

Global Overview of Petroleum Resources

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WORLD ENERGY PROJECT

- **USGS 2000** — New estimate of future world oil and gas resources—30 year time frame (1995-2025)—Not Ultimate, 1st time, 32,000 pages, documentation
- **Undiscovered** Resource Estimates are Geologically Based using Total Petroleum Systems (Fluids not just rocks)—1st time
- **Reserve (Field) Growth** are Statistically Based Estimates for the World (30 Year Forecast)-1st 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 by the IEA, DOE (EIA); Climate Modelers (Stanford, MIT, PEW); Individuals (Cavallo, 2002; Edwards, 2002; Greene, 2004)
- All Information is Digital (DDS-60, 4 CDs, 13 other CDs on regional geology— 115,000 distributed), 346 publications
- Website (<http://energy.usgs.gov>)~1.2 million downloads/yr

USGS World Petroleum Assessment 2000

- Undiscovered Resources (TPS) and Reserve Growth Components
- Natural Gas Revolution (the missing 0.5 TBOE of natural gas)
- Calibration of USGS 2000 World Assessment
- Arctic—the New Frontier
- Unconventional Resources—the Barnett--Texas
- Summary



THE VOCABULARY OF RESOURCE ASSESSMENT:

Cumulative production

Reserves

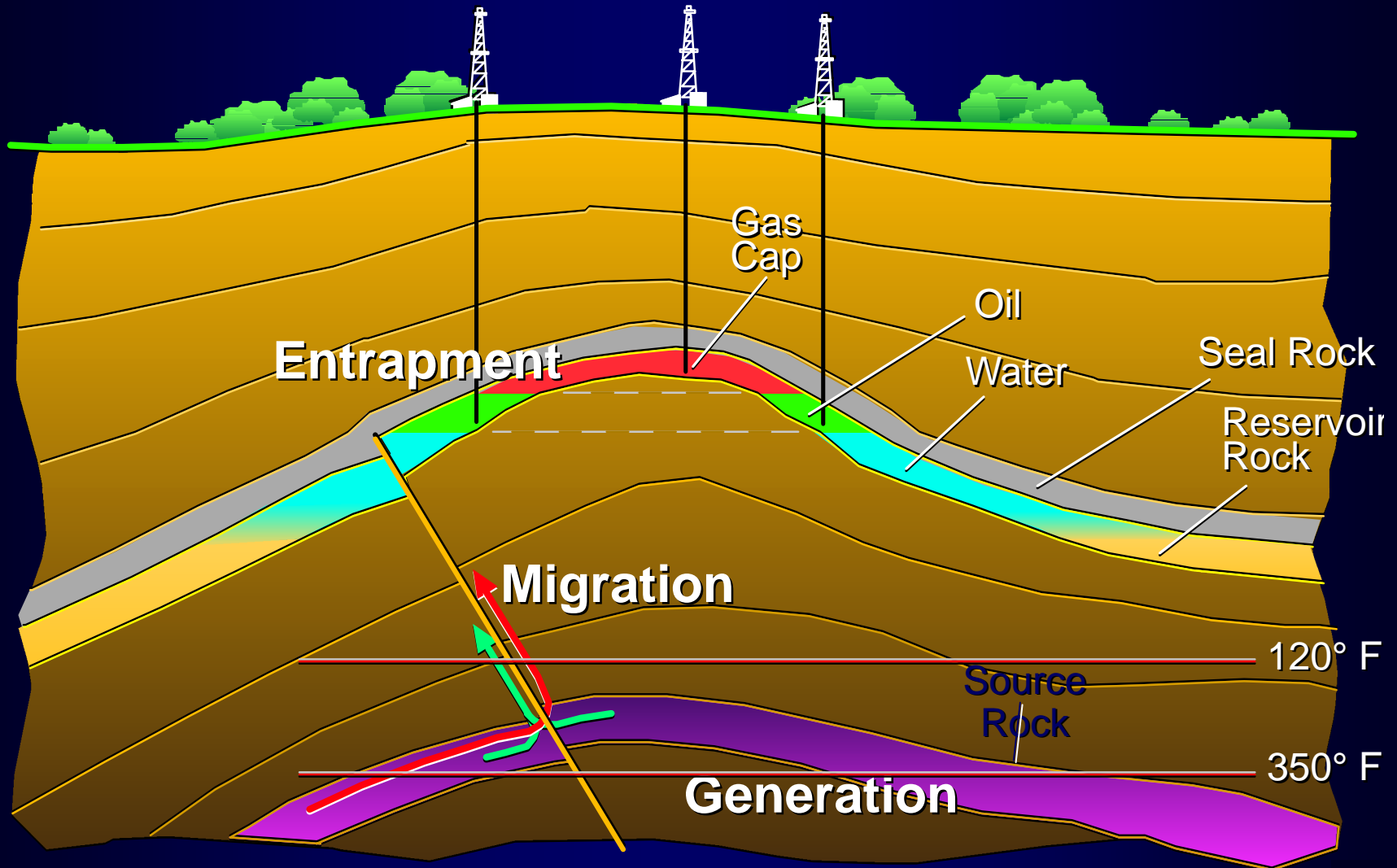
Reserve growth

Undiscovered resources

Conventional

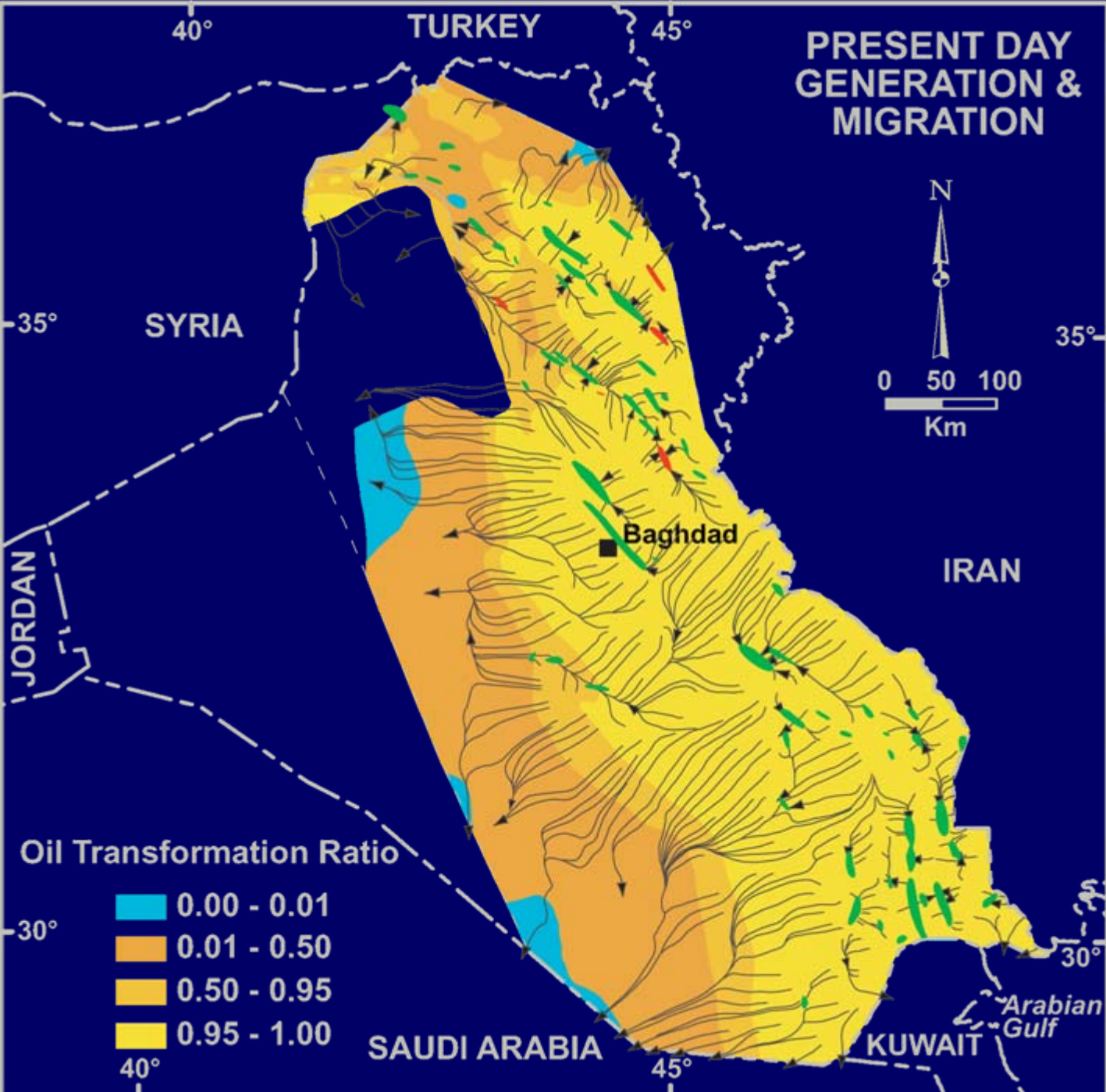
Unconventional (continuous)

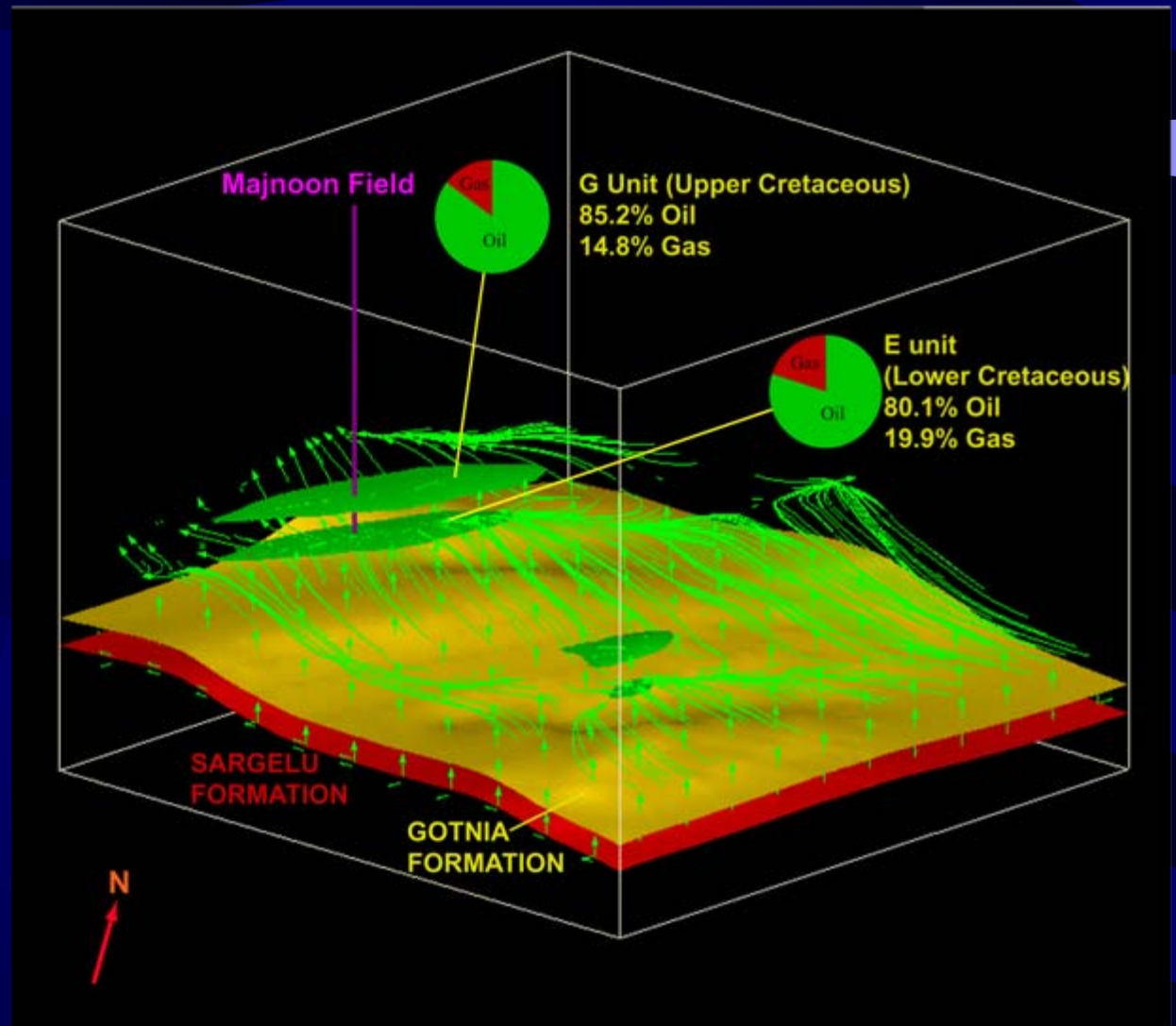
Total Petroleum System Processes (Includes Undiscovered Resources)











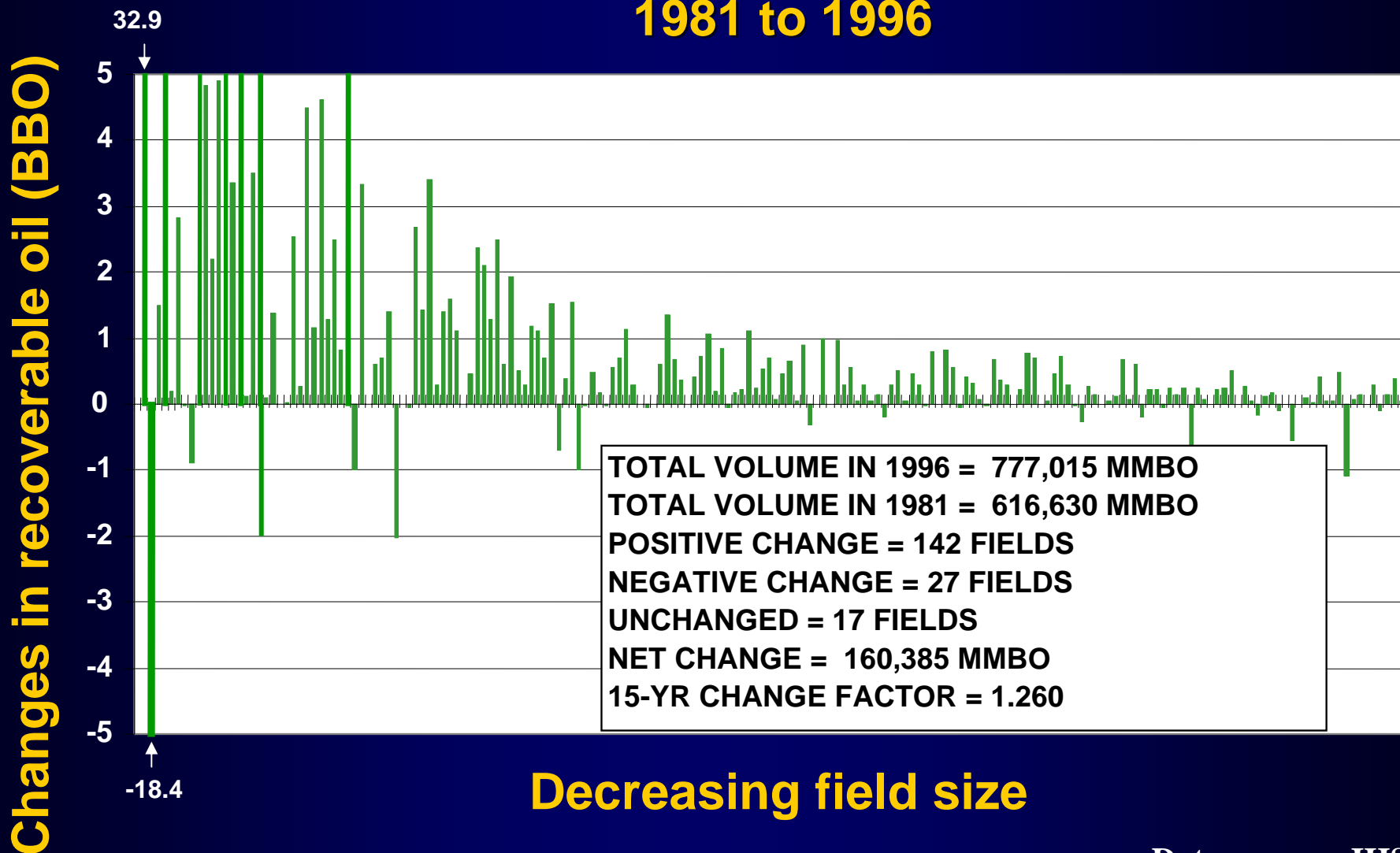
The Wild Card: Reserve Growth

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)

