

# Future Oil and Gas Resources of the World

Thomas Ahlbrandt  
World Energy Project Chief

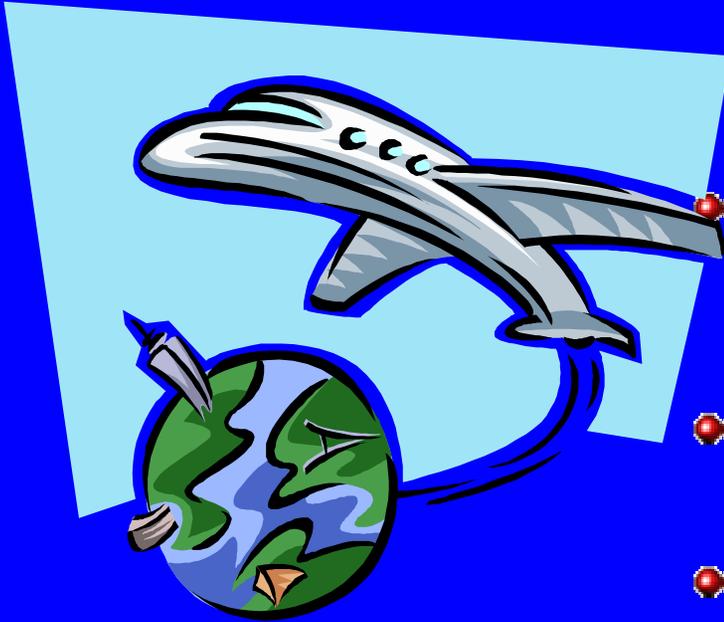
U.S. Department of the Interior

U.S. Geological Survey



# USGS World Petroleum Assessment 2000

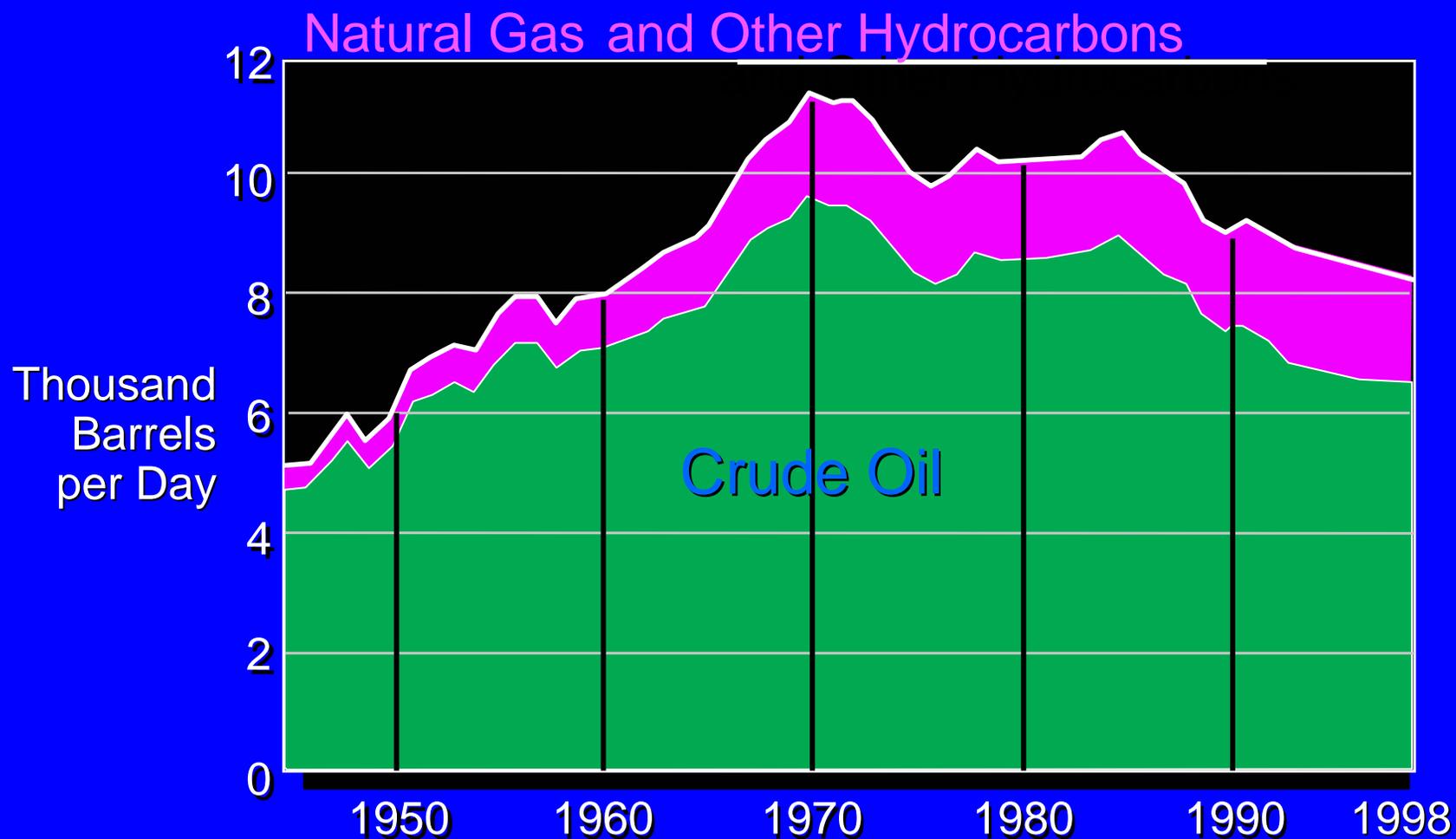
- USGS World Energy Project—DDS-60, 4CDs, 32,000 pages—Estimates of Undiscovered & Field Growth; Ancillary Data—Gas Composition, Drilling & Water Depths
- Perspectives--onshore, offshore, OPEC / OECD, Peaking Soon?, North America Gas
- Modeling (Added Value, Arctic, Climate)
- New Geologic Insights
- Increasing Role of Unconventional & Renewable Resources
- Summary



# WORLD ENERGY PROJECT

- WPA 2000 --New estimate of future world oil and gas resources- 30 year time frame (1995-2025)—Not Ultimate, 1<sup>st</sup> time, 32,000 pages, documentation
- Reserve (Field) Growth Estimates for the World (30 Year Forecast)-1<sup>st</sup> Time
- **Geologically Based** Estimates using Total Petroleum Systems (Fluids not just rocks)—1<sup>st</sup> time
- Extensive Methodology Review and Endorsement (AAPG, NAS) 5 year project (1995-2000), 41 Employees (100 man year), transparency of methodology
- World Energy Consortium—38 organizations
- It is a benchmark—used in IEA World Energy Outlook 2000, 2001; EIA, International Energy Outlook 2001, 2002, Stanford, MIT, PEW Climate Reference
- All Information is Digital (DDS-60, 4 CDs, 9 other CDs on regional geology-- 70,000 distributed), 170 publications
- Website (<http://energy.usgs.gov>)--1.2 million hits/10 mo.

# US Domestic Production



American Petroleum Institute, 1999

# Major Suppliers of Oil to the U.S.

Millions of Barrels Per Day

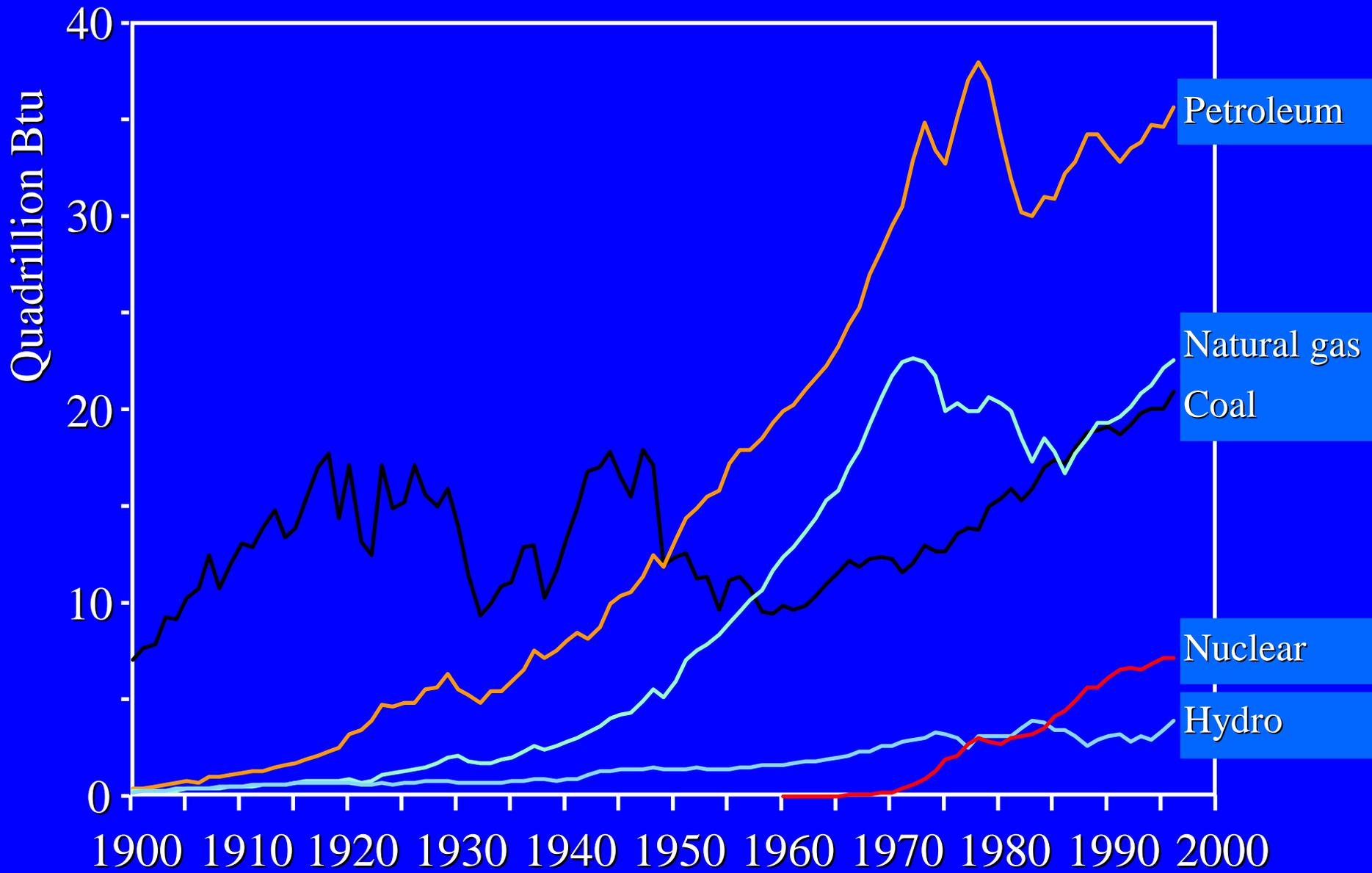
1.68	1.61	1.48	1.36
Venezuela	Canada	Saudi Arabia	Mexico



U.S. Dept. of Energy  
Embassy of Venezuela  
12/98 U.S. News & World Report

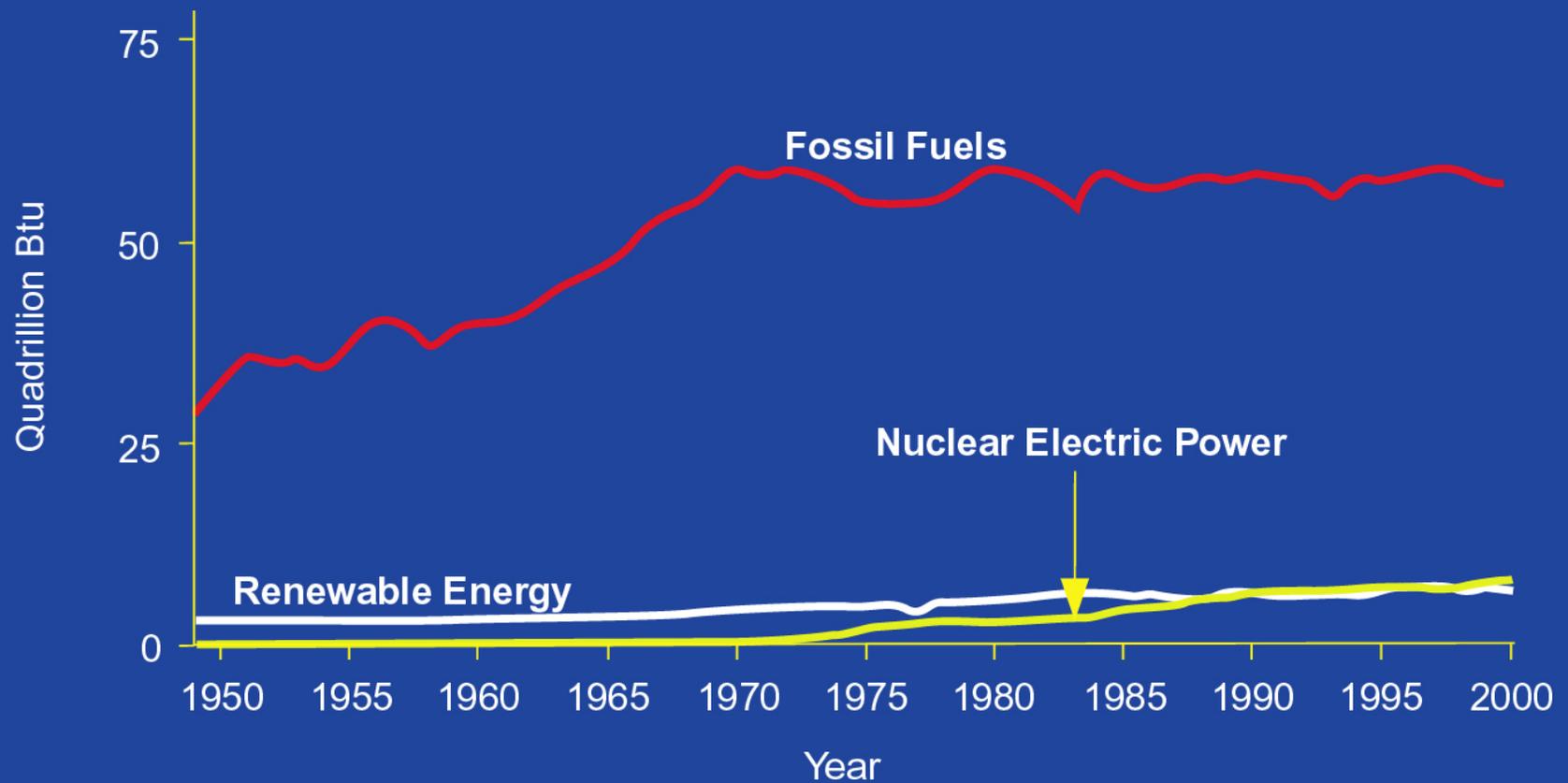
# The Evolving Energy Mix

# U.S. Consumption



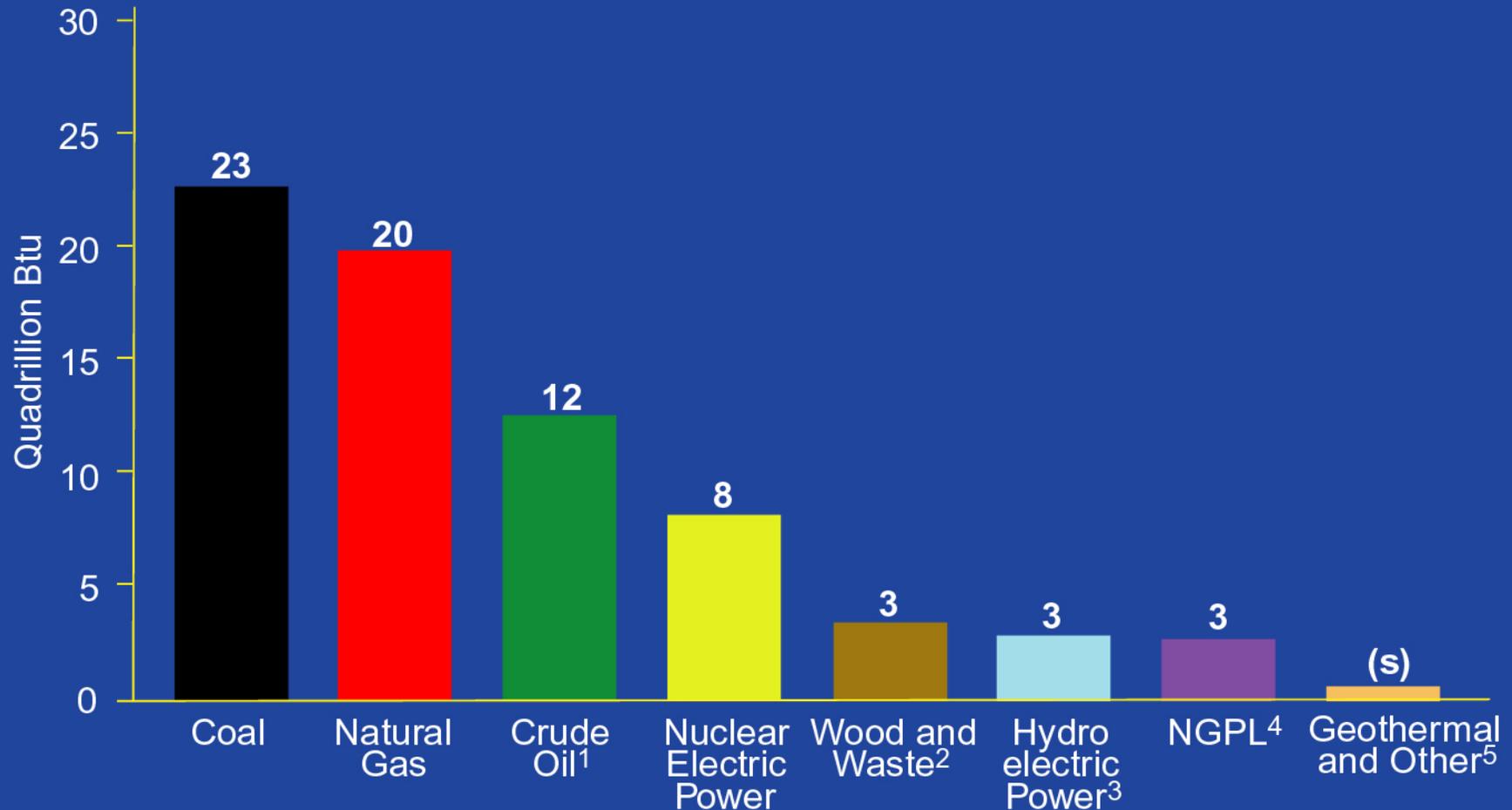
# U.S. Energy Production

By Fossil Fuels, Nuclear Electric Power, and Renewable Energy, 1949 - 2000



EIA, 2001

## By Source, 2000



1 Includes lease condensate.

2 Includes ethanol blended into motor gasoline.

3 Conventional and pumped-storage hydroelectric power.

4 Natural gas plant liquids.

<sup>5</sup> Solar and wind.

(s) = Less than 0.5 quadrillion Btu.

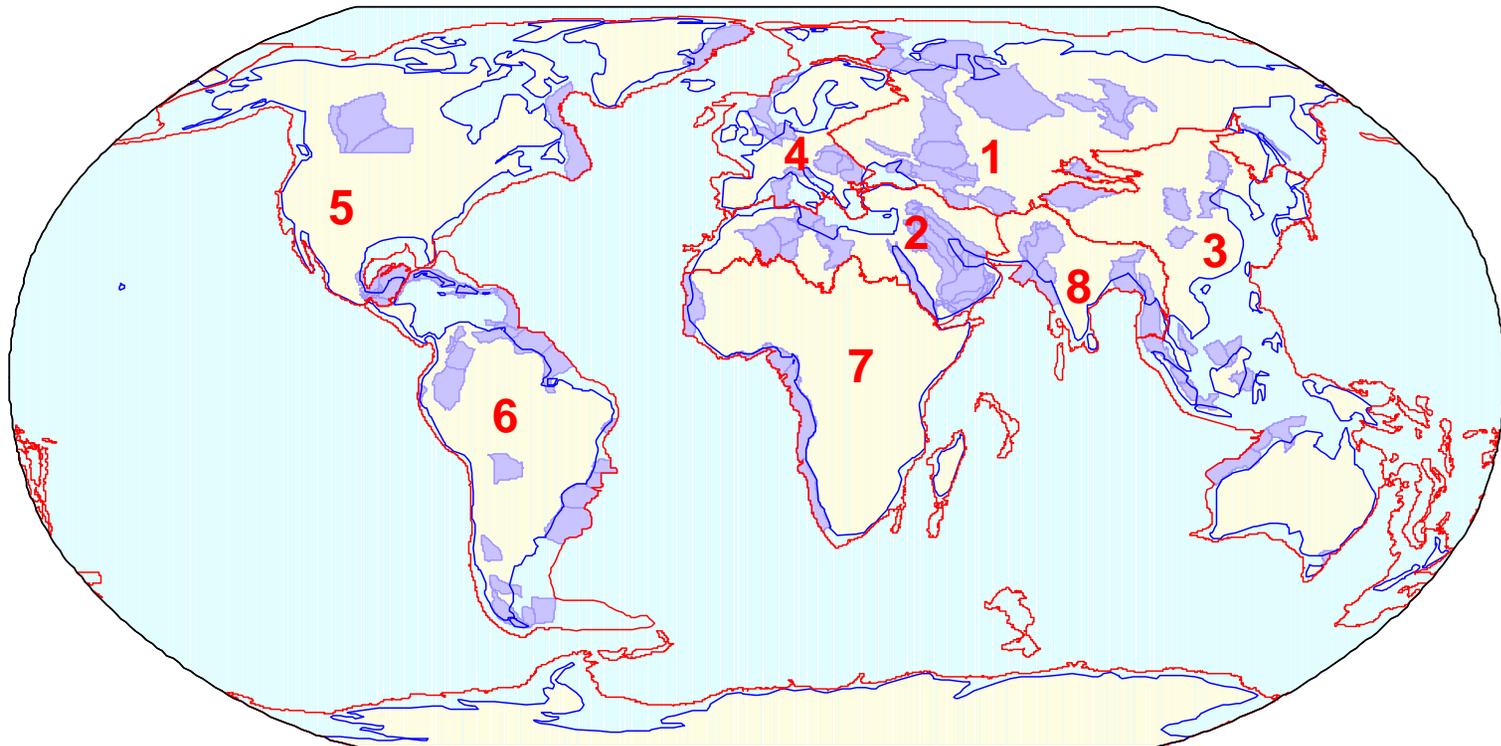
**Top 20 Producers of Liquid Petroleum  
(Crude Oil and Natural Gas Liquids)**

**Year 2000 production in million barrels per day**

<b>Saudi Arabia</b>	<b>9.12</b>
<b>United States</b>	<b>9.06</b>
<b>Russia</b>	<b>6.71</b>
<b>Iran</b>	<b>3.78</b>
<b>Mexico</b>	<b>3.48</b>
<b>Norway</b>	<b>3.32</b>
<b>China</b>	<b>3.25</b>
<b>Venezuela</b>	<b>3.14</b>
<b>Canada</b>	<b>2.76</b>
<b>Iraq</b>	<b>2.59</b>
<b>United Arab Emirates</b>	<b>2.57</b>
<b>United Kingdom</b>	<b>2.55</b>
<b>Kuwait</b>	<b>2.25</b>
<b>Nigeria</b>	<b>2.15</b>
<b>Brazil</b>	<b>1.54</b>
<b>Indonesia</b>	<b>1.51</b>
<b>Libya</b>	<b>1.47</b>
<b>Algeria</b>	<b>1.44</b>
<b>Oman</b>	<b>0.94</b>
<b>Qatar</b>	<b>0.87</b>

**Data from Energy Information Administration 2001**

## World Petroleum Assessment 2000

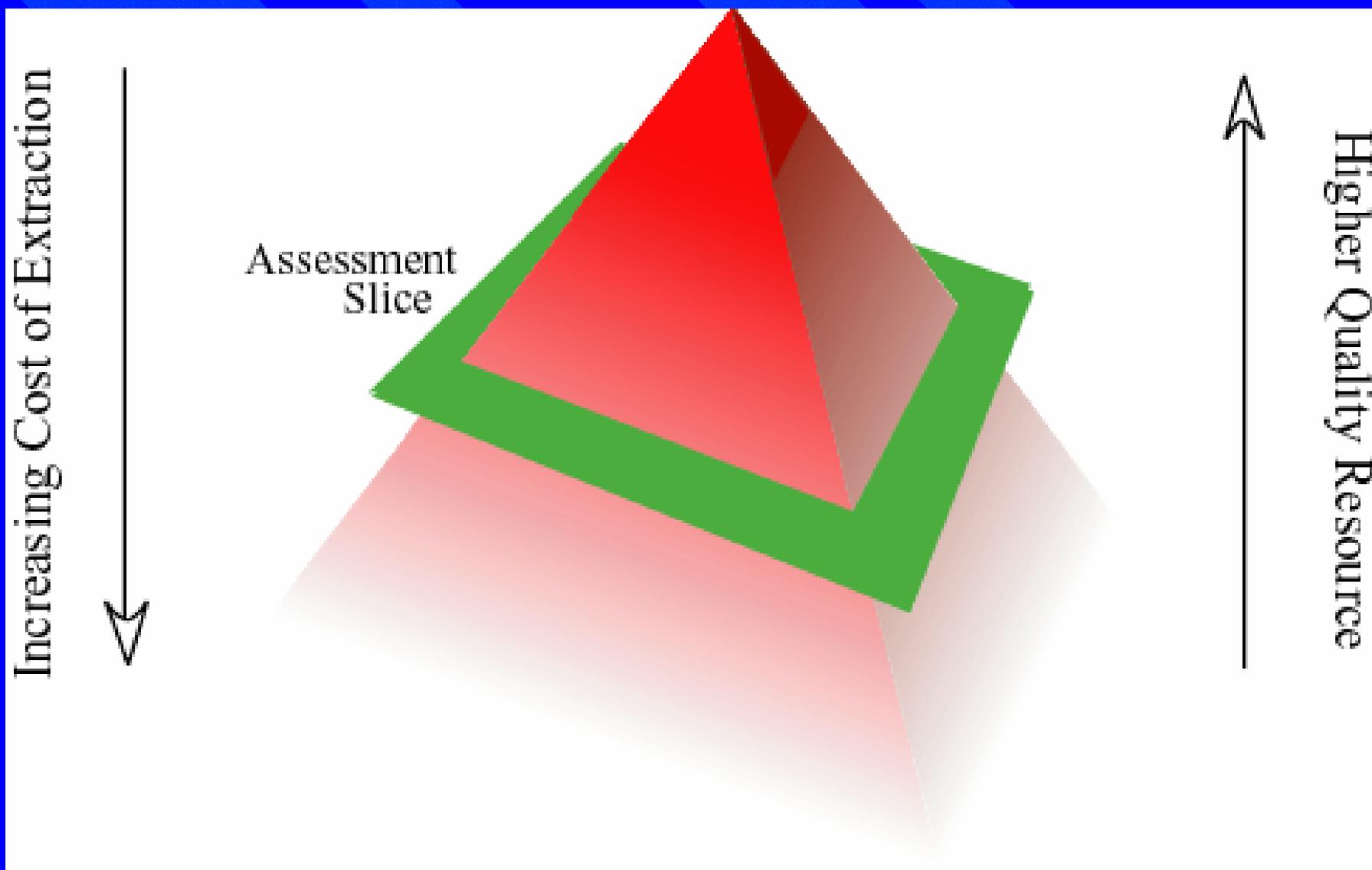


### Assessed Geologic Provinces

- 1 Former Soviet Union
- 2 Middle East and North Africa
- 3 Asia Pacific
- 4 Europe
- 5 North America
- 6 Central and South America
- 7 Sub-Saharan Africa and Antarctica
- 8 South Asia

