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science for a changing world

Future Oil and Gas Resources of the World -- Unresolved Issues

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USGS WORLD ENERGY PROJECT

New estimate of future world oil and gas resources-30 year time frame(1995-2025)—Not Ultimate

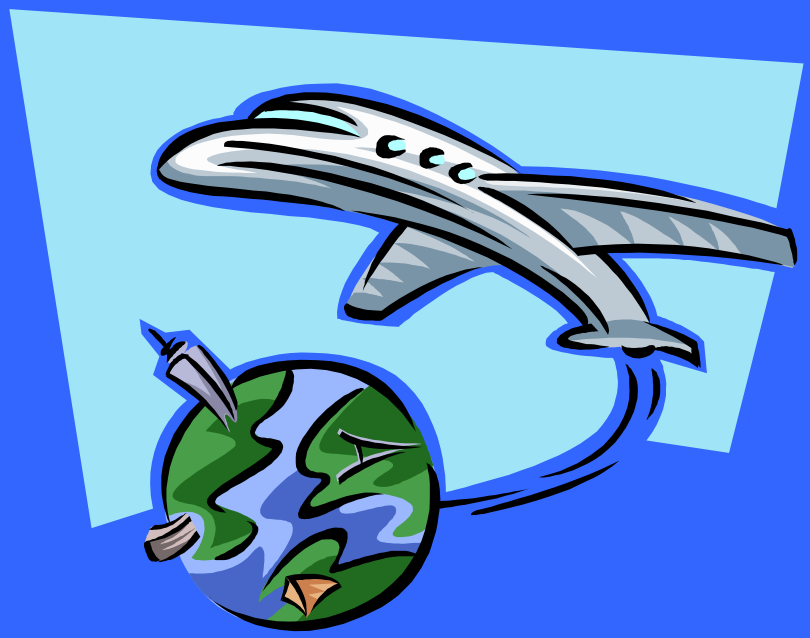
Reserve (Field) Growth Estimates for the World (30 Year Forecast)-1st Time

Geologically Based Estimates using Total Petroleum Systems (Fluids not just rocks)—Extensive Methodology Review and Endorsement, 5 year project (1995-2000), 41 Employees

All Information is Digital (DDS-60, 4 CDs, 9 other CDs on regional geology-- 60,000 distributed)

Website (http://energy.usgs.gov)--heavily used

USGS World Petroleum Assessment 2000



- **USGS World Energy Project—DDS-60, 4CDs, 32,000 pages**
- **Estimates--Undiscovered & Field Growth; Ancillary Data—Gas Composition, Drilling & Water Depths**
- **Perspectives--onshore, offshore, OPEC / OECD**
- **Geologic Insights**
- **Modeling (Added Value, North Sea, Arctic, Climate)**
- **Summary**

THE VOCABULARY OF RESOURCE ASSESSMENT:

- Cumulative production
- Reserves
- Reserve growth
- Undiscovered resources
  - Conventional
  - Unconventional (continuous)

World Oil

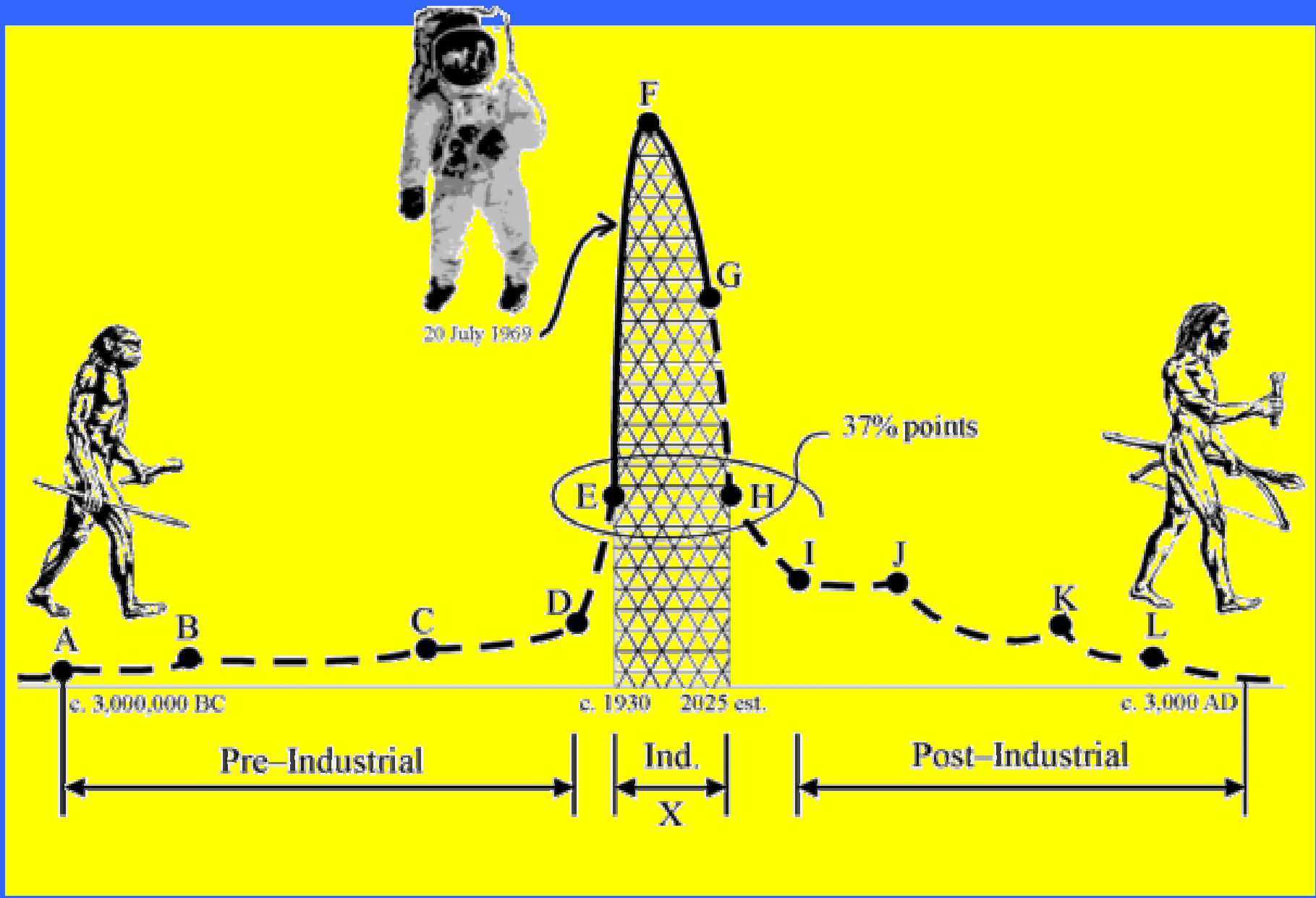
Currently Consuming about 28 BBO / Year

Remaining Reserves ~891 BBO (1/1/96)

Future volume is important—read GeoDestinies: The inevitable control of earth resources over nations and individuals (Youngquist)

Differing Views

- In 1994, C.J. Campbell predicted peaking 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
- World Petroleum Reserves are at all time high



The Olduvai Theory of Industrial Civilization by R.C. Duncan (1997)

(www.oilcrisis.com)

OR is it World Gas?