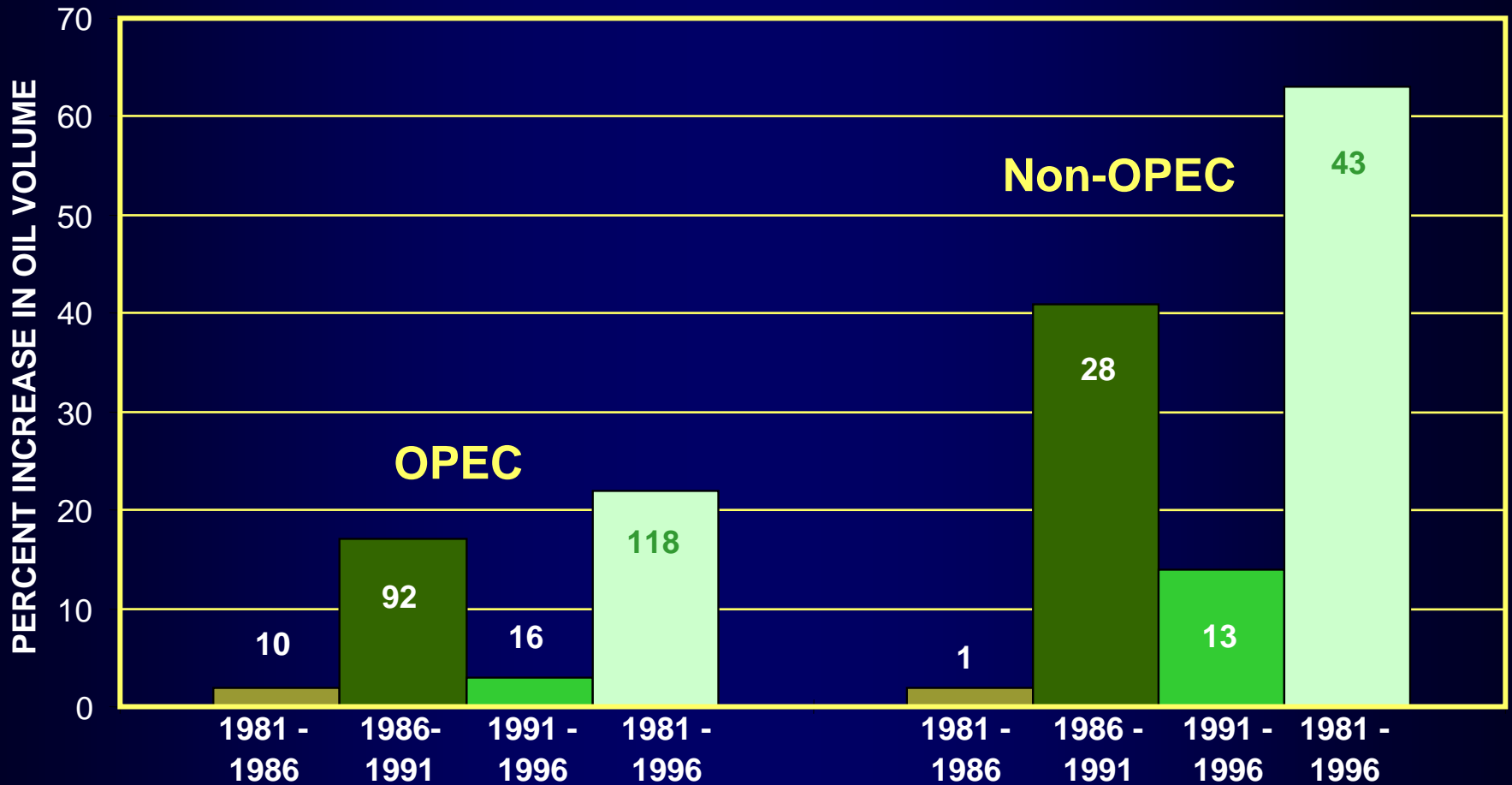
Giant Oil Fields of the World (≥ 500 MMBO, excl. U.S. and Canada), 1981 to 1996



Data source: IHS

From Klett and Schmoker, 2003

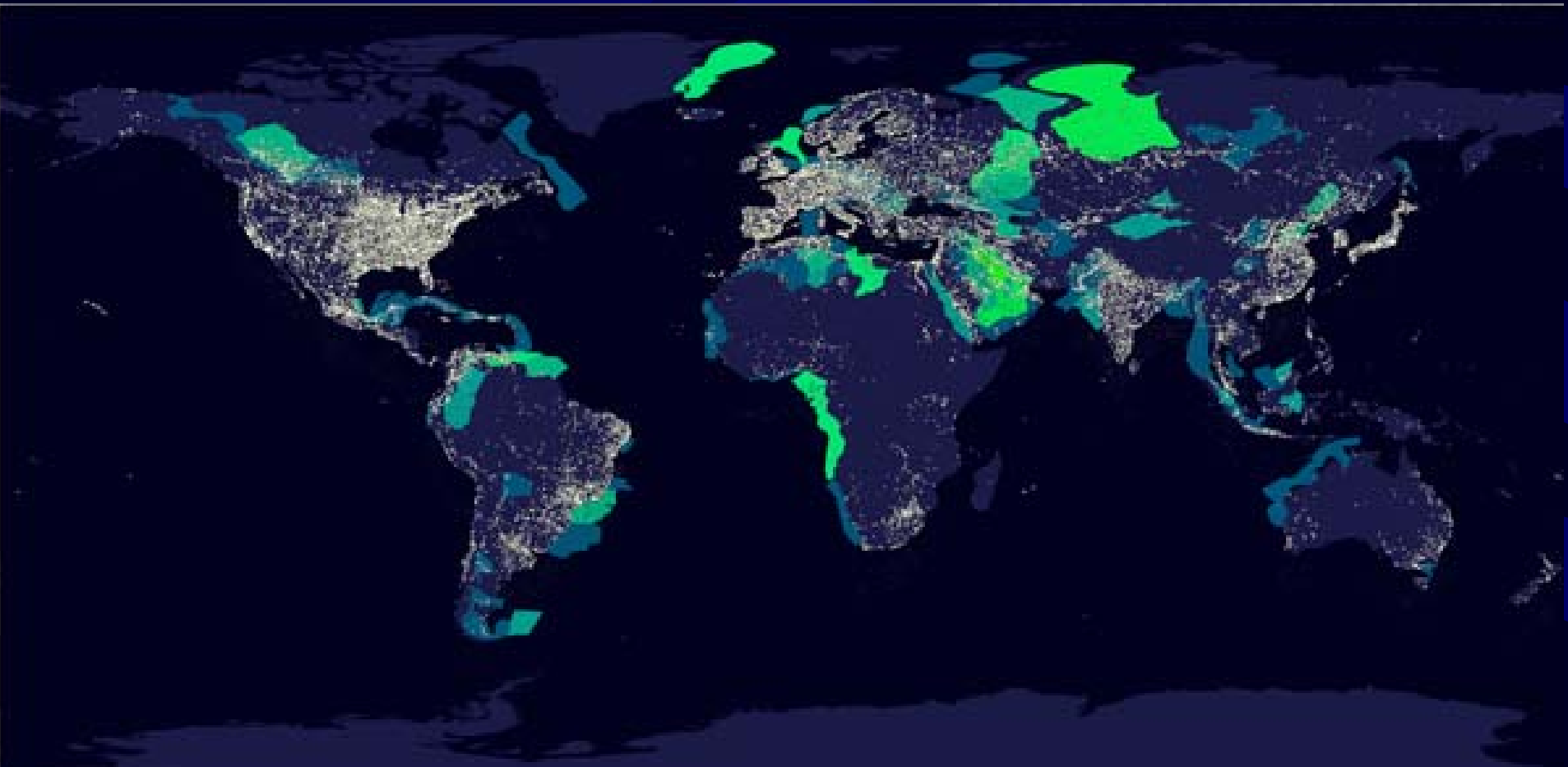
Relative Amount of Field Growth in Giant Oil Fields (excl. U.S. and Canada)



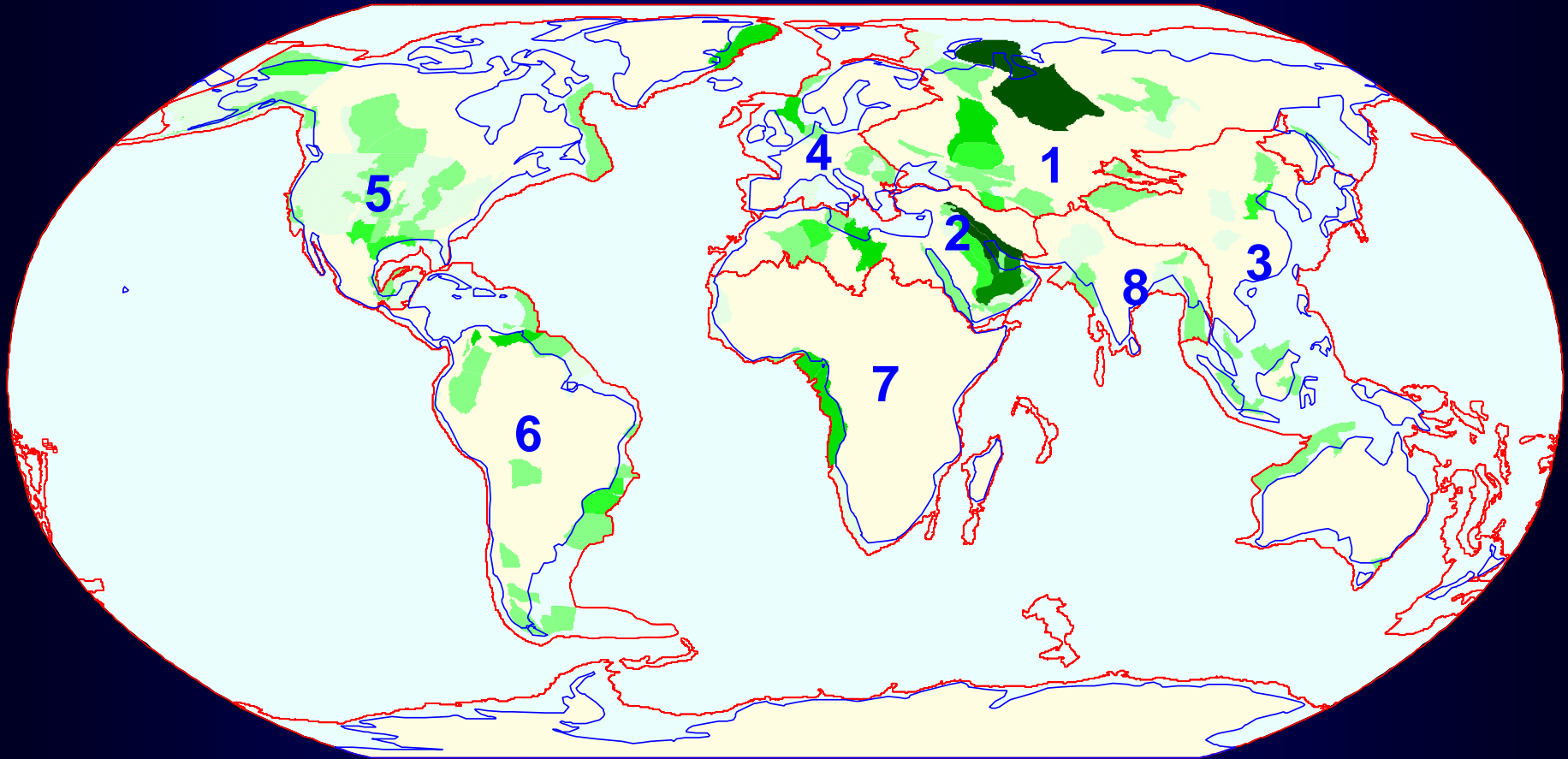
Reserve Growth Summary

- **In U.S. has accounted for 85% of all reserve additions in last 15 years**
- **First time assessed for world by USGS, known for 30 years (Odell, 1973)**
- **In USGS 2000, we estimated it to be 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)**

**USGS 2000 Oil Endowment
(graduated green color)
of assessed provinces superimposed on
“Earth by Night” image**



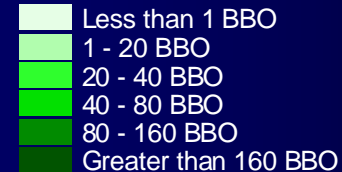
World Petroleum Assessment 2000



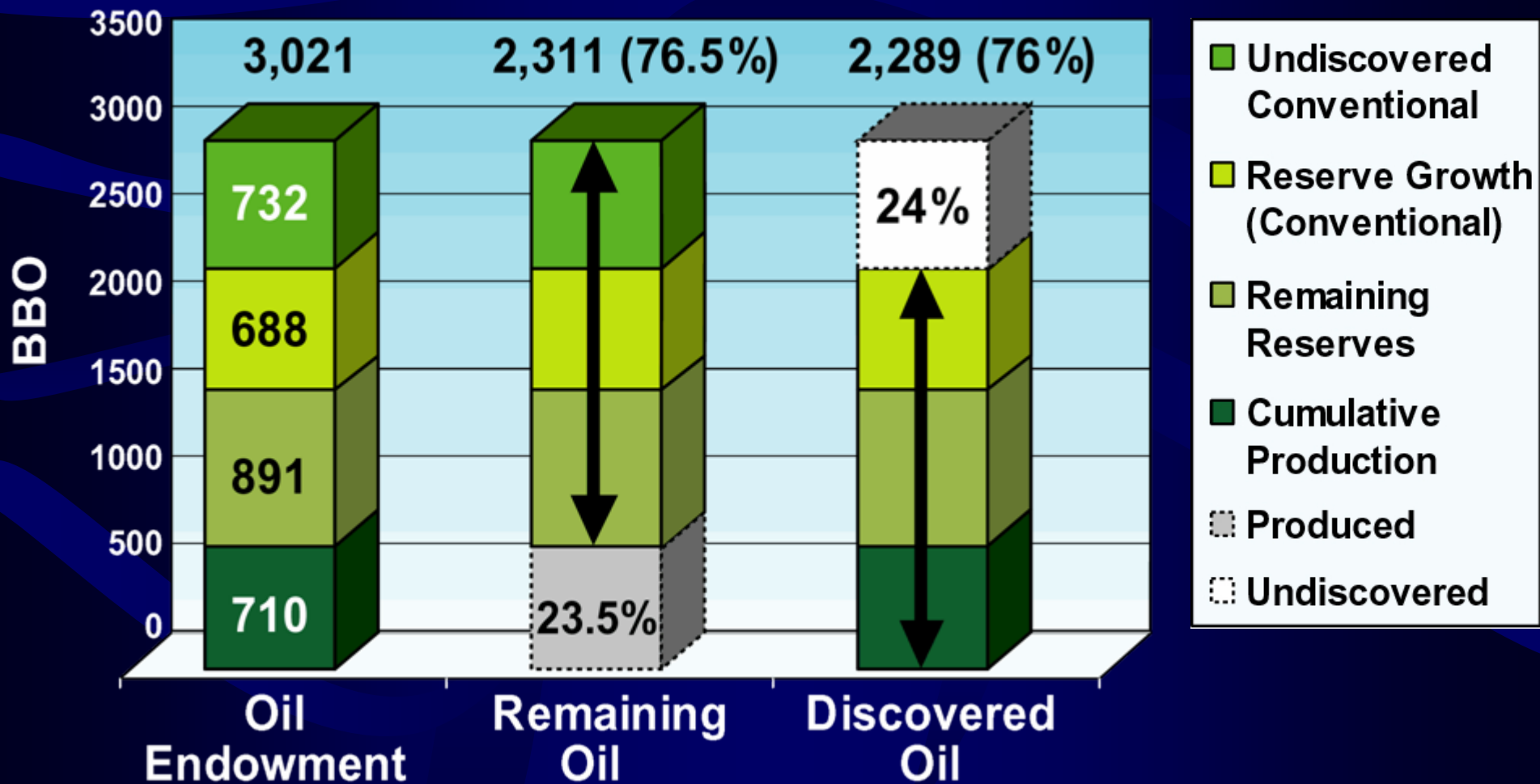
Conventional Oil Endowment of the World

- 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

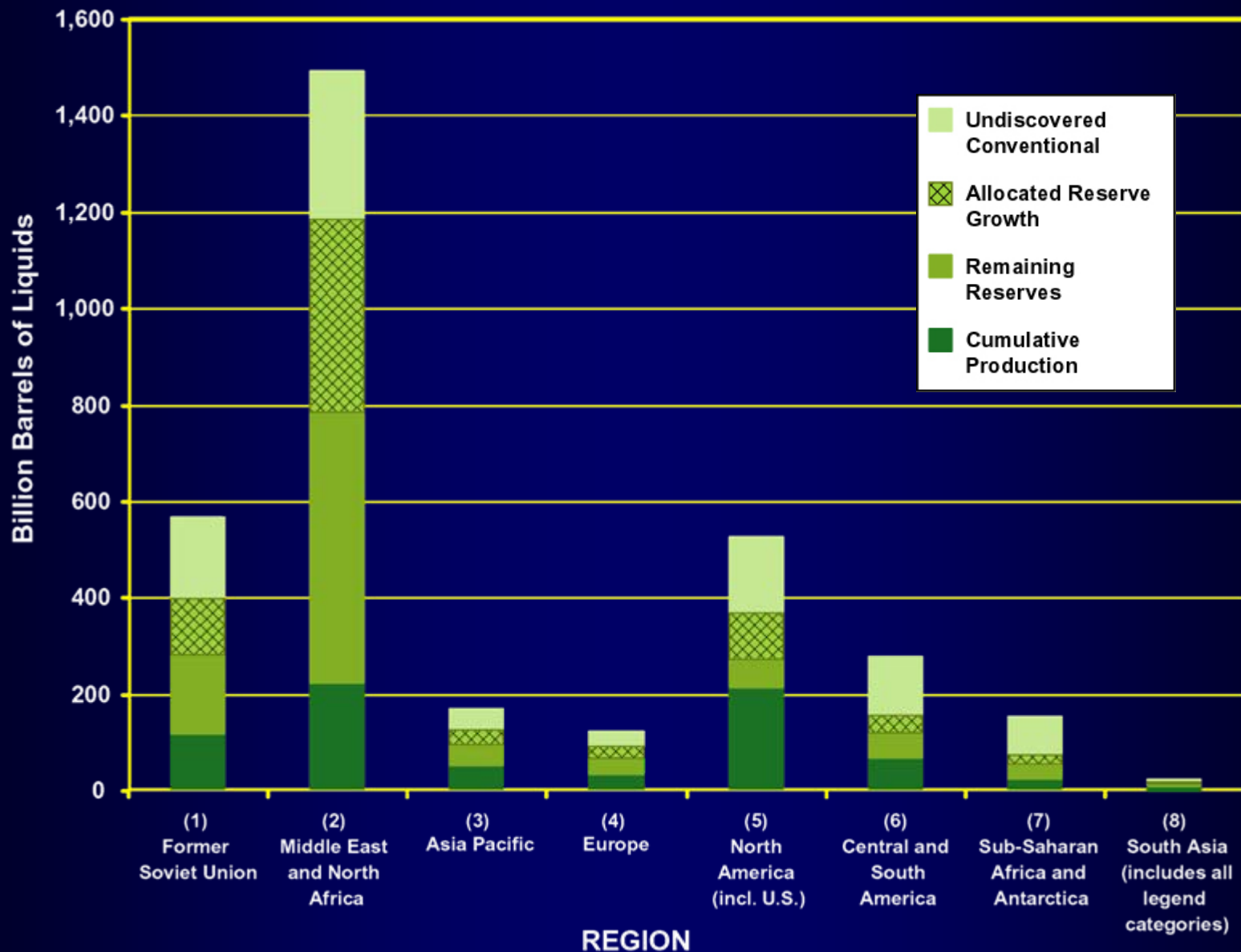
Conventional Oil Endowment in Billions of Barrels



