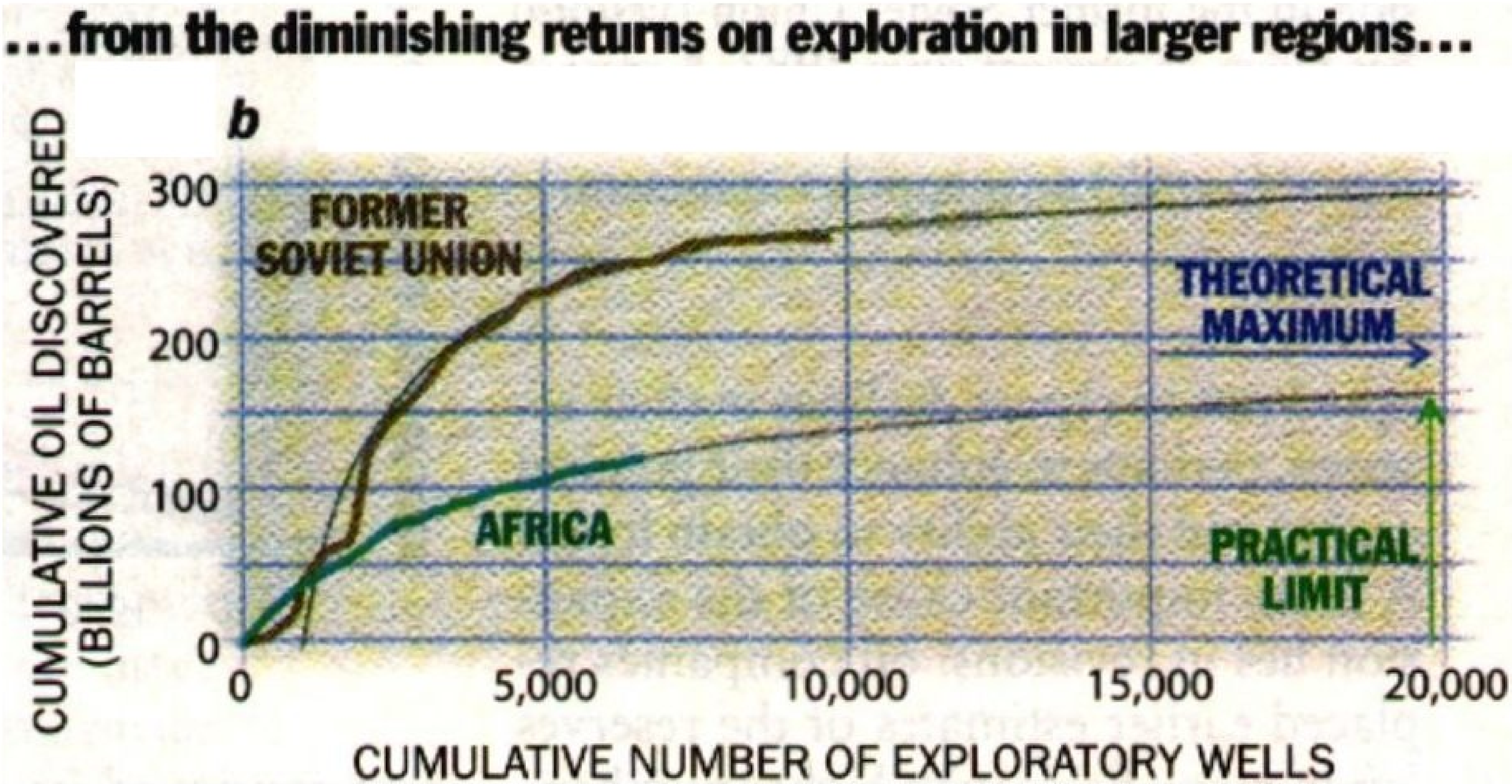


GROWTH IN OIL RESERVES since 1980 is an illusion caused by belated corrections to oil-field estimates. Back-dating the revisions to the year in which the fields were discovered reveals that reserves have been falling because of a steady decline in newfound oil (*blue*).