 Assessed geologic province

# The Resource Pyramid



# **THE VOCABULARY OF RESOURCE ASSESSMENT:**

**Cumulative production**

**Reserves**

**Reserve growth**

**Undiscovered resources**

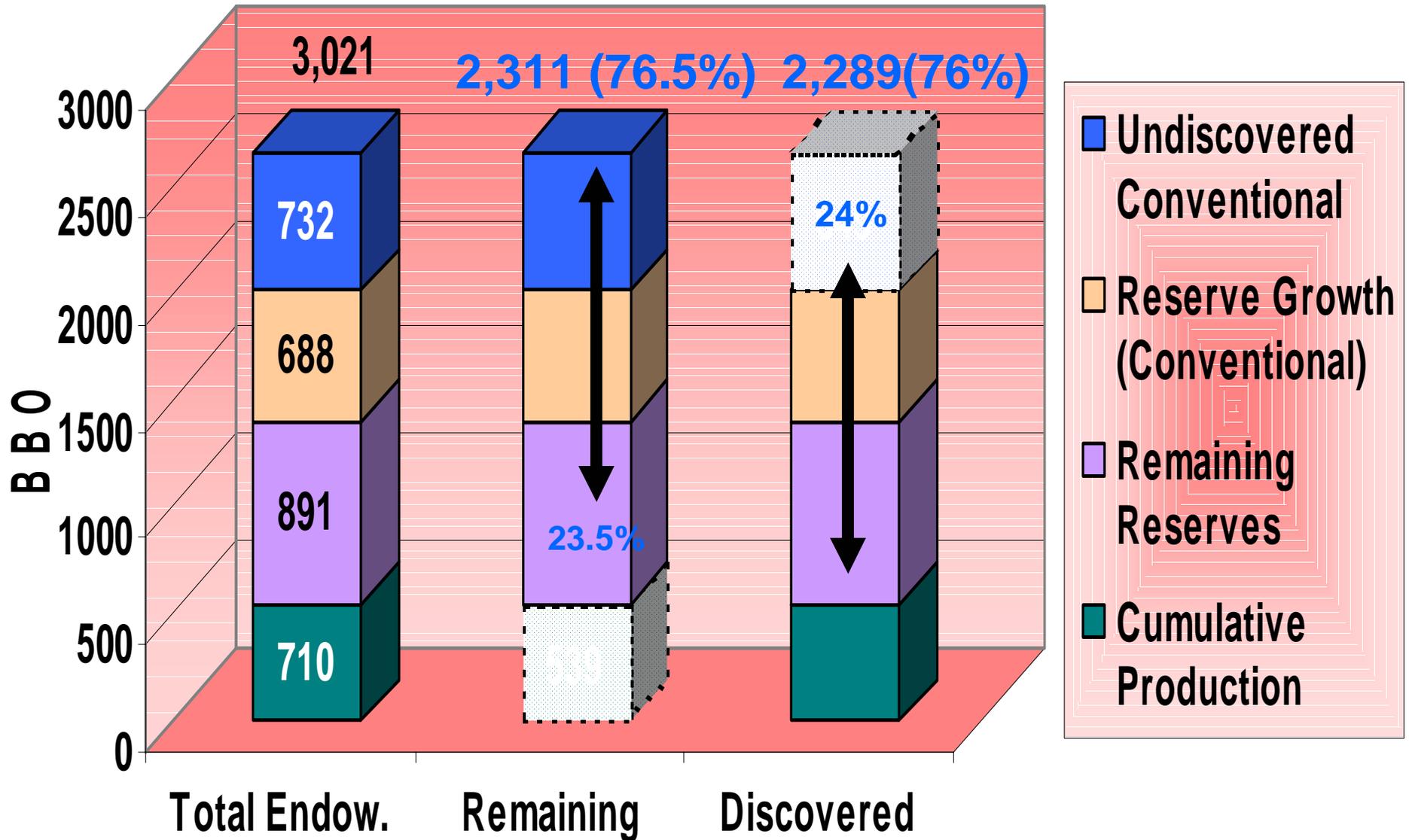
**Conventional**

**Unconventional (continuous)**



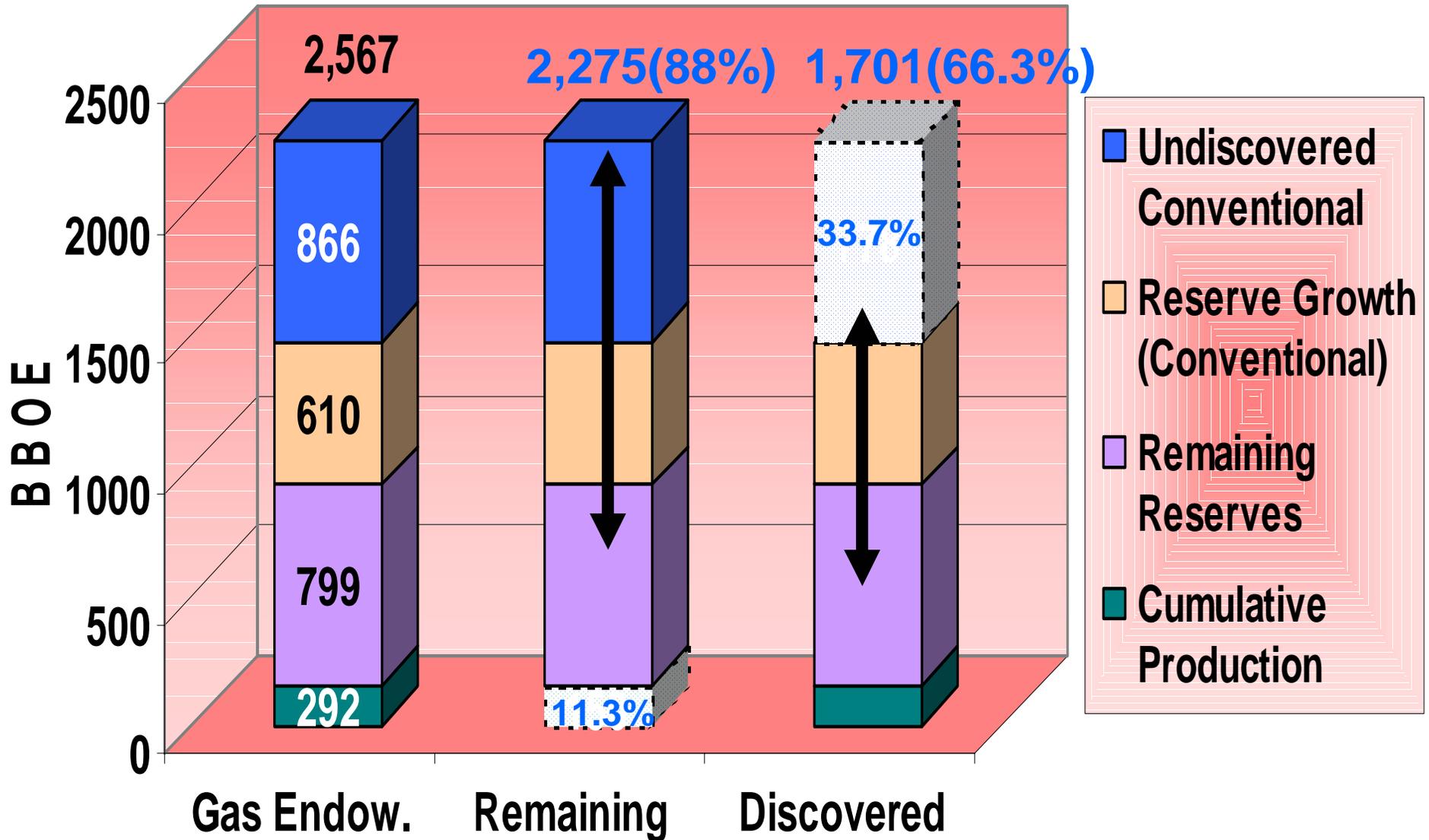
# USGS World Petroleum Assessment 2000

## OIL (128 World Provinces & U.S., Means Billion barrels) EFF. 1/1/96



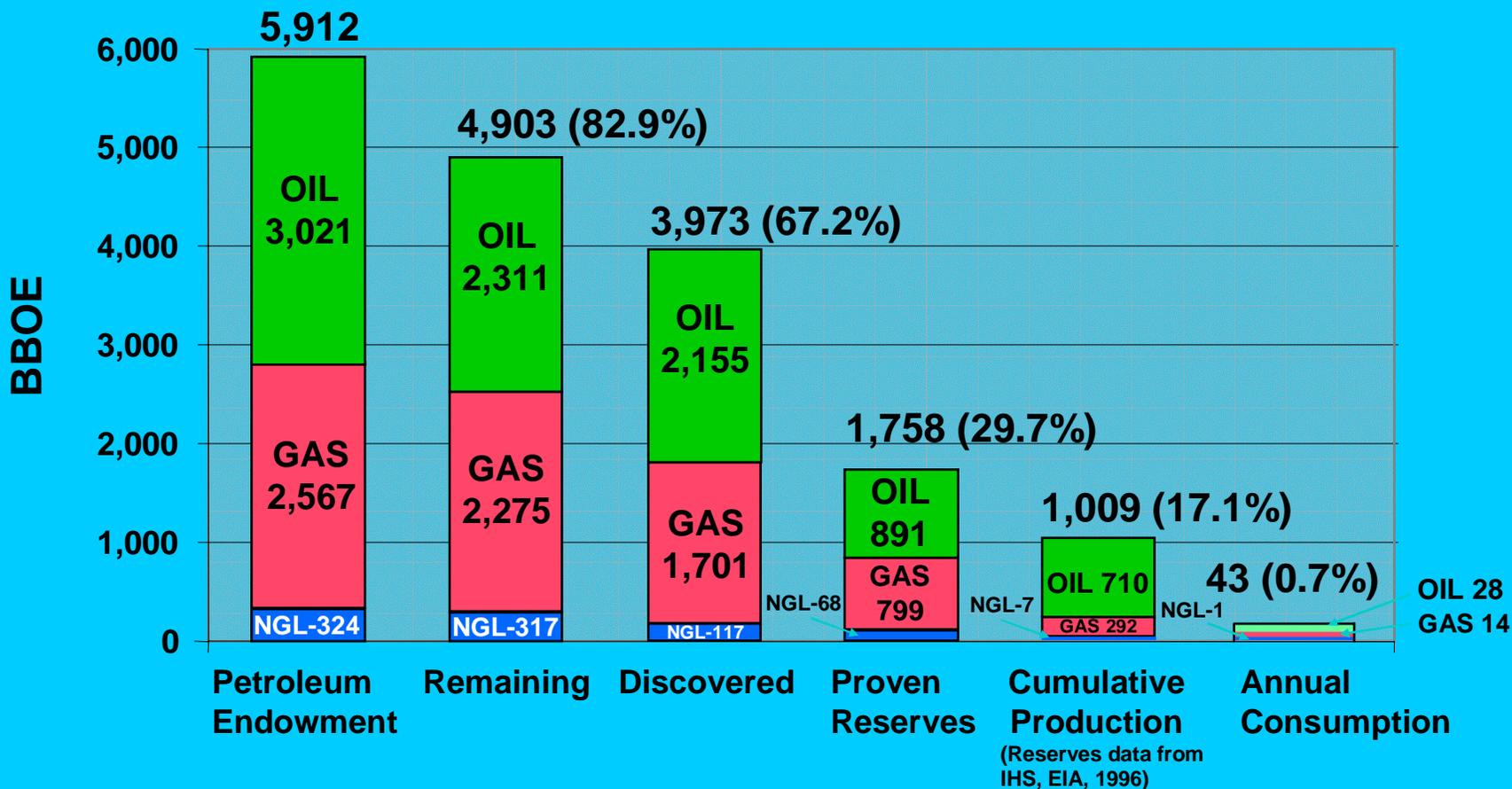
# USGS World Petroleum Assessment 2000

**GAS** (128 World Provinces & U.S., Means Billion barrels oil equivalent [BBOE]) EFF. 1/1/96





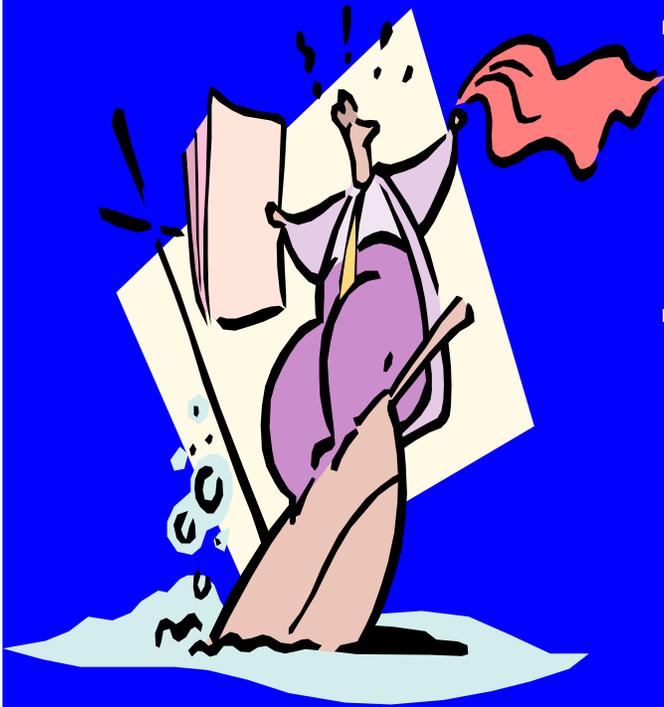
**USGS World Petroleum Assessment 2000**  
**World Petroleum Endowment (128 World Provinces & U.S.)**  
**(Conventional Oil, Gas, NGL, Means in Billion Barrels, EFF. 1/1/96)**



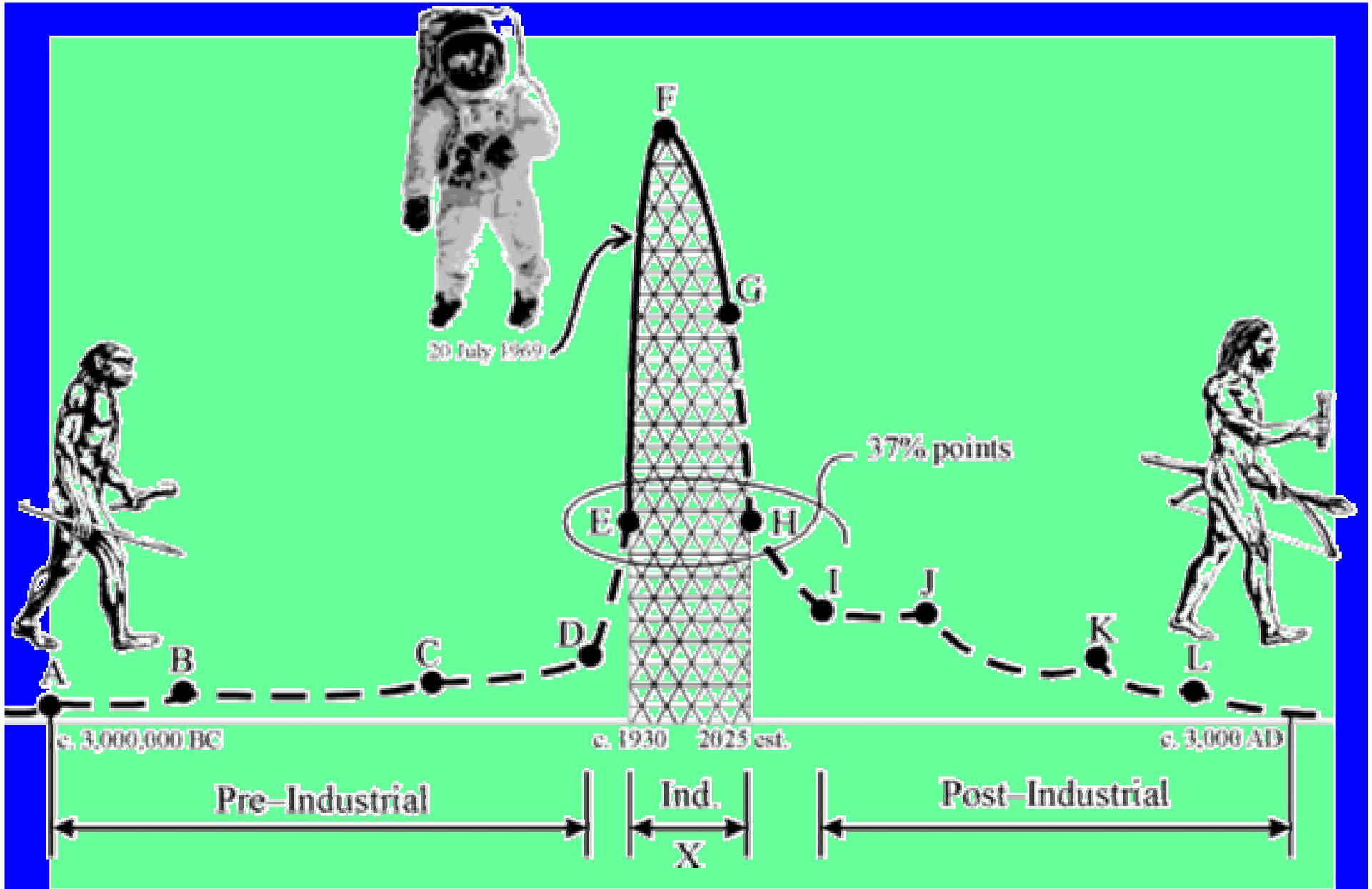
# Critiques

- Oilcrisis.com (Campbell, LaHerrere, and Duncan) and dieoff.com (I don't advise going to this site) view us unfavorably although LaHerrere partially agrees
- Strong endorsement from AAPG (“leveled the playing field”), trade journals, research groups
- IEA Paris 2001: “The most authoritative source of data on global oil and gas resources including both proven reserves and undiscovered resources, is the USGS World Petroleum Assessment 2000.”
- Cavallo (2002), DOE, “USGS WPA 2000 is certainly the best such evaluation that exists to date.....The depth and breadth of this work indicates that these estimates should be the reference values used to understand the future of the petroleum industry.”

# The Coming Oil Crisis?

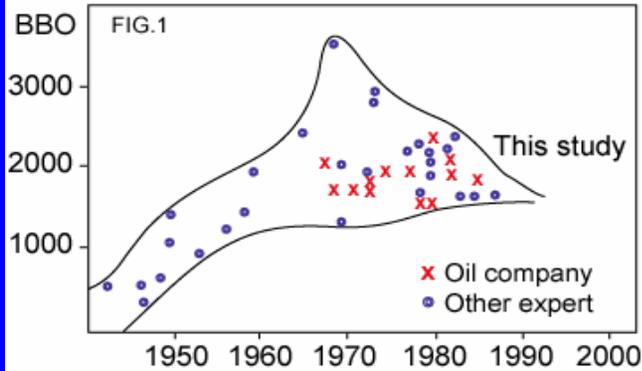


- “..the peak of production will soon be passed—possibly within three years— Dave White, Chief Geologist, USGS, 1919
- “the peak of production will be reached in 1989, Campbell, 1989; prior to 2000”—Campbell, 1994; Duncan, 1997; “in 2004”—Campbell, 1997; “in 2010”, Campbell, 2000--subsequently very dire consequences—most people die, we return to caves-- “Olduvai Theory”



The Olduvai Theory of Industrial Civilization by R.C. Duncan (1997)  
 As posted on oilcrisis.com

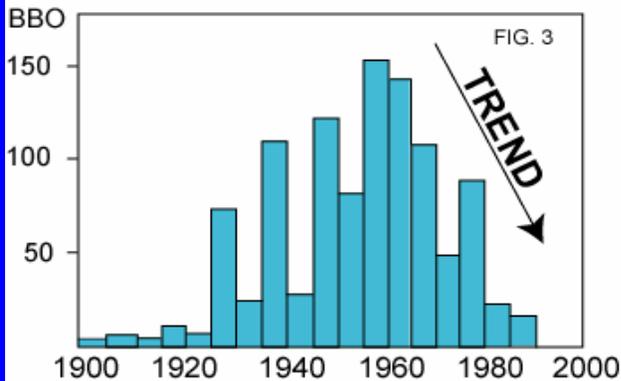
### EXPERT ESTIMATES OF WORLD ULTIMATE OIL RECOVERY



### CONVENTIONAL OIL ONLY

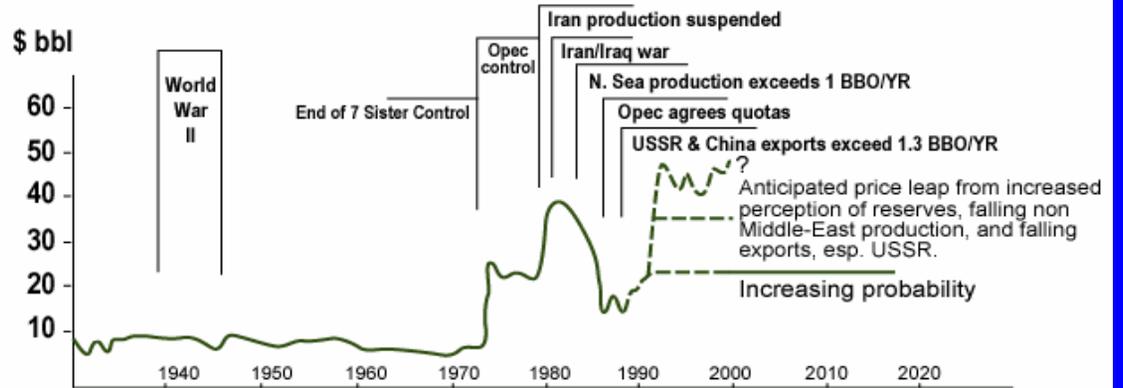
Ignores:  
 "Unconventional" enhanced recovery  
 Tar sands  
 Oil shales  
 Gas liquification advances

### GIANT DISCOVERIES 400 FIELDS >0.5 BBO

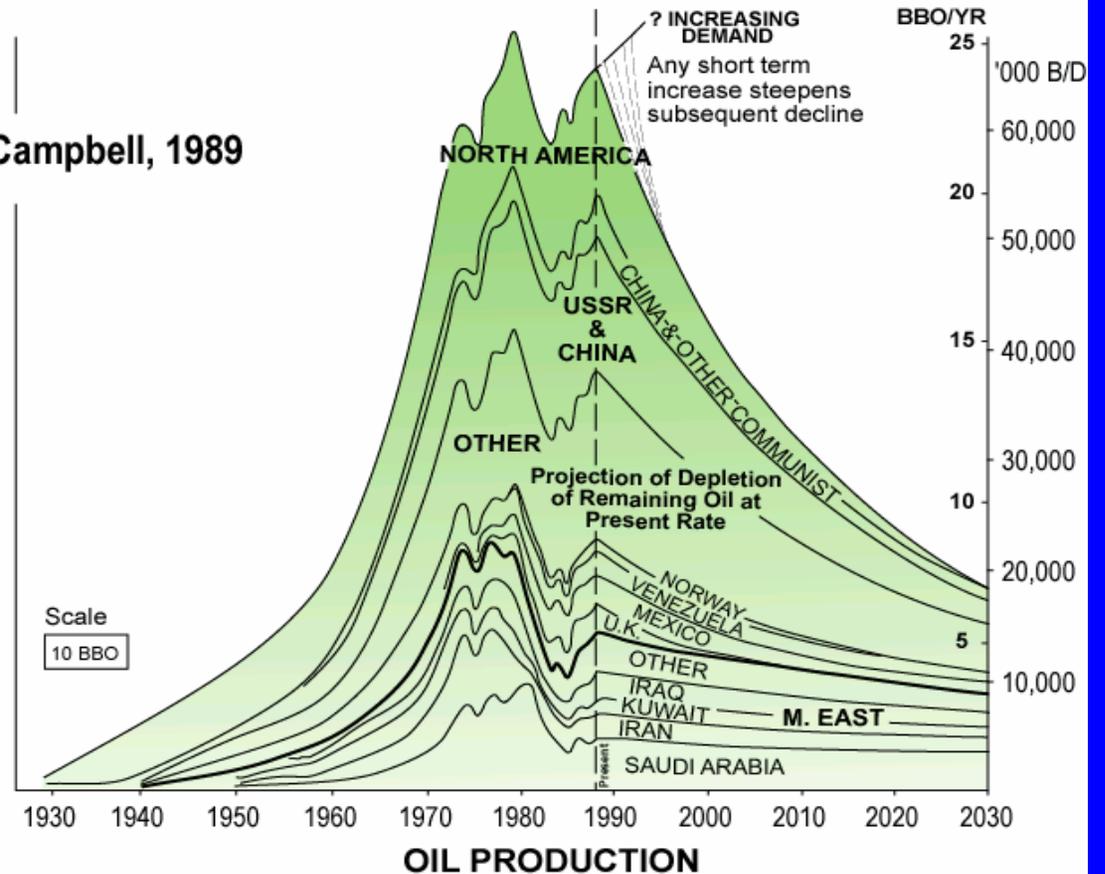


TREND HERALDS END OF GIANT DISCOVERIES--  
 50% of all discovered to date came from GIANT FIELDS