- Much less utilized worldwide than oil (7% produced vs. 20% for oil)
- LNG and GTL technology make it increasingly viable
- Environmental benefits or detriments
- Where is it, is it economic, and in what time frame?

World Energy Consortium- Quarterly Geologic Meetings, Many Visits

INDUSTRY

EXXON (now EMEC)
BP-AMOCO
MOBIL
CONOCO
PHILLIPS
SHELL
TEXACO
ORYX
PETRO-CANADA
CHEVRON / ENRON
OCCIDENTAL
KERR-MCGEE

ORGANIZATIONS

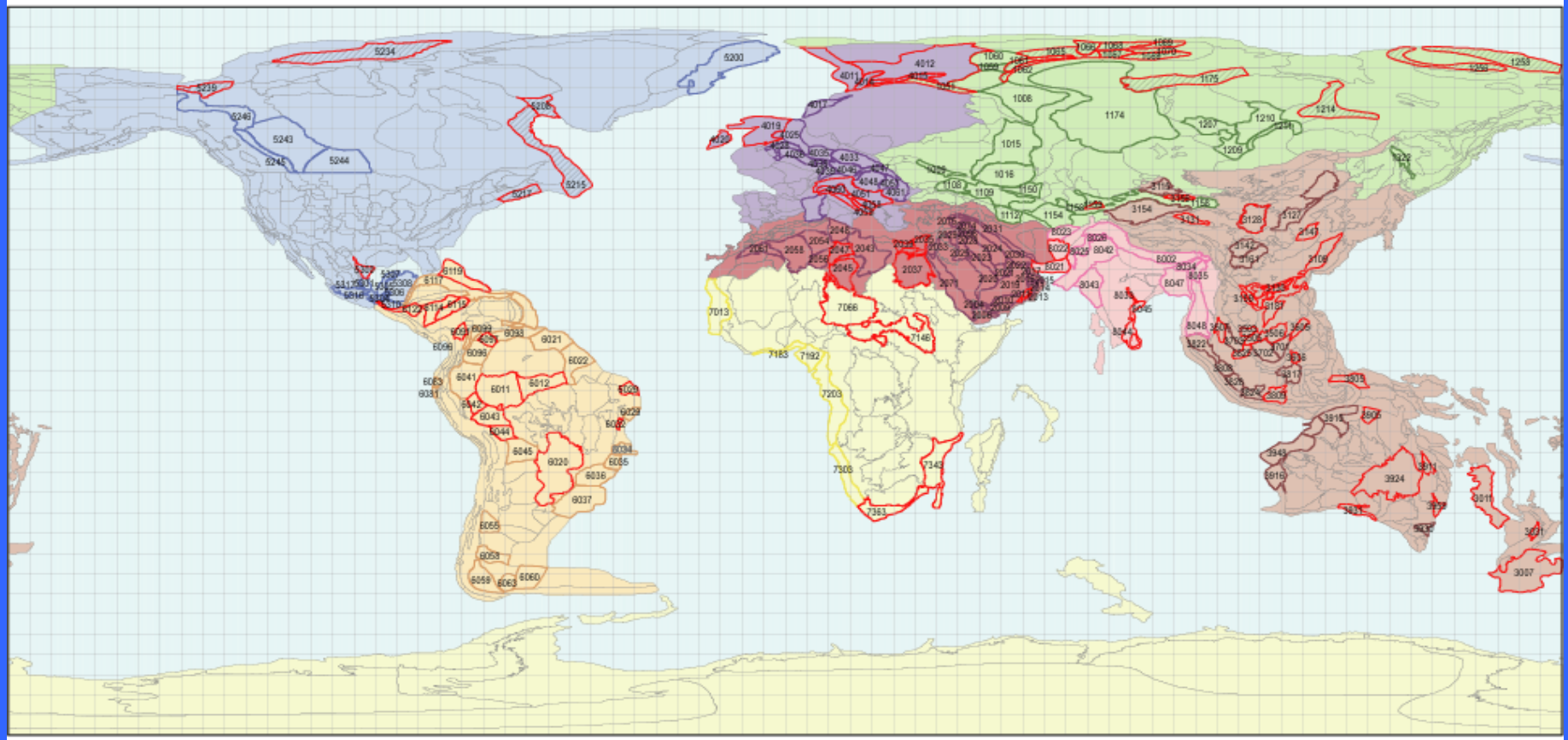
DOE / EIA
PETROCONSULTANTS
GLOBAL CENTER FOR ENERGY STUDIES
GEOMARK
ESRI
UNESCO / BDGM (agreements)
INTERNATIONAL ENERGY AGENCY
U.S. AID, STATE DEPT.
DOD, INTELLIGENCE GROUPS

Total Petroleum Systems

All Genetically Related Petroleum that Occurs in Shows and Accumulations (Discovered and Undiscovered) that Has Been Generated by a Pod or Closely Related Pods of Mature Source Rock

Basic Geologic Unit for WPA 2000: Assessed 128 Provinces, 149 TPS, 246 Assessment Units in DDS-60 with ancillary data for each