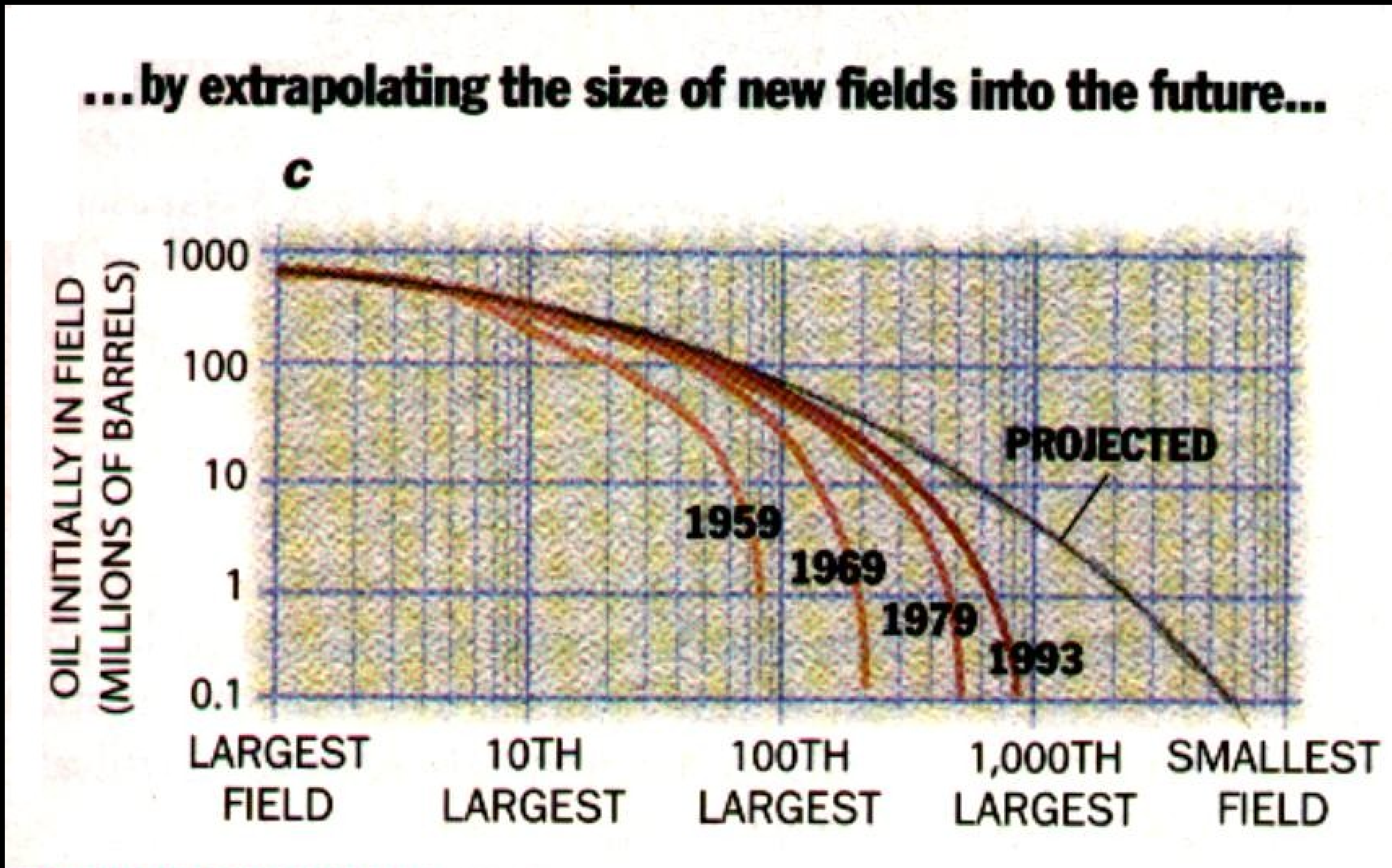
Campbell & Lherrere (1998)