### CRUDE OIL PRICE 1987 \$



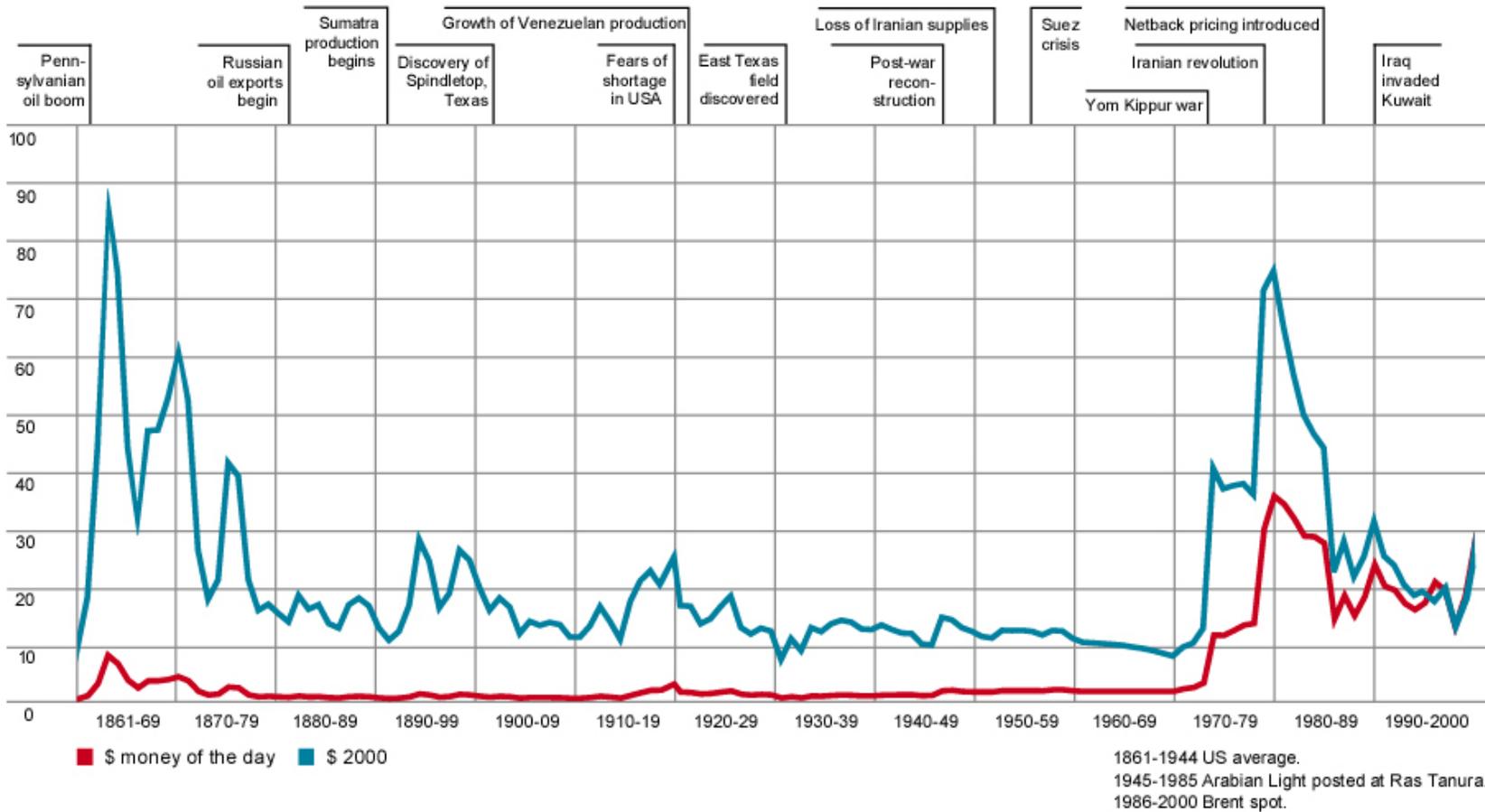
### Campbell, 1989



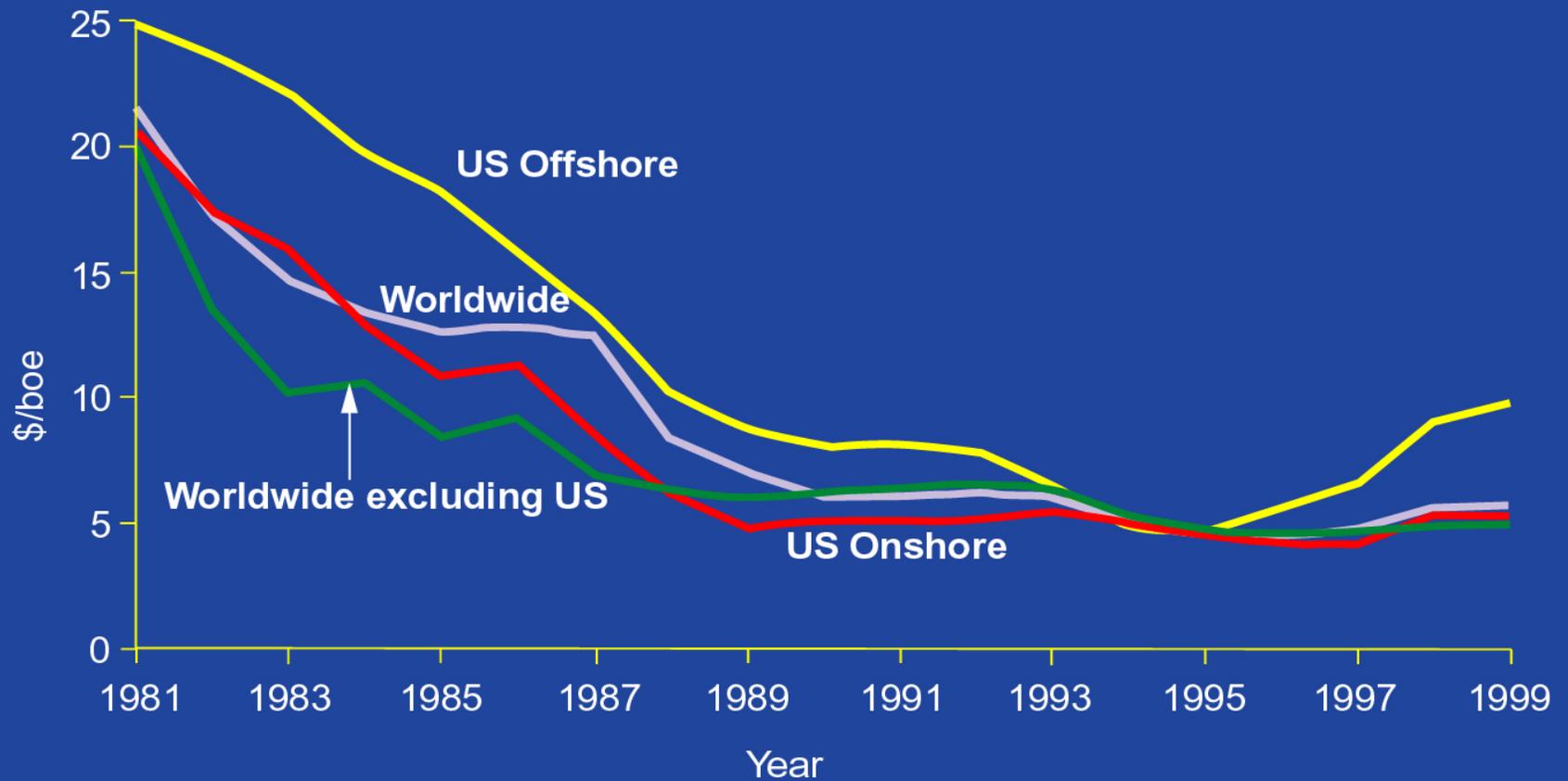
# Crude oil prices since 1861

## US dollars per barrel

World events

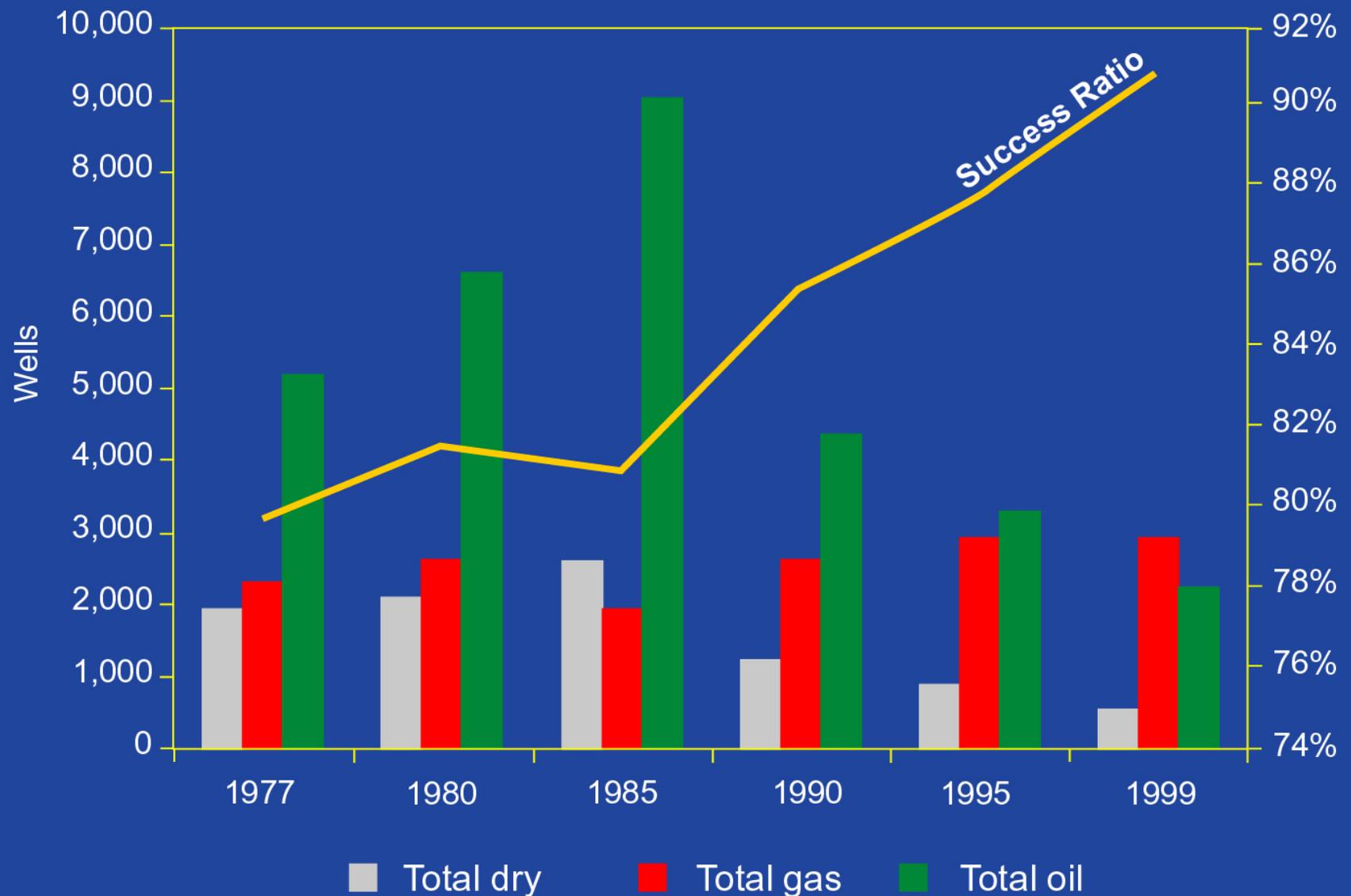


## Trends in Finding & Developing Costs, Three-Year Moving Averages, 1979-1981 to 1997-1999



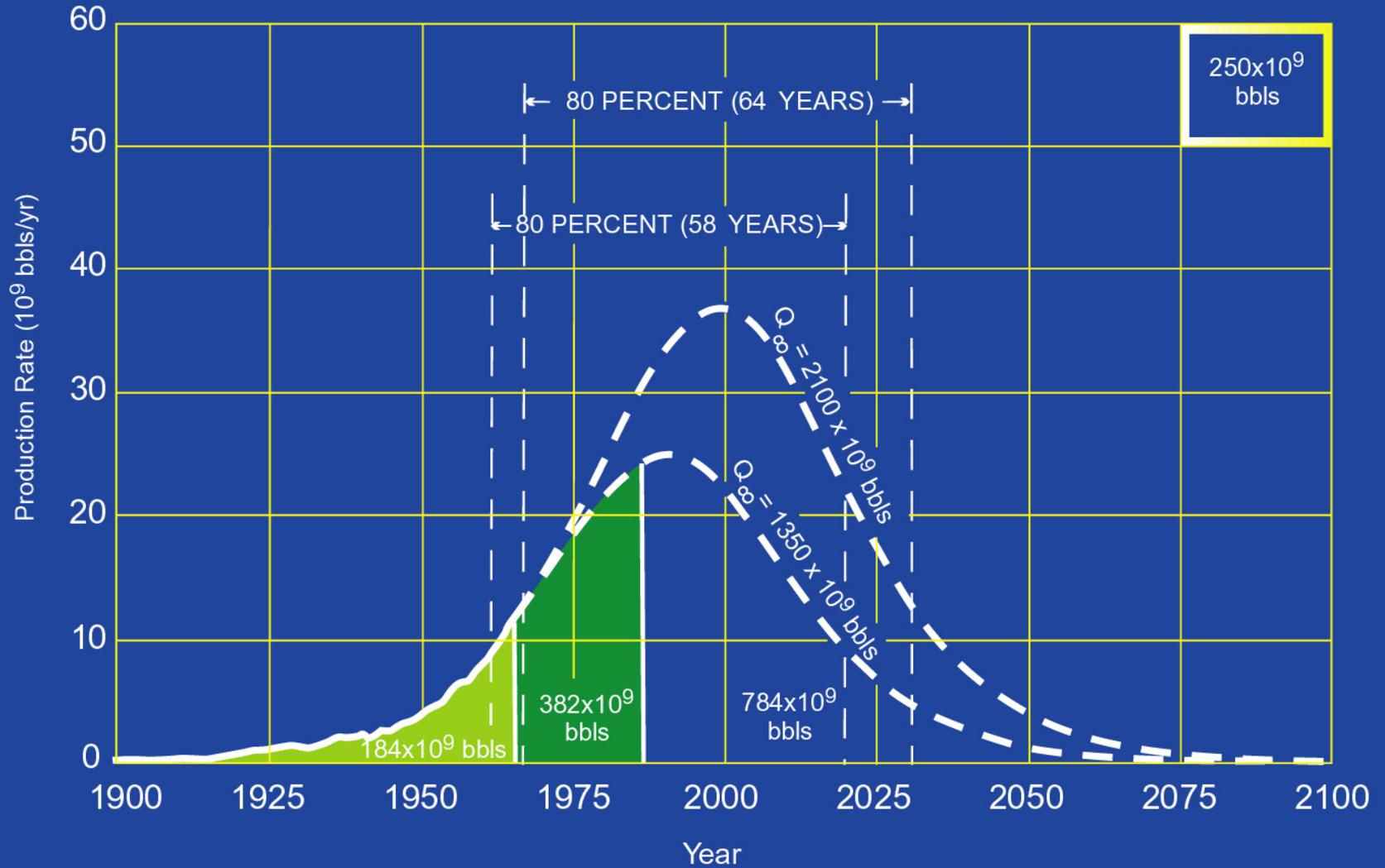
IEA, EIA, 2001

## Trends in Oil and Gas Well Drilling and Success Ratio For The World



IEA, EIA, 2001

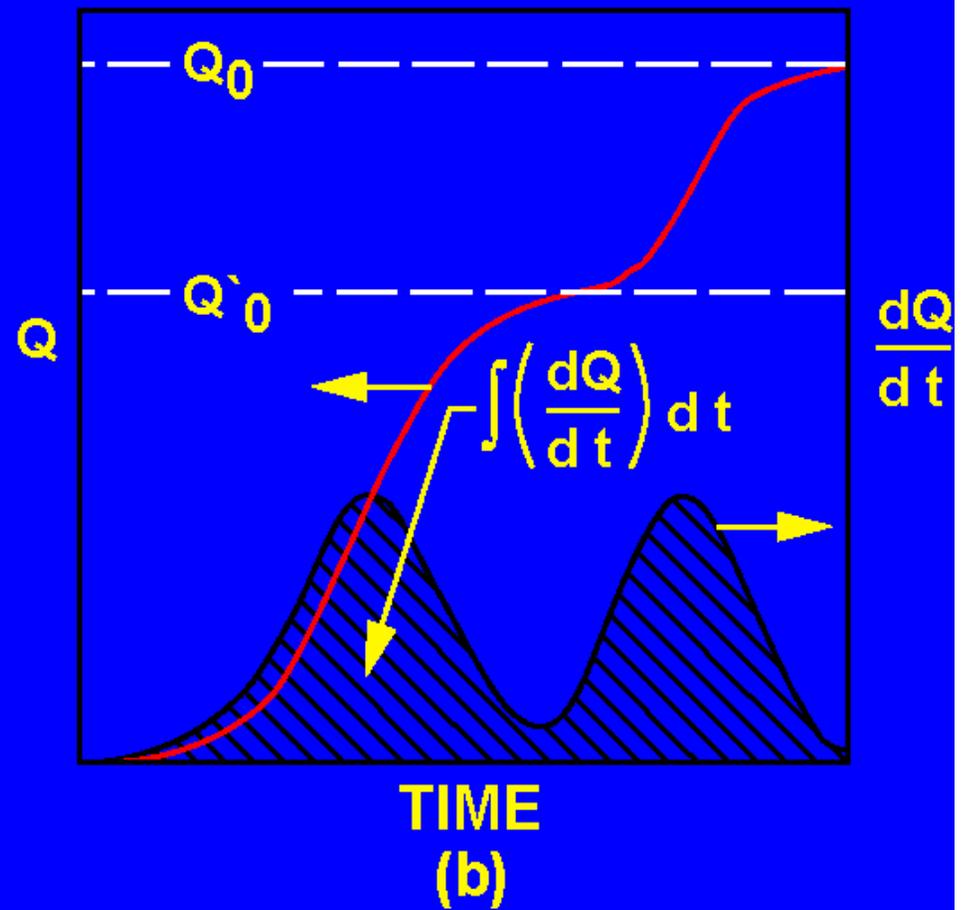
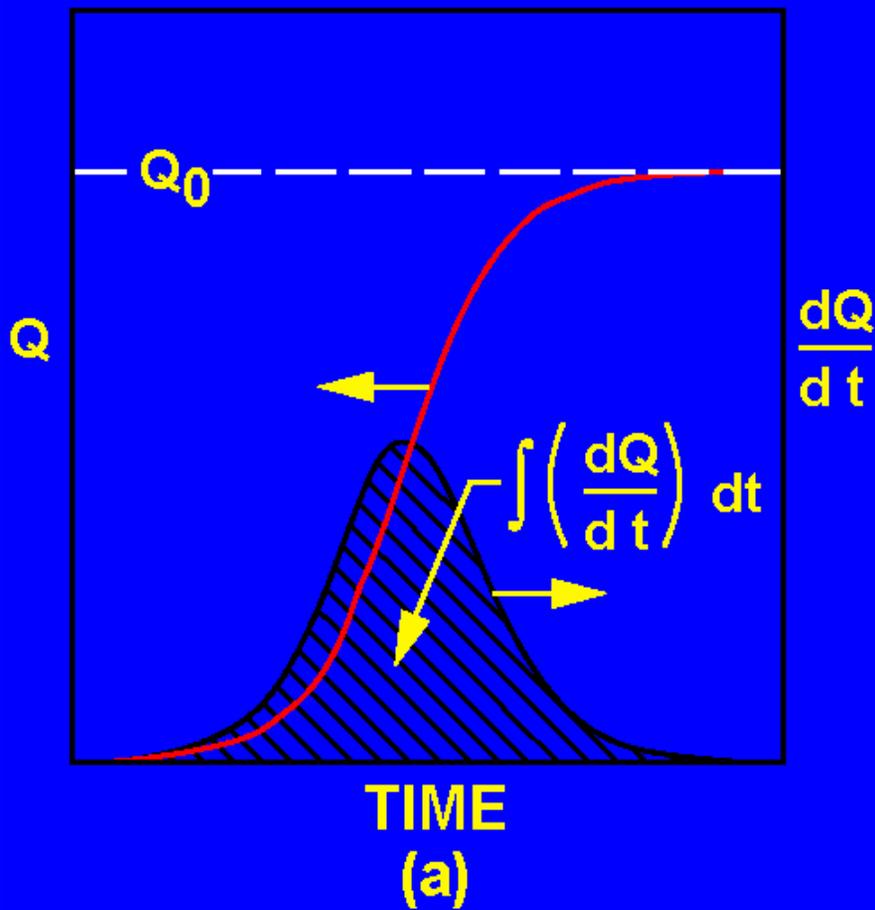
# World Oil Supply



**HUBBERT, 1969**

$1 \times 10^9$  bbls - 1 BBO

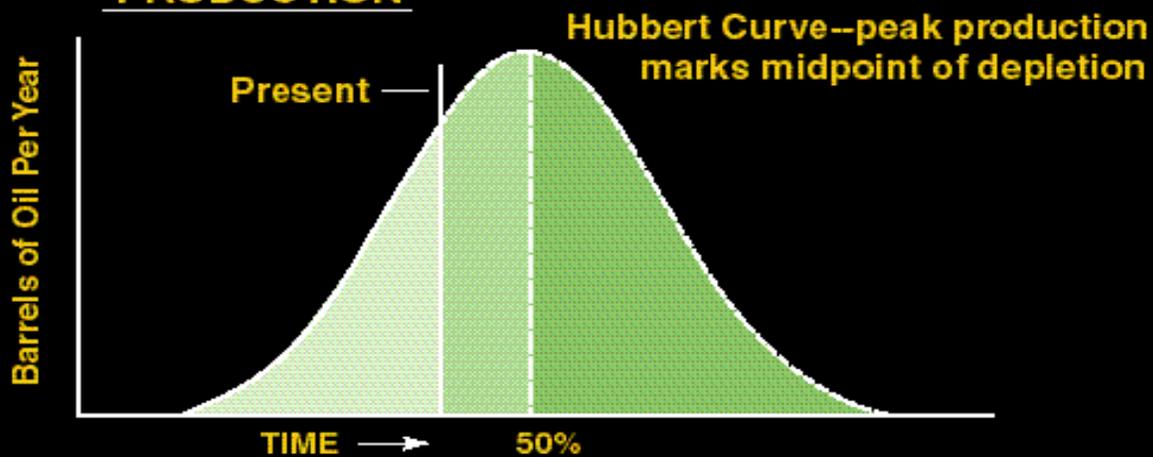
**Logistic growth curves of cumulative production and their derivatives which give the rates of production (Hubbert, 1959)**



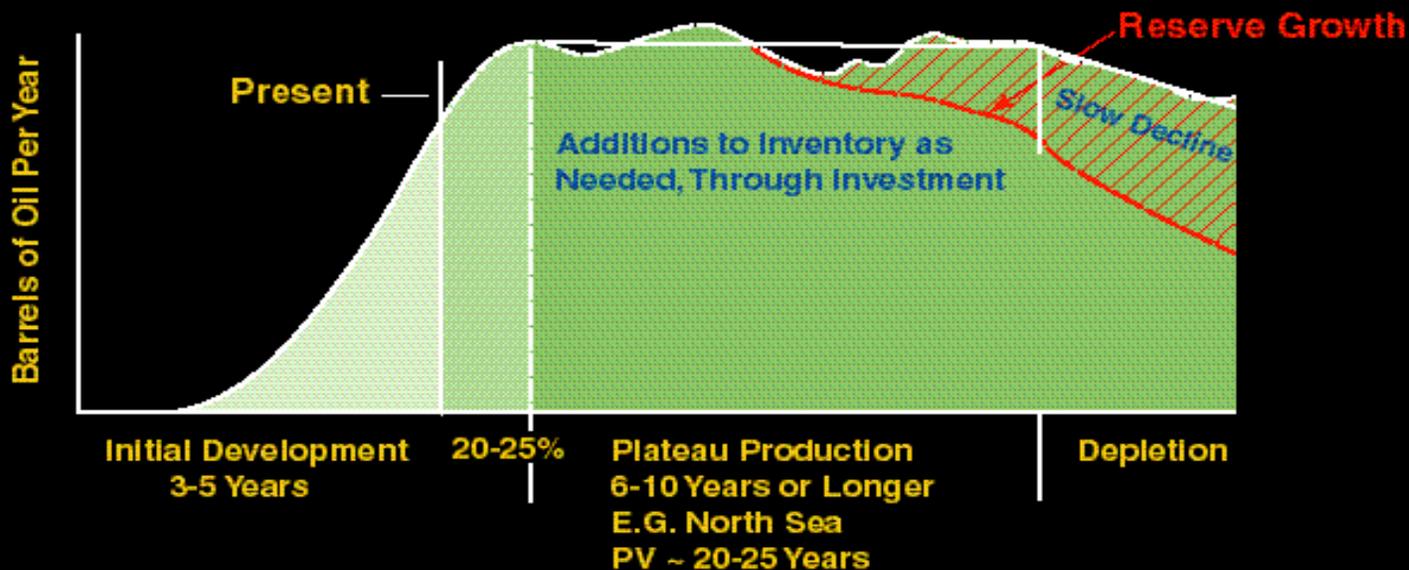
**(a) single-cycle curve**

**(b) multiple-cycle curve**

**PRODUCTION**



**PLATEAU CONCEPT**

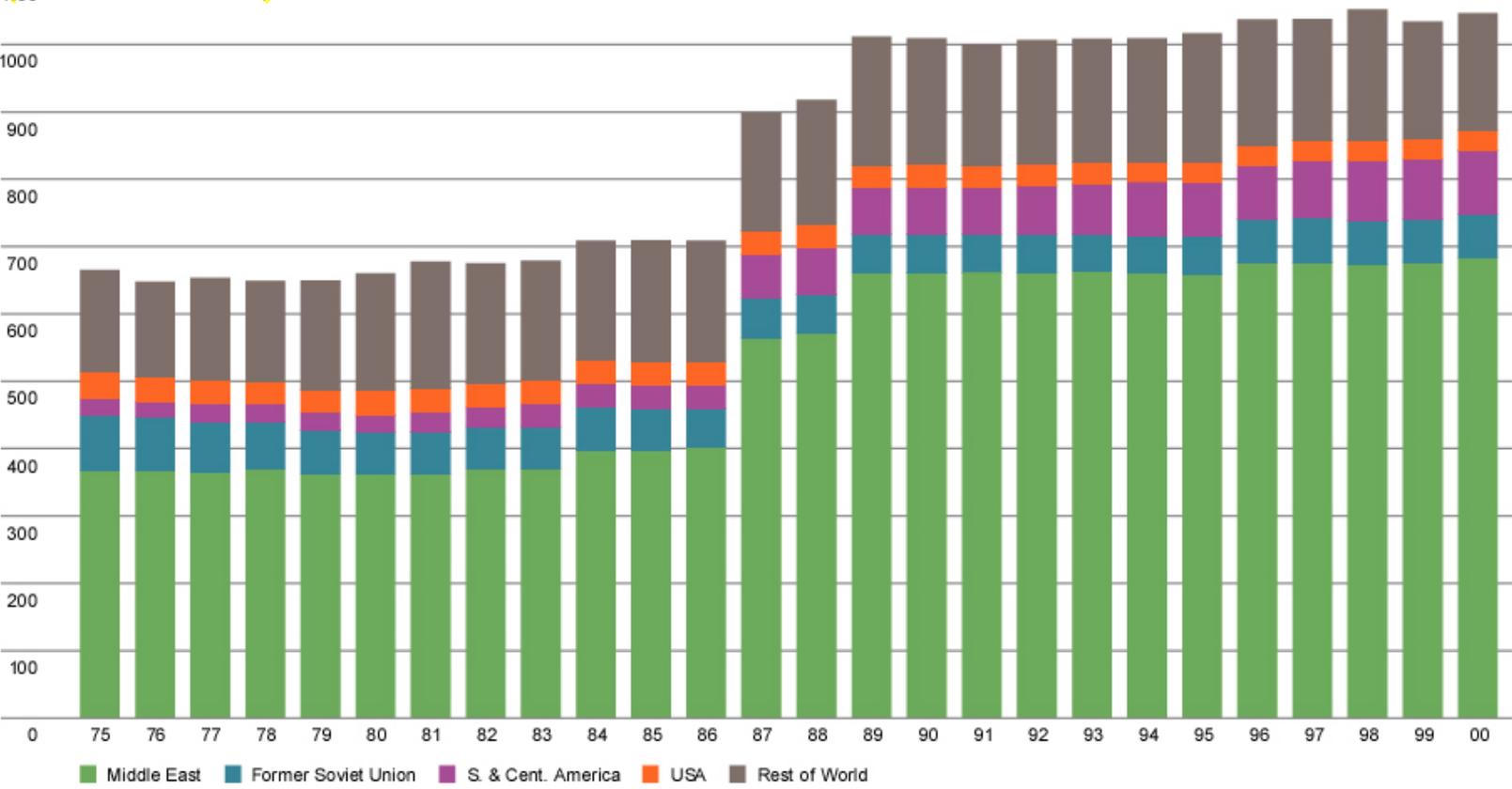


# Increasing Proved Oil & NGL *Reserve Estimates*

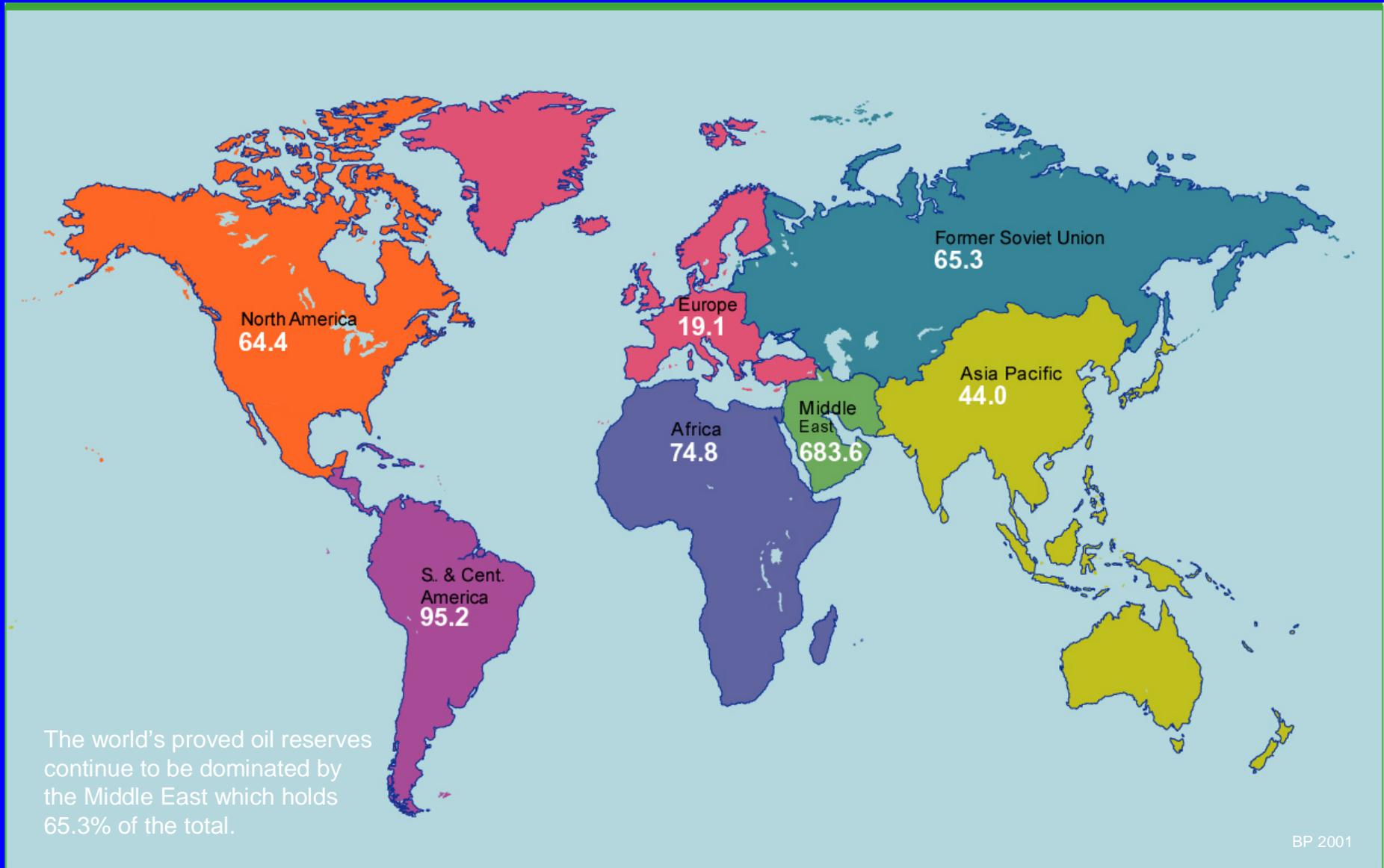
■ IHS Energy	1,100 BBO	12/2000
■ OPEC	1,078 BBO	12/2000
■ World Energy Council	1,051 BBO	12/1999
■ Oil and Gas Journal	1,028 BBO	12/2000
■ World Oil	1,003 BBO	12/2000
■ USGS 2000/ IHS DATA	960 BBO	12/1995
■ Campbell 2000	845 BBO	12/2000
■ Campbell 1988	725 BBO	12/1988

# Oil proved reserves

(billion barrels)



# Oil proved reserves at end 2000 (billion barrels)



# Major oil trade movements

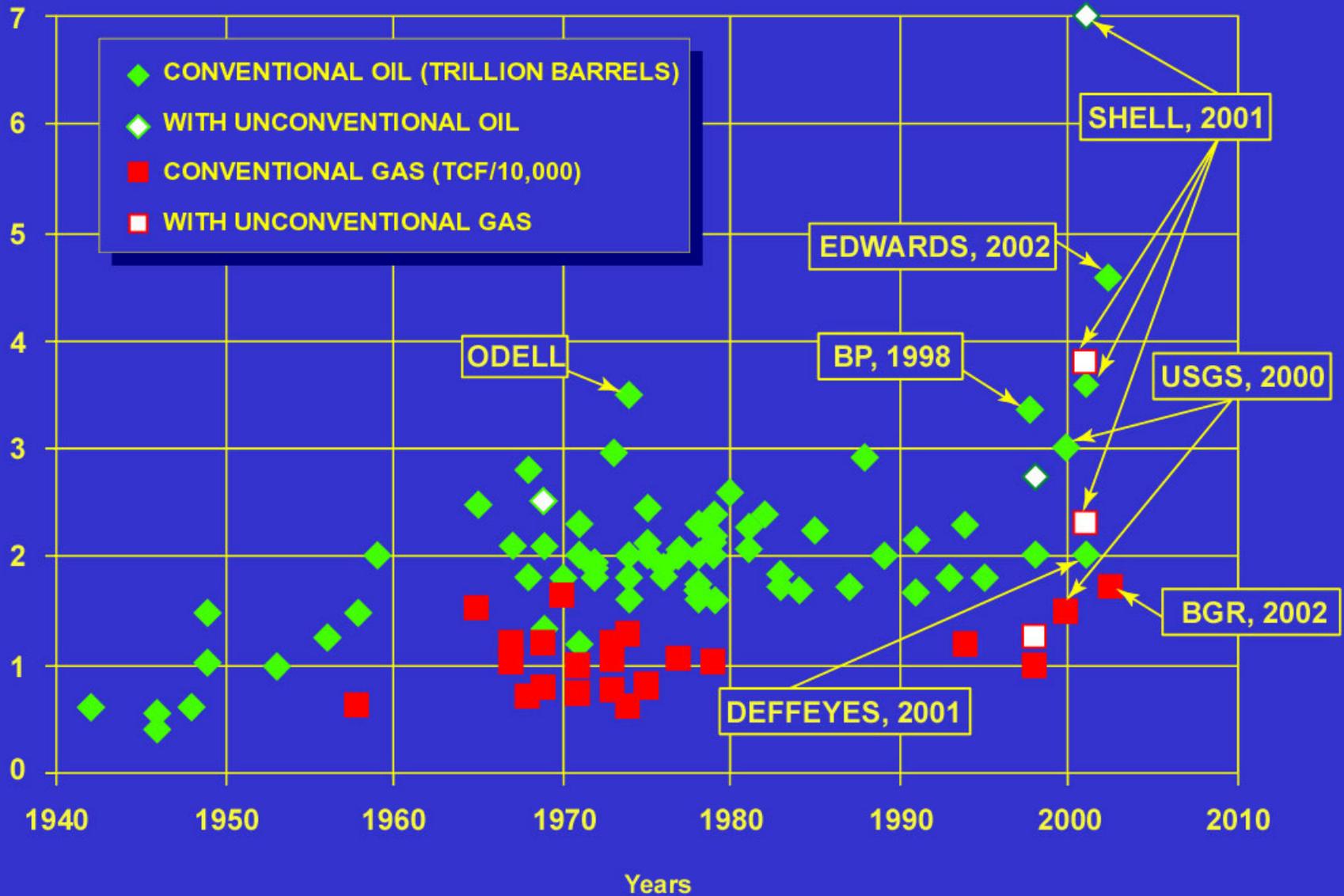
## Trade flows worldwide (million barrels of oil\*)