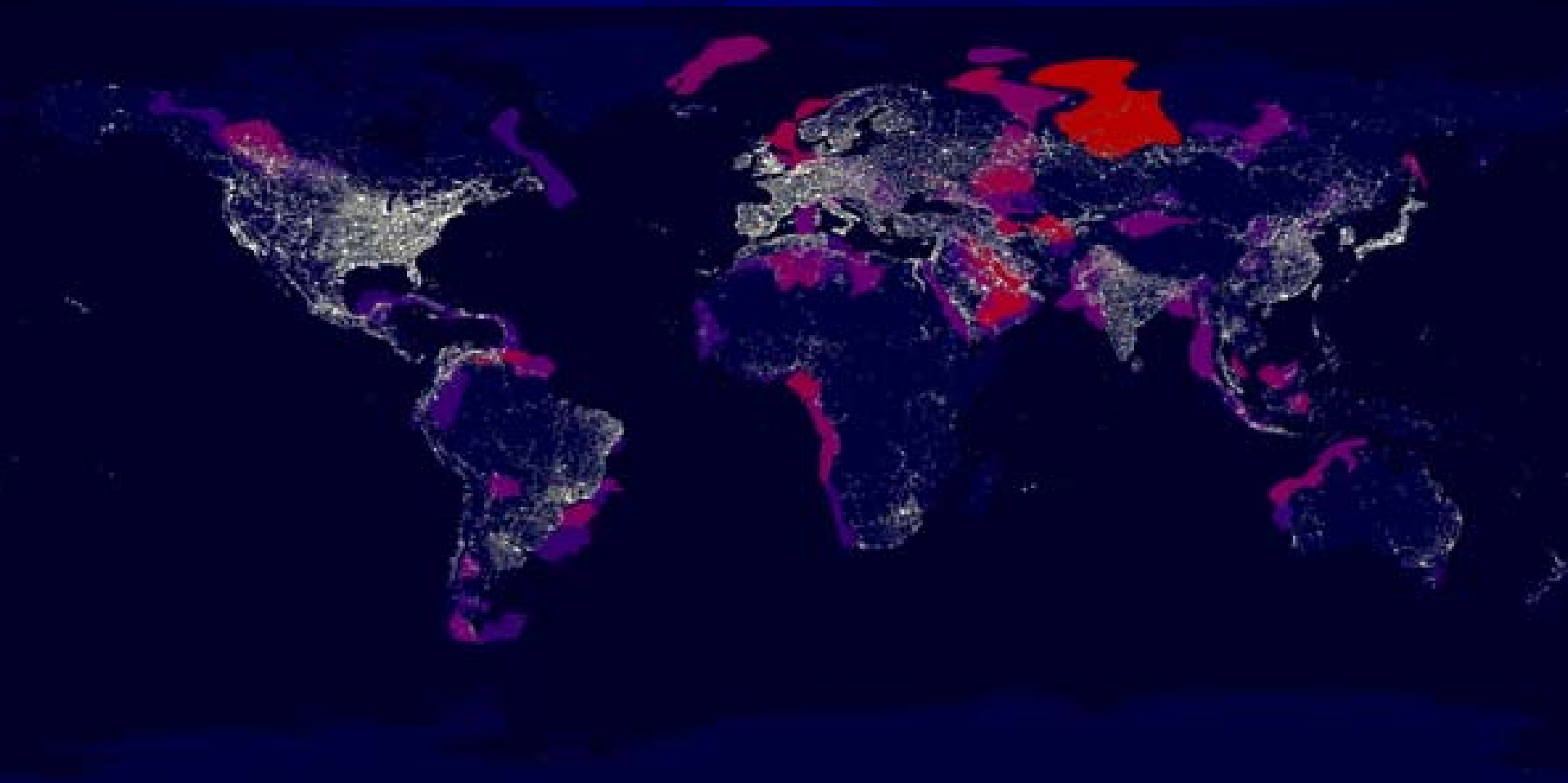
USGS World Petroleum Assessment 2000 Oil (128 World Provinces & U.S., Means Billion barrels) EFF. 1/1/96



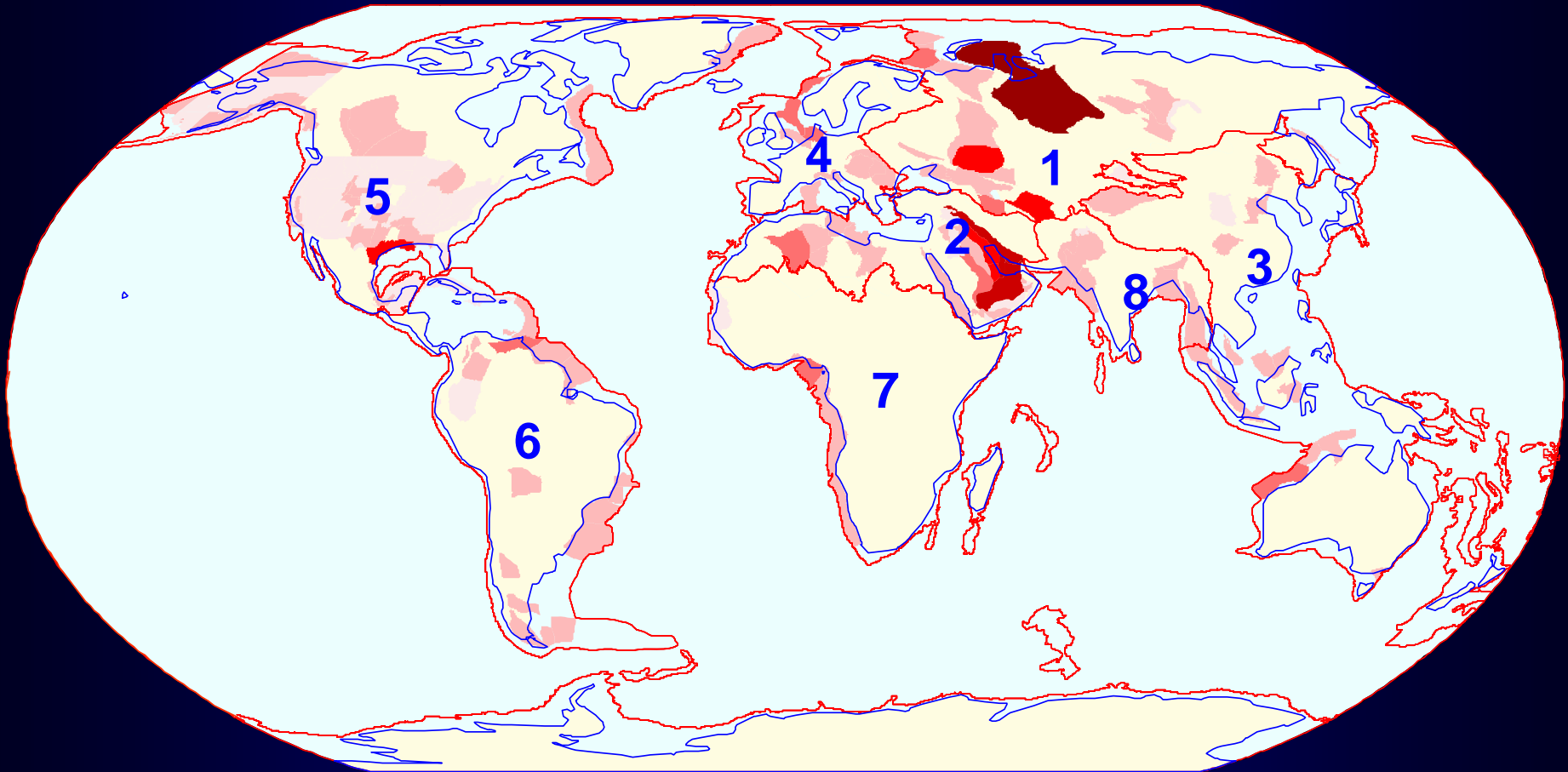
Conventional Liquid (Oil and Natural Gas Liquids) Endowment for the Eight Regions of the World, USGS 2000



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



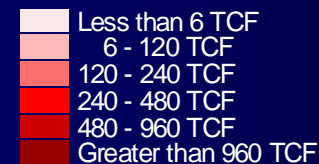
World Petroleum Assessment 2000



Conventional Natural Gas Endowment of the World

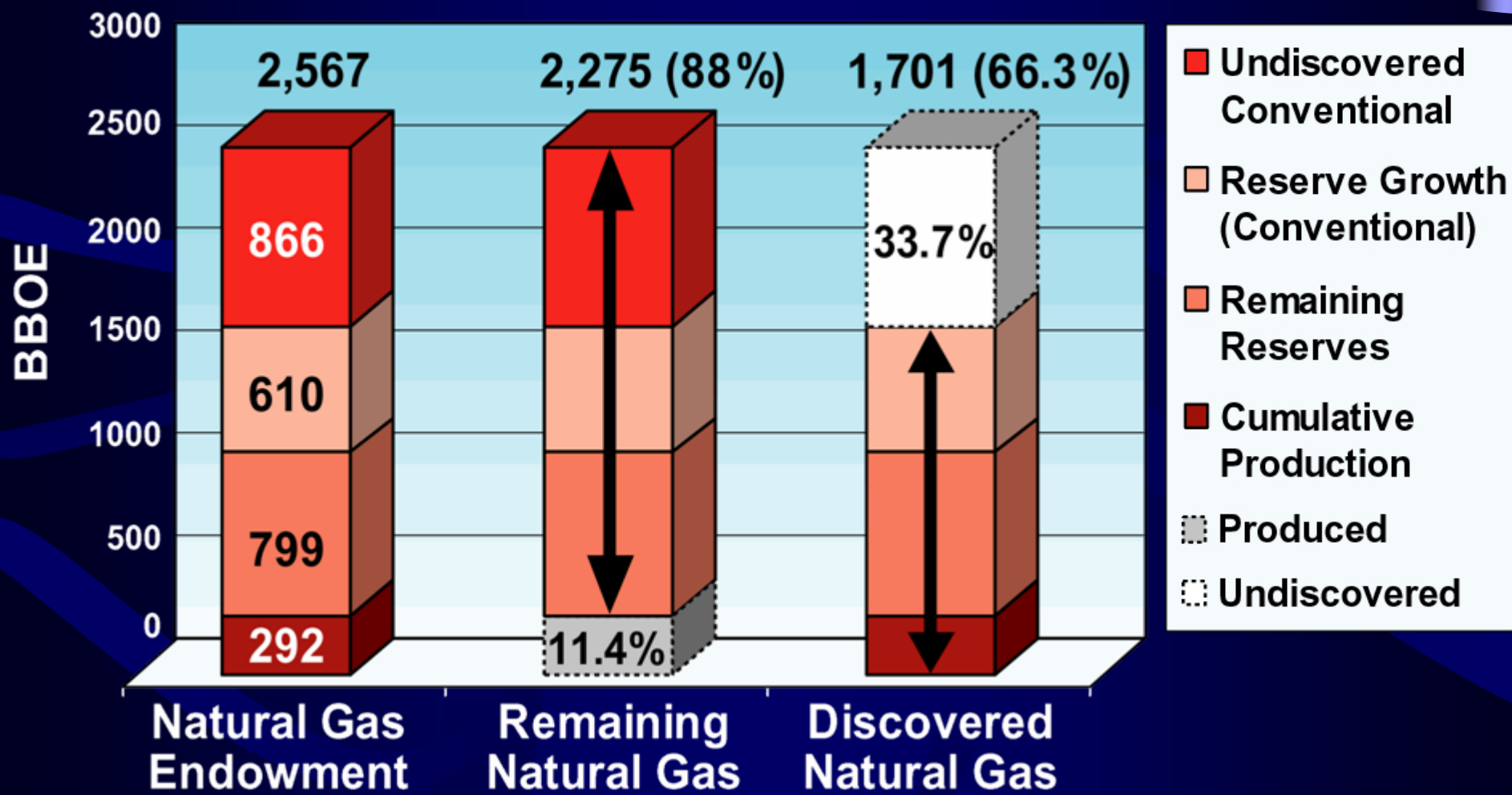
- 1 Former Soviet Union
- 2 Middle East and North Africa
- 3 Asia Pacific
- 4 Europe
- 5 North America
- 6 Central and South America
- 7 Sub-Saharan Africa and Antarctica
- 8 South Asia

Conventional Natural Gas Endowment in Trillions of Cubic Feet

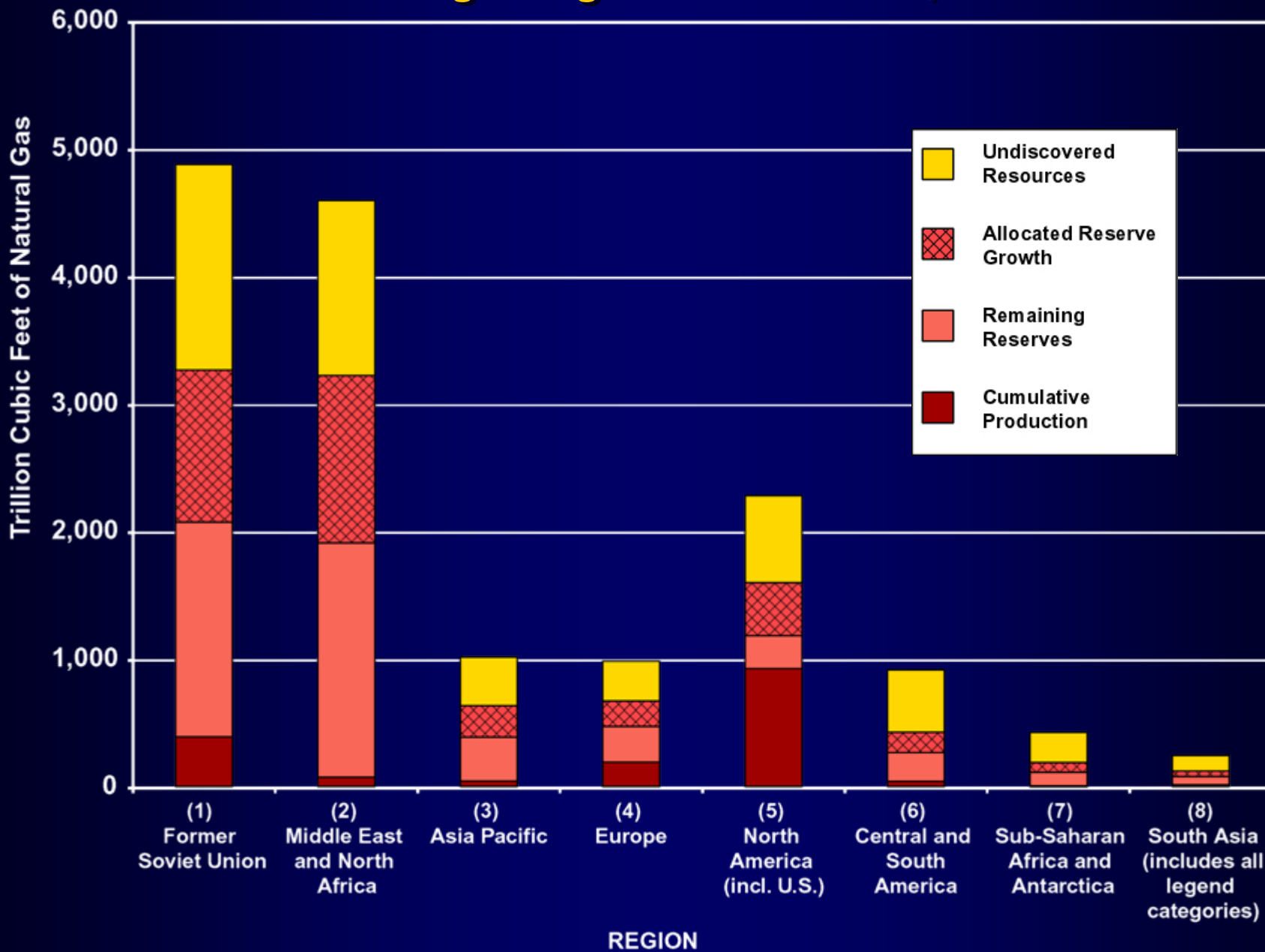


Conventional gas endowment

USGS World Petroleum Assessment 2000 Natural Gas (128 World Provinces & U.S., Means Billion barrels oil equivalent [BBOE] EFF. 1/1/96