Preliminary Map of Proposed Provinces
World Energy Assessment 2001

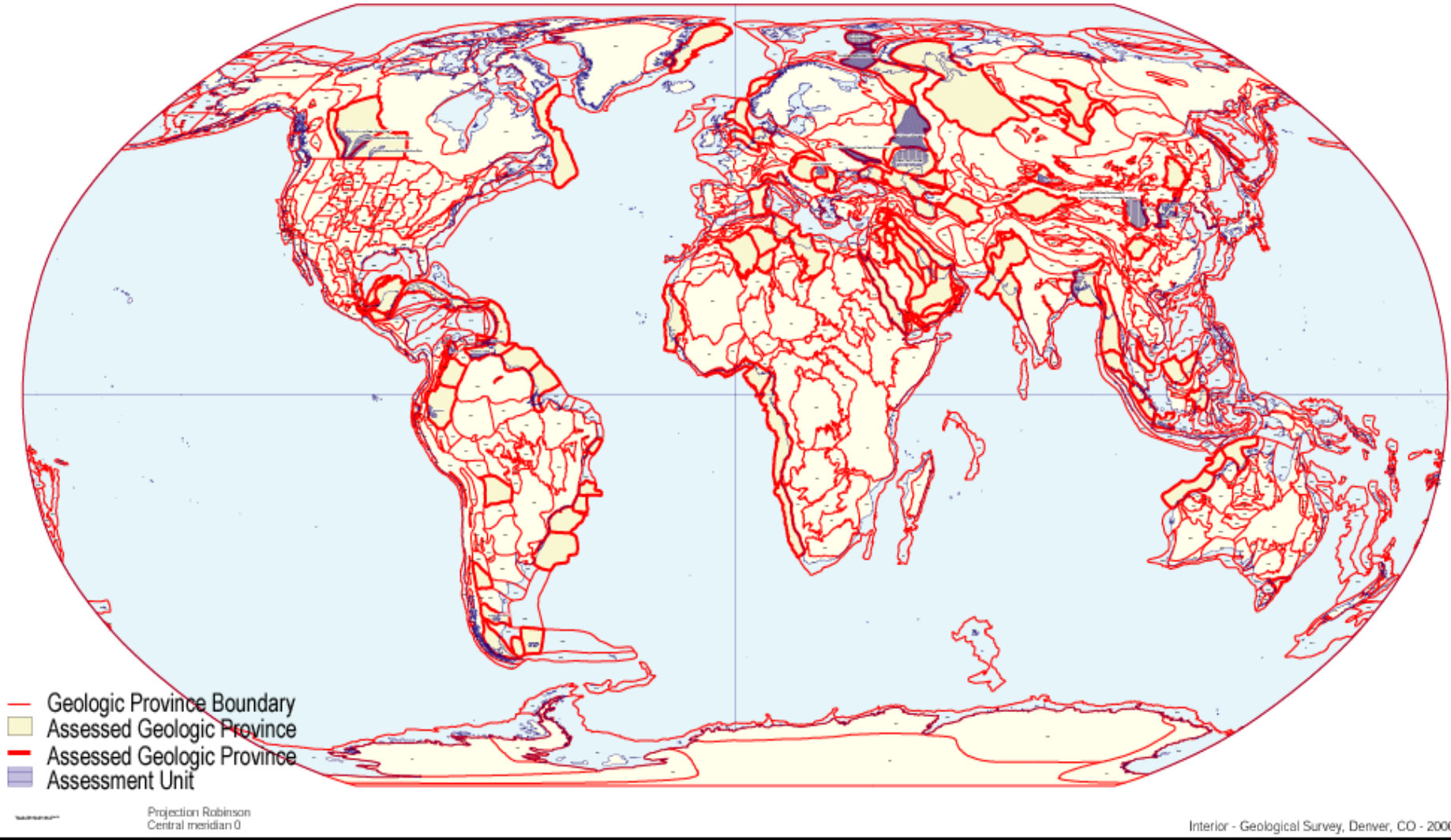


Region 1
Region 2
Region 3
Region 4
Region 5
Region 6
Region 7
Region 8

Assessed provinces outlined in darker shade of province color
Proposed provinces outlined in red
Provinces with cross pattern part of proposed High Arctic Assessment

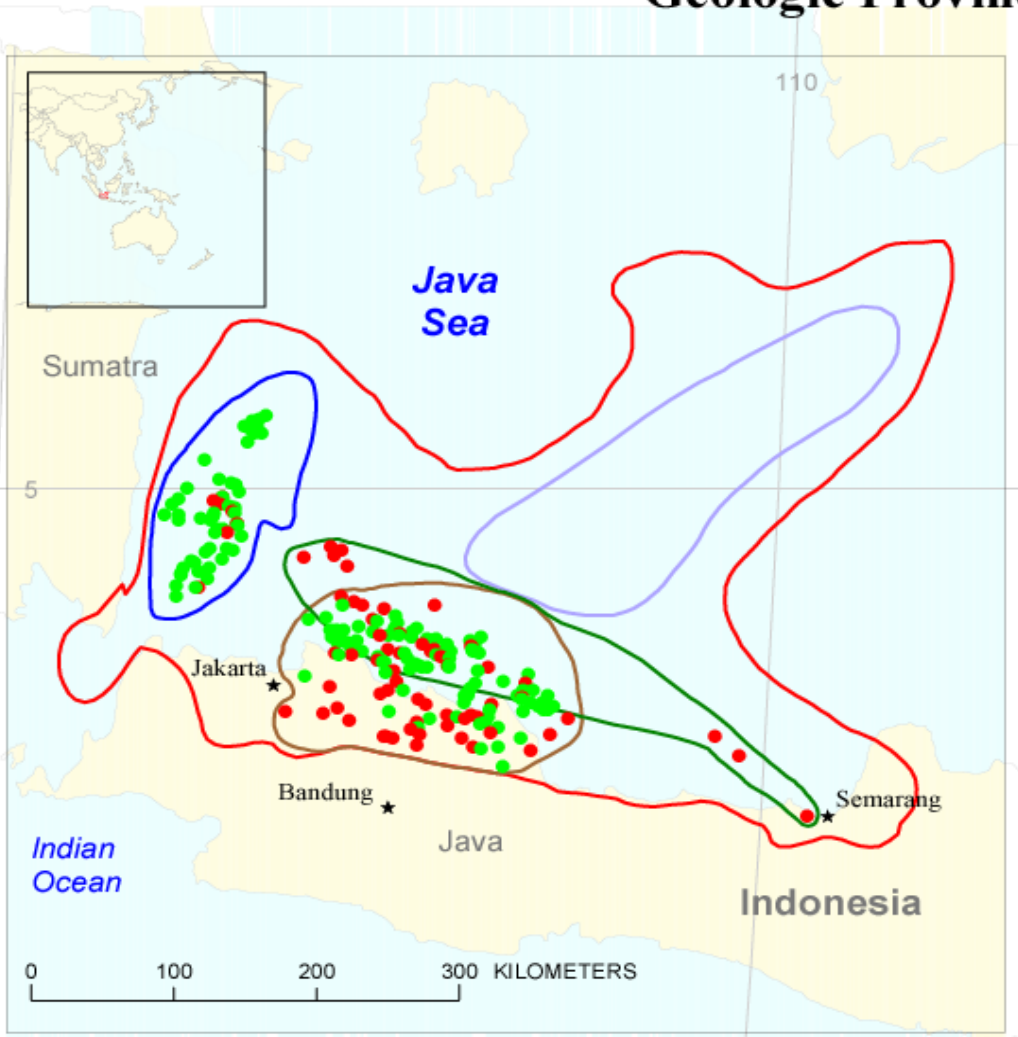
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

DDS-60



ASSESSMENT UNITS WITH CONTINUOUS TYPE OR UNCONVENTIONAL RESOURCES

Northwest Java Basin
Geologic Province 3824



Banuwati-Oligocene/Miocene Total Petroleum System 382401
Jatibarang/Talang Akar-Oligocene/Miocene Total Petroleum System 382402
Tertiary-Parigi Total Petroleum System 382403
Tertiary-Cenozoic Total Petroleum System 382404
Northwest Java Basin Geologic Province 3824