\*based on average 33API

# WORLD'S OIL (& LIQUIDS) AND GAS ULTIMATES

Ultimate Oil in Trillion Barrels, Gas in Trillion Cubic Feet/10,000



# World Oil

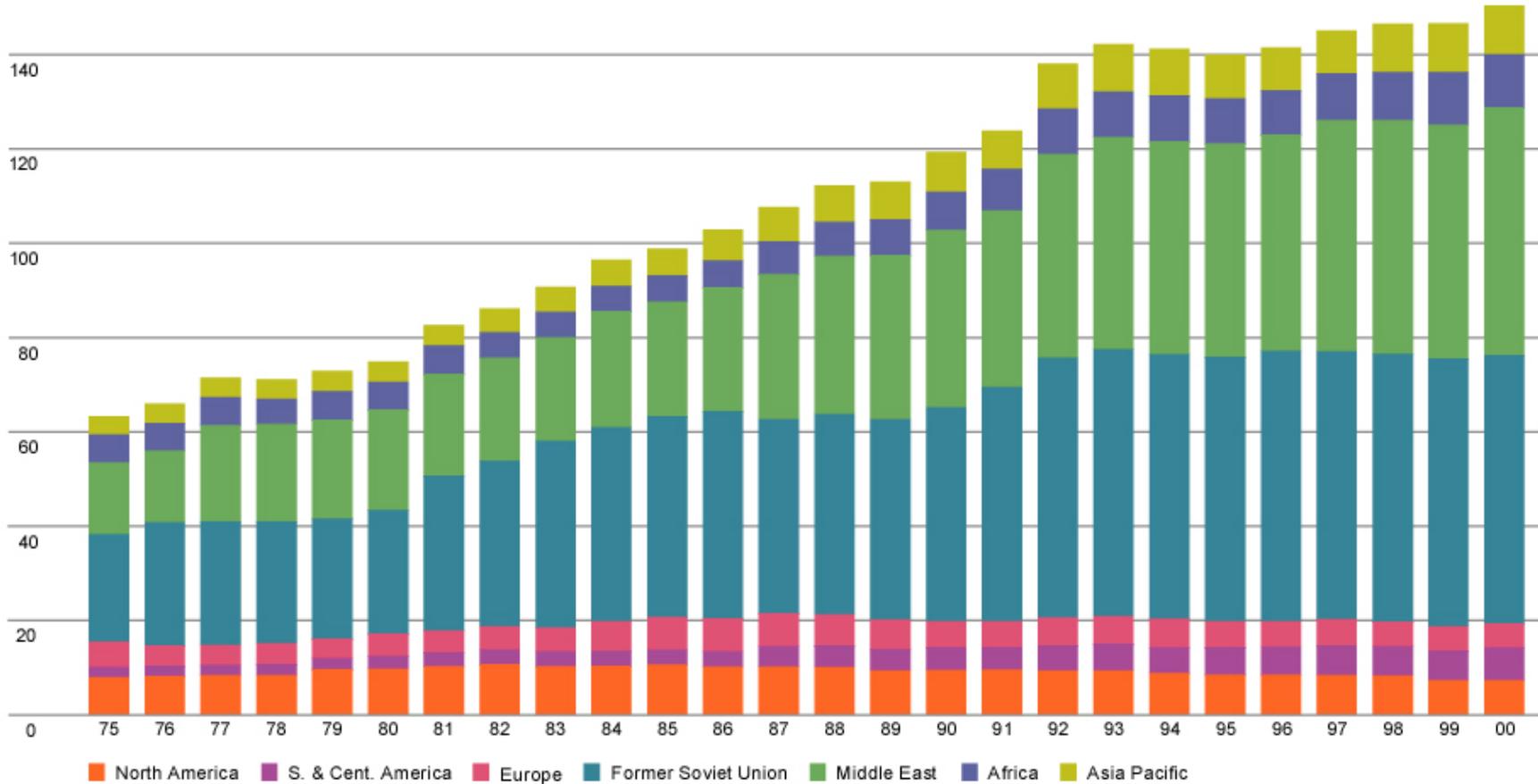
- Currently Consuming about 28 BBO / Year
- Remaining Reserves ~891 BBO (1/1/96), 1,100 BBO as of 1/1/2001)—Increase of 15%
- Differing Views
  - In 1989, C.J. Campbell predicted peaking in 1989, in 1994 predicted within 5 years (before 2,000); with a total endowment of ~1,800 BBO
  - In 2000, USGS estimated an oil endowment of ~3,000 BBO, and DOE/EIA using this data predicted peaking in ~2036; **Revised to 2015-2020 for Non-OPEC (Cavallo, 2002)**
  - World Petroleum Reserves are at all time high
  - Oil and Gas Discoveries have both increased in the 90's

## OR is it World Gas?

- Much less utilized worldwide than oil (11% produced vs. 23% for oil)
- LNG and GTL technology make it increasingly viable—The Natural Gas Revolution
- Environmental benefits or detriments
- The conventional / unconventional linkage—news on gas hydrates
- Where is it, is it economic, and in what time frame?

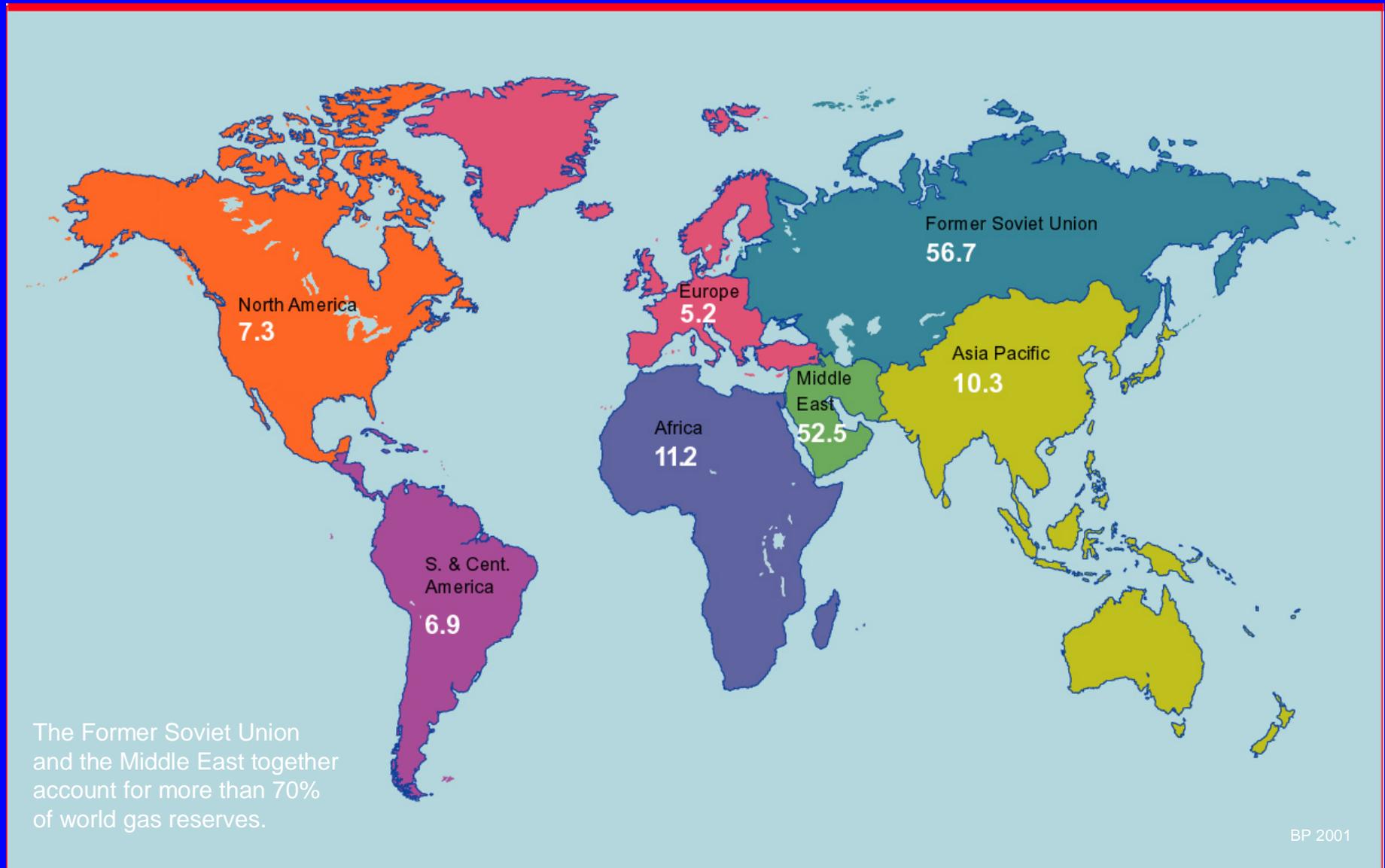
# Proved reserves

Trillion cubic metres



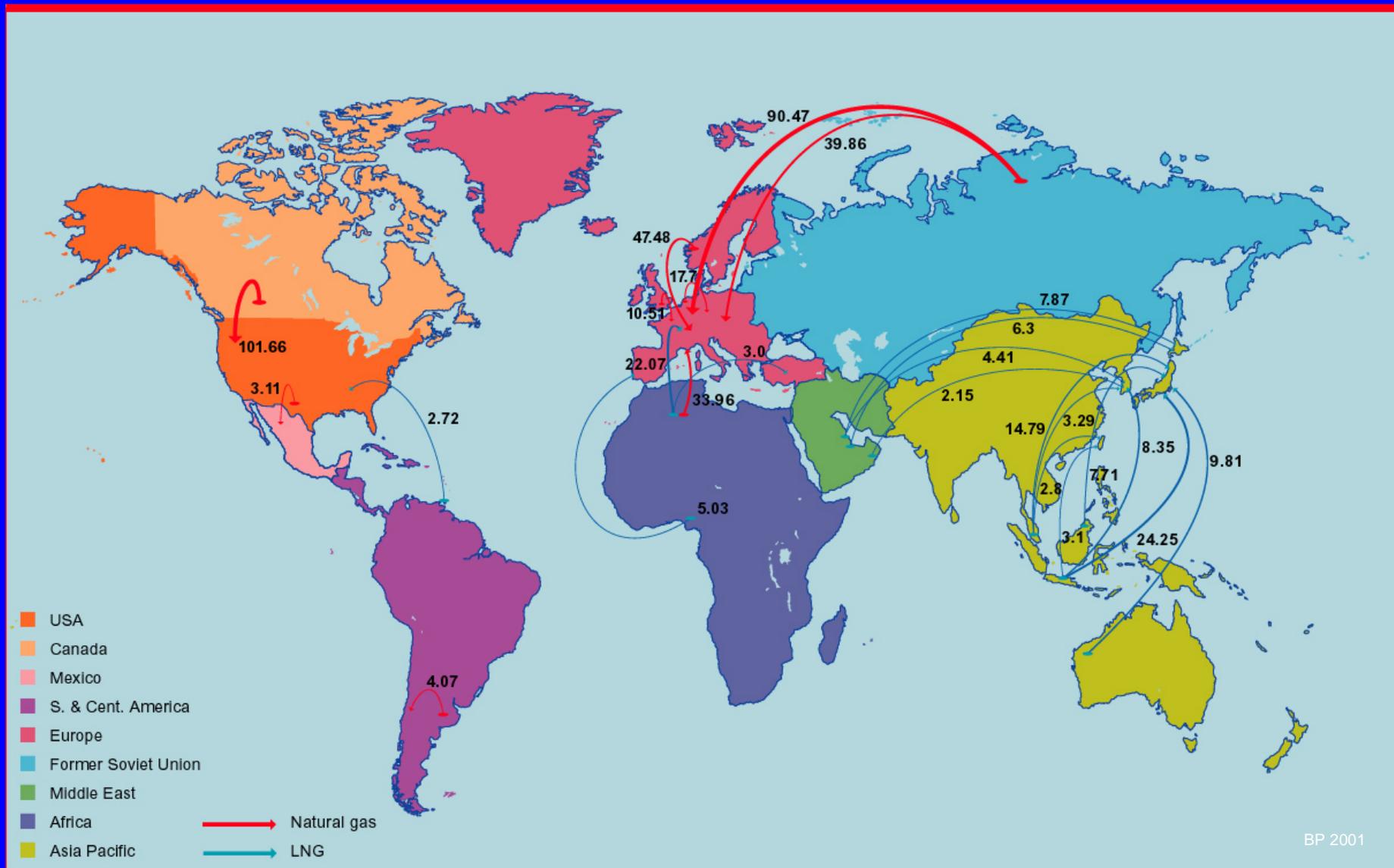
# Gas proved reserves at end 2000

Trillion cubic metres

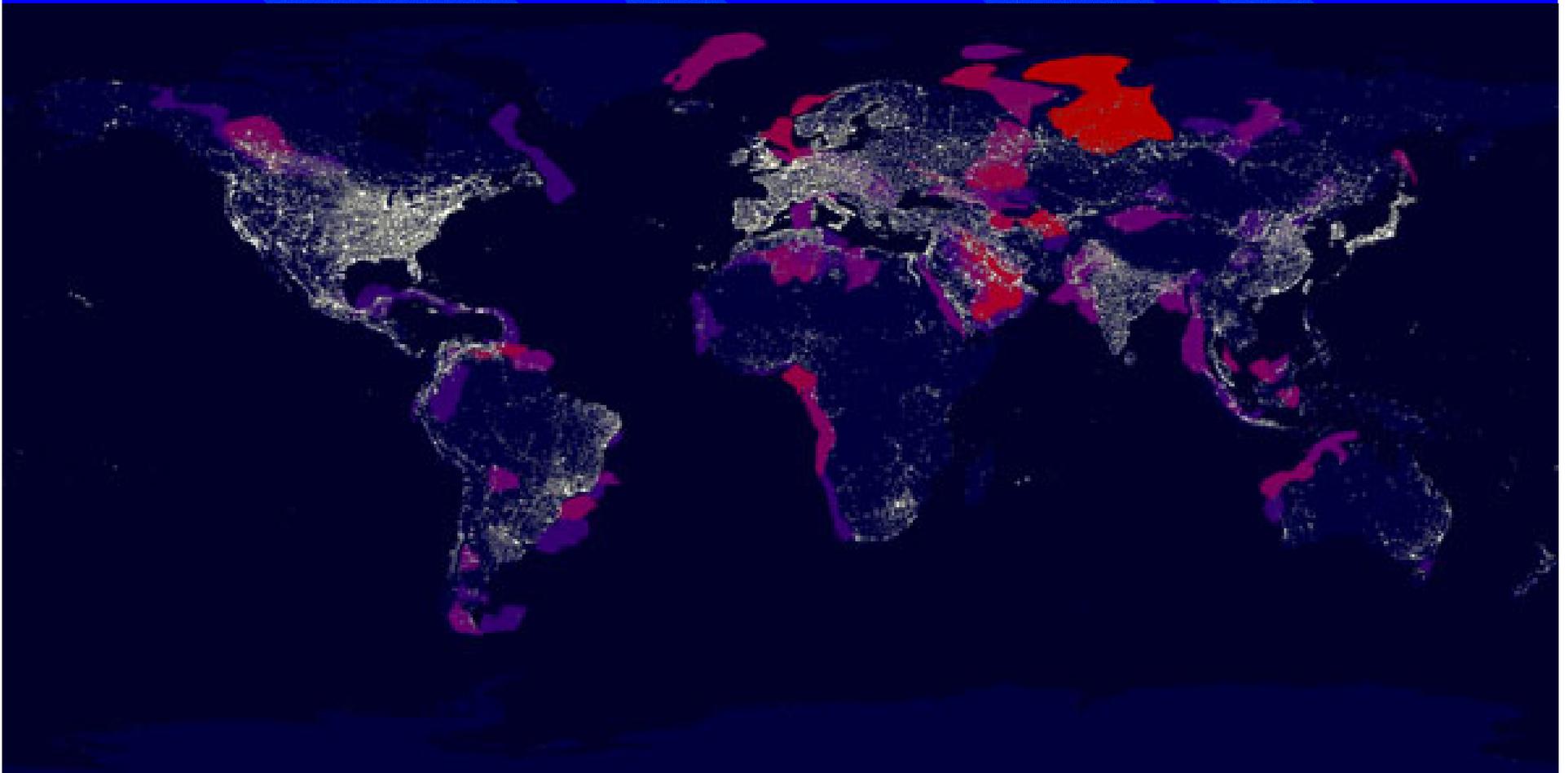


# Major gas trade movements

## Trade flows worldwide (billion cubic metres)



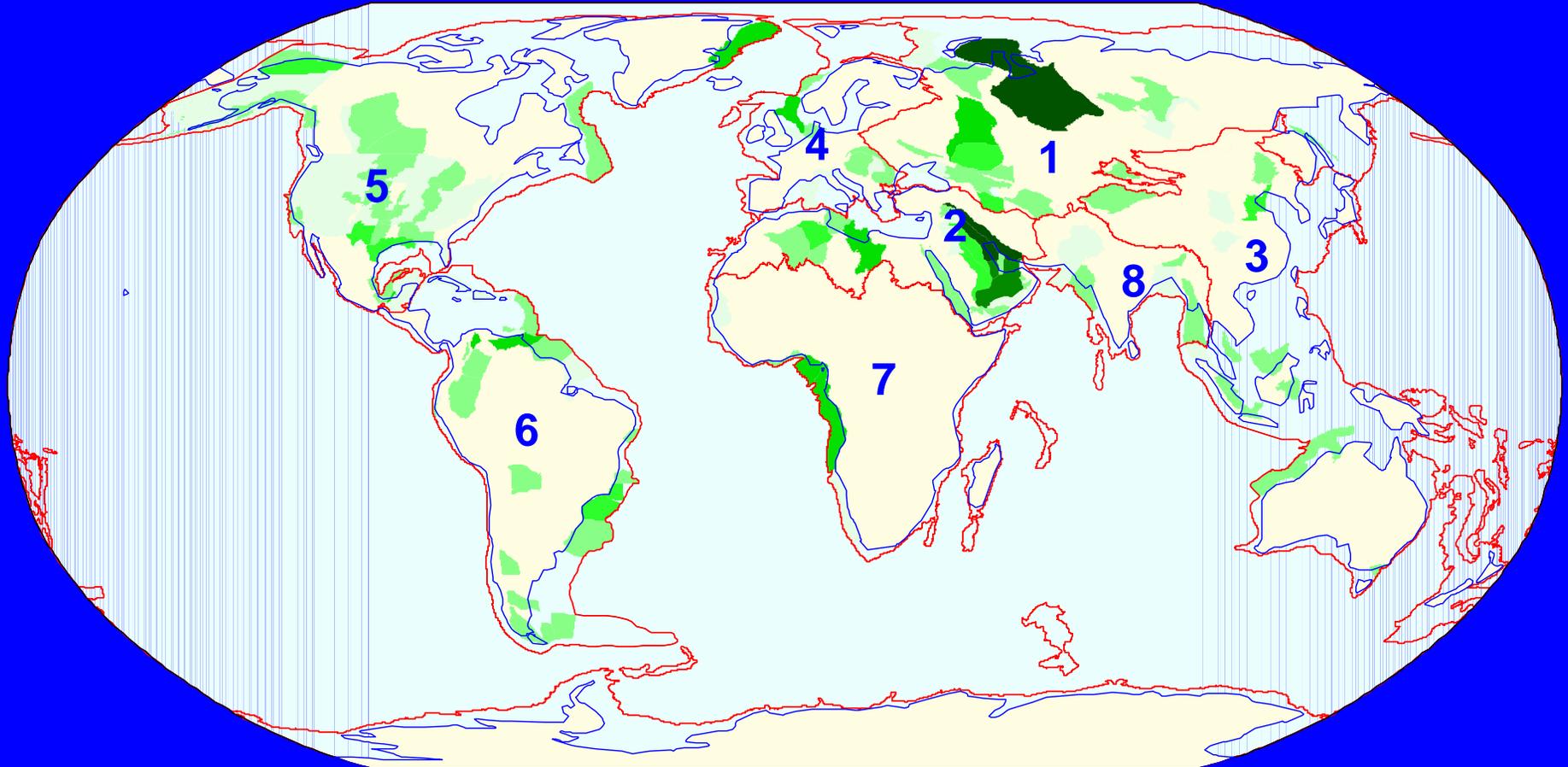
# USGS 2000 Gas endowment (graduated red color) of assessed provinces superimposed over “Earth at Night” Image





# USGS World Petroleum Assessment 2000

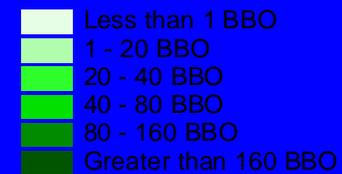
- **Undiscovered Petroleum (Masters vs World w/US. +9.5% at Mean) 1650 BBOE vs 1805 BBOE**
  - **Undiscovered Oil (732BB; +24%)**
  - **Undiscovered Gas (5196TCF or 866 BBOE; -10%)**
  - **Undiscovered NGL (207 BBOE; +104%)**
  - **W/O U.S. (+5% at Mean)**



## Conventional Oil Endowment of the World

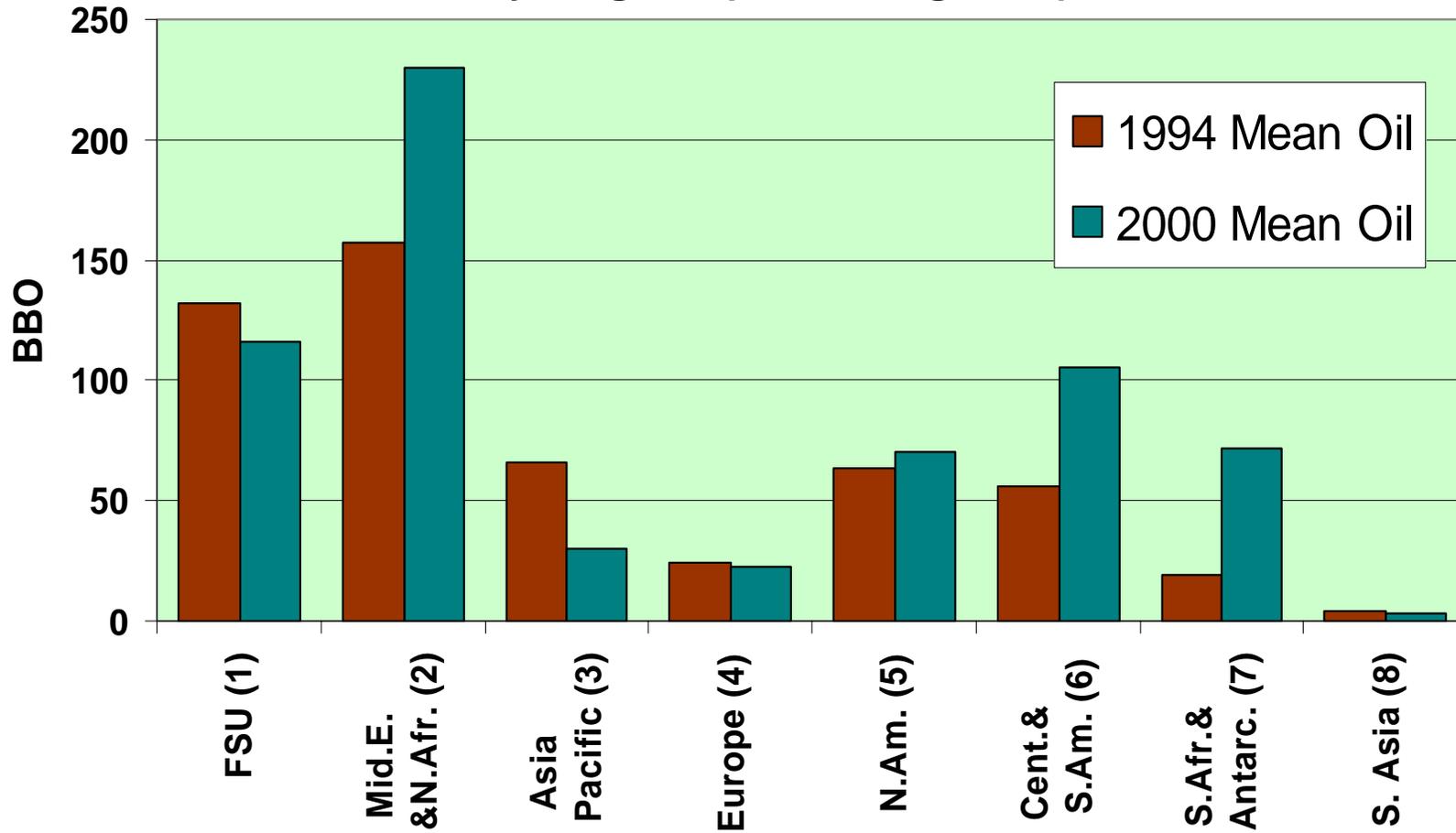
- 1 Former Soviet Union
- 2 Middle East and North Africa
- 3 Asia Pacific
- 4 Europe
- 5 North America
- 6 Central and South America
- 7 Sub-Saharan Africa and Antarctica
- 8 South Asia