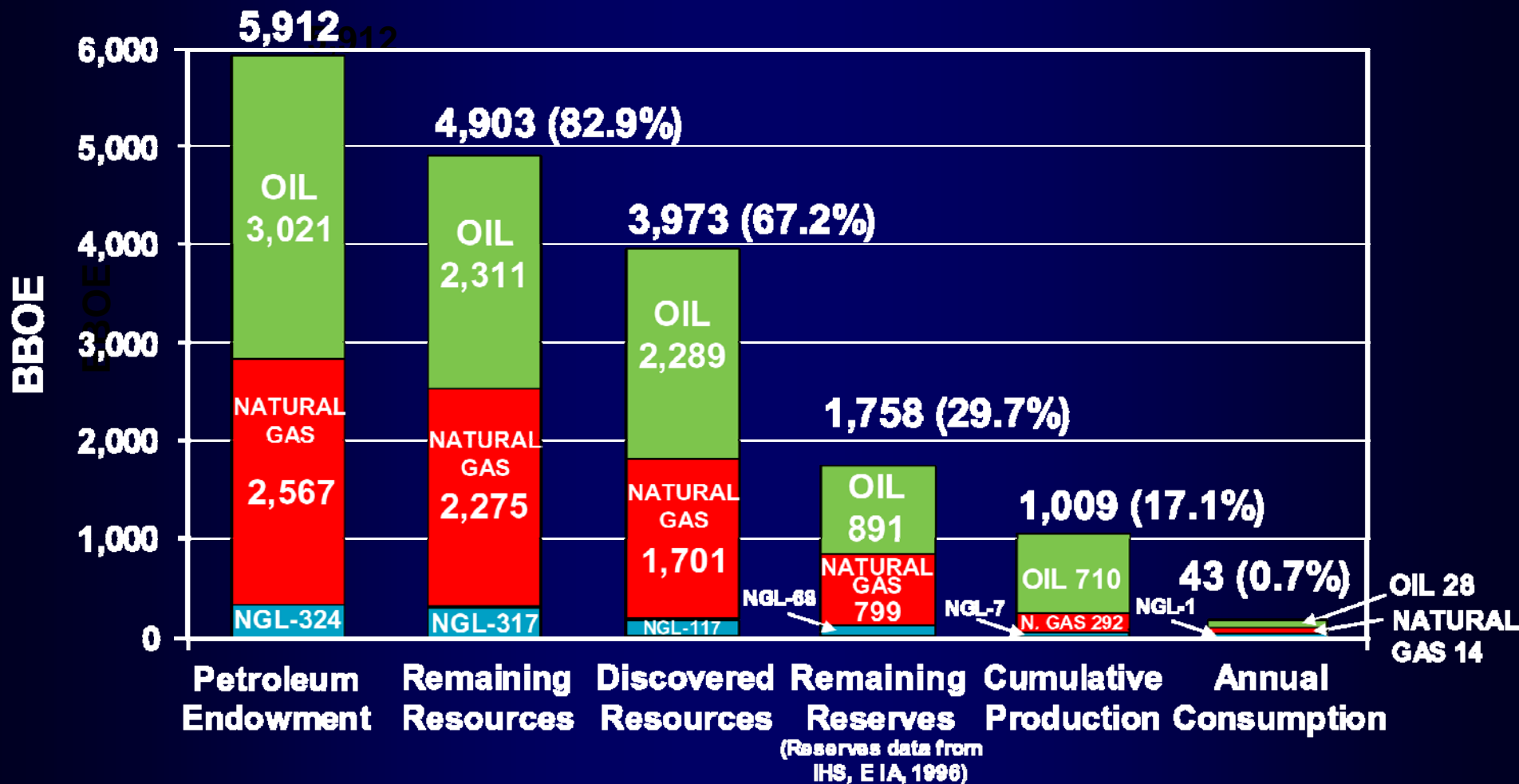


Conventional Natural Gas Endowment for the Eight Regions of the World, USGS 2000

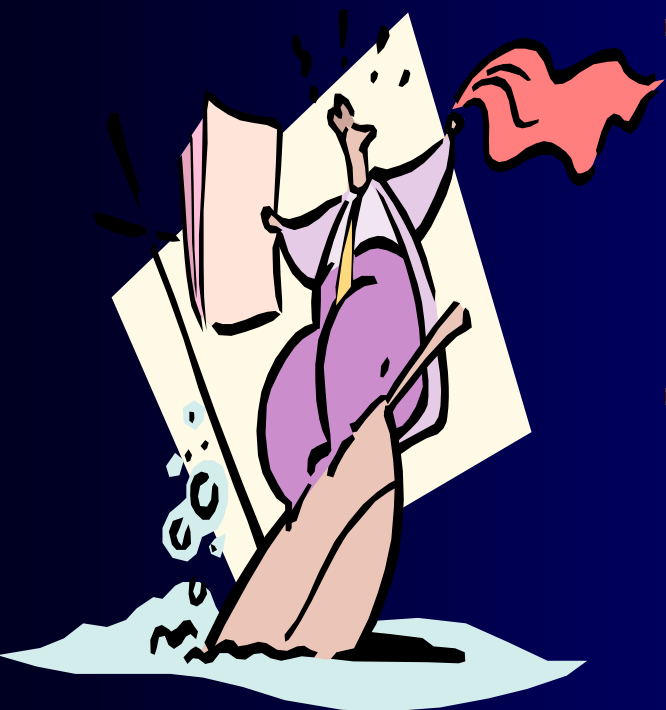


USGS 2000 World Petroleum Endowment (128 World Provinces & U.S.)

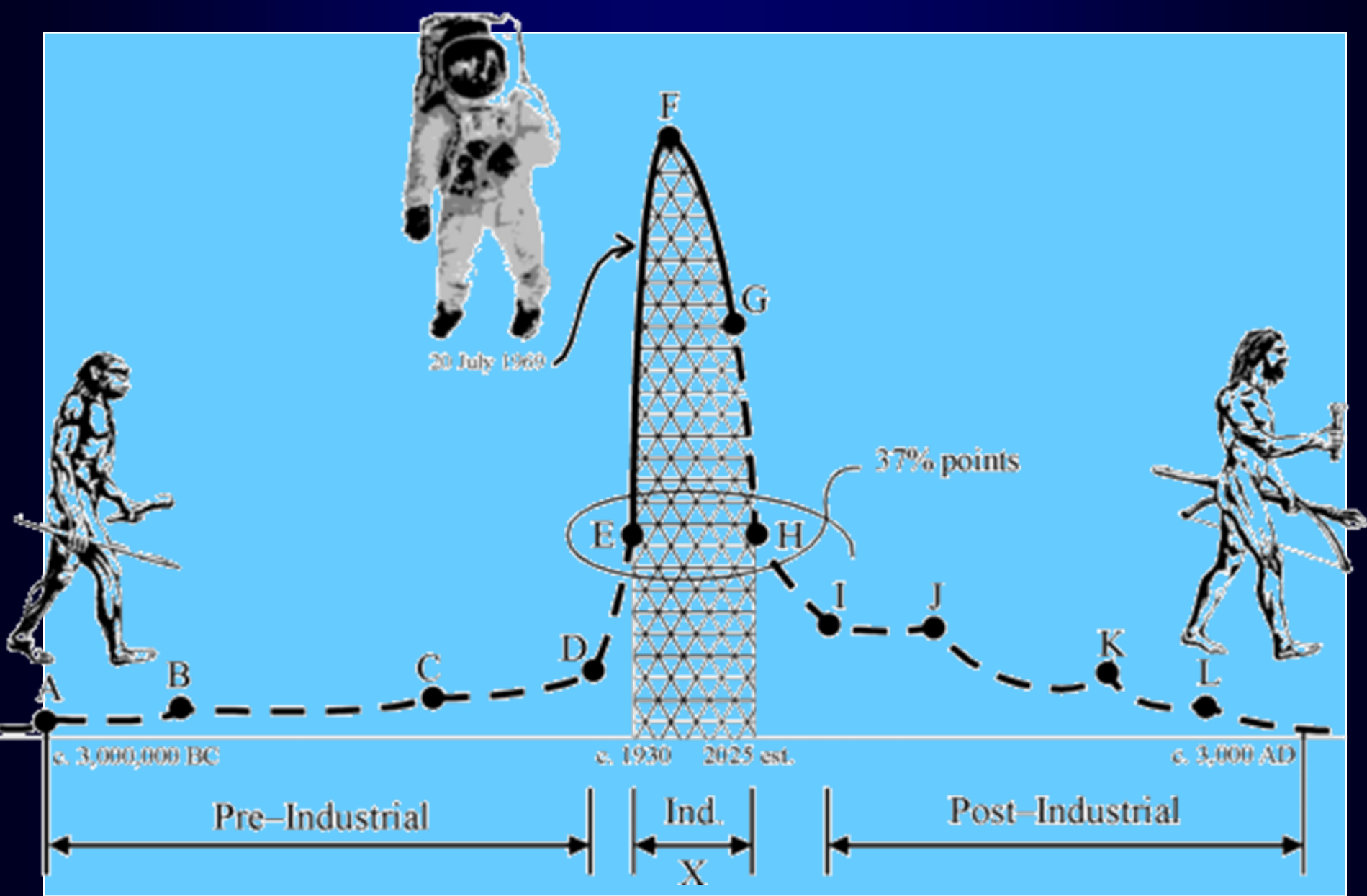
(Conventional Oil, Natural Gas, NGL, Means in Billion Barrels,
EFF. 1/1/96)



The Coming Oil Crisis?

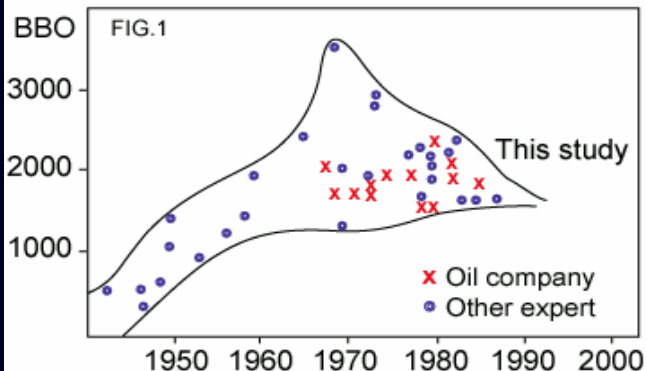


- **“..the peak of production will soon be passed—possibly within three years—
Dave White, Chief Geologist, USGS,
1919**
- **“the peak of production will be reached
in 1989, Campbell, 1989; prior to
2000”—Campbell, 1994; Duncan,
1997; “in 2004”—Campbell, 1997; “in
2010”, Campbell, 2000--subsequently
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

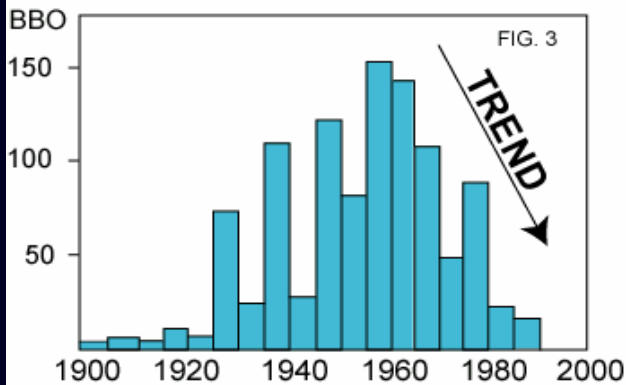
EXPERT ESTIMATES OF WORLD ULTIMATE OIL RECOVERY



CONVENTIONAL OIL ONLY

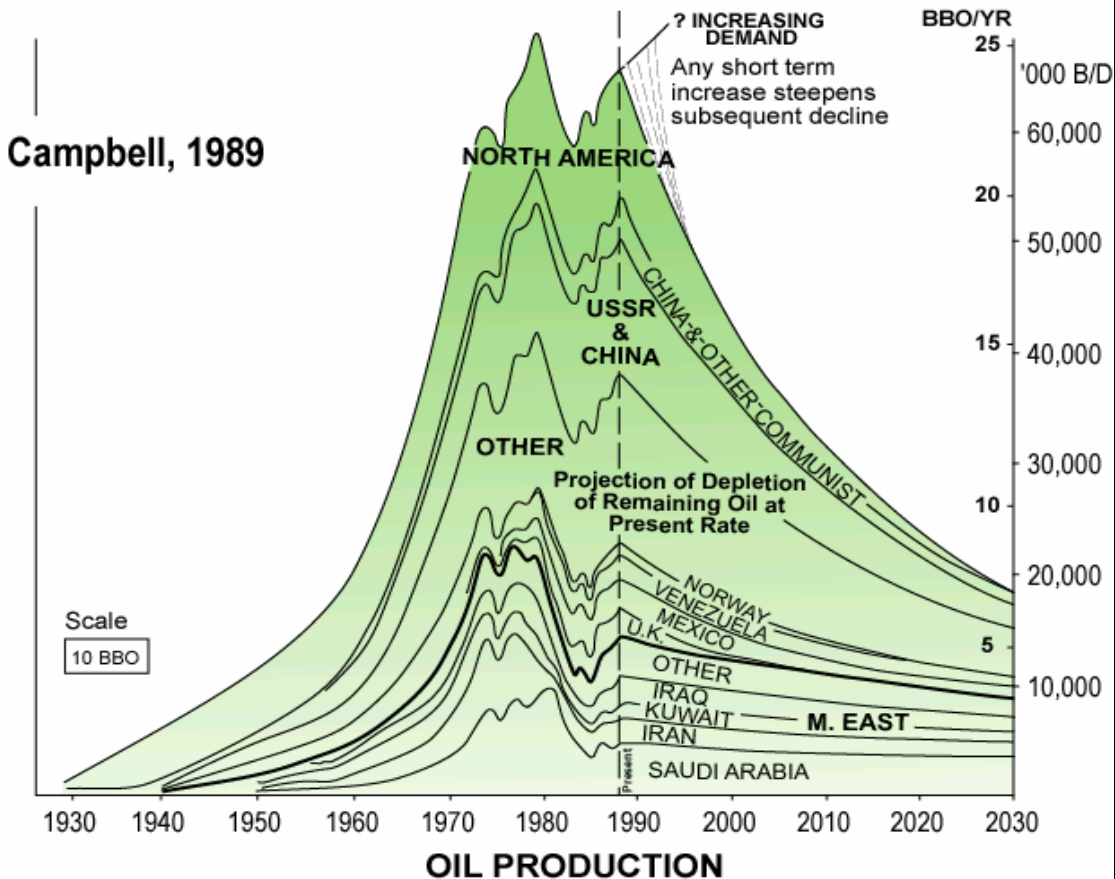
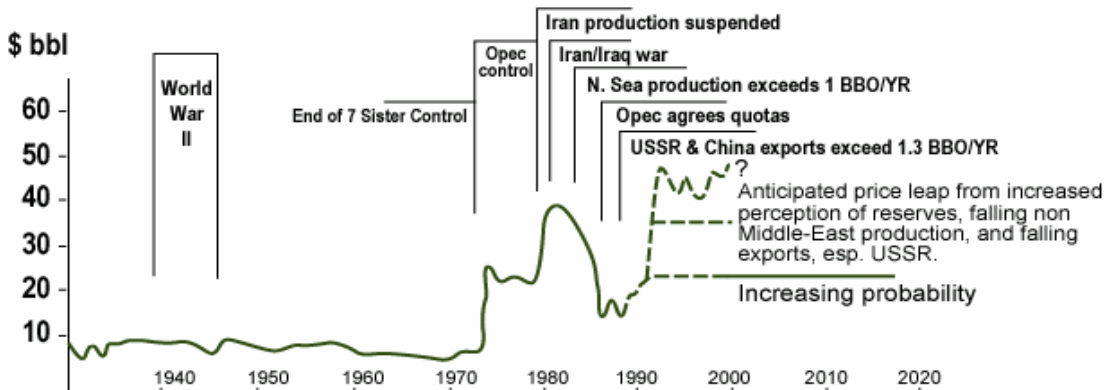
Ignores:
 "Unconventional" enhanced recovery
 Tar sands
 Oil shales
 Gas liquification advances