Province Assessment

Output Summary

Undiscovered Field Size

Distributions

Total Petroleum Systems

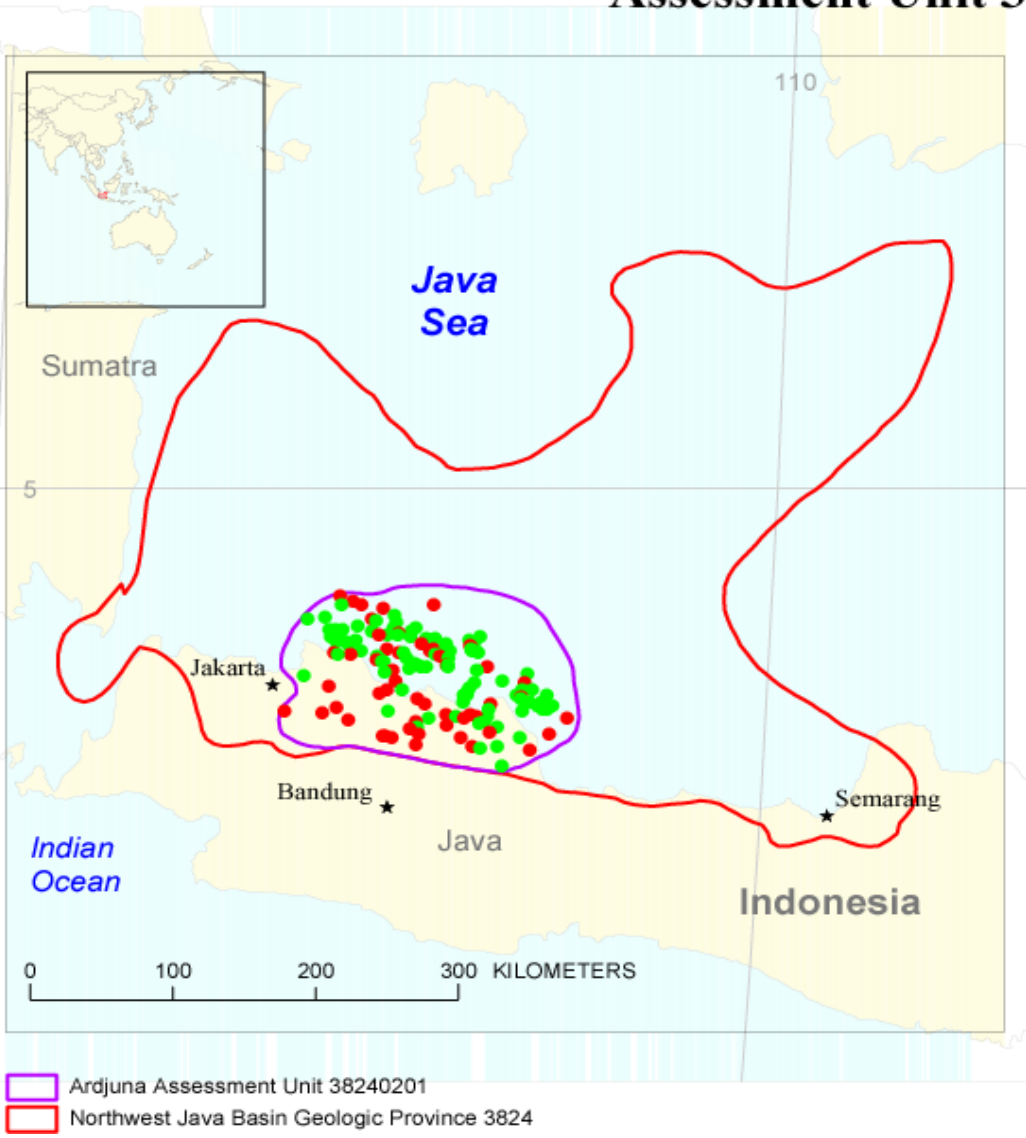
Banuwati-Oligocene/Miocene
Total Petroleum System 382401

Jatibarang/Talang Akar-Oligocene/Miocene
Total Petroleum System 382402

Tertiary-Parigi
Total Petroleum System 382403

Tertiary-Cenozoic
Total Petroleum System 382404

Ardjuna
Assessment Unit 38240201



Geologic Summary

Detailed map of this assessment unit

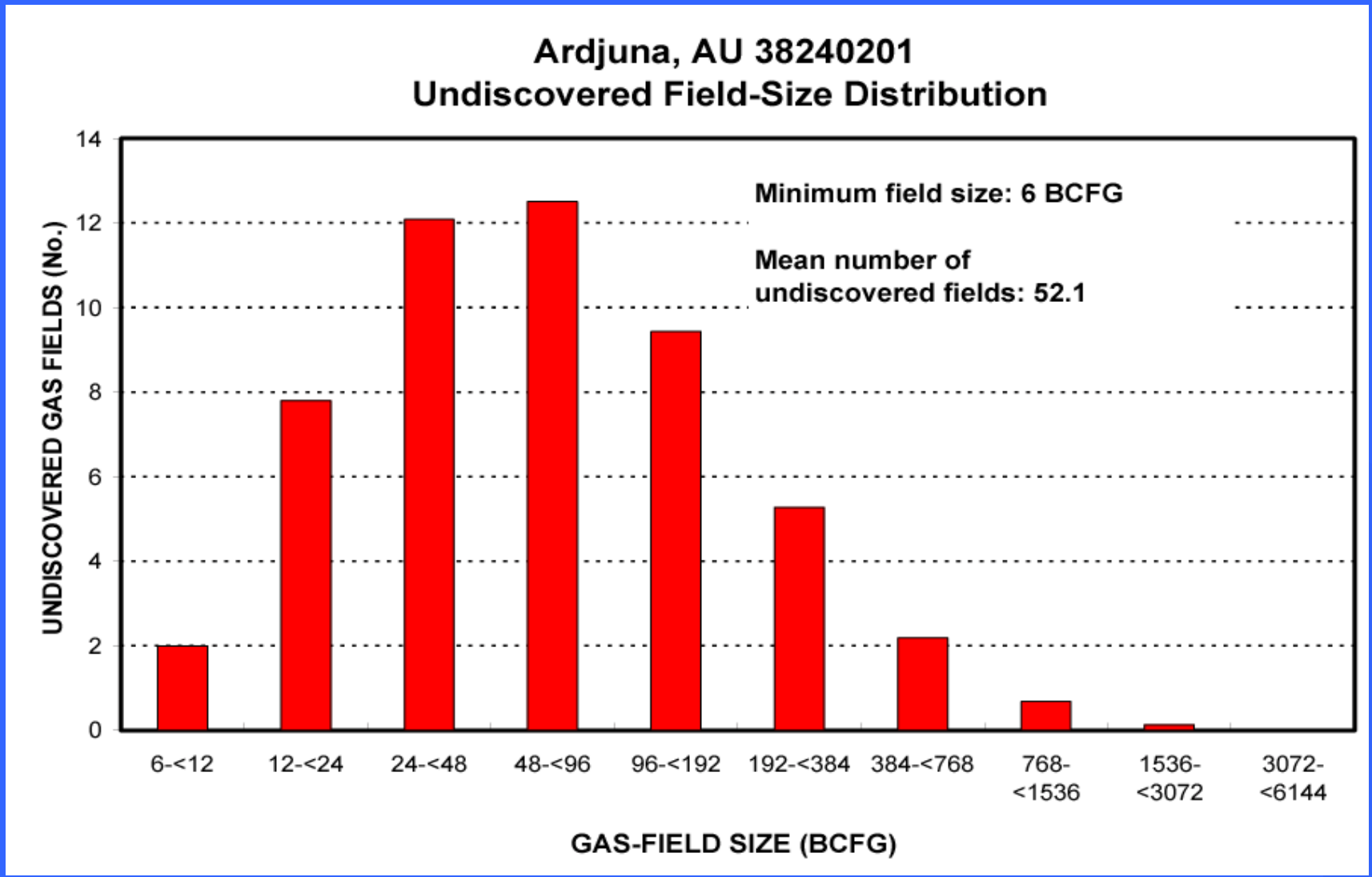
Exploration/Discovery-History Data

- Plots of Known Field Sizes
- Plots of Grown Resources
- Tables

Assessment Input Data

Assessment Results

- Assessment Unit Summary
- Detailed Assessment Results
- Undiscovered Field-Size Distributions


Ardjuna, AU 38240201
Undiscovered Field-Size Distribution
UNDISCOVERED GAS FIELDS (No.)
0
2
4
6
8
10
12
14
Minimum field size: 6 BCFG
Mean number of undiscovered fields: 52.1
6-<12
12-<24
24-<48
48-<96
96-<192
192-<384
384-<768
768-<1536
1536-<3072
3072-<6144
GAS-FIELD SIZE (BCFG)

Environmental Database

How much oil, gas NGS, in what quantities and where? (I.e. what is the composition of the world's oil and gas petroleum—CO2, H2S, API Gravity, GOR…..