Conventional Oil Endowment in Billions of Barrels



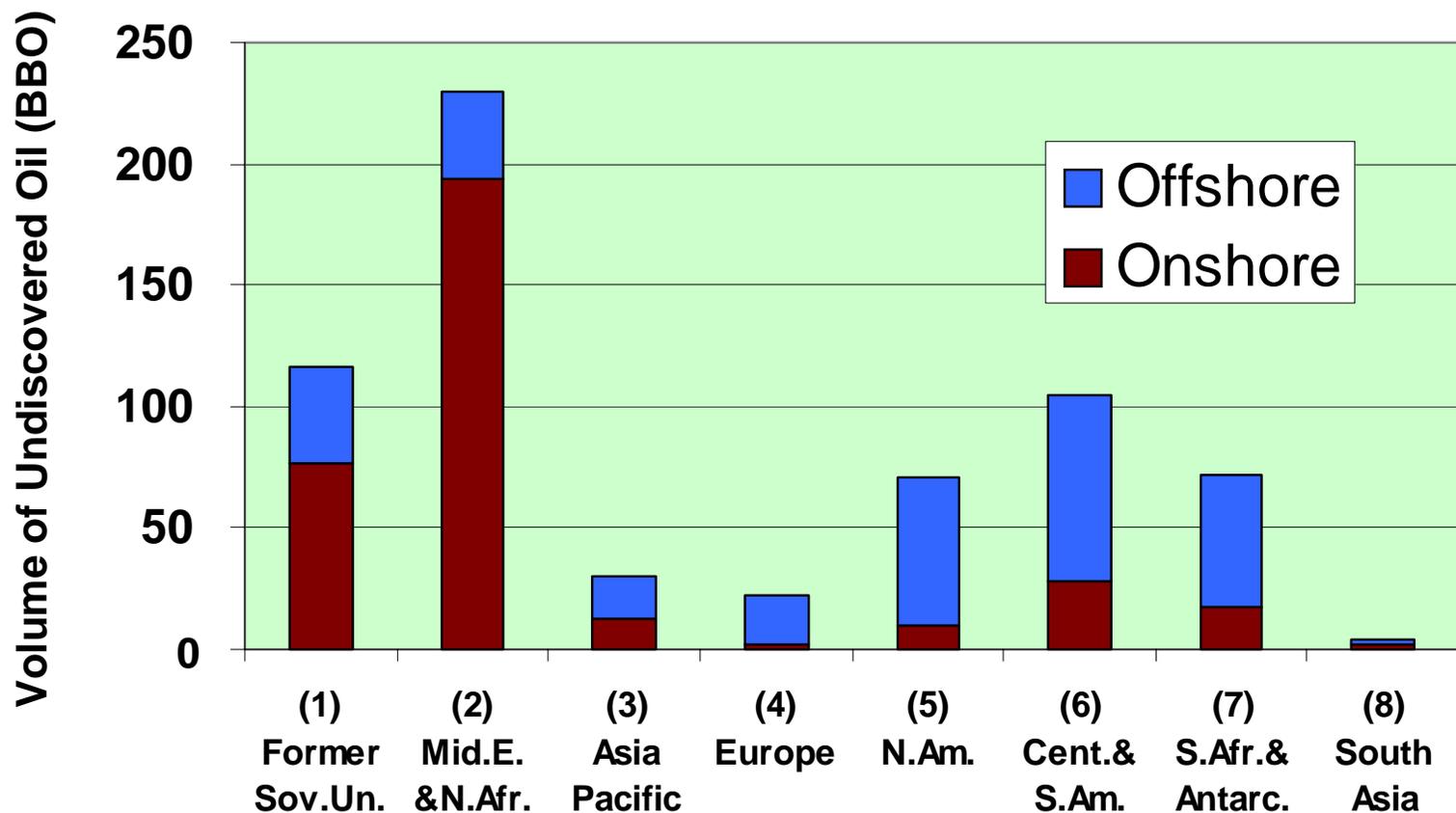
Conventional oil endowment

### Comparison of USGS Mean Undiscovered Oil by Region (excluding U.S.)

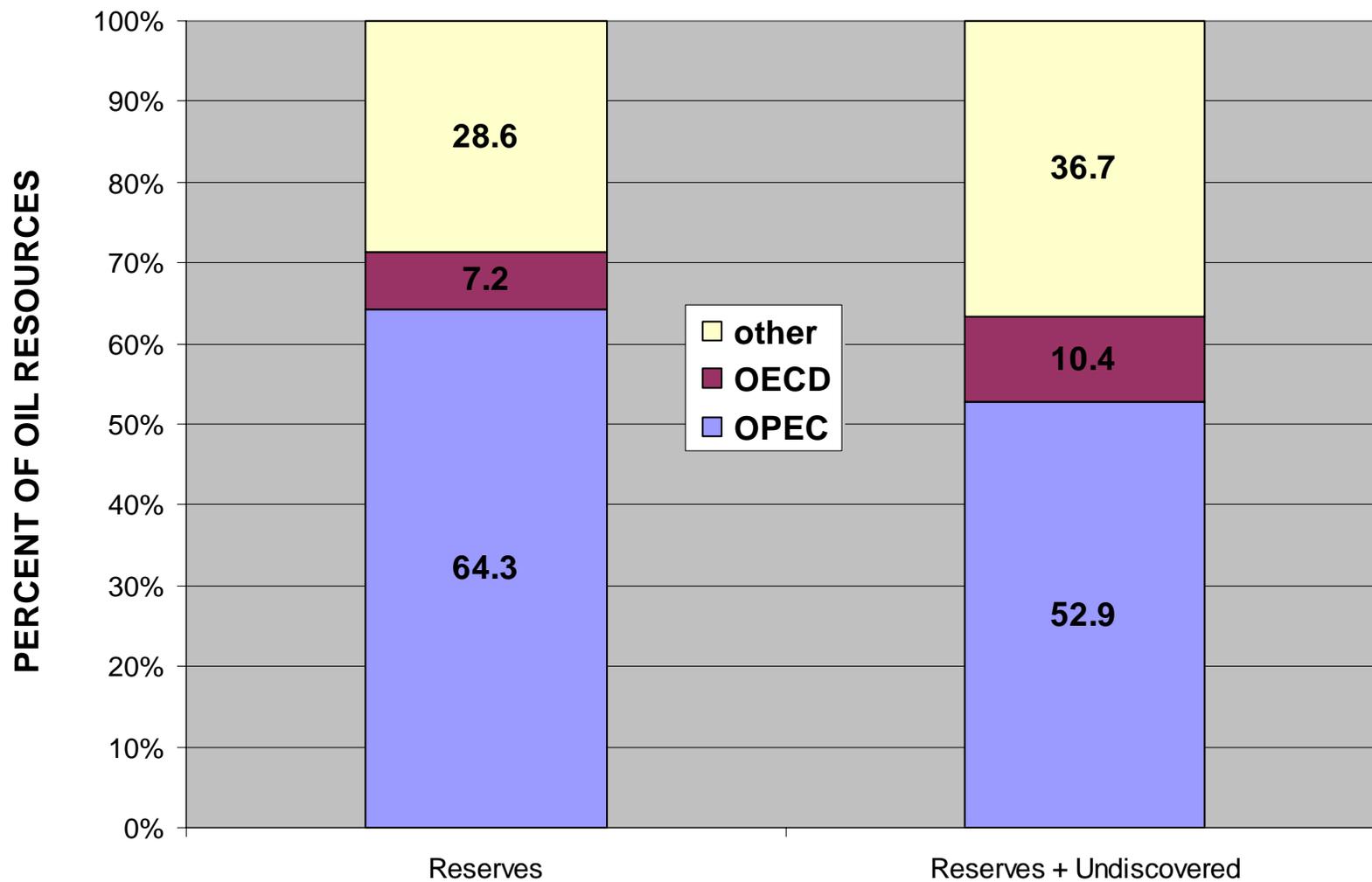


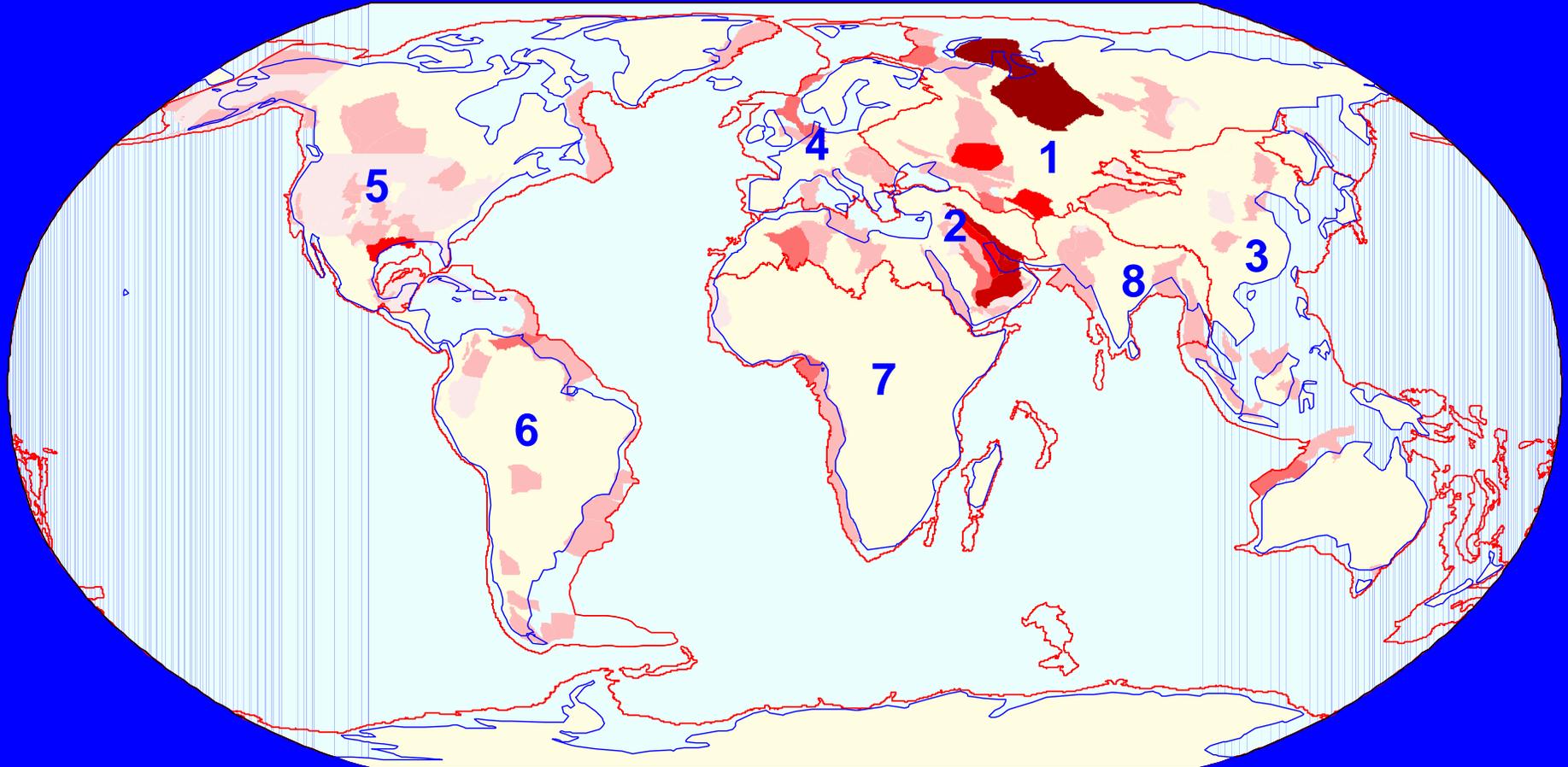
## *USGS World Petroleum Assessment 2000*

### Undiscovered Oil by Region



## Possible Changes in Organization Share of Oil

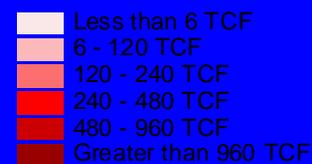




## Conventional Natural Gas Endowment of the World

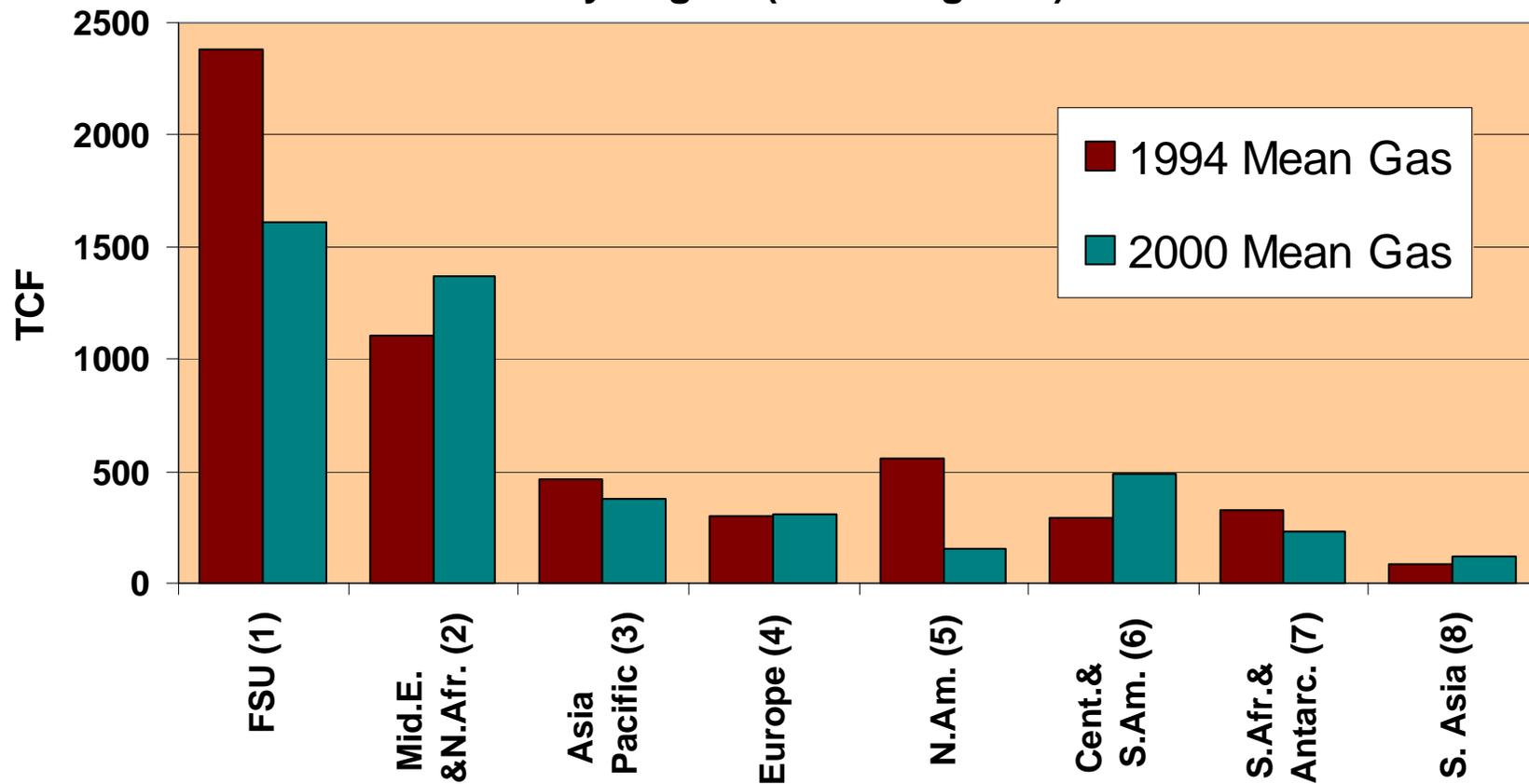
- Former Soviet Union
- Middle East and North Africa
- Asia Pacific
- Europe
- North America
- Central and South America
- Sub-Saharan Africa and Antarctica
- South Asia

Conventional Natural Gas Endowment in Trillions of Cubic Feet

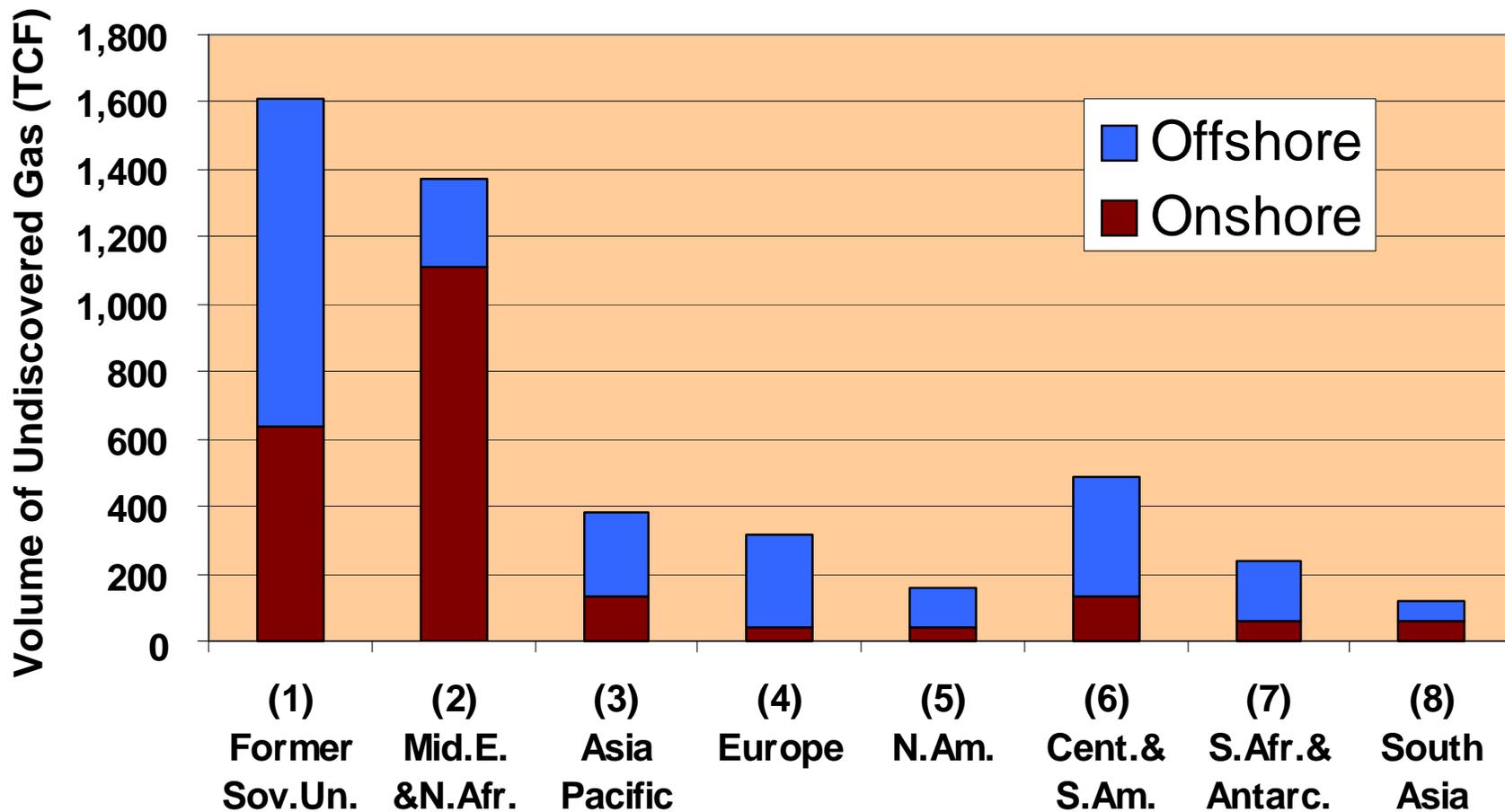


Conventional gas  
 endowment

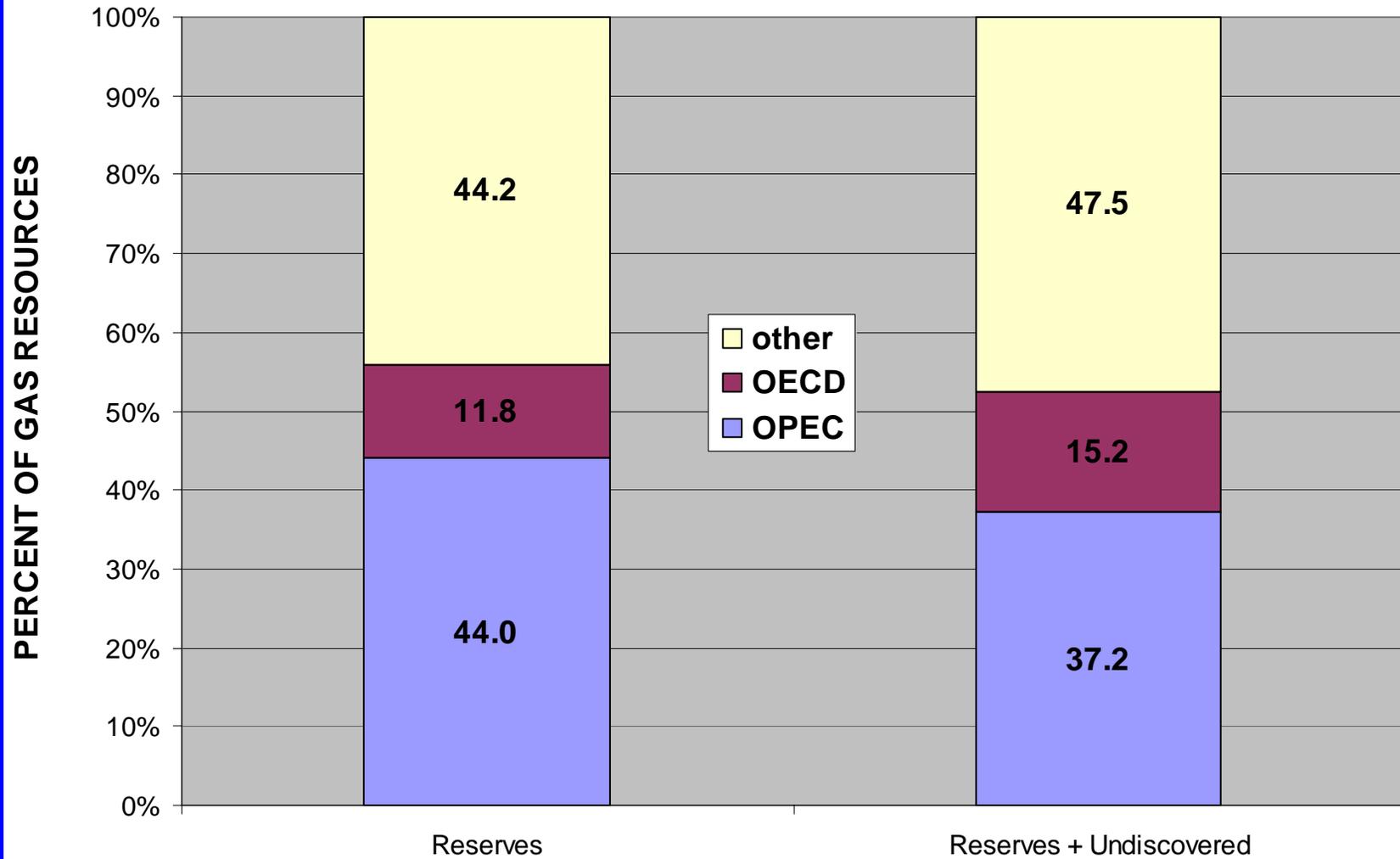
### Comparison of USGS Mean Undiscovered Gas by Region (excluding U.S.)



## USGS World Petroleum Assessment 2000 Undiscovered Gas by Region



## Possible Changes in Organization Share of Gas



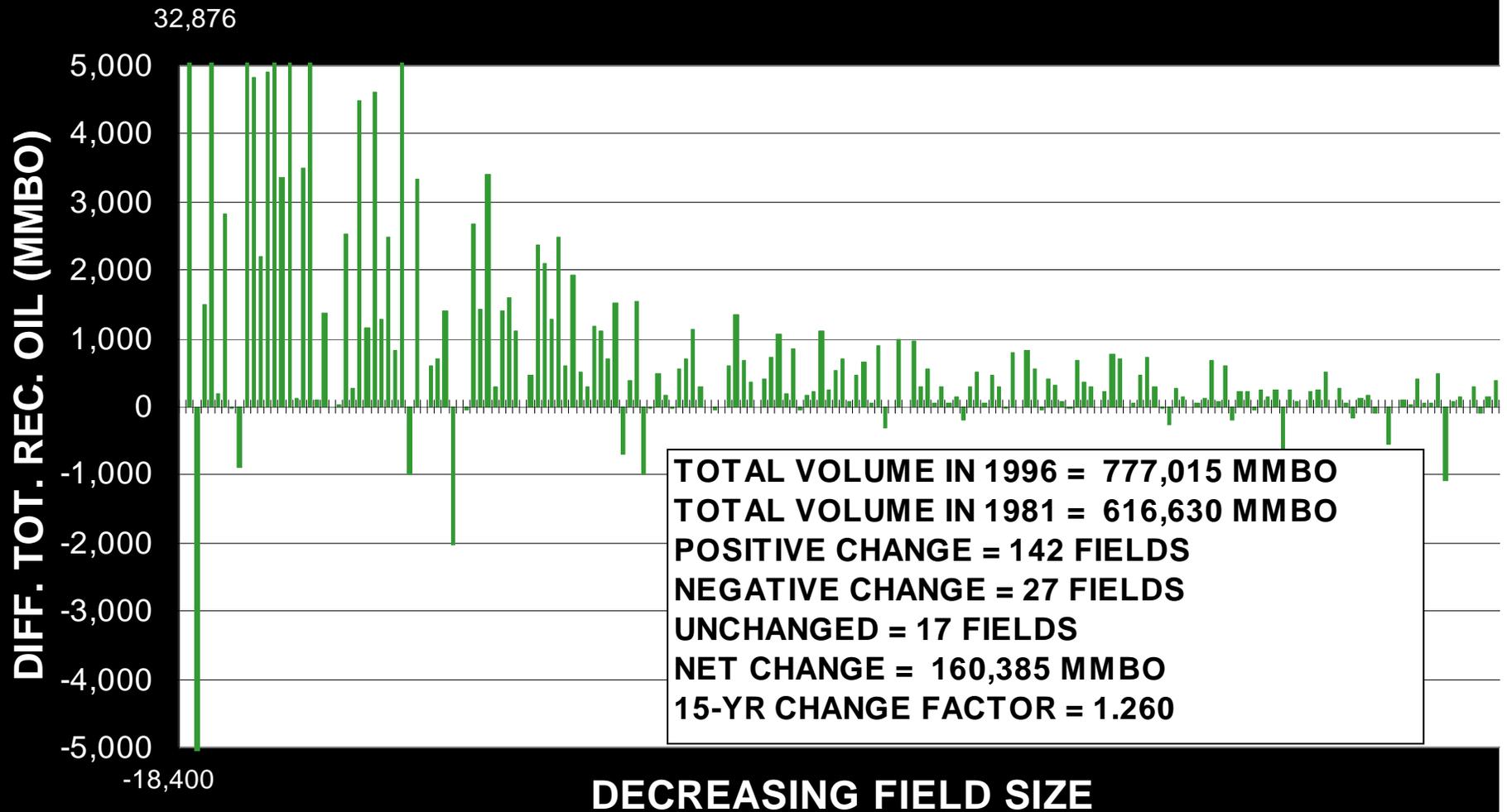
# The Wild Card: Reserve Growth

**Definition:** Reserve growth is the observed increase in reserves for a particular field over time. That is, the initial estimates of reserves in many fields is lower than the ultimate volume of oil produced from that field.

## **Causes of reserve growth:**

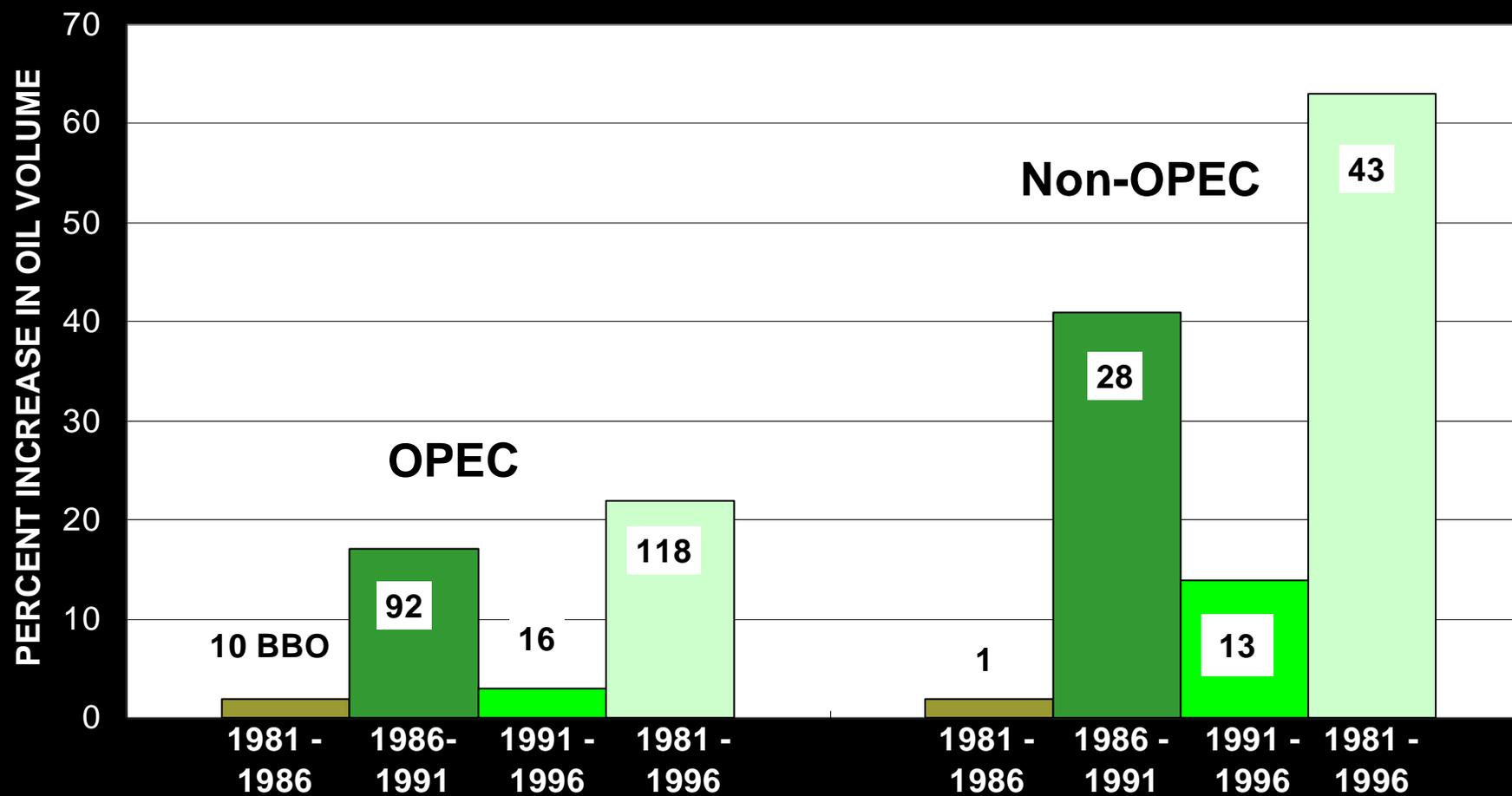
- Conservative initial estimates (SEC requirements, corporate psychology)
- Exploration technology (e.g., 3-D, 4-D seismic)
- Drilling technology (horizontal, multilateral, directional)
- Production technology (enhanced oil recovery)

# Giant Oil Fields of the World ( $\geq 500$ MMBO, excl. U.S.A. and Canada), 1981 to 1996



Source: Petroconsultants database (1991 through 1996)