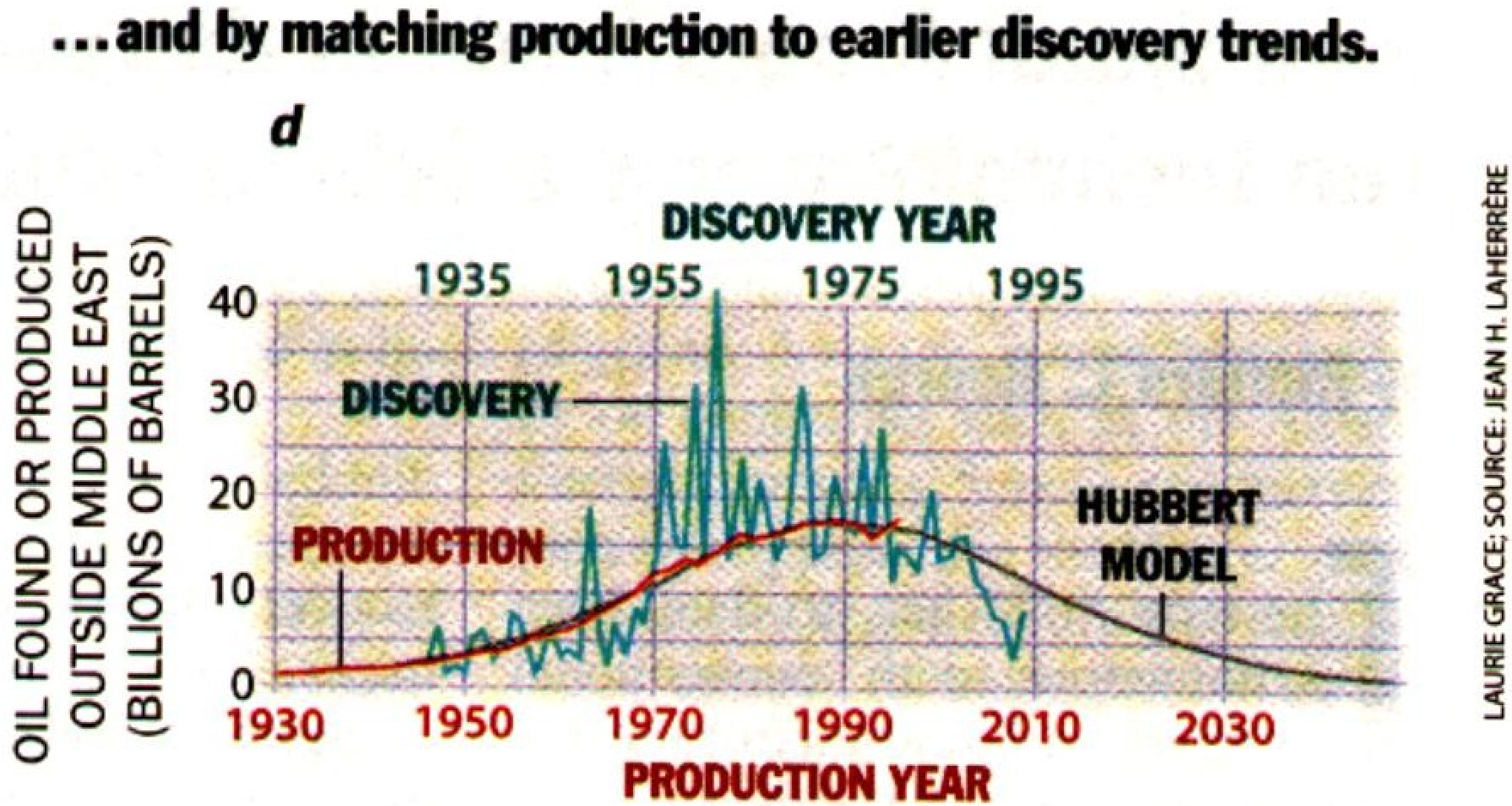
Campbell & Lherrere (1998)



Campbell & Lherrere (1998)