What drilling depth?

What water depth?

Detailed for 246 Assessment Units in 149 Total Petroleum Systems in 128 Provinces in DDS-60

SEVENTH APPROXIMATION
NEW MILLENNIUM WORLD PETROLEUM ASSESSMENT
DATA FORM FOR CONVENTIONAL ASSESSMENT UNITS

Date:	5/26/99		
Assessment Geologist:	R.T. Ryder		
Region:	Asia Pacific	Number:	3
Province:	Northwest Java Basin	Number:	3824
Priority or Boutique	Priority		
Total Petroleum System:	Jatibarang/Talang Akar-Oligocene/Miocene	Number:	382402
Assessment Unit:	Ardjuna	Number:	38240201
* Notes from Assessor	MMS growth function.		

CHARACTERISTICS OF ASSESSMENT UNIT

Oil (<20,000 cfg/bo overall) **or** Gas (≥20,000 cfg/bo overall): Oil

What is the minimum field size? 1 mmboe grown (≥1mmboe)
(the smallest field that has potential to be added to reserves in the next 30 years)

Number of discovered fields exceeding minimum size: Oil: 78 Gas: 47
Established (>13 fields) X Frontier (1-13 fields) Hypothetical (no fields)

Median size (grown) of discovered oil fields (mmboe):
1st 3rd 17 2nd 3rd 7 3rd 3rd 10

Median size (grown) of discovered gas fields (bcfg):
1st 3rd 72 2nd 3rd 68 3rd 3rd 139

Assessment-Unit Probabilities:

Attribute	Probability of occurrence (0-1.0)
1. **CHARGE:** Adequate petroleum charge for an undiscovered field ≥ minimum size	1.0
2. **ROCKS:** Adequate reservoirs, traps, and seals for an undiscovered field ≥ minimum size	1.0
3. **TIMING OF GEOLOGIC EVENTS:** Favorable timing for an undiscovered field ≥ minimum size	1.0
Assessment-Unit GEOLOGIC Probability (Product of 1, 2, and 3):	1.0
4. **ACCESSIBILITY:** Adequate location to allow exploration for an undiscovered field ≥ minimum size	1.0

UNDISCOVERED FIELDS

Number of Undiscovered Fields: How many undiscovered fields exist that are ≥ minimum size?:
(uncertainty of fixed but unknown values)

Oil fields:	min. no. (>0)	10	median no.	25	max no. 50
Gas fields:	min. no. (>0)	15	median no.	50	max no. 100

Size of Undiscovered Fields: What are the anticipated sizes (**grown**) of the above fields?:
(variations in the sizes of undiscovered fields)

Oil in oil fields (mmbo)	min. size	1	median size	4	max. size 150
Gas in gas fields (bcfg):	min. size	6	median size	60	max. size 2500

Assessment Unit (name, no.)
Ardjuna, 38240201

AVERAGE RATIOS FOR UNDISCOVERED FIELDS, TO ASSESS COPRODUCTS

(uncertainty of fixed but unknown values)

Oil Fields:	minimum	median	maximum
Gas/oil ratio (cfg/bo)	1000	2000	3000
NGL/gas ratio (bngl/mmcfg)	30	60	90

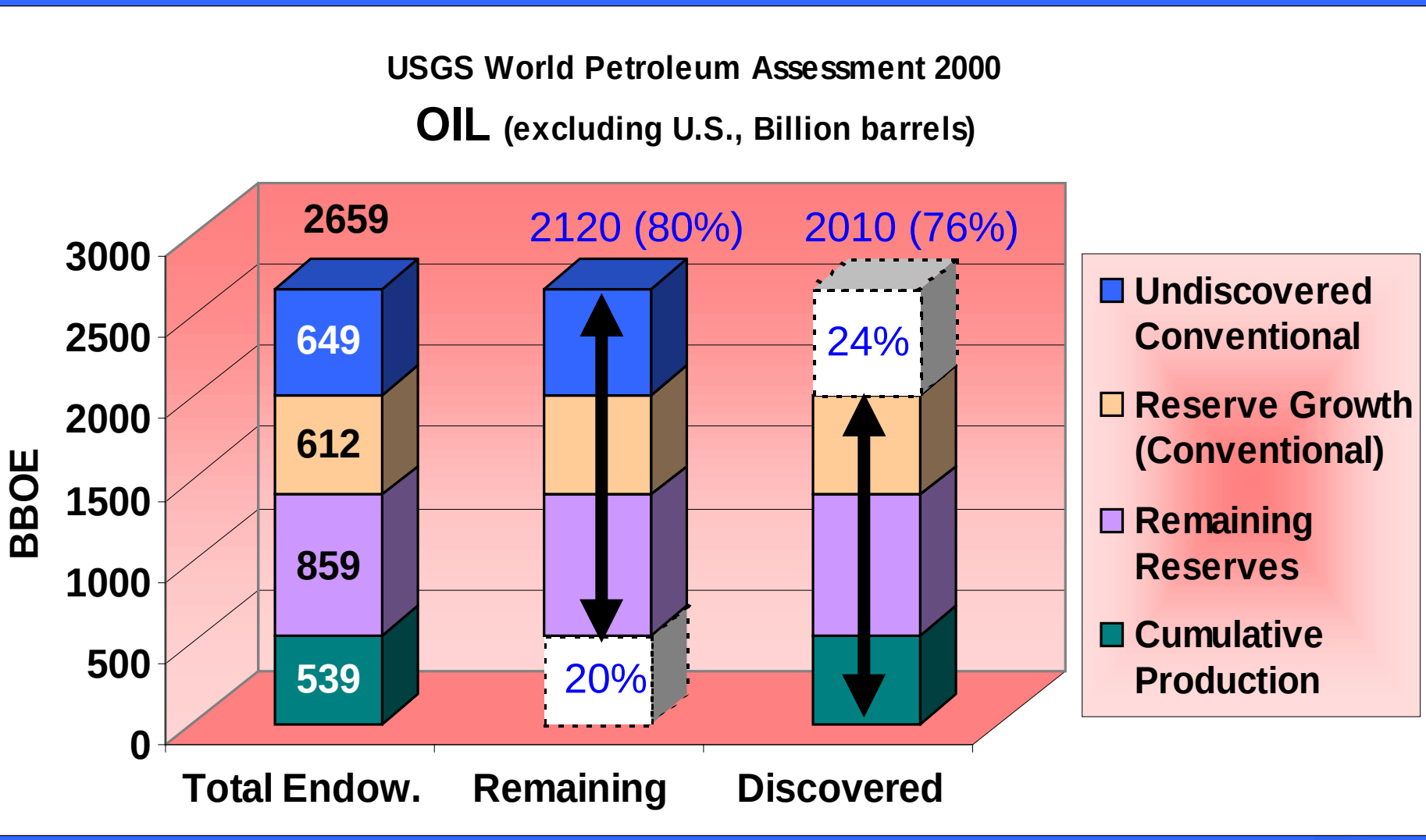
Gas fields:	minimum	median	maximum
Liquids/gas ratio (bngl/mmcfg)	5	10	20
Oil/gas ratio (bo/mmcfg)			