## Relative Amount of Field Growth in Giant Oil Fields (Excl. U.S. and Canada)



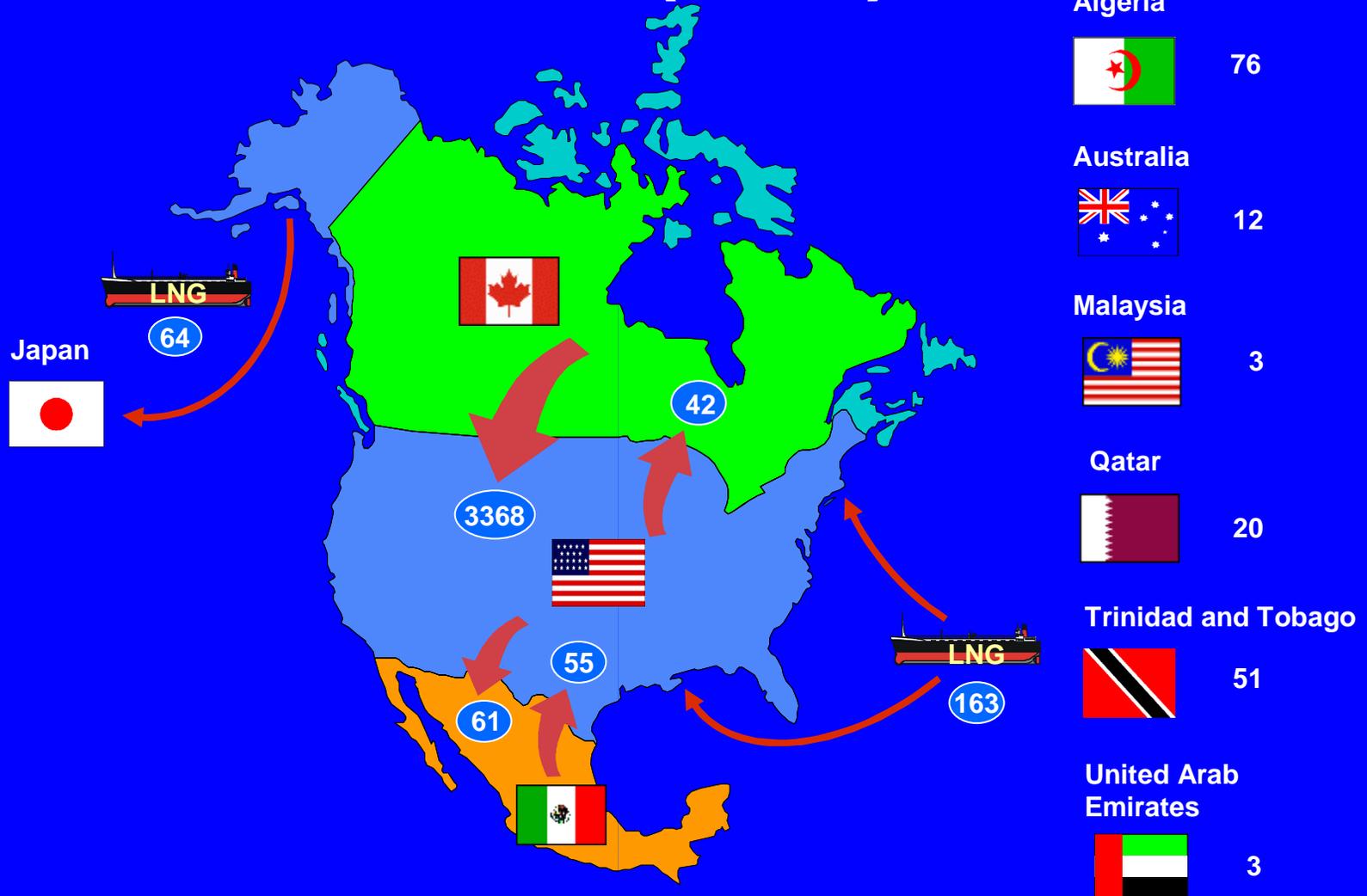
# Reserve Growth Summary

- **In U.S. has accounted for 85% of all reserve additions in last 15 years**
- **First time assessed for world**
- **Nearly as much as Undiscovered conventional resources (World & U.S.)**
  - **Oil Reserve Growth (688 BB)**
  - **Natural Gas Reserve Growth (3660 TCF; 610 BBOE)**
  - **NGL Reserve Growth (42 BB)**

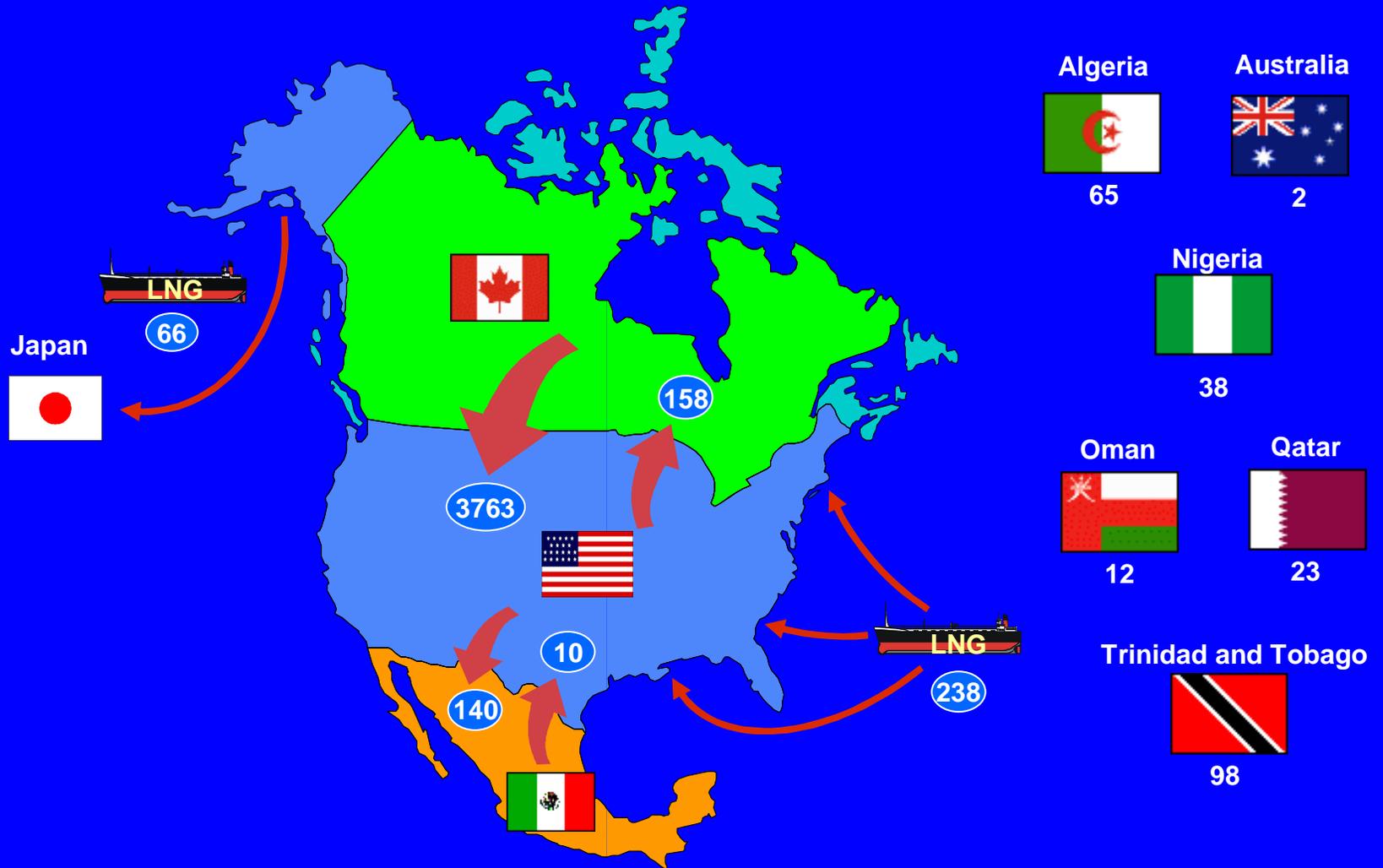
# North America Gas Supply Issues

- USGS reduced gas resource estimates in Southern Canada by order of magnitude, all subsequent estimates lower, where will the 10 TCF/yr for US come from? Canadian meeting 4/2002, Special Publication
- Burgos Basin, Mexico gas— supported study in progress—the 100 TCF dream?
- US has real gas supply problems on both borders

# Natural Gas Imports & Exports, 1999 (BCF)

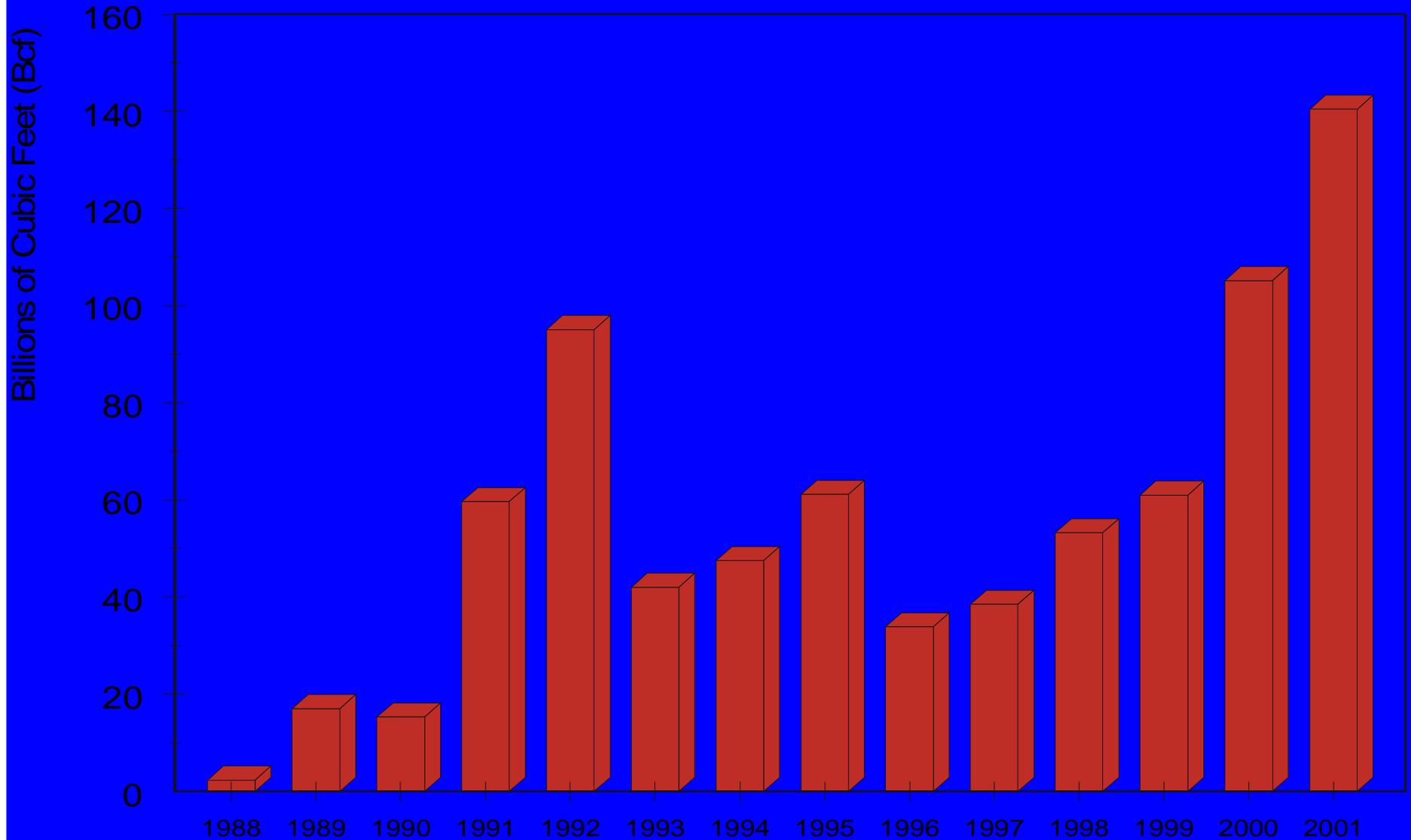


# Natural Gas Imports & Exports, 2001 (BCF)

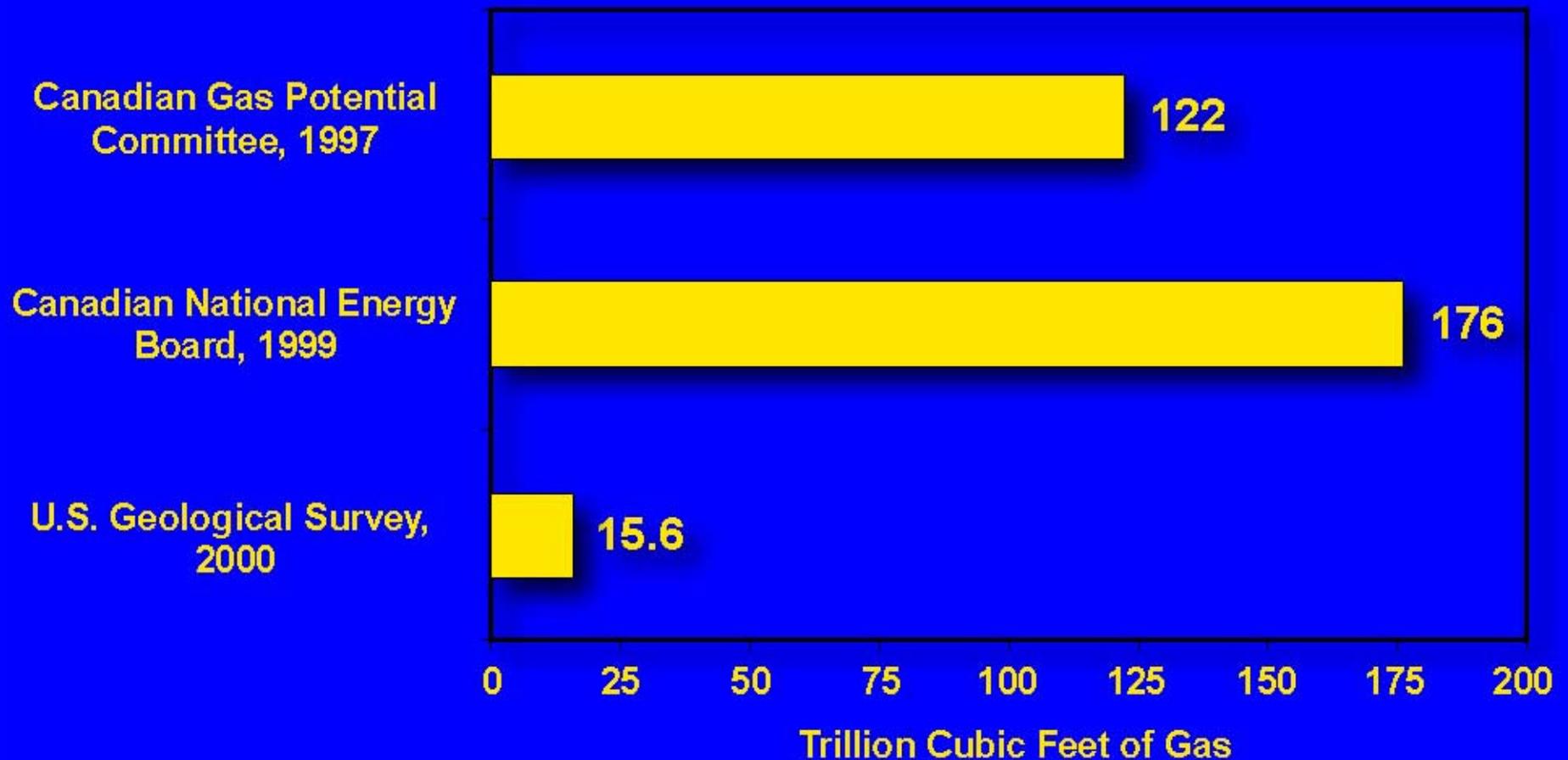


# Natural Gas Exports To Mexico

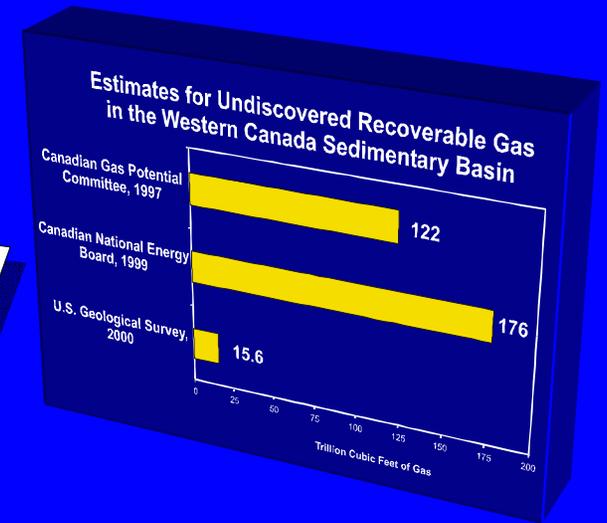
(1988 - 2001)



## Estimates for Undiscovered Recoverable Gas in the Western Canada Sedimentary Basin



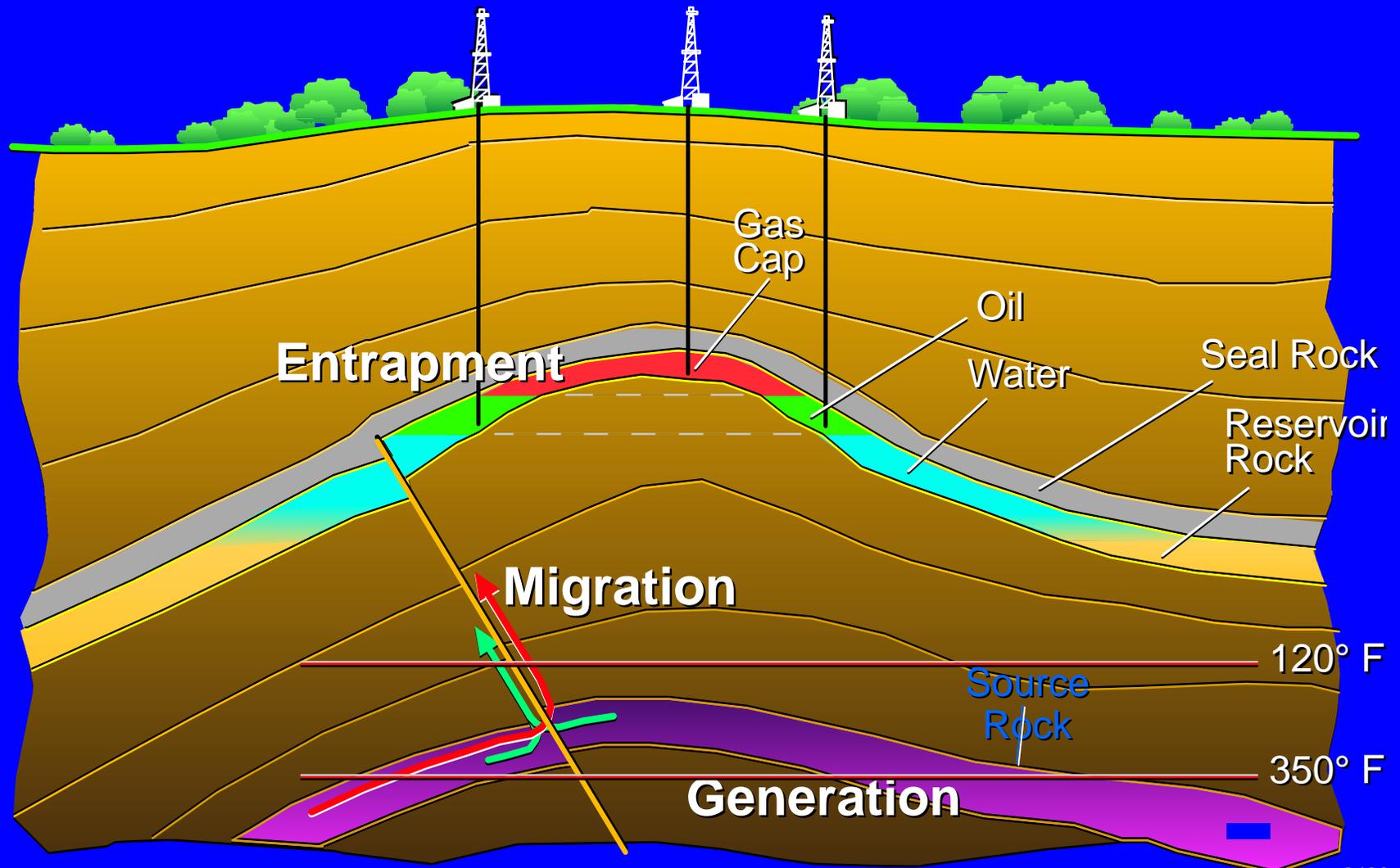
## Why are the estimates different?



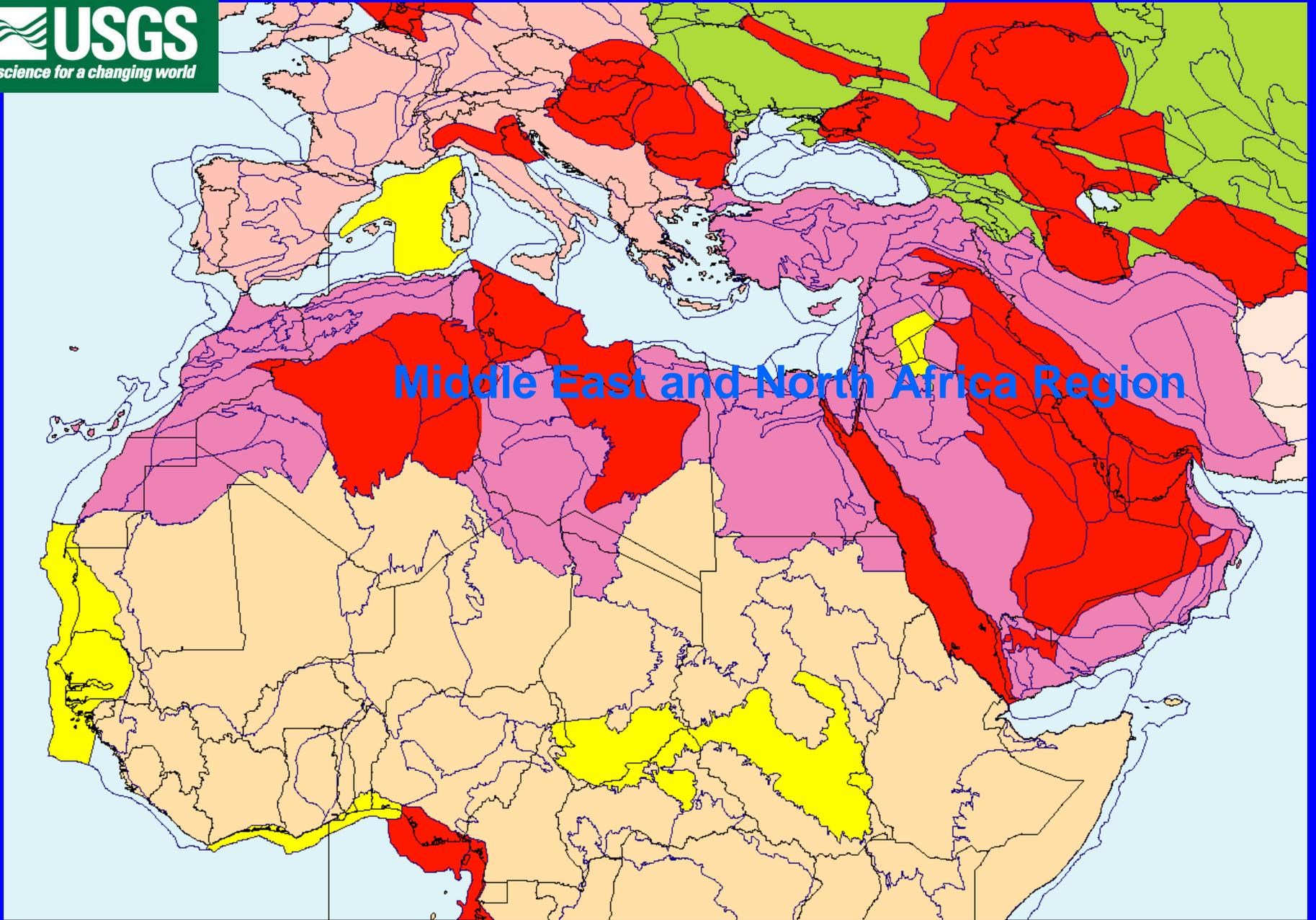
- Different areas assessed
- In-place versus recoverable
  - Different definition of recoverable
- Unconventional included or not
  - Different definition of unconventional
- Associated/dissolved gas assessed or not
- Pool grown assessed or not
- Different minimum pool size
- Different hypotheses about the geology
- Different methodologies
- Different assumption about pool size distributions

# WPA 2000 Analyses Challenge Conventional Wisdom of Petroleum Resources

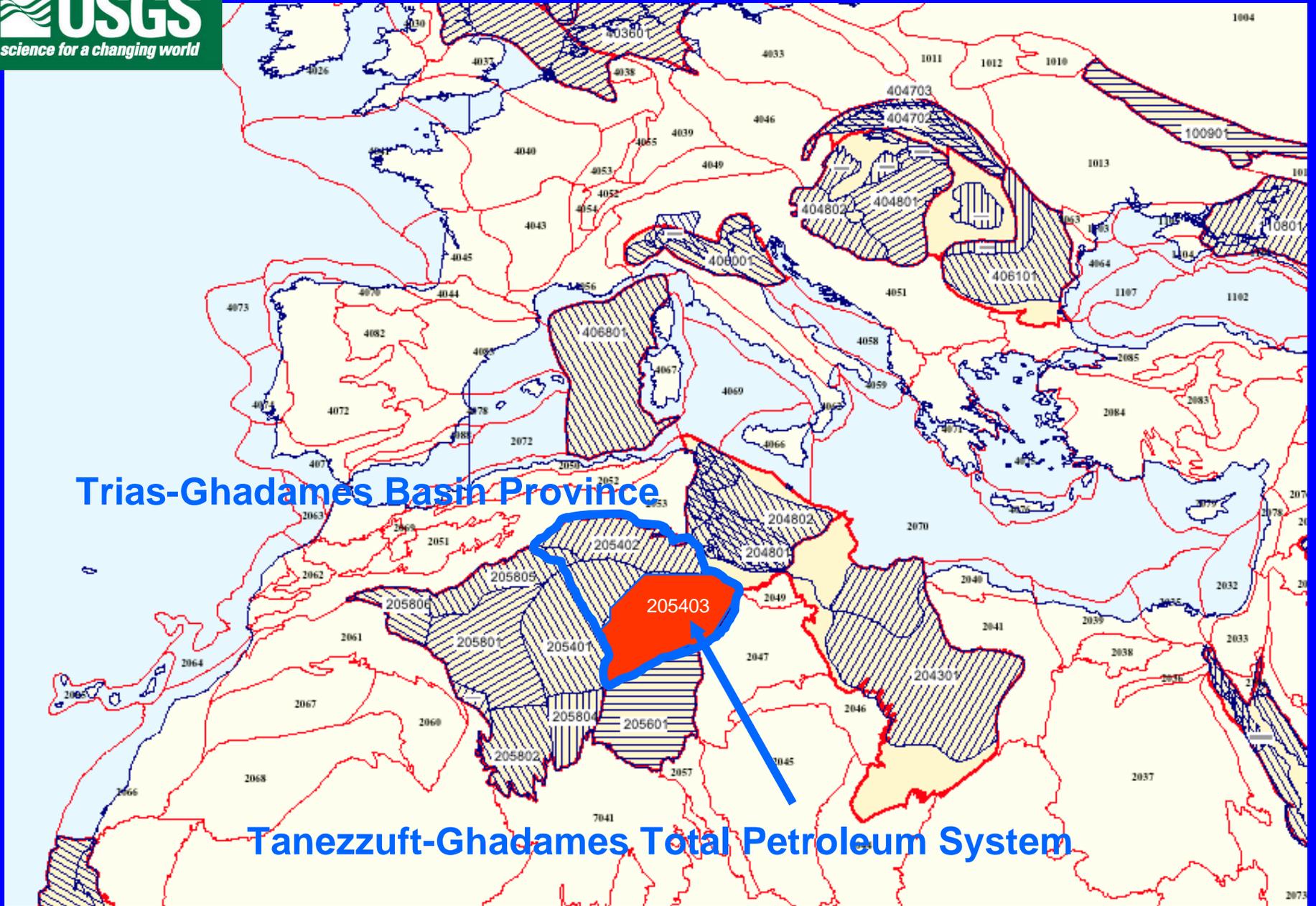
# Total Petroleum System Processes (Includes Undiscovered Resources)

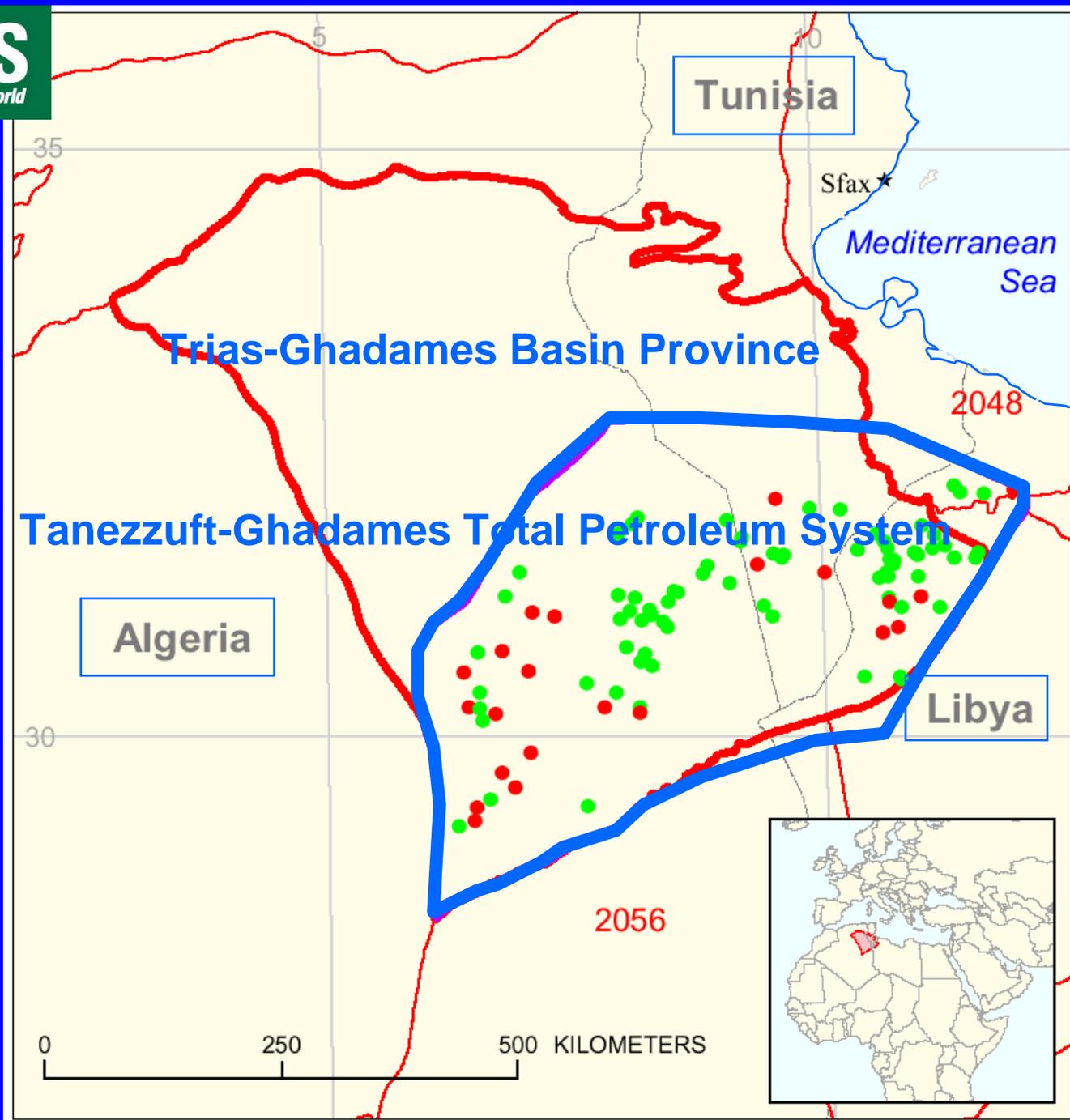


Total Petroleum System (TPS)  
Analysis Provided New  
Opportunities for Areas  
Considered Mature  
Example: Trias Ghadames  
Province, Algeria