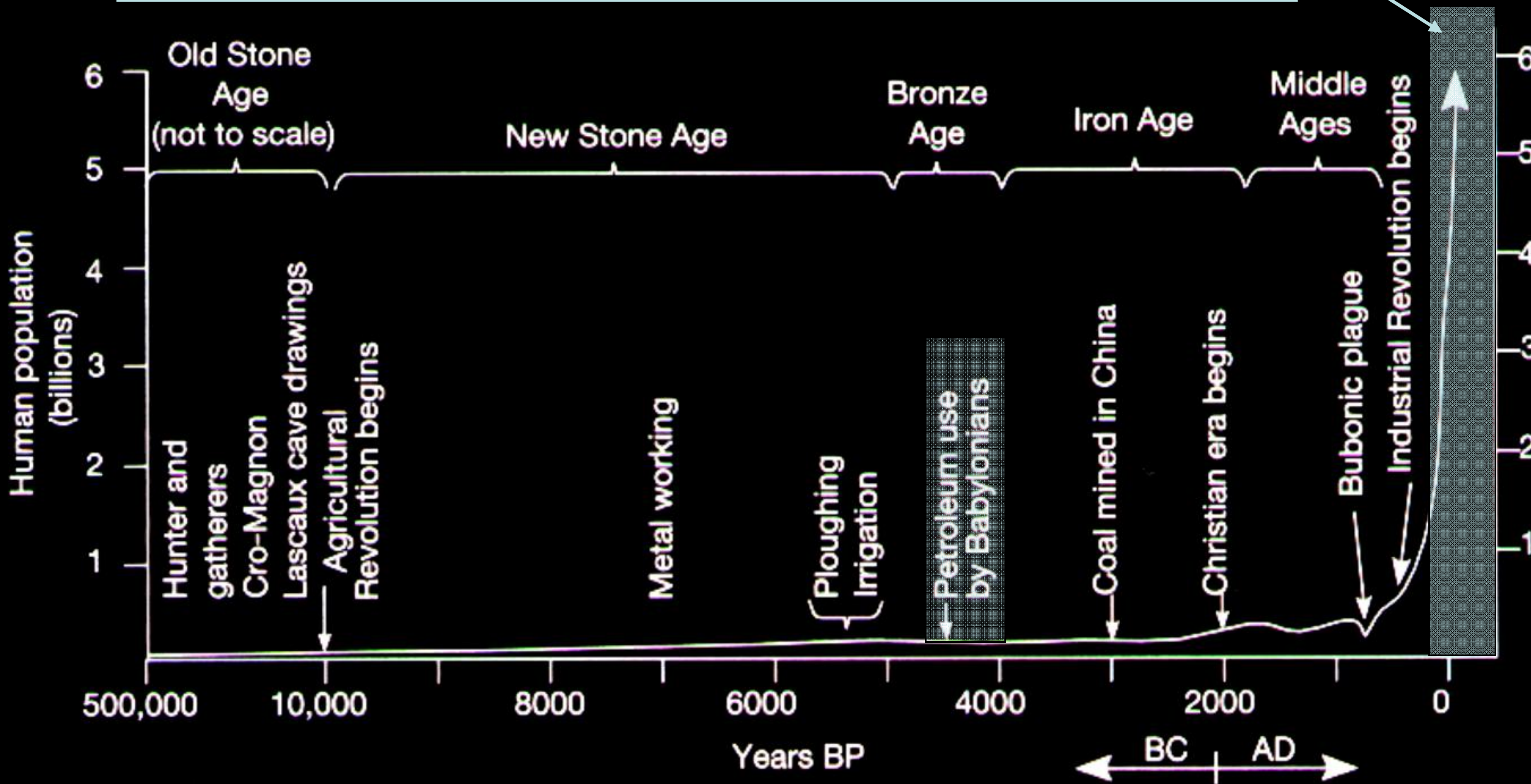


Campbell & Lherrere (1998)