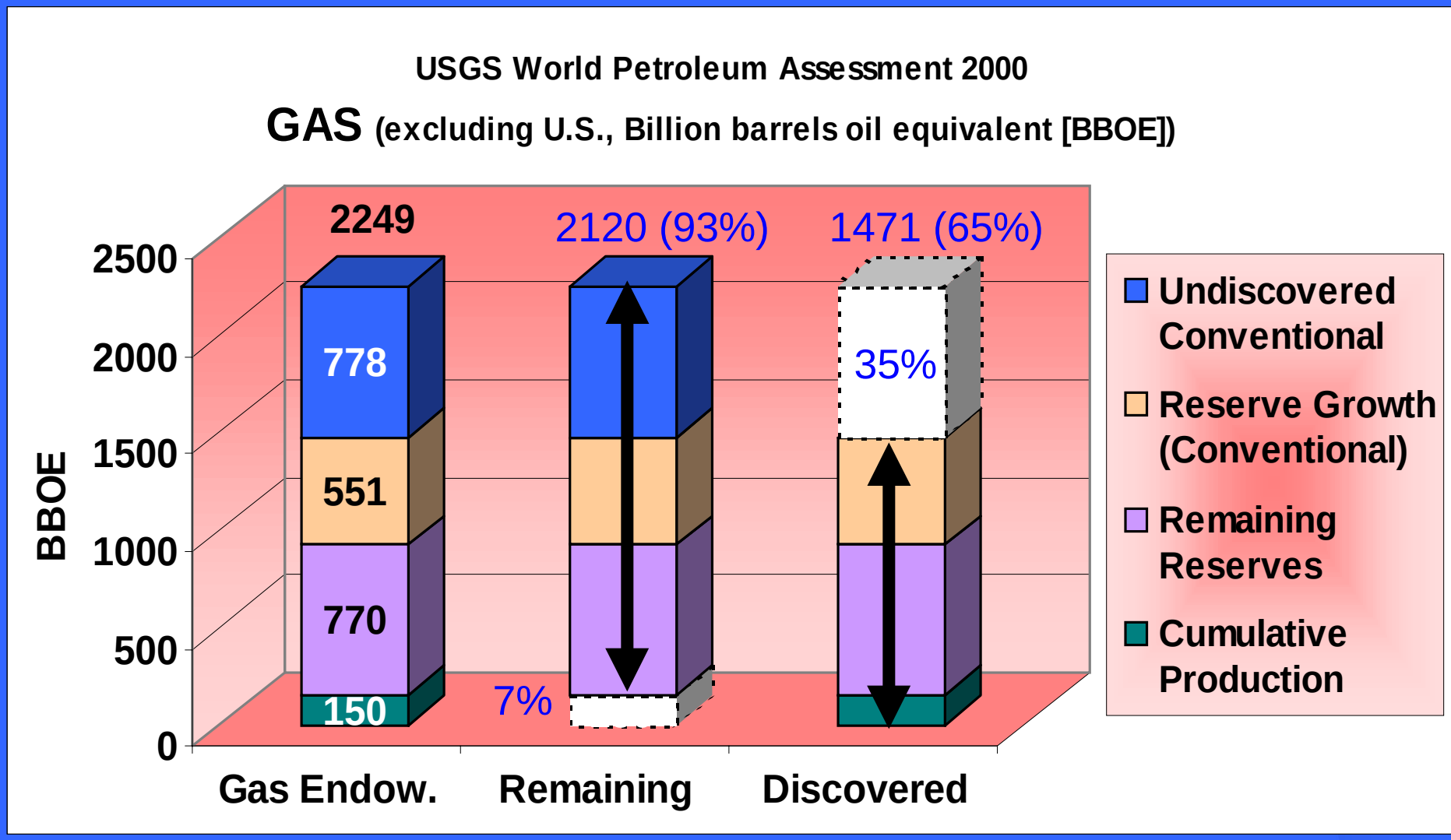
SELECTED ANCILLARY DATA FOR UNDISCOVERED FIELDS

(variations in the properties of undiscovered fields)

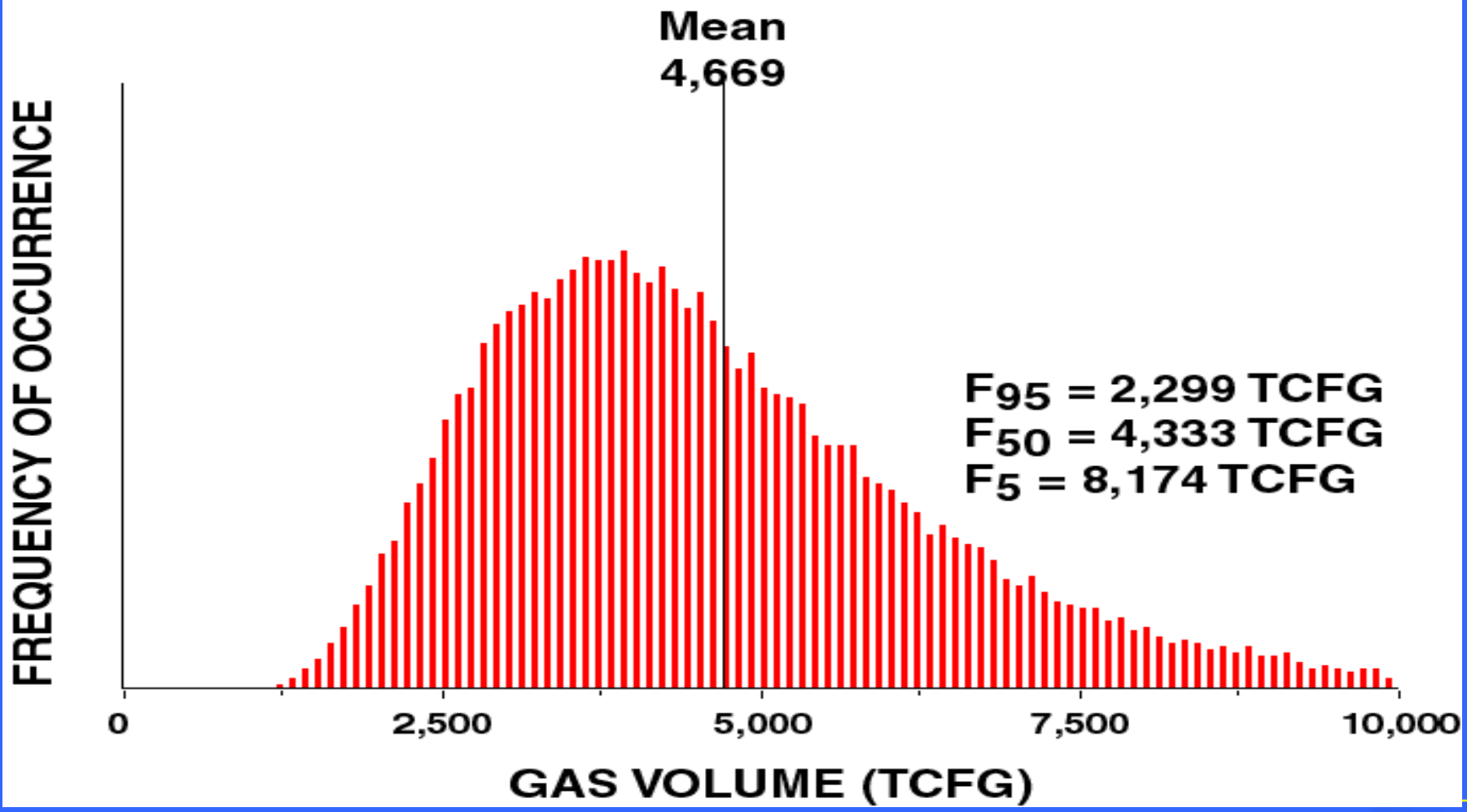
Oil Fields:	minimum	median	maximum
API gravity (degrees)	19	36	55
Sulfur content of oil (%)	0.03	0.1	0.6
Drilling Depth (m)	500	1500	3500
Depth (m) of water (if applicable)	0	40	400