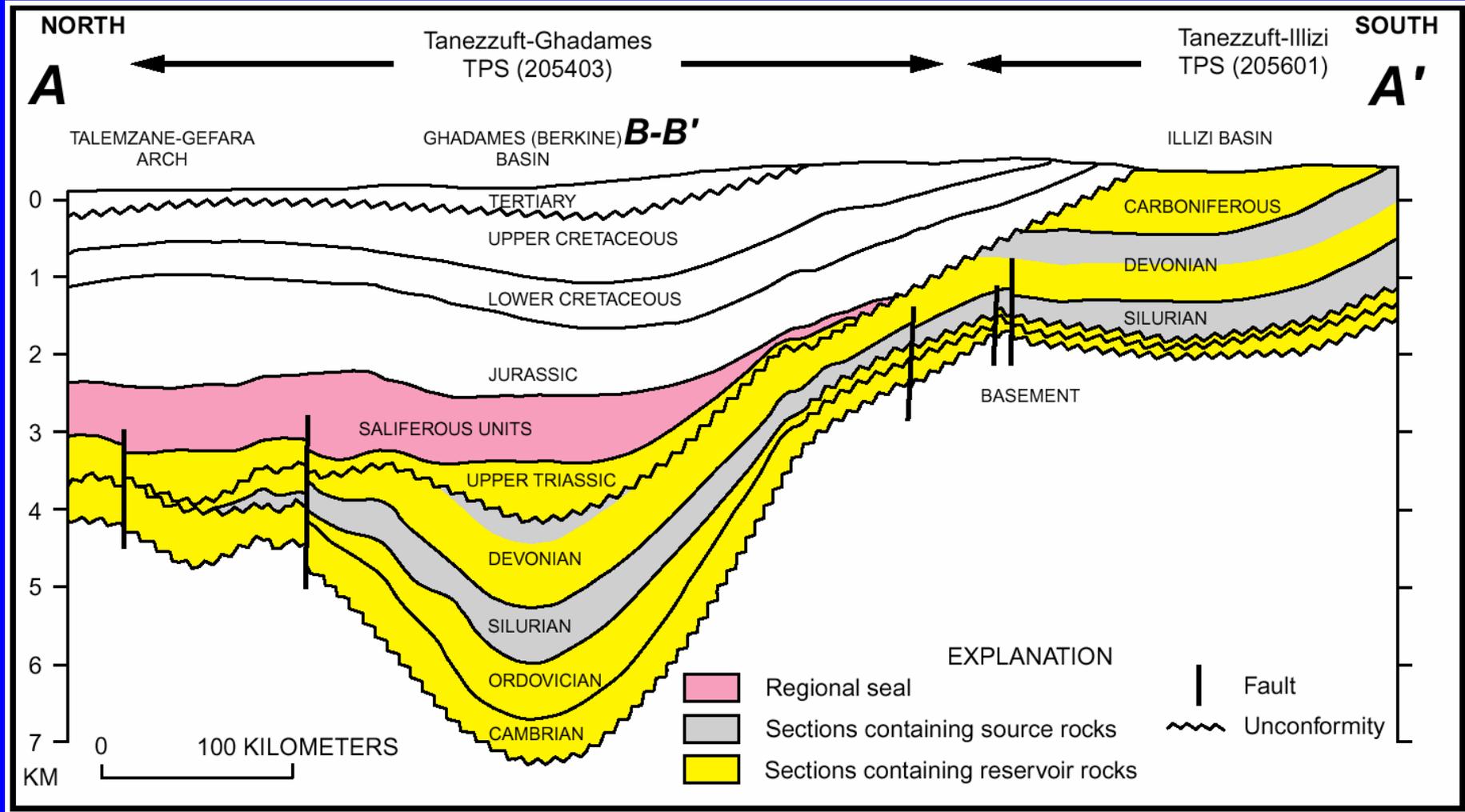


Middle East and North Africa Region





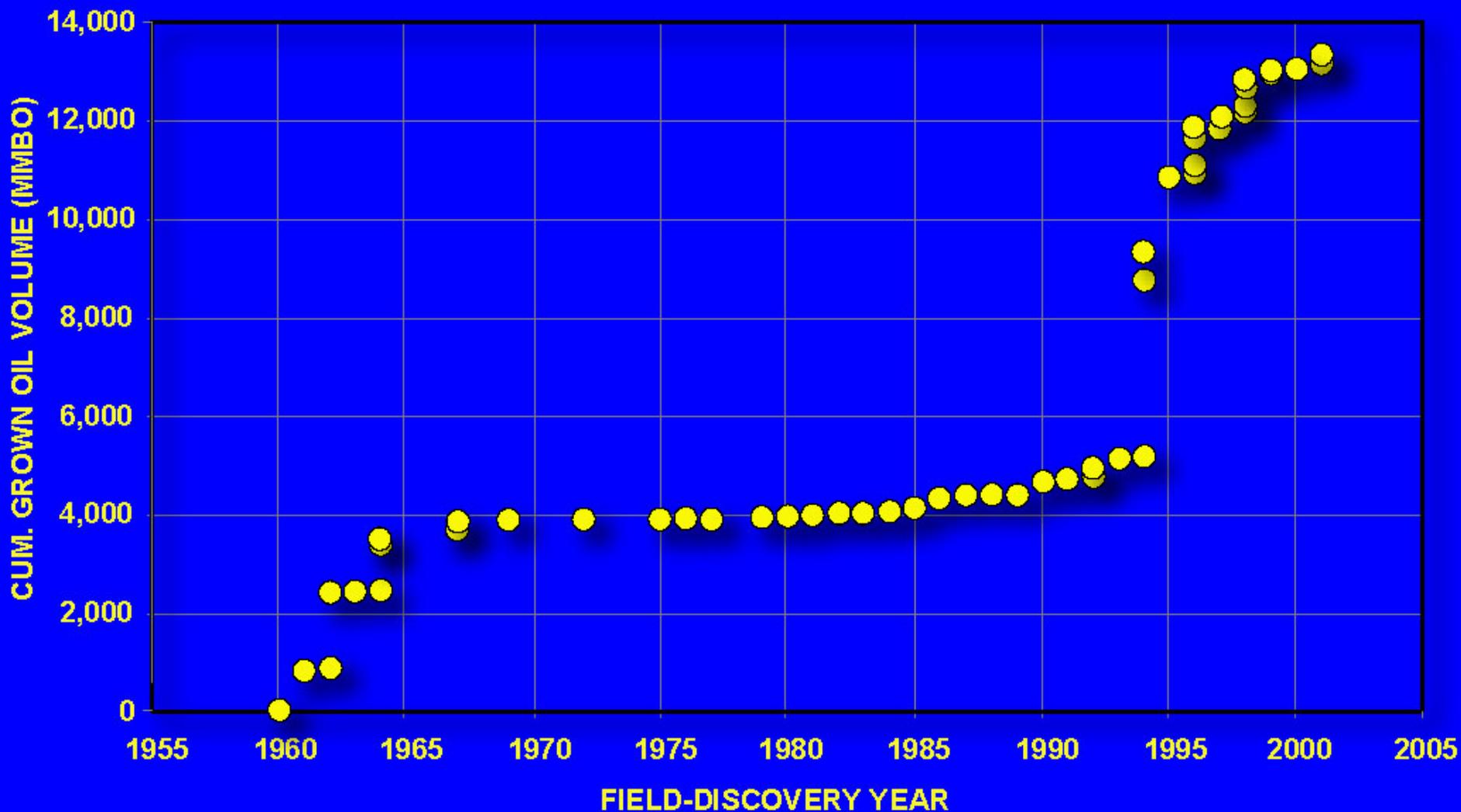
# Tanezzuft-Ghadames Total Petroleum System



Oil: 4.5 billion barrels

Gas: 12 tcf

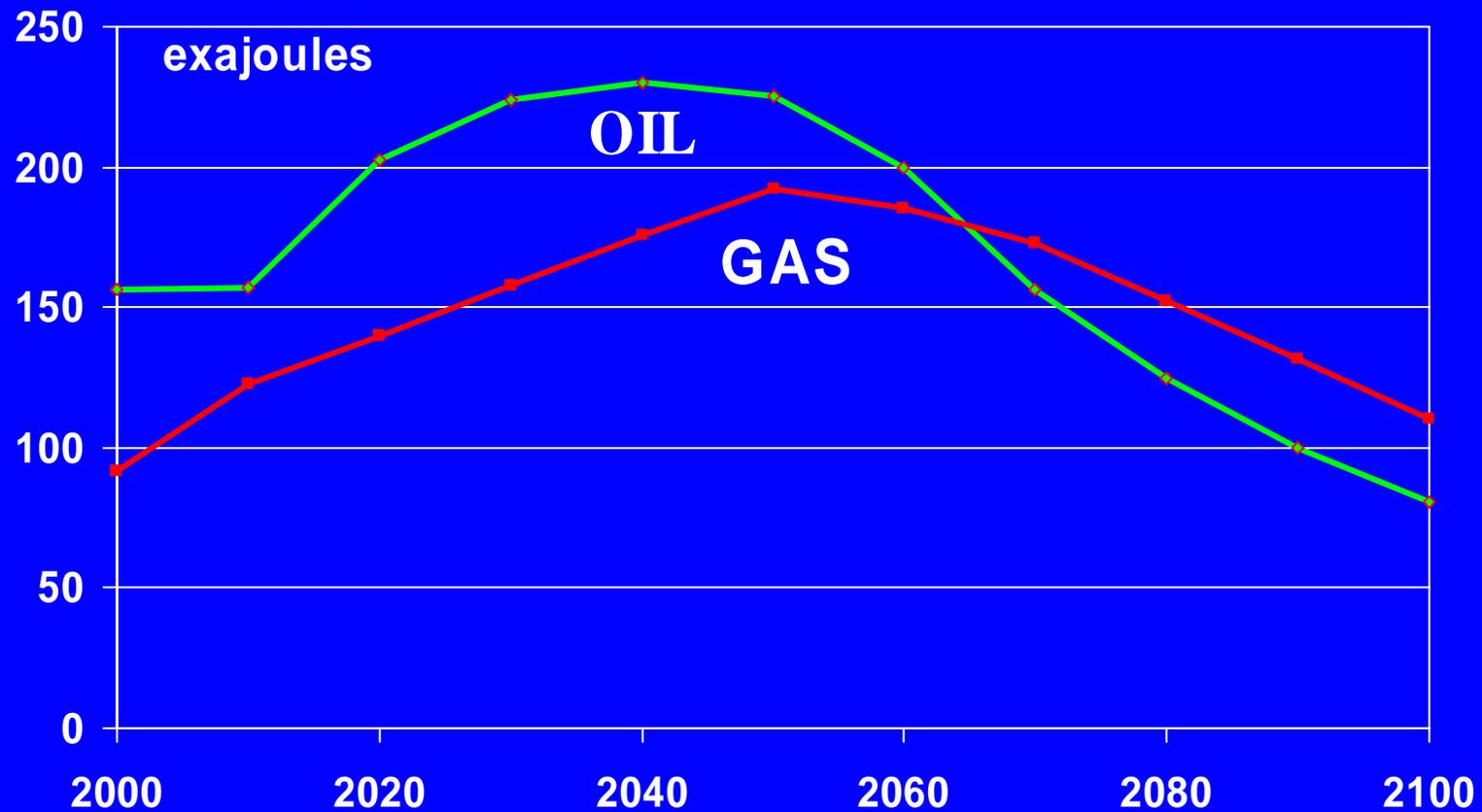
## Tanezzuft-Ghadames Structural/Stratigraphic, Assessment Unit 20540301



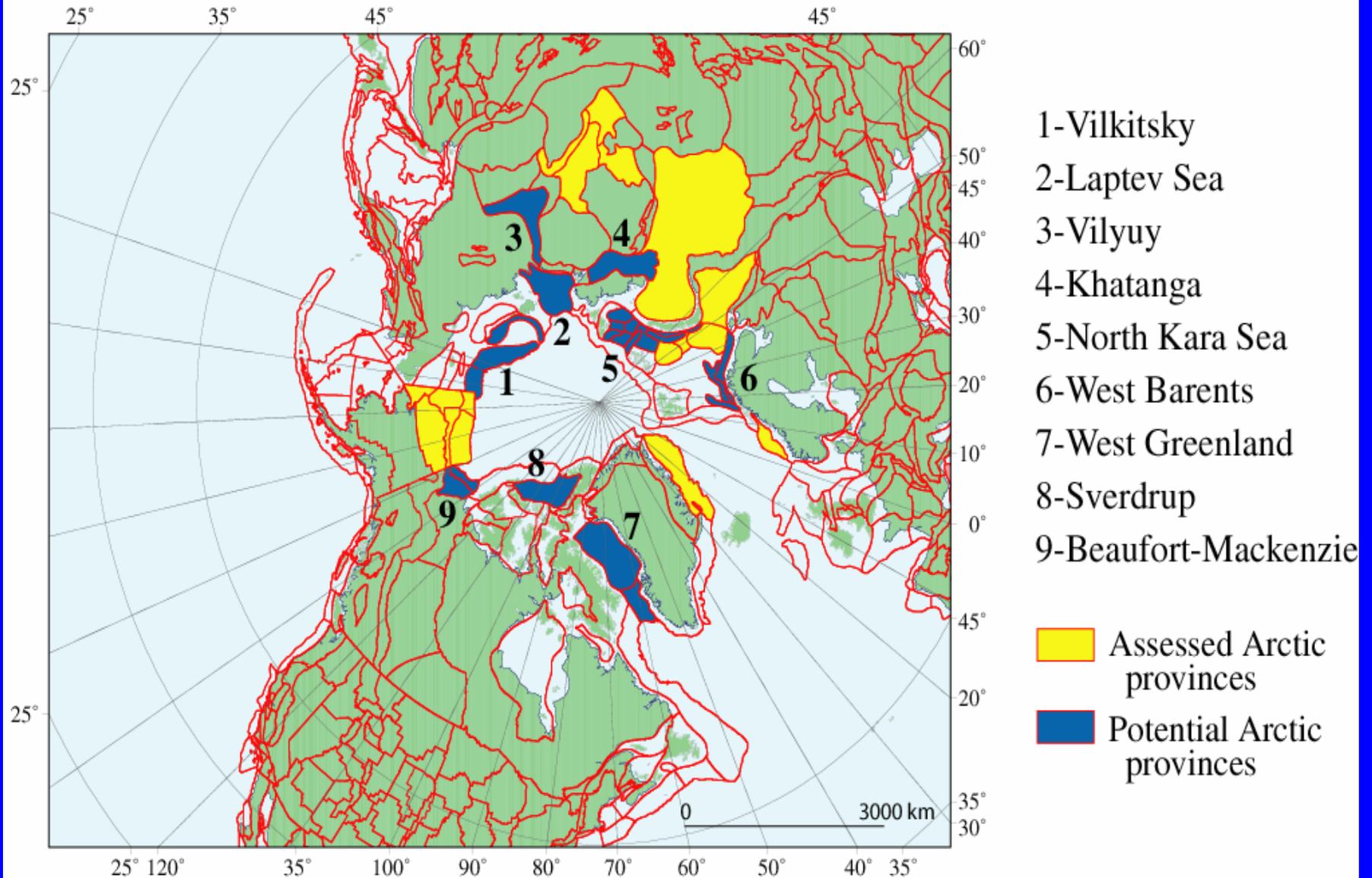
# Resource Assessments as Inputs to Economic, Climatic Decisions