GIANT DISCOVERIES 400 FIELDS >0.5 BBO

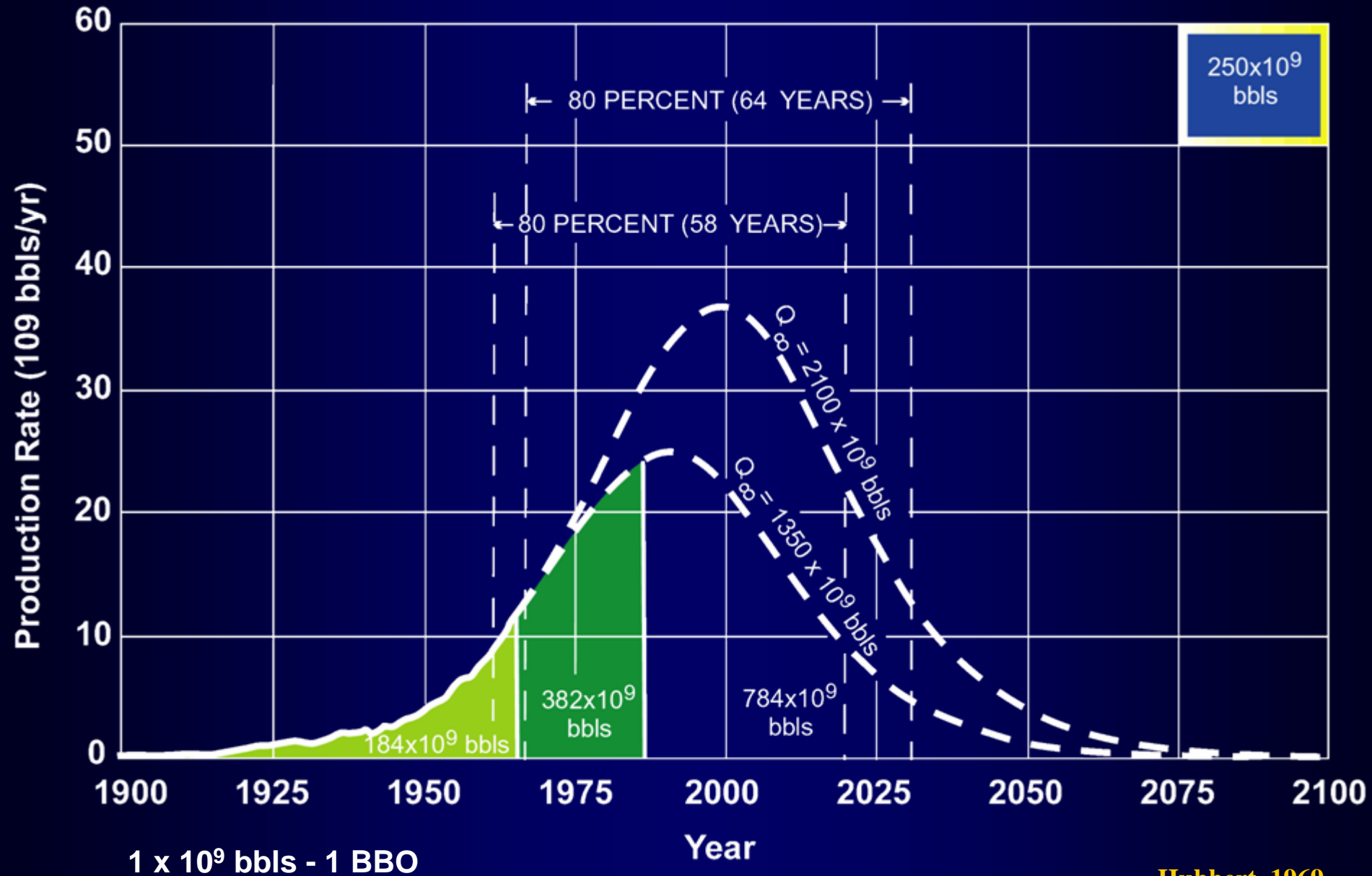


TREND HERALDS END OF GIANT DISCOVERIES--
 50% of all discovered to date came from GIANT FIELDS

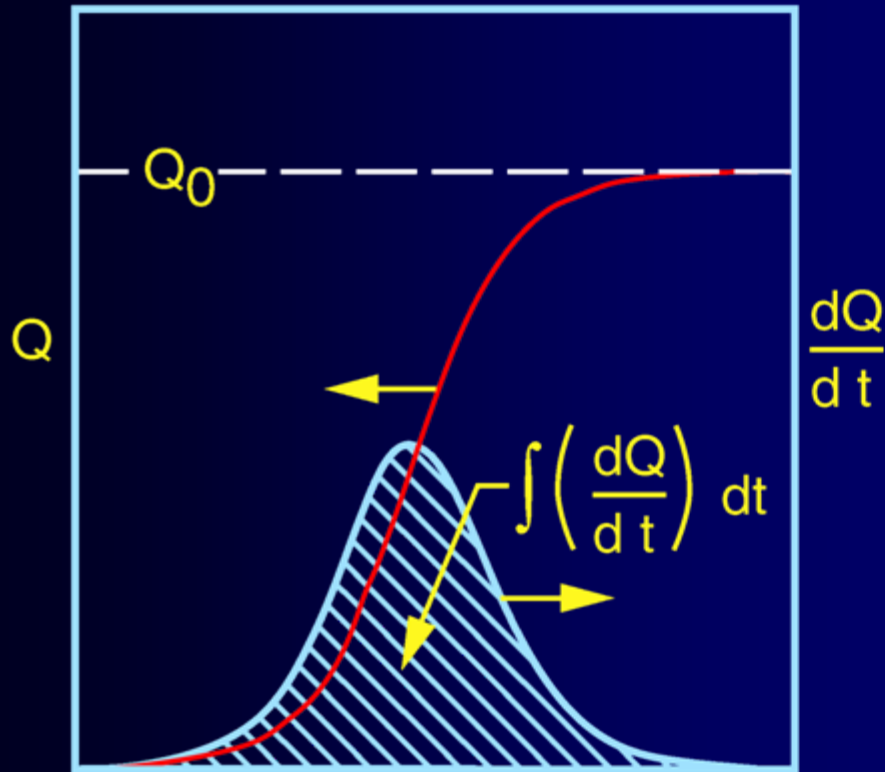
CRUDE OIL PRICE 1987 \$



World Oil Supply

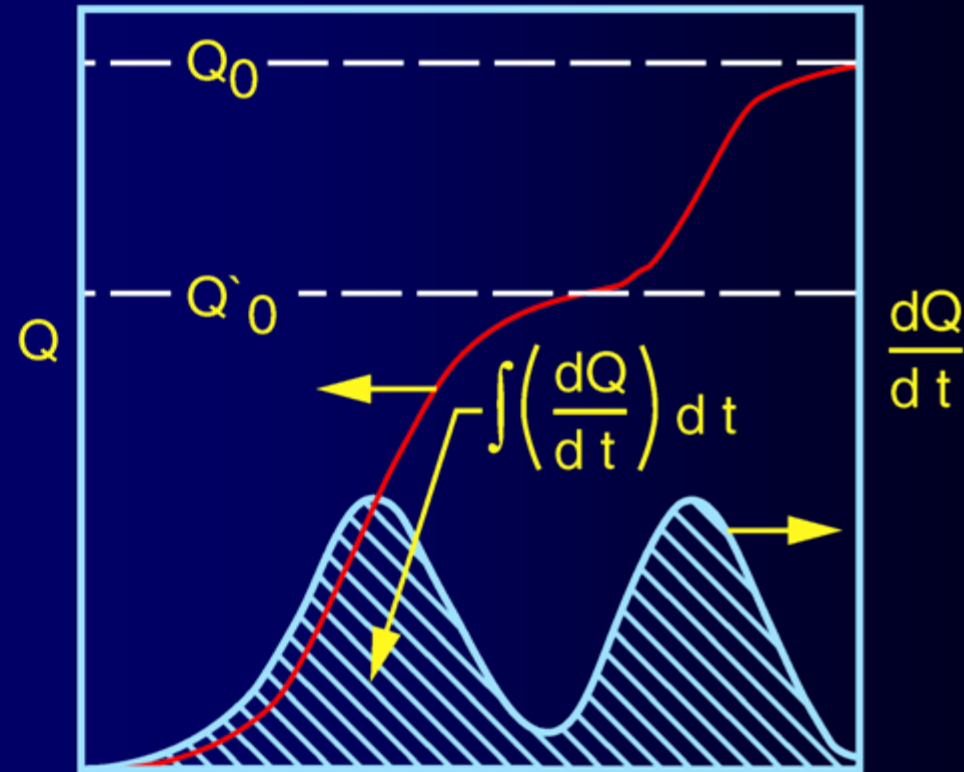


Logistic growth curves of cumulative production and their derivatives which give the rates of production



TIME
(a)

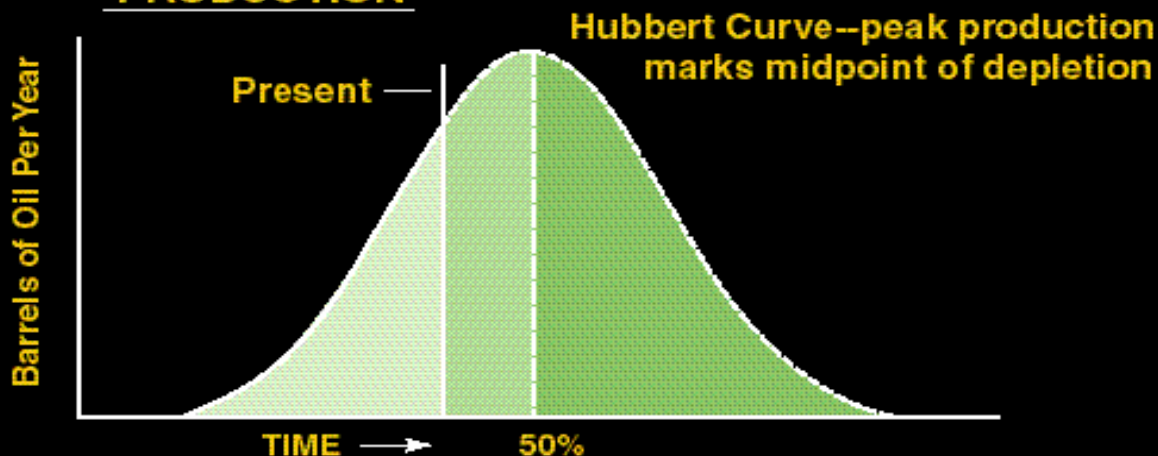
(a) single-cycle curve



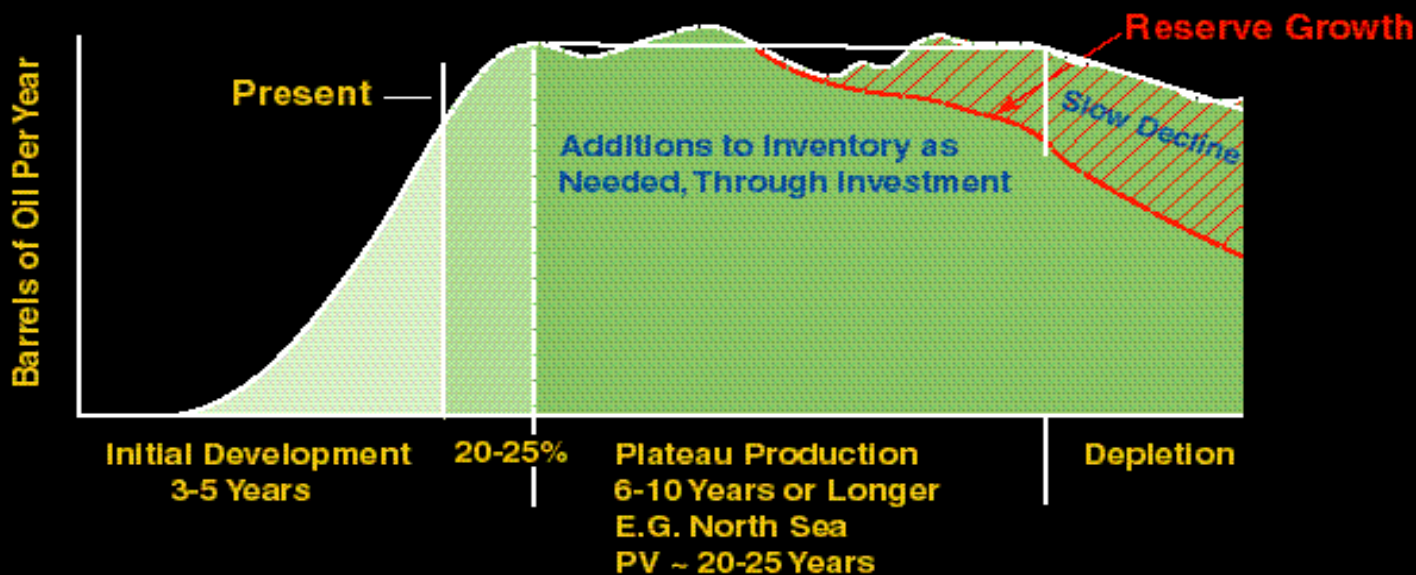
TIME
(b)