Gas Fields:	minimum	median	maximum
Inert gas content (%)	0.2	1.3	12.1
CO_2 content (%)	0.2	3.5	58
Hydrogen-sulfide content (%)	0	0	0
Drilling Depth (m)	500	2000	3000
Depth (m) of water (if applicable)	0	40	400


USGS World Petroleum Assessment 2000
OIL (excluding U.S., Billion barrels)
BBOE
3000
2500
2000
1500
1000
500
0
2659
2120 (80%)
2010 (76%)
649
612
859
539
20%
24%
Total Endow.
Remaining
Discovered
Undiscovered Conventional
Reserve Growth (Conventional)
Remaining Reserves
Cumulative Production


USGS World Petroleum Assessment 2000
GAS (excluding U.S., Billion barrels oil equivalent [BBOE])
BBOE
2500
2000
1500
1000
500
0
2249
778
551
770
150
2120 (93%)
7%
1471 (65%)
35%
Gas Endow.
Remaining
Discovered
Undiscovered Conventional
Reserve Growth (Conventional)
Remaining Reserves
Cumulative Production

World Undiscovered Petroleum Resources
Gas



USGS World Petroleum Assessment 2000

Undiscovered Petroleum (Masters vs World w/o US. +5% at Mean) 1556 BBOE vs 1634 BBOE

- Undiscovered Oil (649BB; +20.5%)
- Undiscovered Gas (4669TCF or 778 BBOE; -14.1%)
- Undiscovered NGL (207 BBOE; +130%)

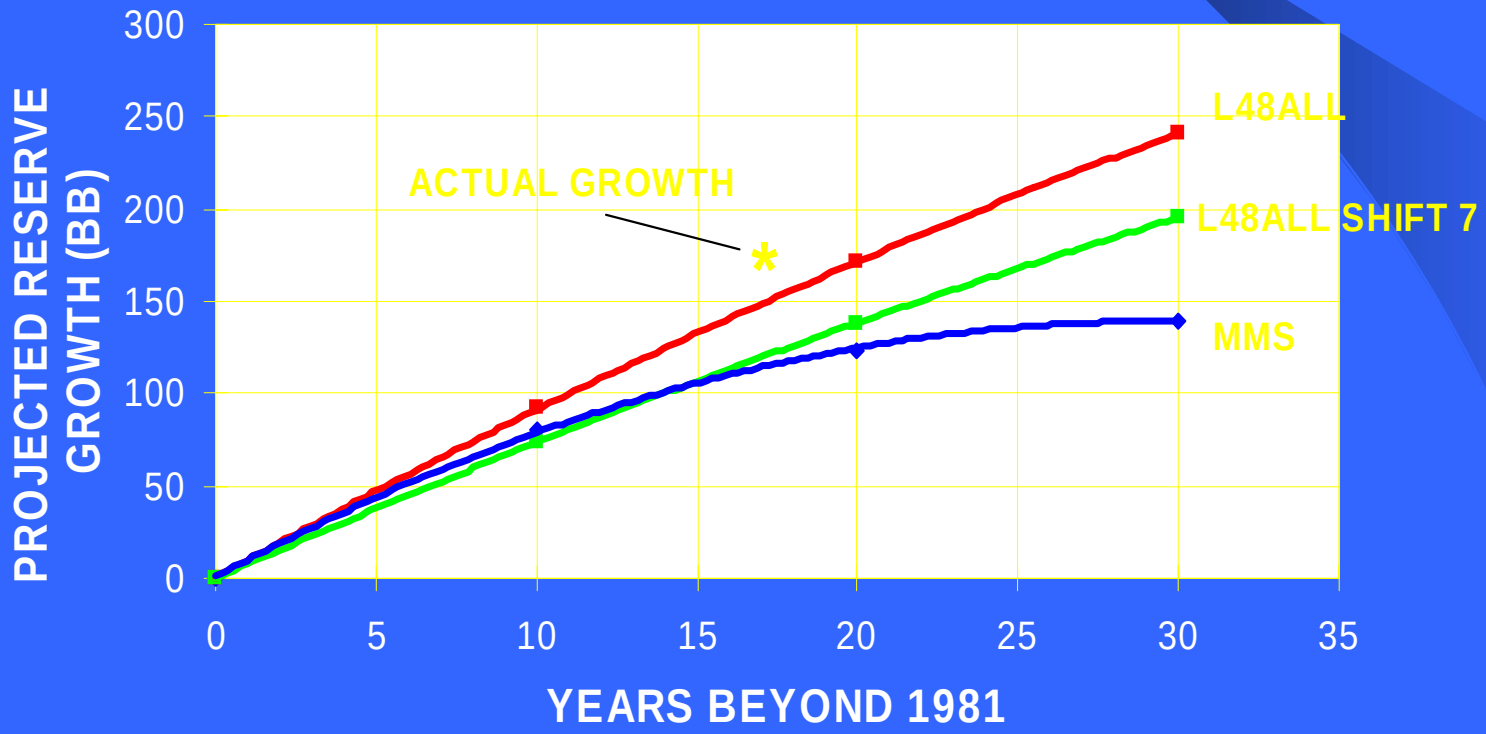
The Wild Card: Reserve Growth

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.