- Global Climate Change and WPA 2000
- Arctic Resources—The next frontier

## World oil and gas production – USGS reference case (Stanford MERGE Model, Mann, 2001)



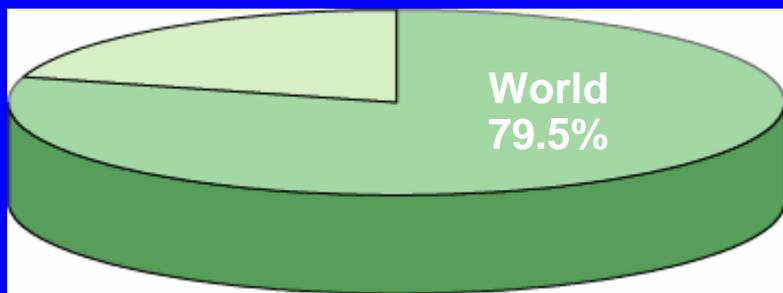
## Arctic Provinces for Study in 2002



# ARCTIC SHARE OF UNDISCOVERED PETROLEUM

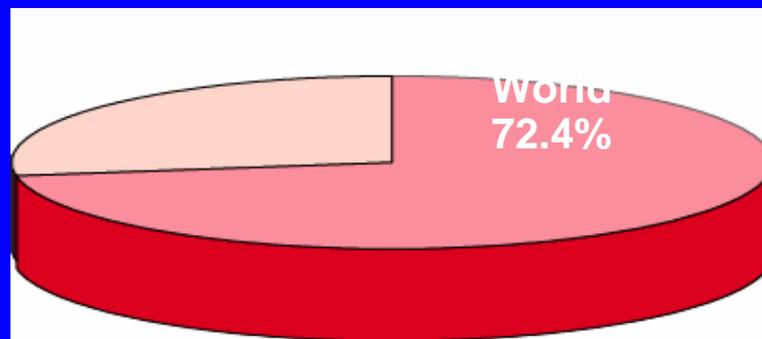
## OIL & NGL

Arctic  
20.5%



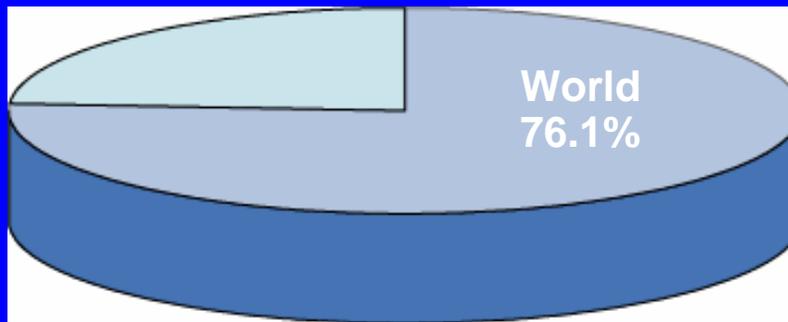
## GAS

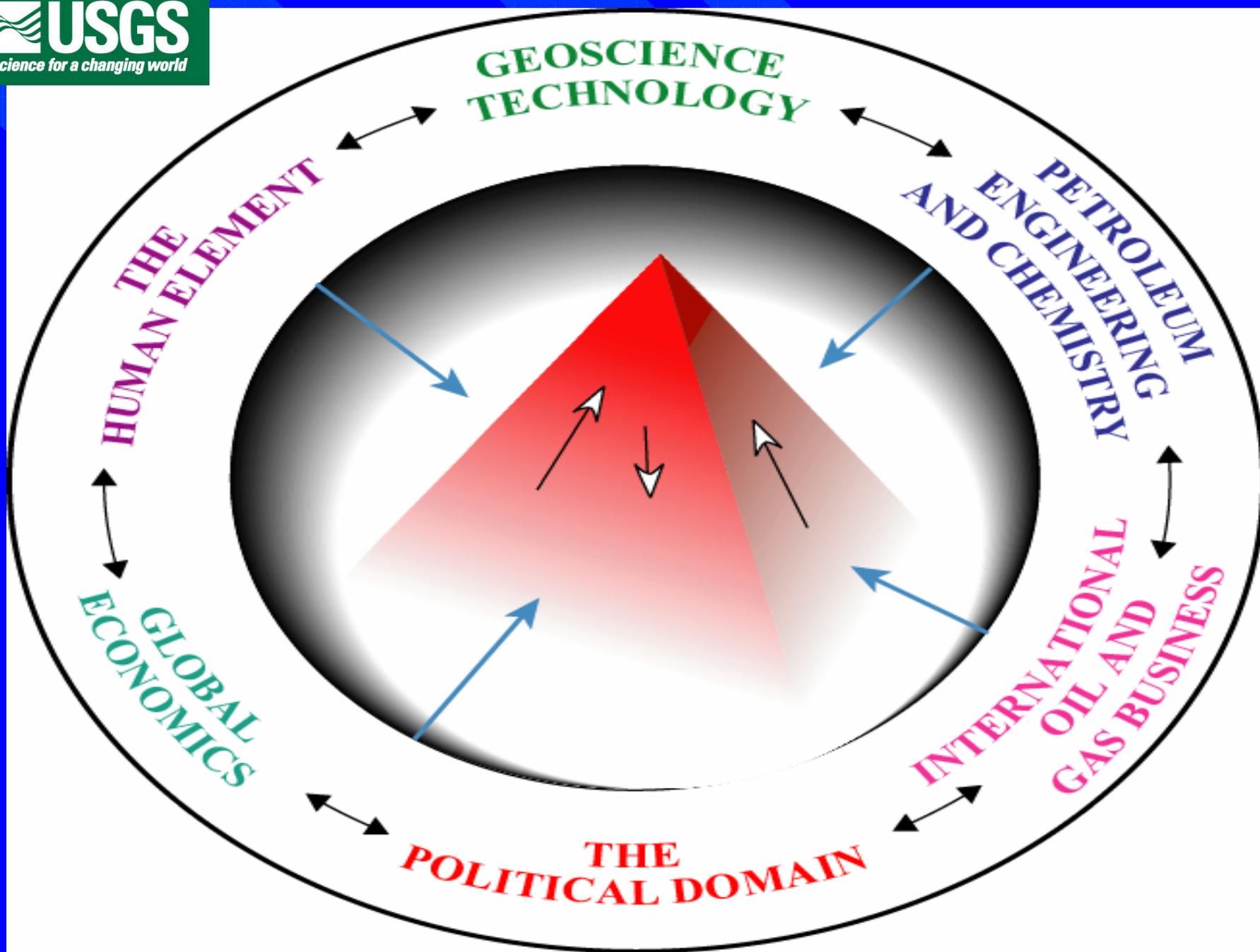
Arctic  
27.6%

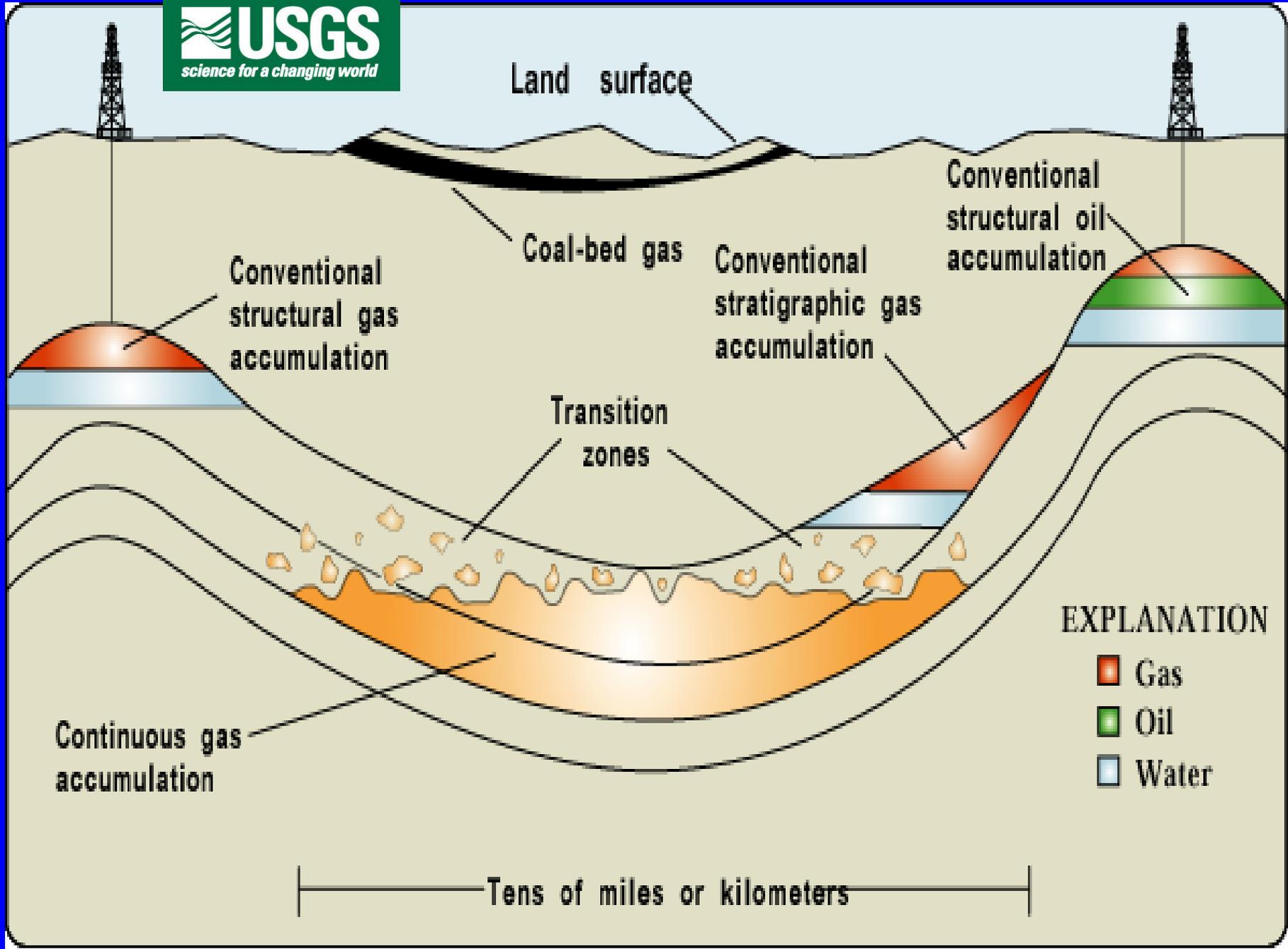


## BOE

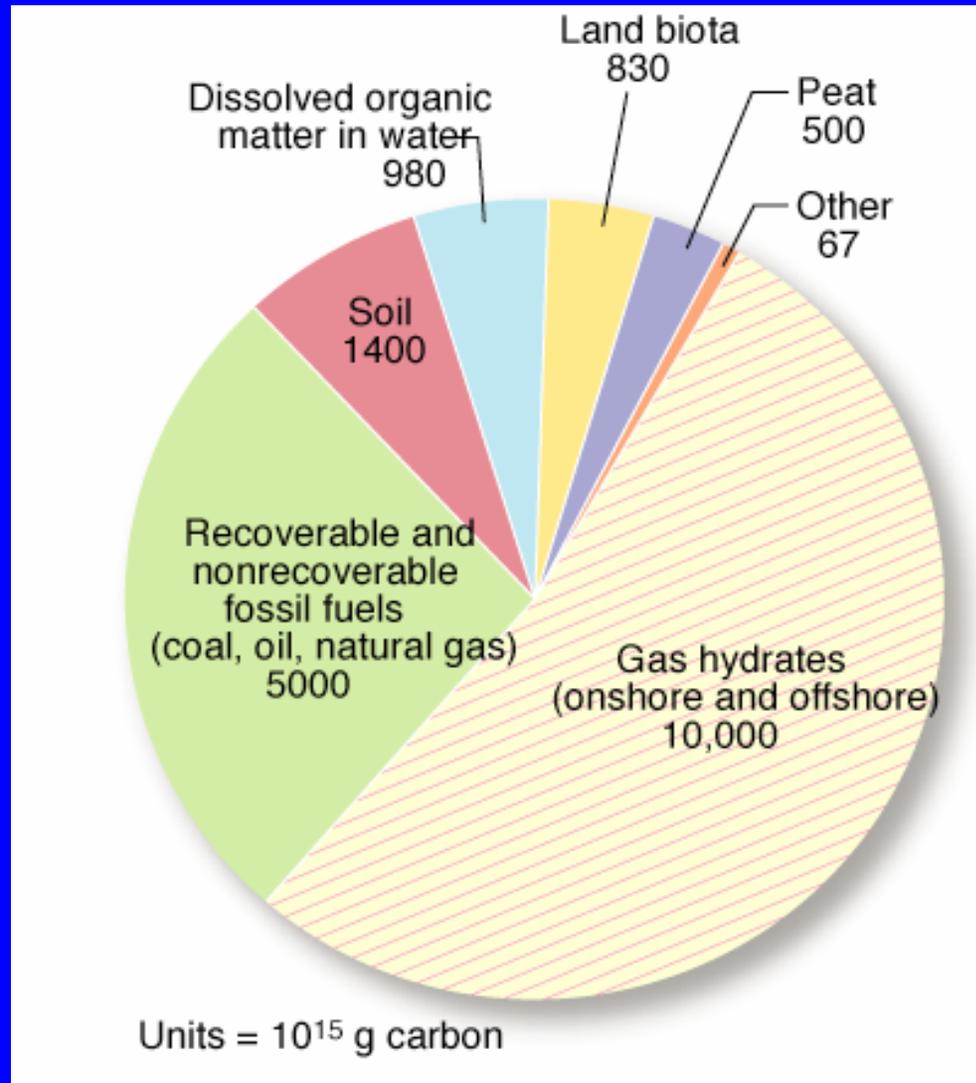
Arctic  
23.9%







# Organic Carbon Distribution

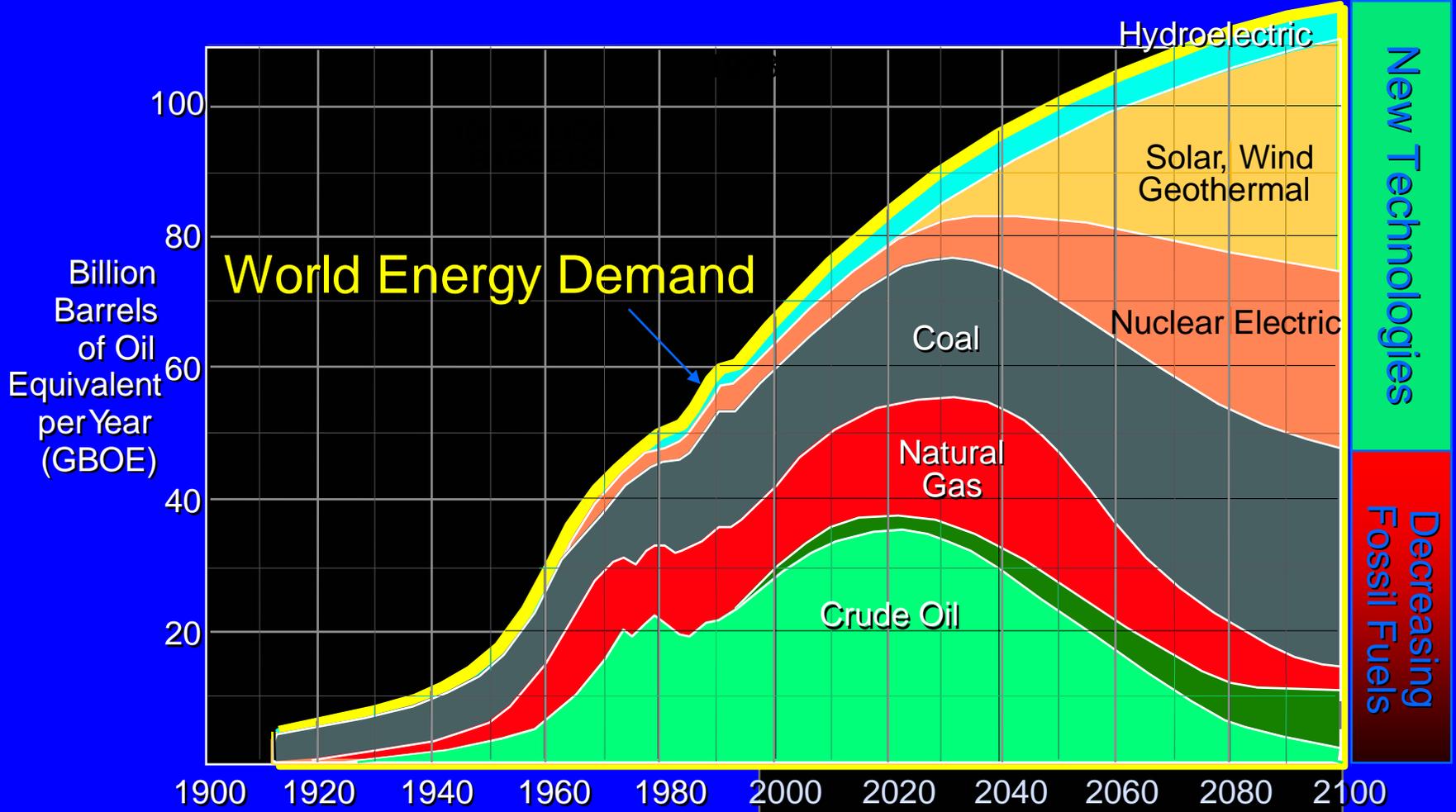


# Or Non-Hydrocarbon ? (Nuclear, Hydrogen)

- Decarbonization, Efficiency and Economic Substitution lead to Non-Hydrocarbons
- When?—certainly by 2<sup>nd</sup> half of 21<sup>st</sup> Century
- Why? Oil peaking by 2030-2040 by many groups using USGS numbers—considered optimistic by some; revised to 2015-2020
- Shifting to a methane economy in the interim—only 7% of natural gas endowment has been used

# Projected World Energy Supplies

## One Vision



after Edwards,  
AAPG 8/97

# Summary

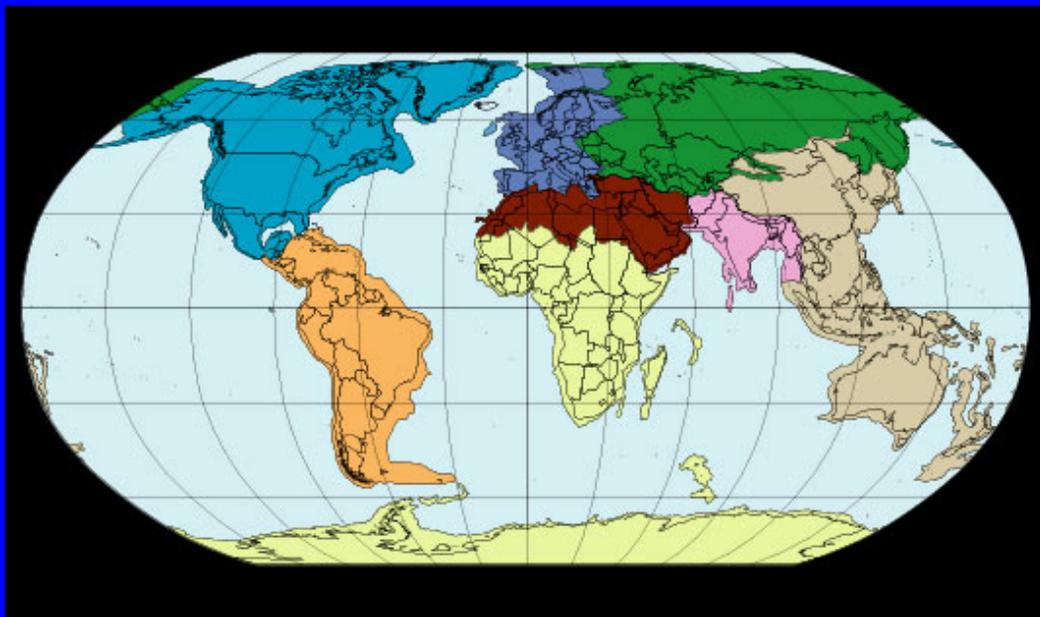
- **Geologically Based** Estimates of Undiscovered Petroleum are up (+9.5% overall; oil +24.3%, gas -10.4%, NGL +104%) relative to 1994 USGS estimates
- **Field Growth** significant (612 BBO, 3,305 TCF Gas at mean). Large growth potential in Iraq, Iran, Saudi Arabia, Volga Ural, West Siberia, Algeria as supported by detailed, proprietary studies
- **New 2015-2020 Oil Peak for Non-OPEC oil using USGS as Reference**
- OPEC undiscovered largely onshore, OECD and others largely offshore and undiscovered resources less concentrated in OPEC compared to previous estimates. **The Arctic is the next frontier (21 new provinces in the High Arctic).**
- U.S. Reserves—surprising ~12% of world endowment, but **recent U.S. downturn and problems for Southern Canadian and Mexican Gas.**
- Increasing Emphasis on Large Unconventional Resources—Gas Hydrates, Basin Center Gas, Heavy Oil and Tar Sands and Renewables

# Four (Or Two?) Decades of

## Conventional Oil and Then What?

- **CBF—Coal Bridge to the Future**
- **The Natural Gas Revolution**
- **Oil gives way to a Methane Economy (itself peaking by 2060)—Transition to a Hydrogen Economy in latter half of 21<sup>st</sup> Century—Already Starting—Fuel Cells for Vehicles**
- **Nuclear—Electricity Generation and Generation of Hydrogen—Fusion**
- **Portfolio Approach---Unconventionals clearly must play a role as well-particularly heavy oils in the Western Hemisphere (Athabasca, Orinoco), gas hydrates, nuclear, increasing unconventional sources, renewables**

For additional information:



USGS DDS-60

or

<http://energy.cr.usgs.gov>

Or contact [ahlbrandt@usgs.gov](mailto:ahlbrandt@usgs.gov)

# Natural gas and NGL

## Prices

US dollars per million Btu	LNG		Natural gas			Crude oil
	Japan cif	European Union cif	UK (Heren Index)†	USA Henry Hub‡	Canada (Alberta)‡	OECD countries cif
1985	5.23	3.83	—	—	—	4.75
1986	4.10	3.65	—	—	—	2.57
1987	3.35	2.59	—	—	—	3.09
1988	3.34	2.36	—	—	—	2.56
1989	3.28	2.09	—	1.70	—	3.01
1990	3.64	2.82	—	1.64	1.05	3.82
1991	3.99	3.18	—	1.49	0.89	3.33
1992	3.62	2.76	—	1.77	0.98	3.19
1993	3.52	2.53	—	2.12	1.69	2.82
1994	3.18	2.24	—	1.92	1.45	2.70
1995	3.46	2.37	—	1.69	0.89	2.96
1996	3.66	2.43	1.84	2.76	1.12	3.54
1997	3.91	2.65	2.03	2.53	1.36	3.29
1998	3.05	2.27	1.93	2.08	1.42	2.16
1999	3.14	1.73	1.64	2.27	2.00	2.98
2000	4.72	2.85	2.68	4.23	3.75	4.81

†Source: PH Energy

‡Source: Natural Gas Week.

**Note:** cif = cost+insurance+freight (average prices).

## Major Geologic Insights (1/2)

- Petroleum is trapped in many ways—  
structures less than half
- Type II source rocks are vastly dominant
- Mesozoic source rocks are the most important  
volumetrically
- Cenozoic petroleum systems are volumetrically  
dominant, old systems have lost much  
petroleum
- Major TPS are Cyclic and concentrated at era  
boundaries

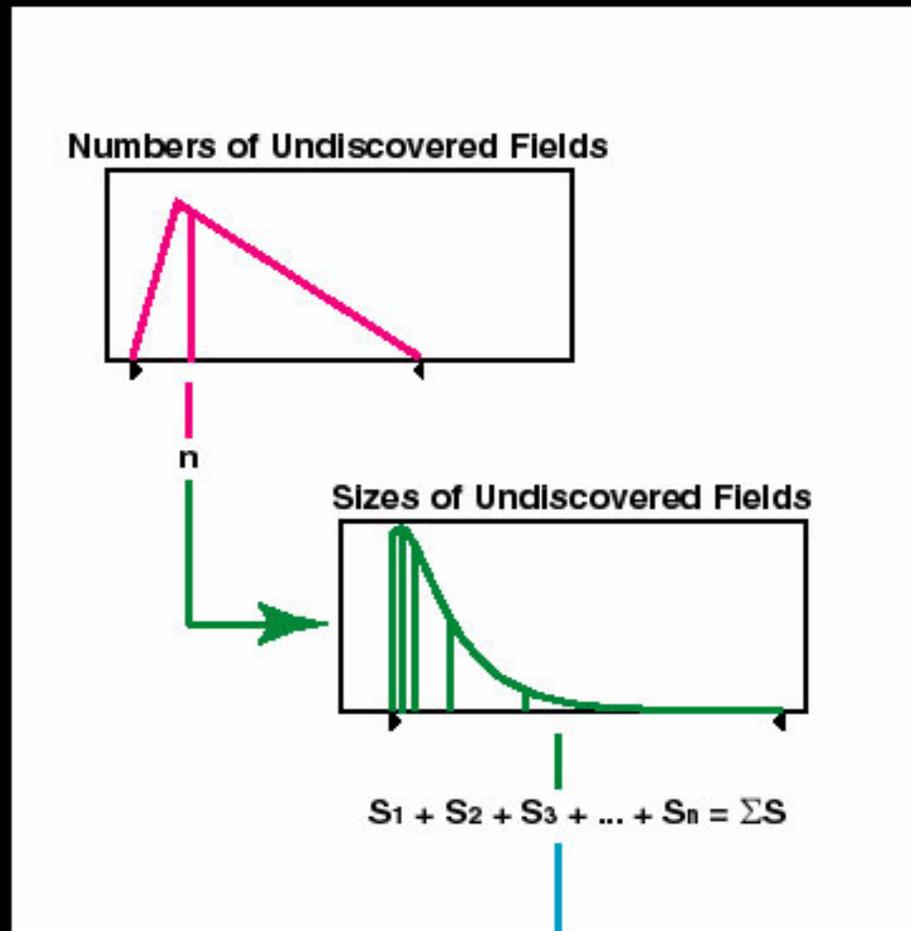
## Major Geologic Insights (2/2)

- **Continental Reservoirs are dominant**
- **Clastic Reservoirs will dominate future discoveries**
- **Vertical migration of petroleum is dominant**
- **Salt is very effective long-term seal and critical to older TPS, shale seals are far more numerous than salt seals, but salt seals clearly better**
- **Major Conventional Natural Gas Systems are closely linked to large Unconventional (Continuous) Resources**

# External Methodology Calibration

- **January, 1995 Methodology Meeting—Denver**
- **AAPG Committee on Resource Evaluation Review—  
Endorsement by AAPG Executive Committee and  
CORE, March, 1999**
- **World Energy Consortium Reviews—Detailed  
briefings from Exxon, Mobil, Amoco, Conoco,  
Unocal, Shell on their assessment methodologies**
- **Industry Review—e.g. BP Amoco--Extensive Onsite  
Evaluation—Prepared Report for internal use**

# Monte Carlo Simulation for the Assessment of Undiscovered Resources

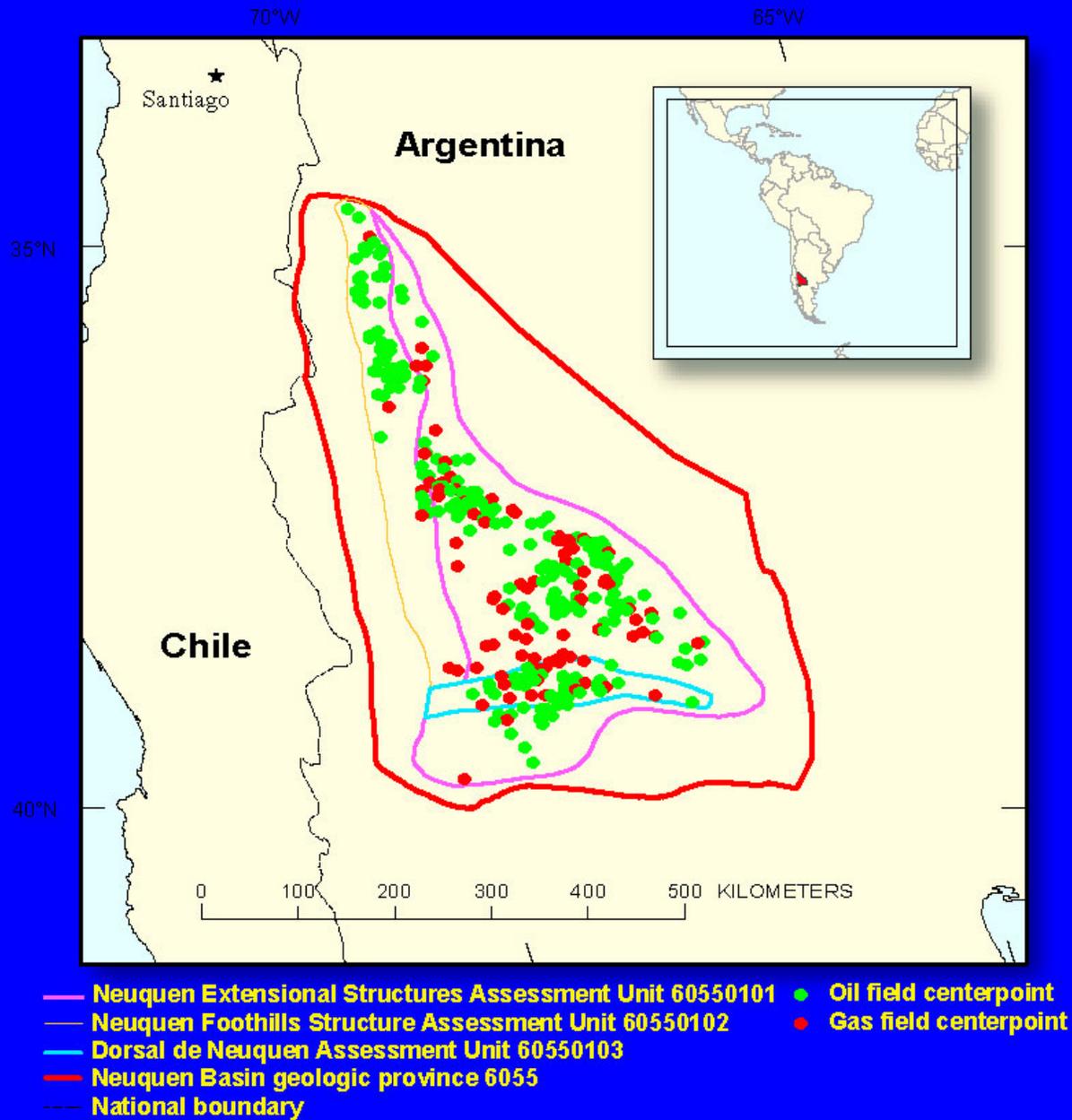


Repeat 50,000 Times

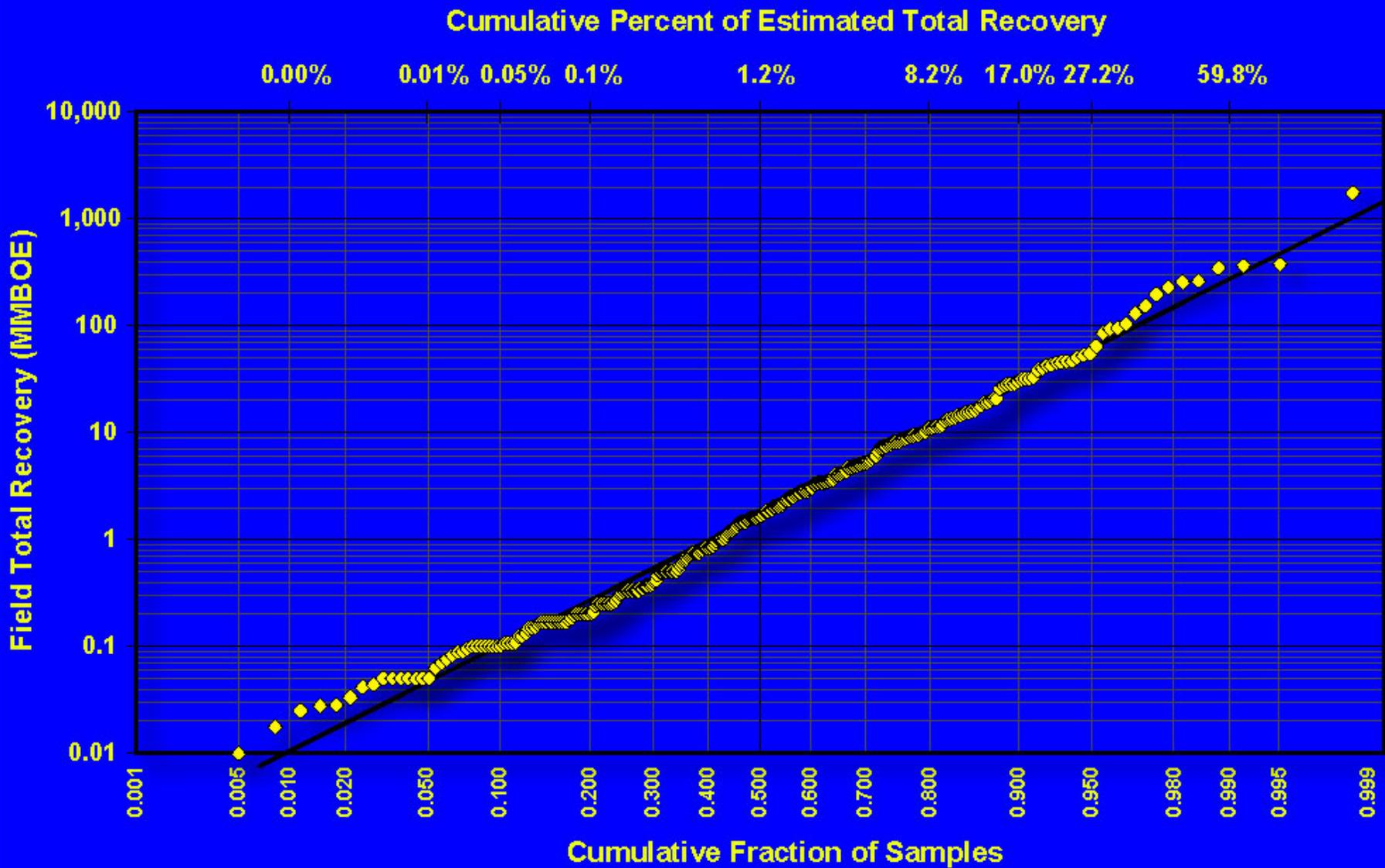
Forecast: Undiscovered Resource



# Neuquen Basin

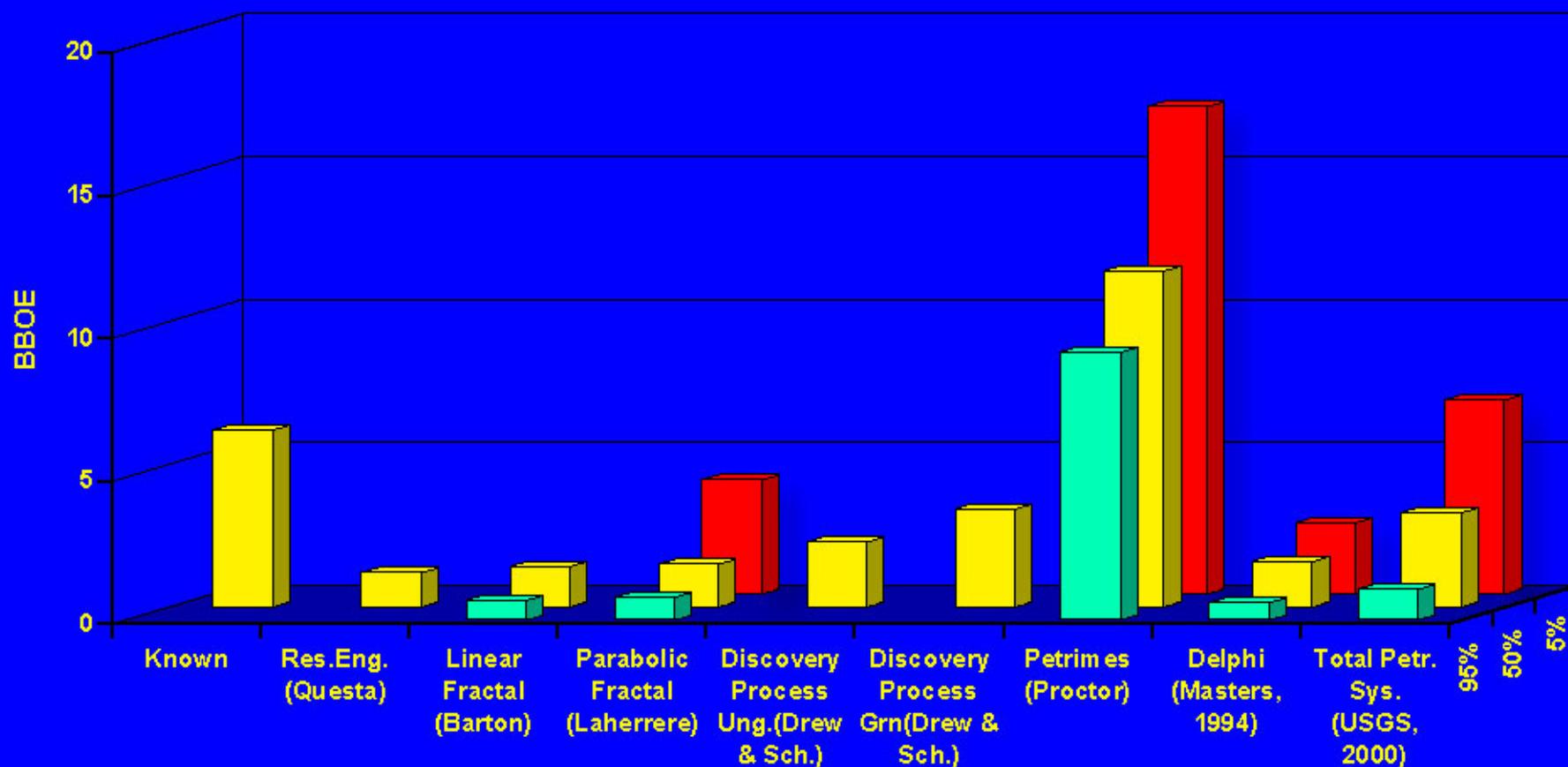


# Neuquen Basin Field Size Distribution



# Comparison of Undiscovered Resources

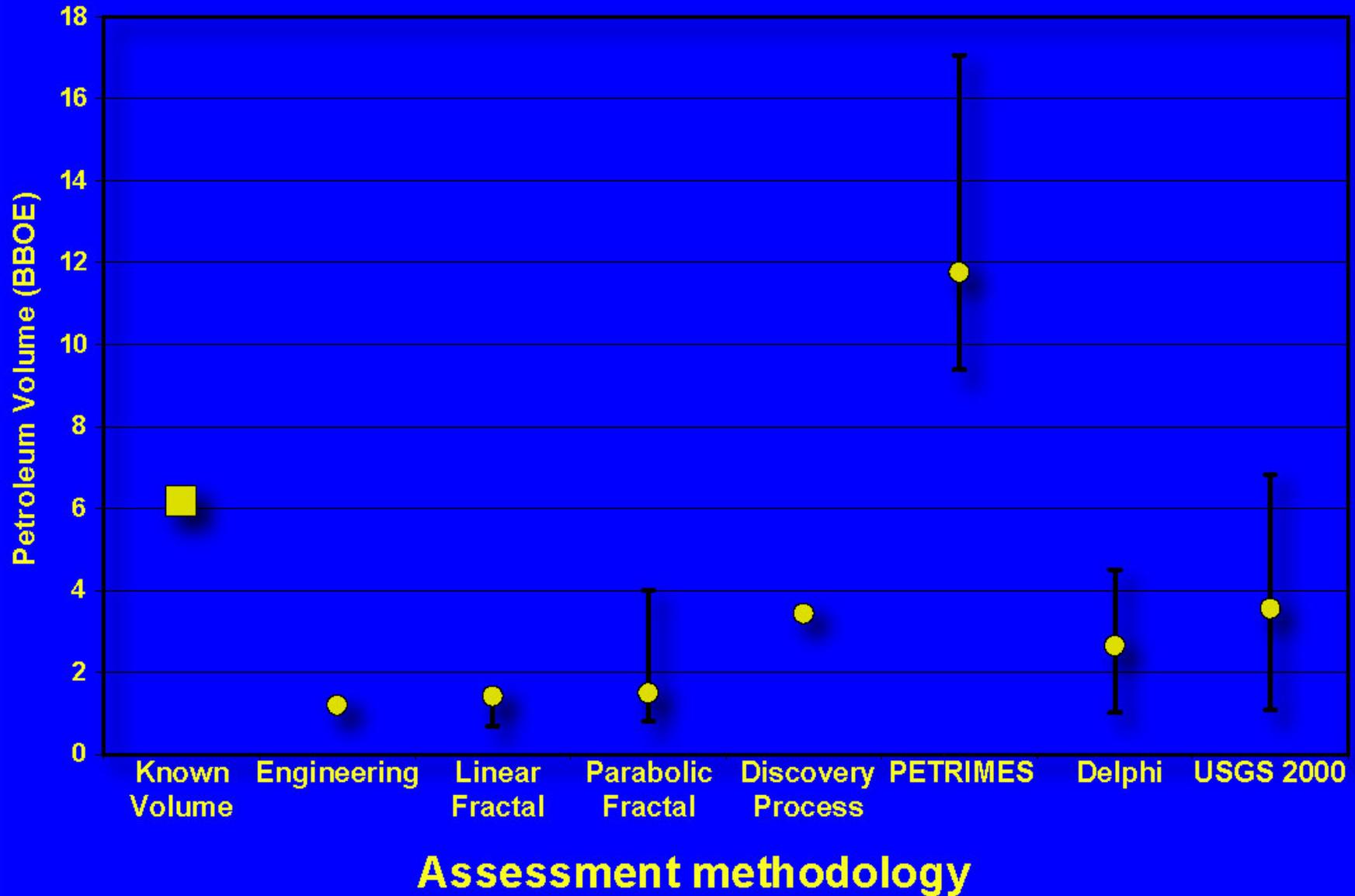
## Neuquen Basin, Argentina



### Assessment Comparison

209 Fields > 1MBOE, 1,041 Wells, Petroconsultants, 1996, 61st Rank, 450 MBOE Discovered from 1996 through 2001

# Neuquen Basin Province



# Neuquen Basin Province