(b) multiple-cycle curve

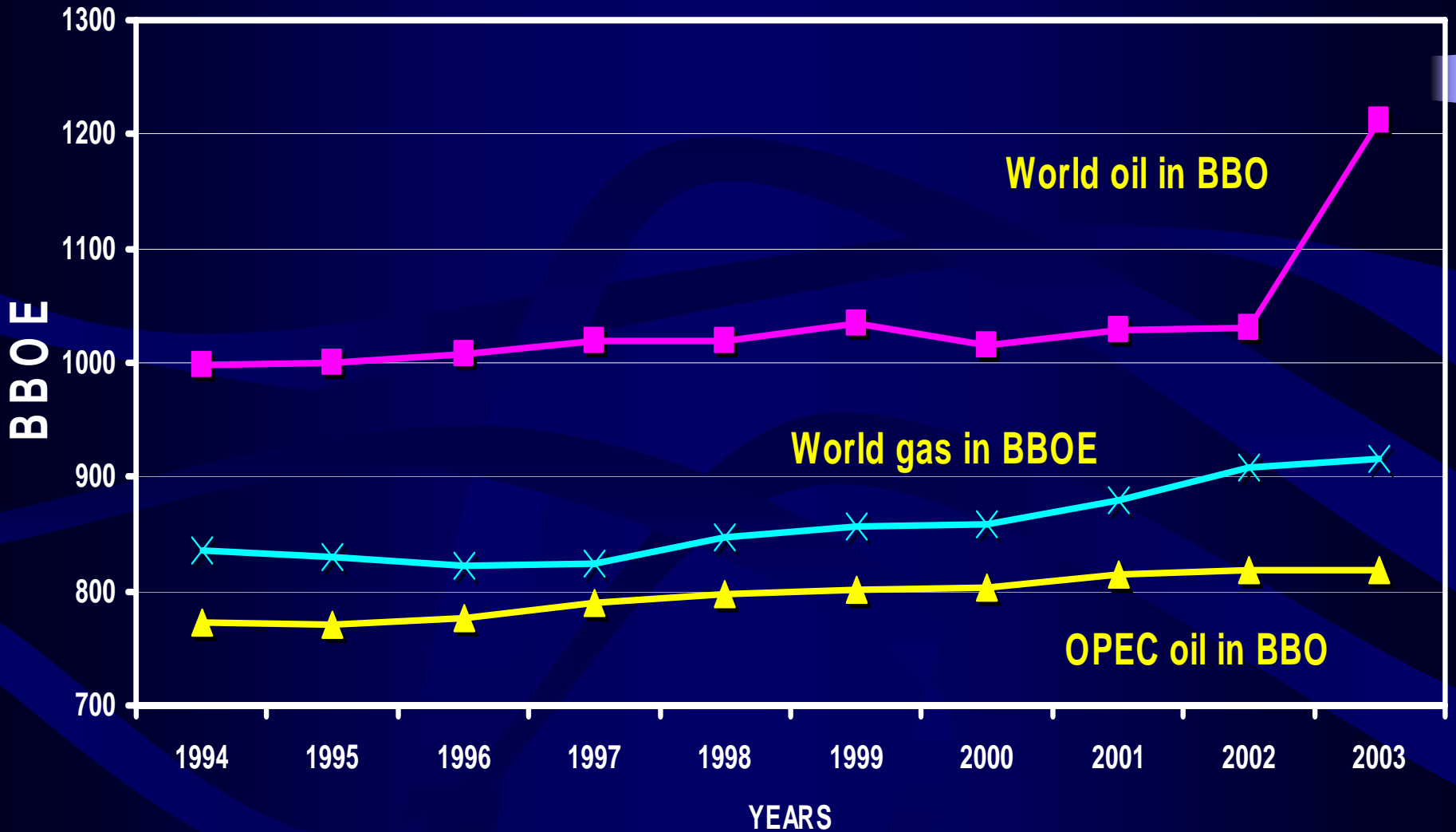
PRODUCTION



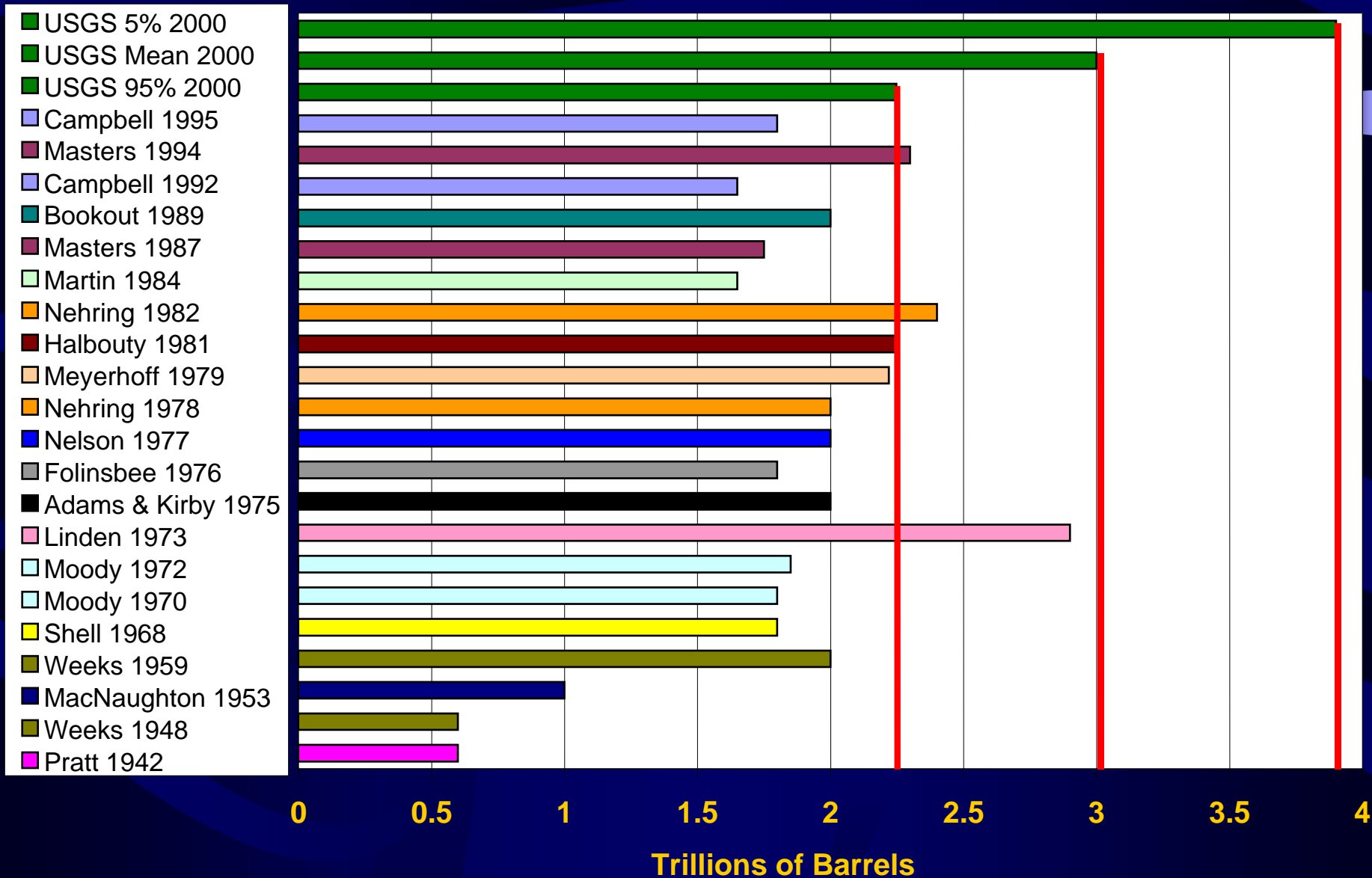
PLATEAU CONCEPT



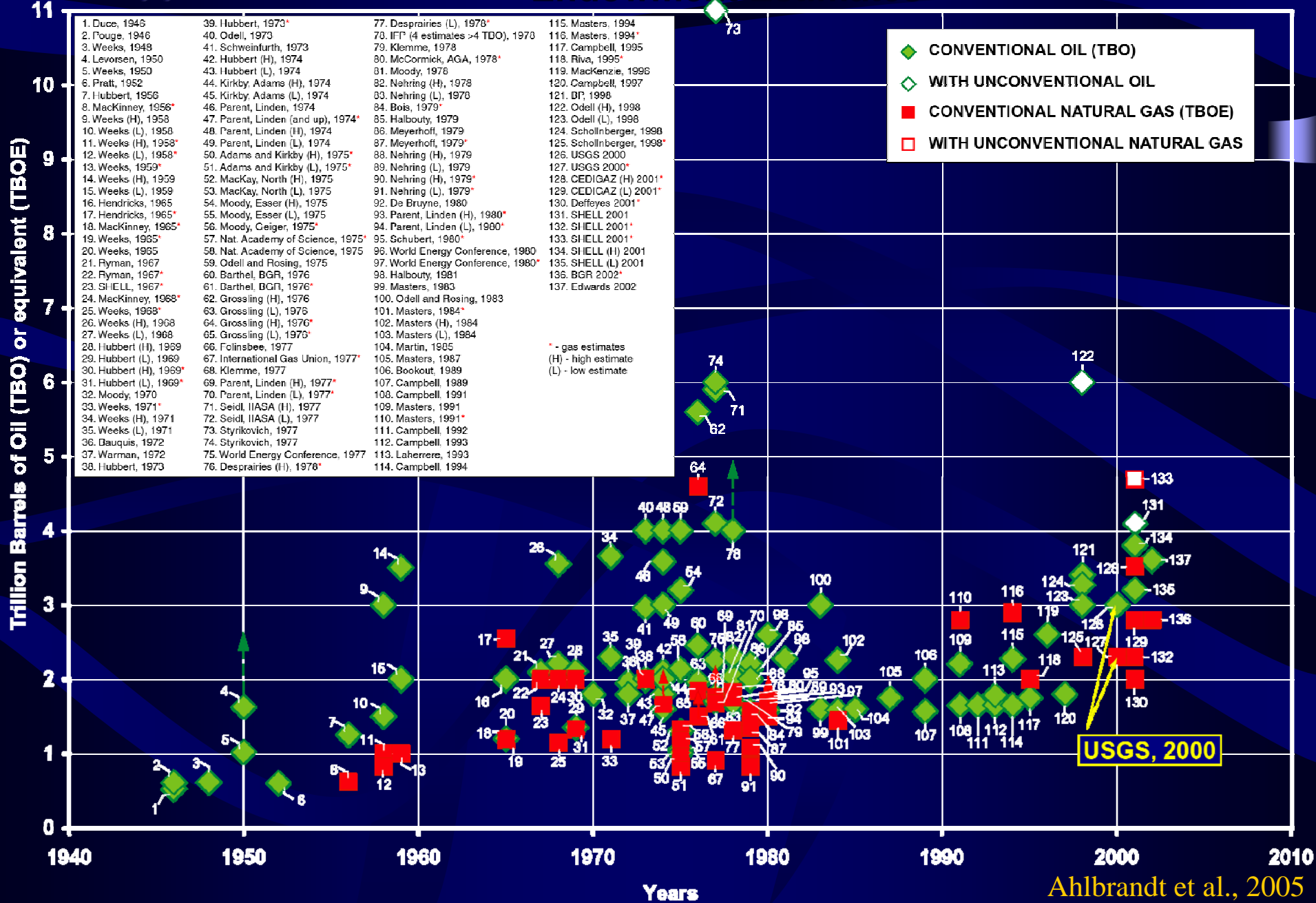
Recent Oil and Natural Gas Reserve Estimates



Published Estimates of World Oil Ultimate Recovery



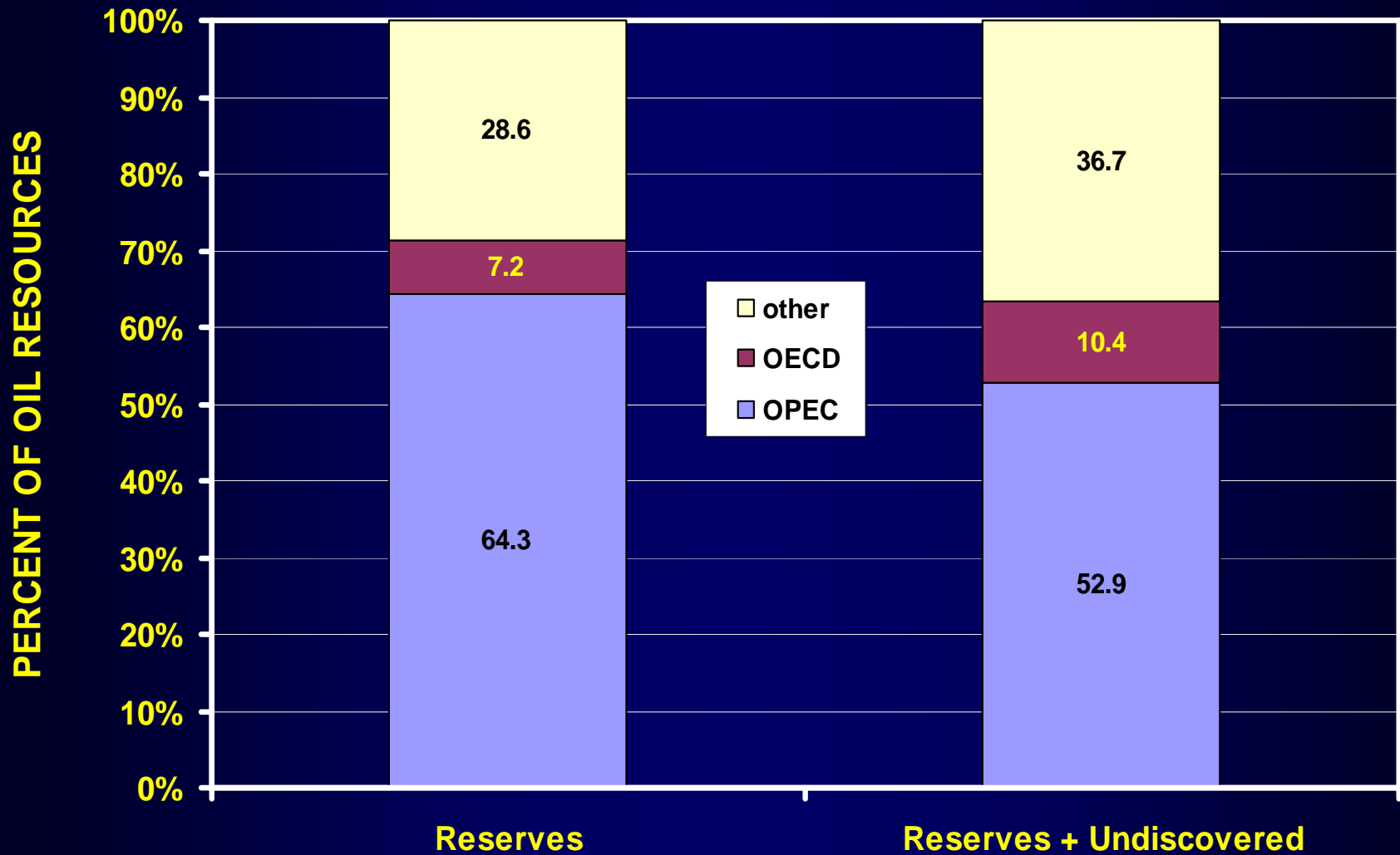
Comparison of World Oil and Natural Gas Resource Endowment Estimates



World Oil

- **World Petroleum Reserves are at all time high about 5 times larger than reserves at end of WWII (1945)**
- **Remaining Reserves ~891 BBO (1/1/96), 1,100 BBO (1/1/2001)—Increase of 15% using IHS Data**
- **Increase of 36% using 2003 O&J Data (includes 175 BBO from Canadian tar sands)**
- **Currently Consuming about 28 BBO / Year**
- **Oil and Natural Gas Reserve Additions Are Increasing**

Possible Changes in Organization Share of Oil



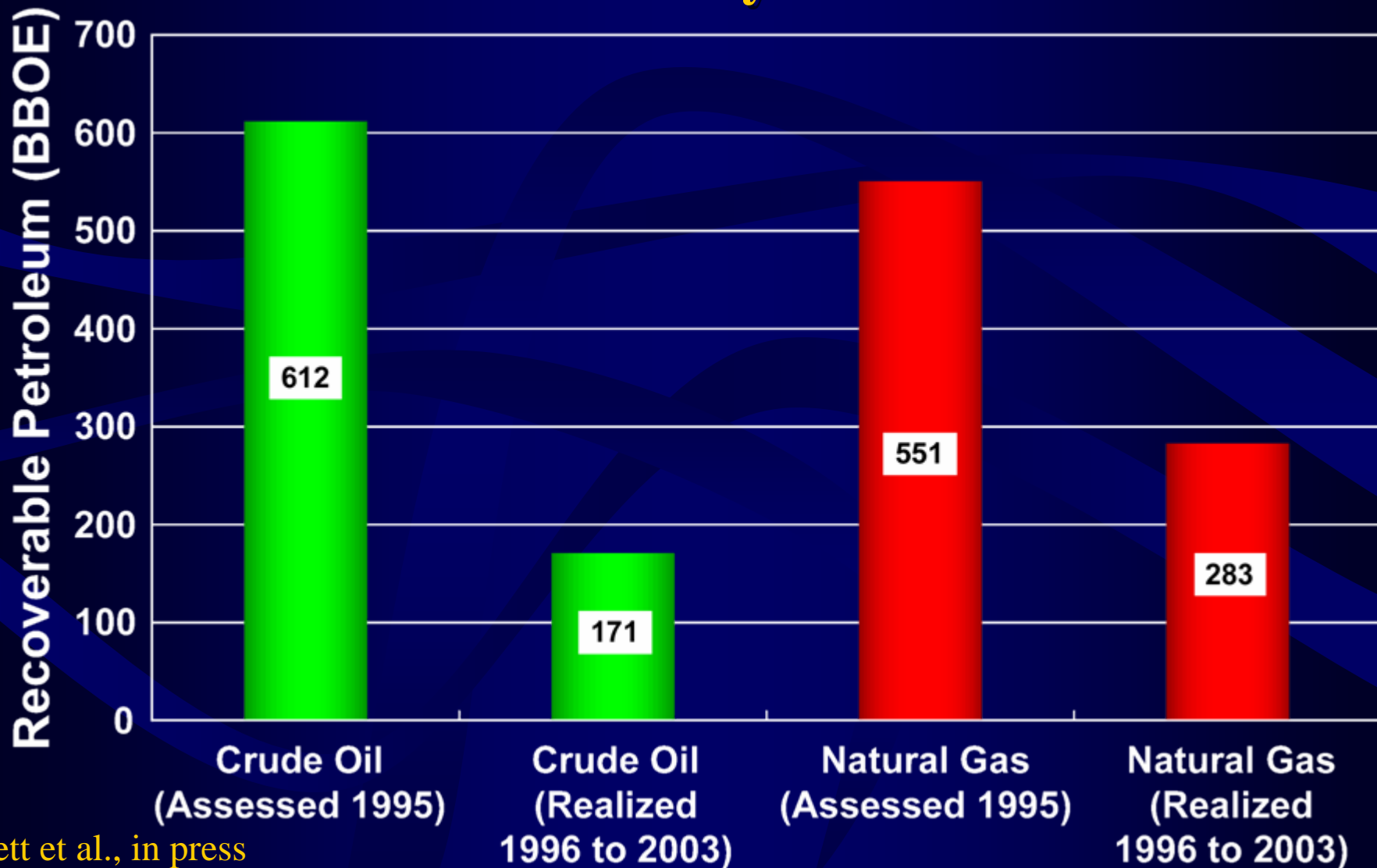
OR is it Natural Gas?

- **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**
- **Where is the missing half trillion BOE of gas?**

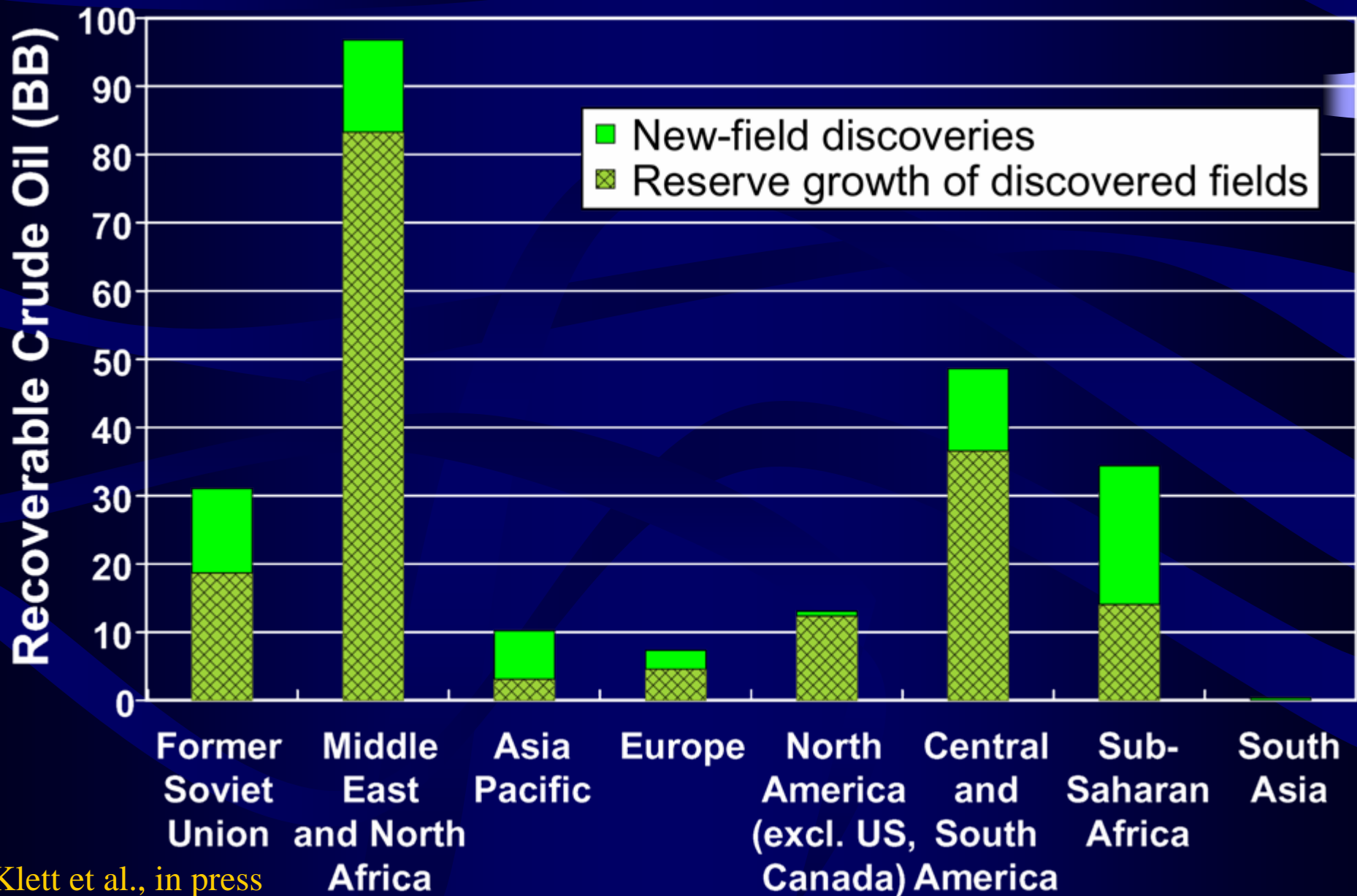
USGS 2000 Calibration

- **In seven years, 23% of oil and 31% of natural gas USGS 2000 estimates (whole world) have been realized**
- **18% of estimated oil and 27% of estimated natural gas have been added (Only provinces assessed)**
- **Reserve growth added three times the volumes of new field discoveries**
 - 26% of estimated oil volume
 - 52% of estimated natural gas volume
- **USGS 2000 estimates seem reasonable assuming linear rate of reserve additions**