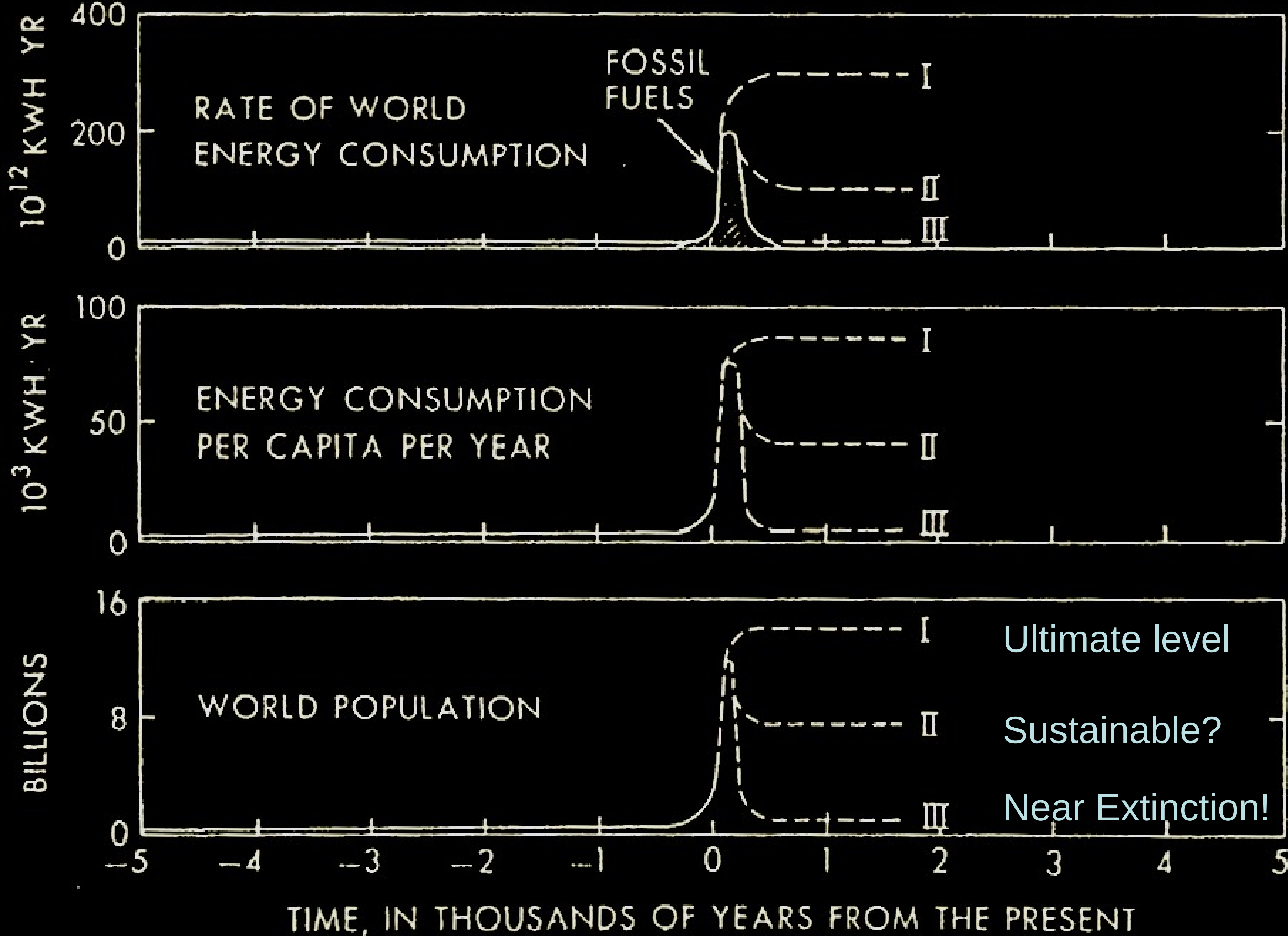
Campbell & Lherrere (1998)

The “Age of Oil” coincides with the massive exponential growth of human population!



Mackenzie (1998)

Hubbert’s Prediction 1977



What's Next?

- When the peak of production is reached somewhat more half the oil is still in the ground.
- At best, we have a few decades to figure out the transition away from oil.
- We must understand the environmental consequences of our success. Exponential growth must be ephemeral.

The 21st century will be the "Revenge of the Earth" era!