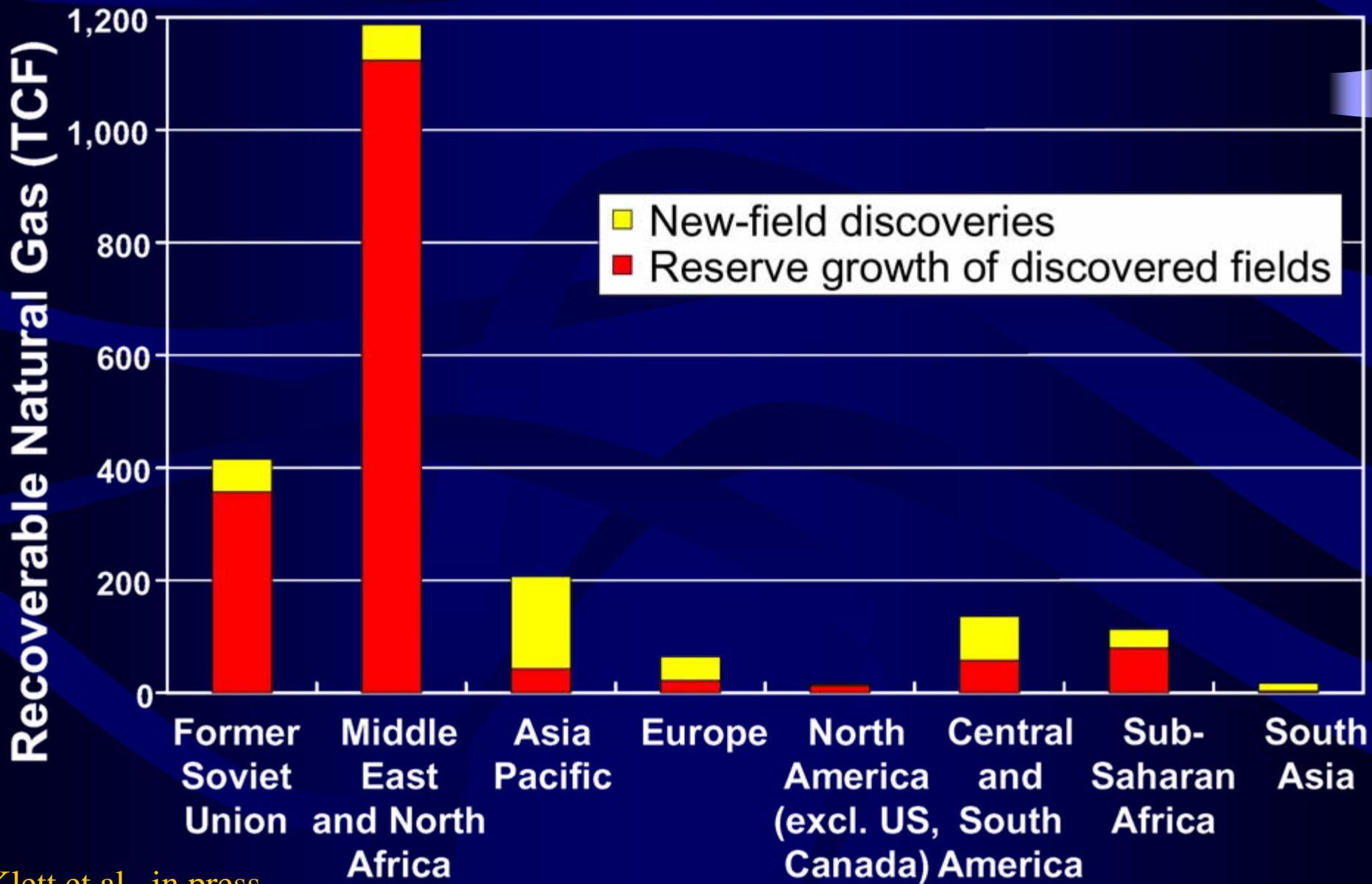
Calibration of USGS Oil and Natural Gas Estimates 1st 7 Years of 30 year forecast



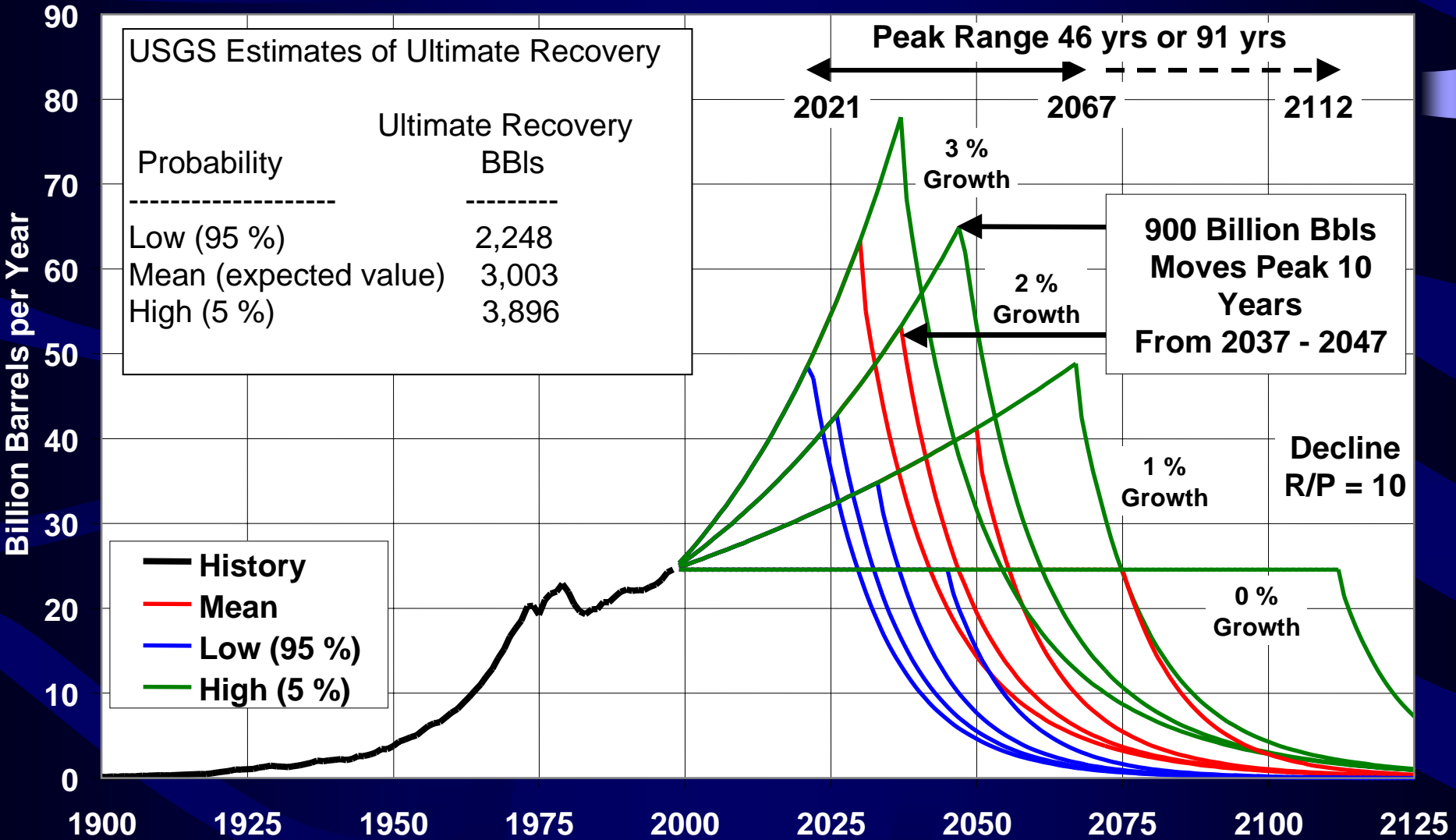
Oil Reserve Additions: Reserve Growth vs. Undiscovered



Natural Gas Reserve Additions: Reserve Growth vs. Undiscovered



12 EIA World Conventional Oil Production Scenarios



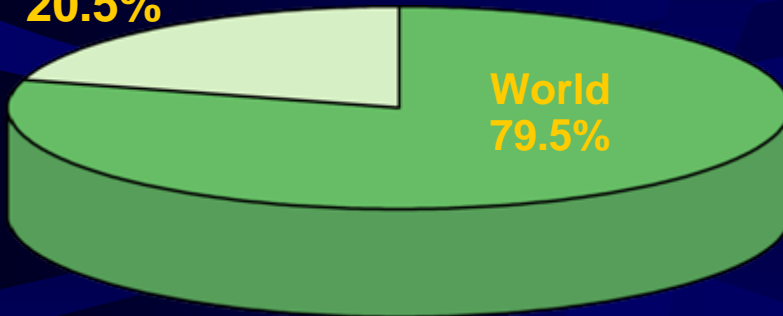
Note: U.S. volumes were added to the USGS foreign volumes to obtain world totals.

Arctic Share of Undiscovered Petroleum

OIL & NGL

Arctic
20.5%

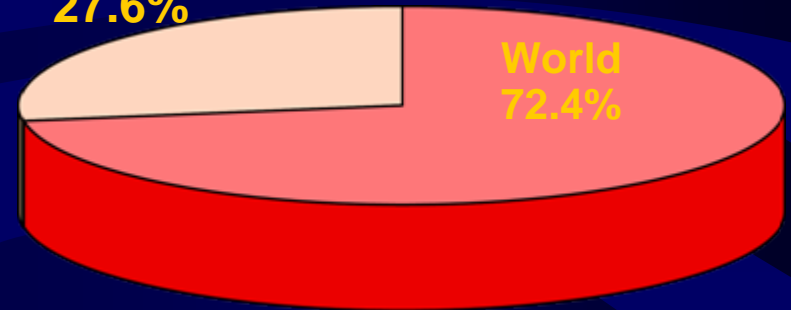
World
79.5%



GAS

Arctic
27.6%

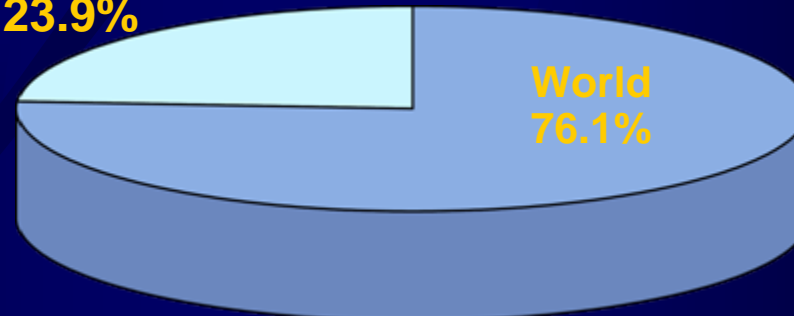
World
72.4%



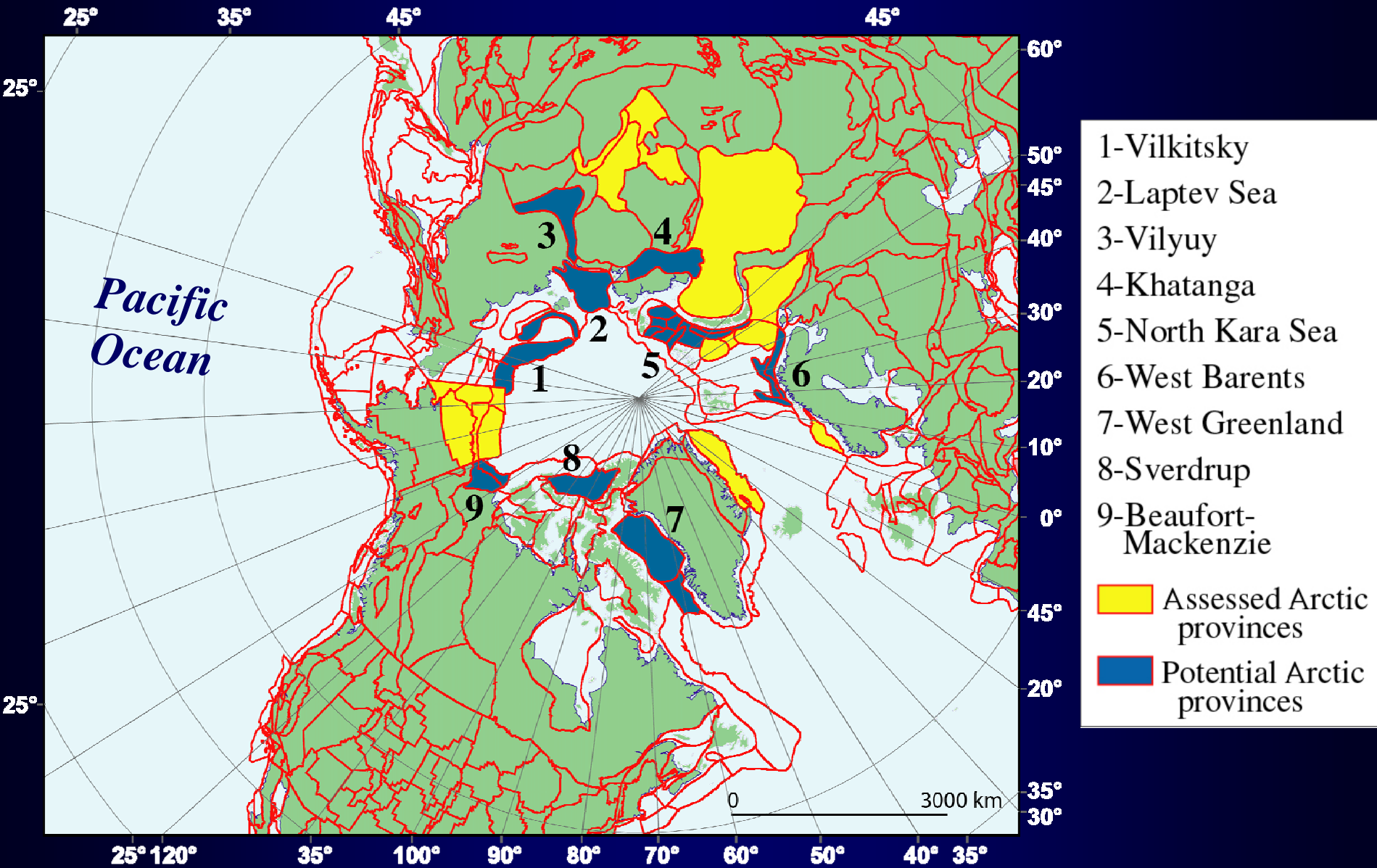
TOTAL PETROLEUM

Arctic
23.9%

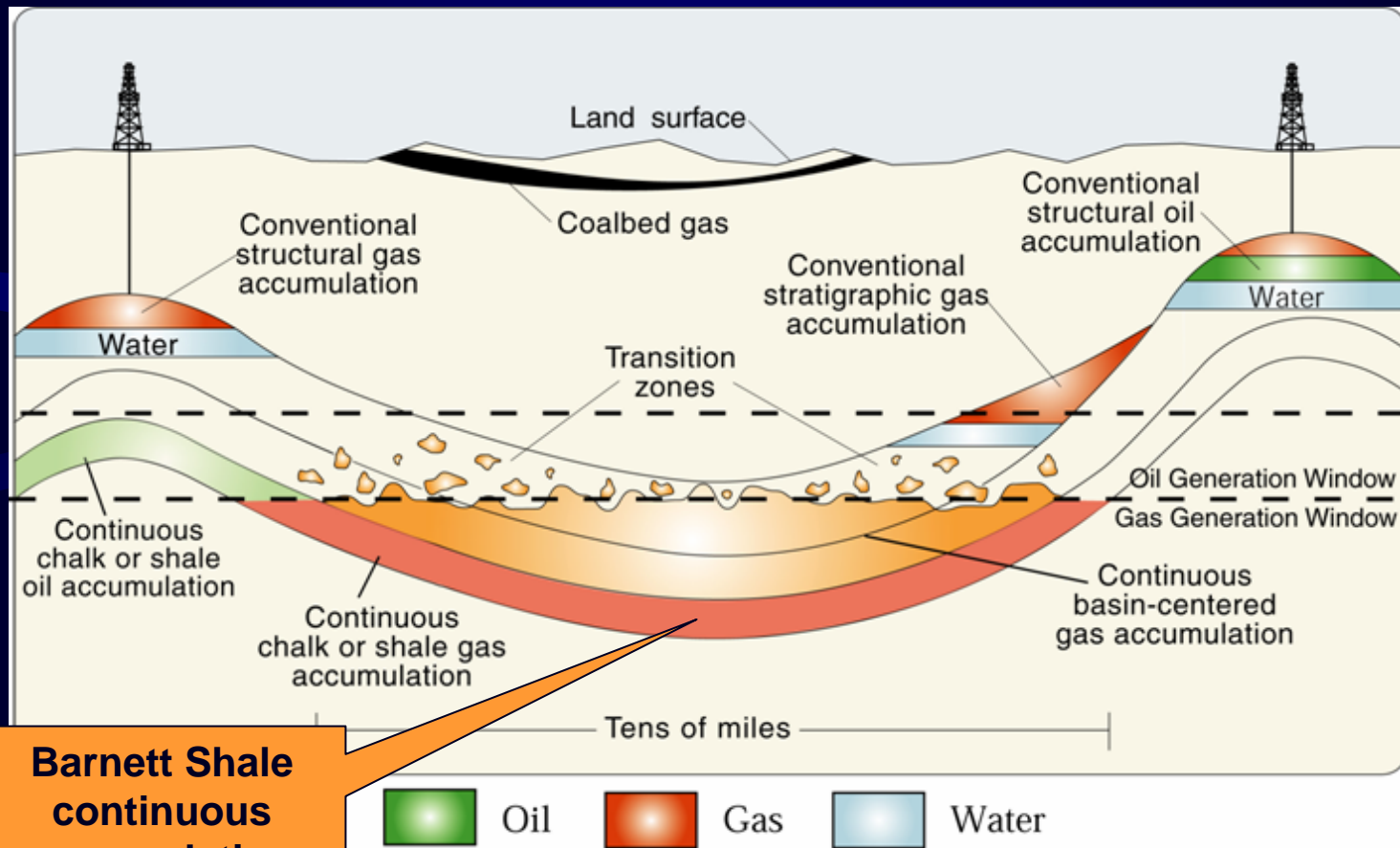
World
76.1%



Arctic Provinces for Study in 2002



The Barnett Shale is a Continuous (Unconventional) Type Accumulation



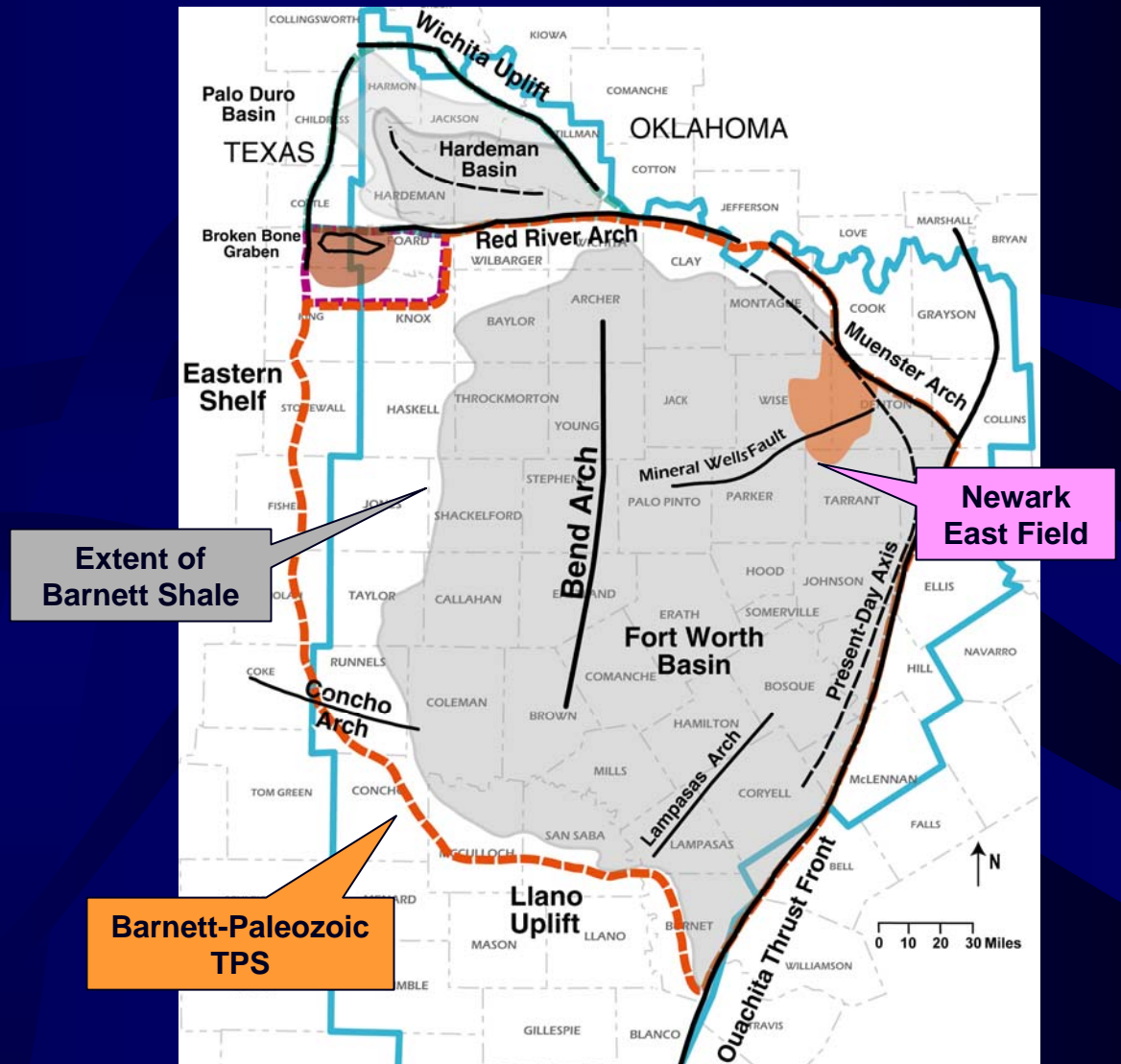
**Barnett Shale
continuous
accumulation**

From Pollastro and others (2003)

Barnett Shale And Barnett-Paleozoic Total Petroleum System (TPS)

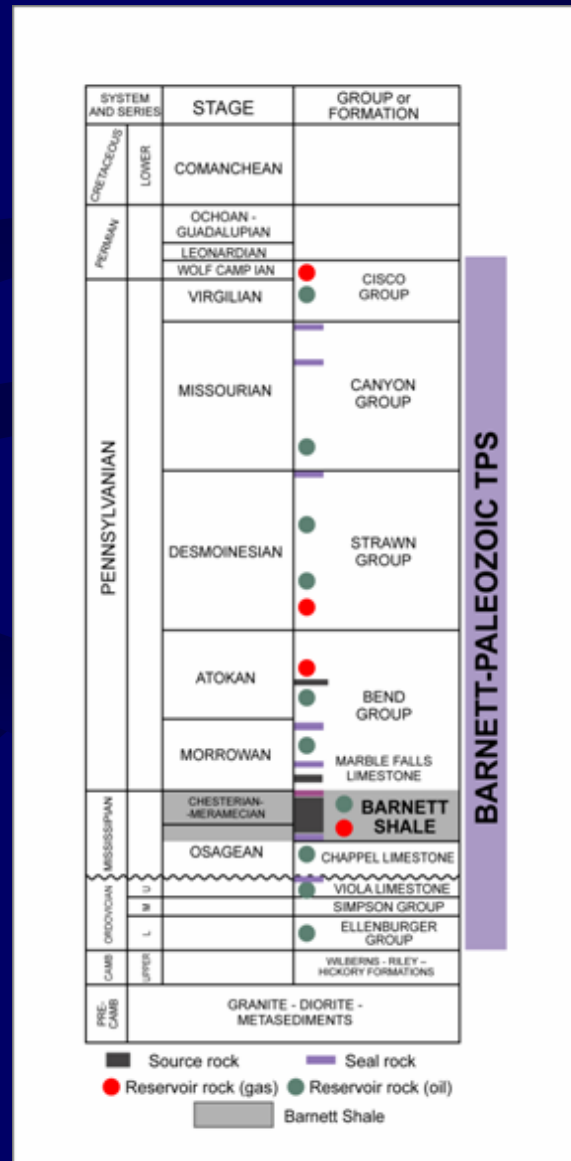
Thermally mature Barnett Shale is present over most of the Fort Worth Basin and Bend Arch is the primary source rock that has produced >2 BBO and >7 TCFG from Paleozoic conventional reservoirs.

Most production from the Barnett Shale is at Newark East field.



Stratigraphic Perspective Of Barnett-Paleozoic TPS

The Barnett Shale is the source rock for both indigenous gas and most conventional oil and natural gas produced from Ordovician to Permian age carbonate- and clastic-rock reservoirs in the Fort Worth Basin-Bend Arch area and thus, defines a Barnett-Paleozoic TPS.



USGS Barnett Shale – Assessment Results

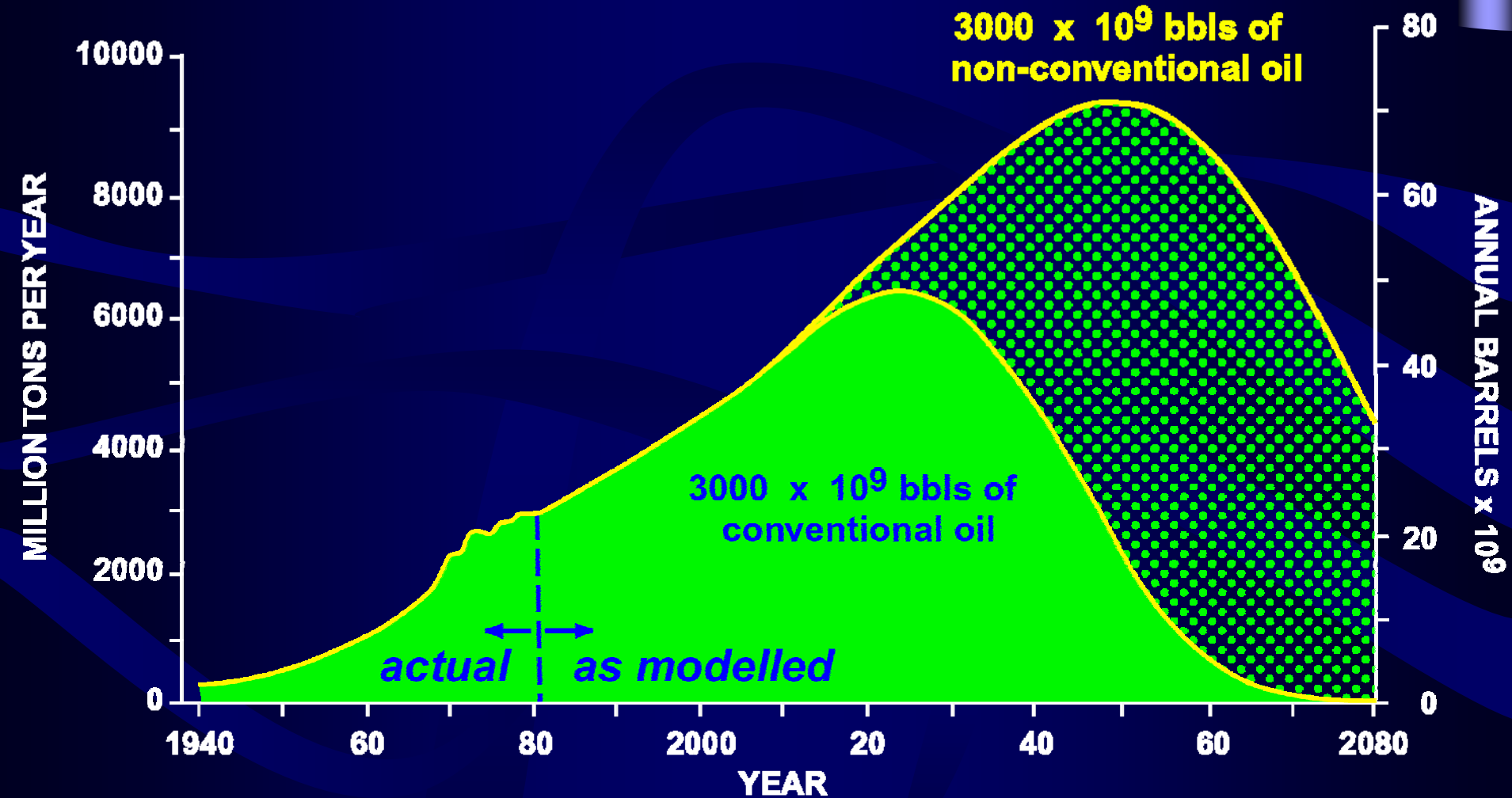
Total Petroleum Systems (TPS) and Assessment Units (AU)	Field Type	Oil (MMBO)				Total undiscovered resources Gas (BCFG)				NGL (MMBNGL)			
		F95	F50	F5	Mean	F95	F50	F5	Mean	F95	F50	F5	Mean
Barnett-Paleozoic TPS													
Greater Newark East Frac-Barrier Continuous Barnett Shale Gas AU	Gas					13,410.69	14,638.36	15,978.42	14,659.13	406.84	573.70	809.00	586.37
Extended Continuous Barnett Shale Gas AU	Gas					8,305.14	11,361.66	15,543.04	11,569.73	282.01	445.28	703.09	462.79
Hypothetical Basin-Arch Barnett Shale Oil AU	Oil					Not quantitatively assessed							
Total Continuous Resources						21,715.83	26,000.02	31,521.46	26,228.86	688.85	1,018.98	1,512.09	1,049.16

Greater Newark East Barnett AU: 14.6 TCFG

Extended Barnett Shale AU: 11.6 TCFG

Total Mean Undiscovered Resource: 26.2 TCFG

A Prospective Depletion Curve for the World's Conventional and Non-Conventional Oil to 2080

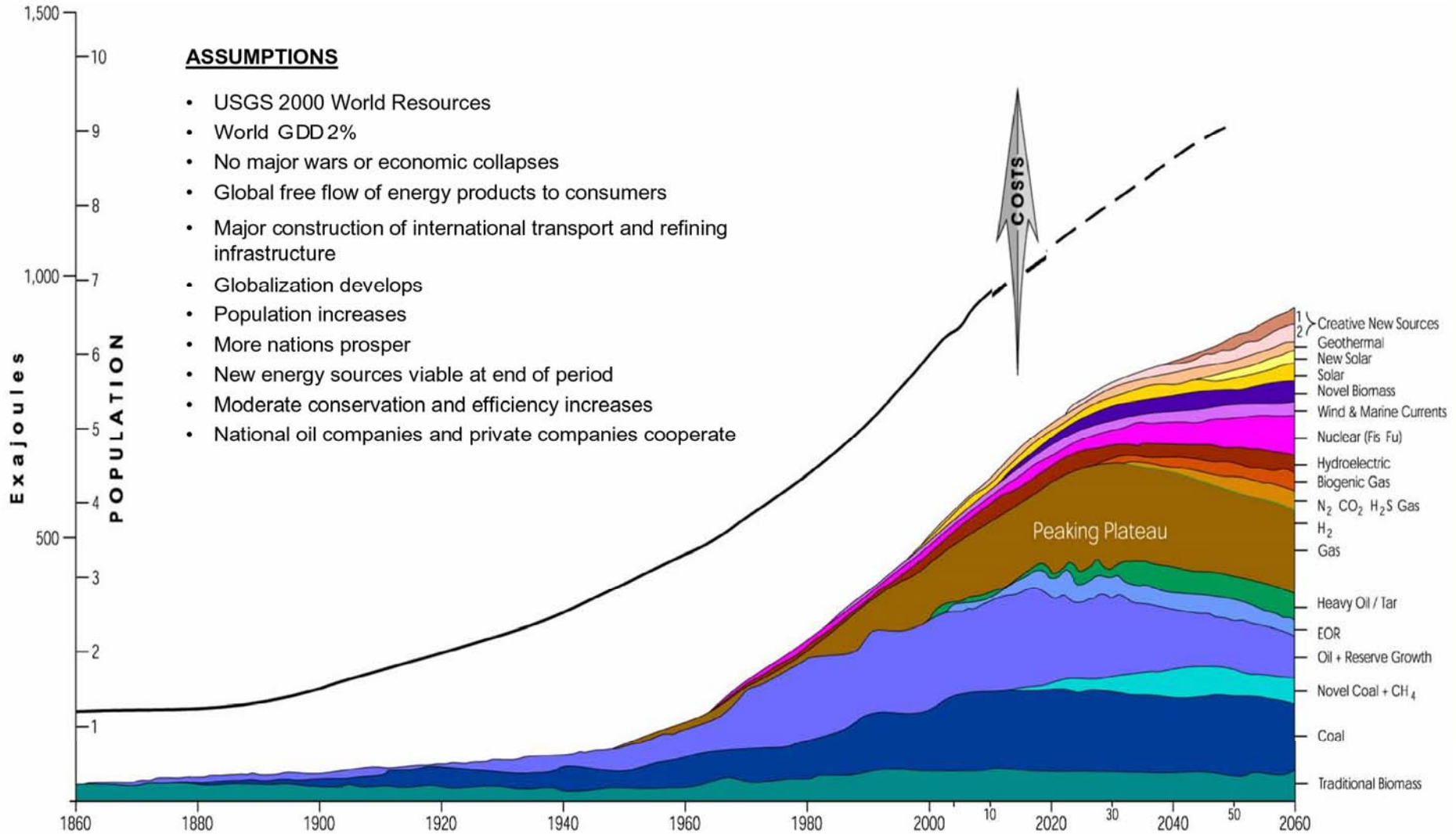


An Energy Scenario

A Complex Story of Interacting Variables and Uncertain Reserve Figures

ASSUMPTIONS

- USGS 2000 World Resources
- World GDD 2%
- No major wars or economic collapses
- Global free flow of energy products to consumers
- Major construction of international transport and refining infrastructure
- Globalization develops
- Population increases
- More nations prosper
- New energy sources viable at end of period
- Moderate conservation and efficiency increases
- National oil companies and private companies cooperate



Arthur R. Green / 2004

Summary

- **(TPS) Estimates of Future Oil and Gas Resources made by USGS in 2000 are reasonable and on trend**
- **Reserve Growth** is three times more significant than new field discoveries. Large potential in Middle East, Volga Urals, West Siberia, Algeria, North Sea– USGS detailed studies
- **2015-2020 Oil Peak for Non-OPEC oil using USGS 2000?**
- **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)**
- **Transition to natural gas is occurring, is the missing half Trillion BOE of natural gas in the Arctic?**
- **Increasing Emphasis on Unconventional Resources**