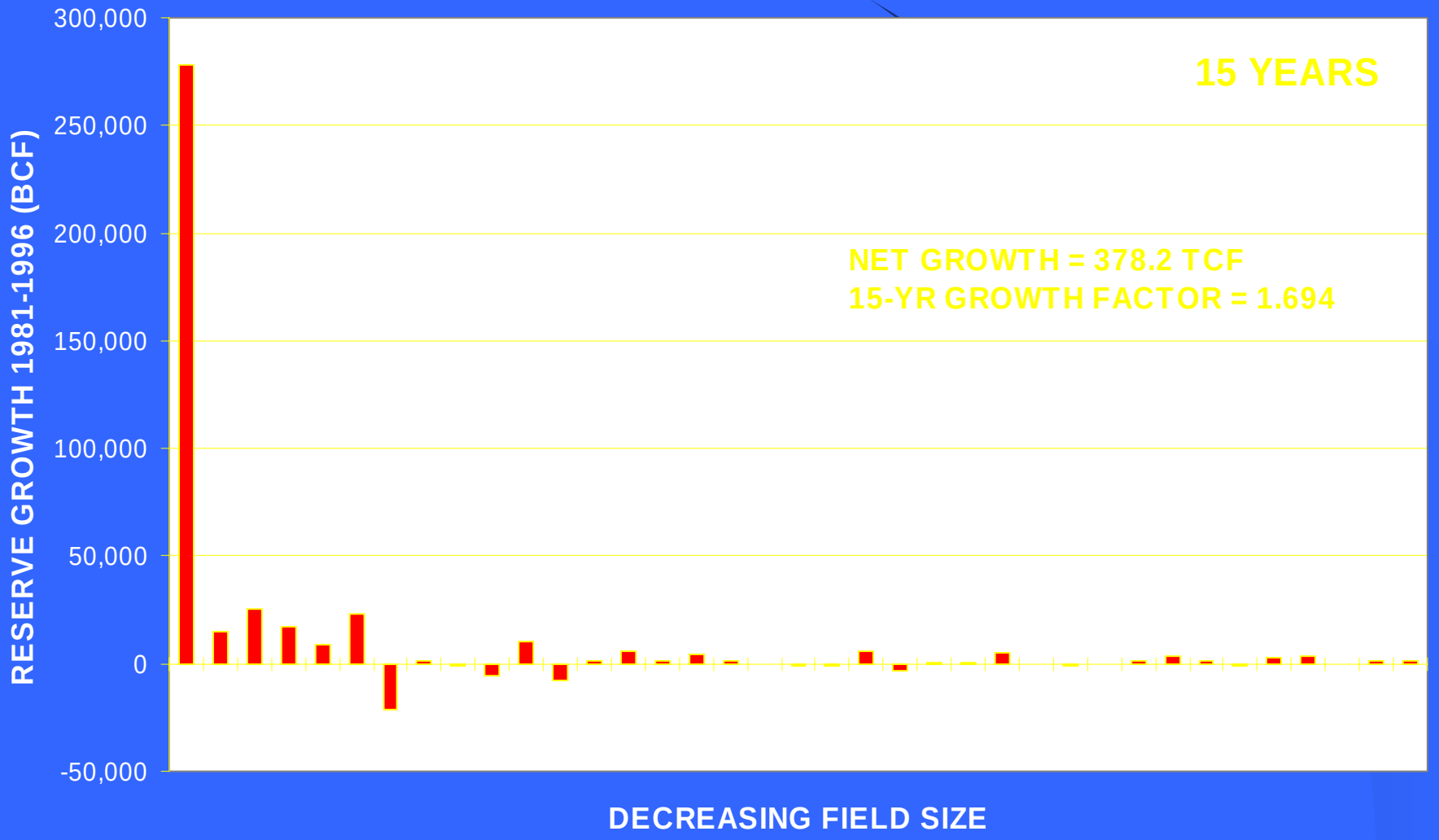
Causes of reserve growth:

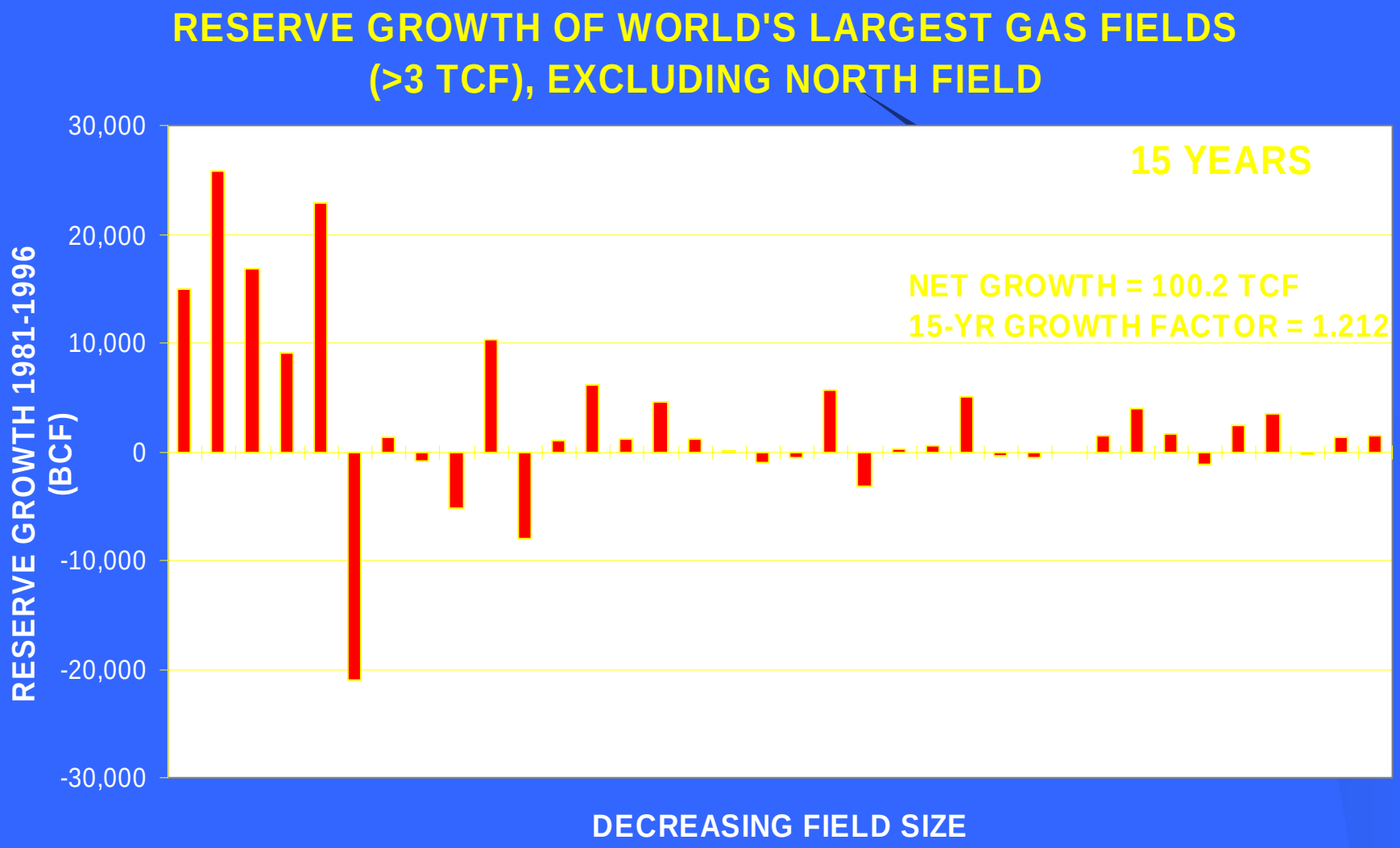
- Conservative initial estimates (SEC requirements, corporate psychology)
- Exploration technology (e.g., 3-D, 4-D seismic)
- Drilling technology (horizontal, multilateral, directional)
- Production technology (enhanced oil recovery)

RESERVE GROWTH HISTORY MATCHING: LARGE OIL FIELDS



RESERVE GROWTH OF WORLD'S LARGEST GAS FIELDS (>3 TCF)




RESERVE GROWTH OF WORLD'S LARGEST GAS FIELDS
(>3 TCF), EXCLUDING NORTH FIELD
15 YEARS
NET GROWTH = 100.2 TCF
15-YR GROWTH FACTOR = 1.212
RESERVE GROWTH 1981-1996
(BCF)
30,000
20,000
10,000
0
-10,000
-20,000
-30,000
DECREASING FIELD SIZE

USGS World Petroleum Assessment 2000

Summary

Reserve Growth

First time assessed for world

Nearly as much as Undiscovered resources

- Oil Reserve Growth (612 BB)
- Natural Gas Reserve Growth (3,305 TCF)
- NGL Reserve Growth (42 BB)

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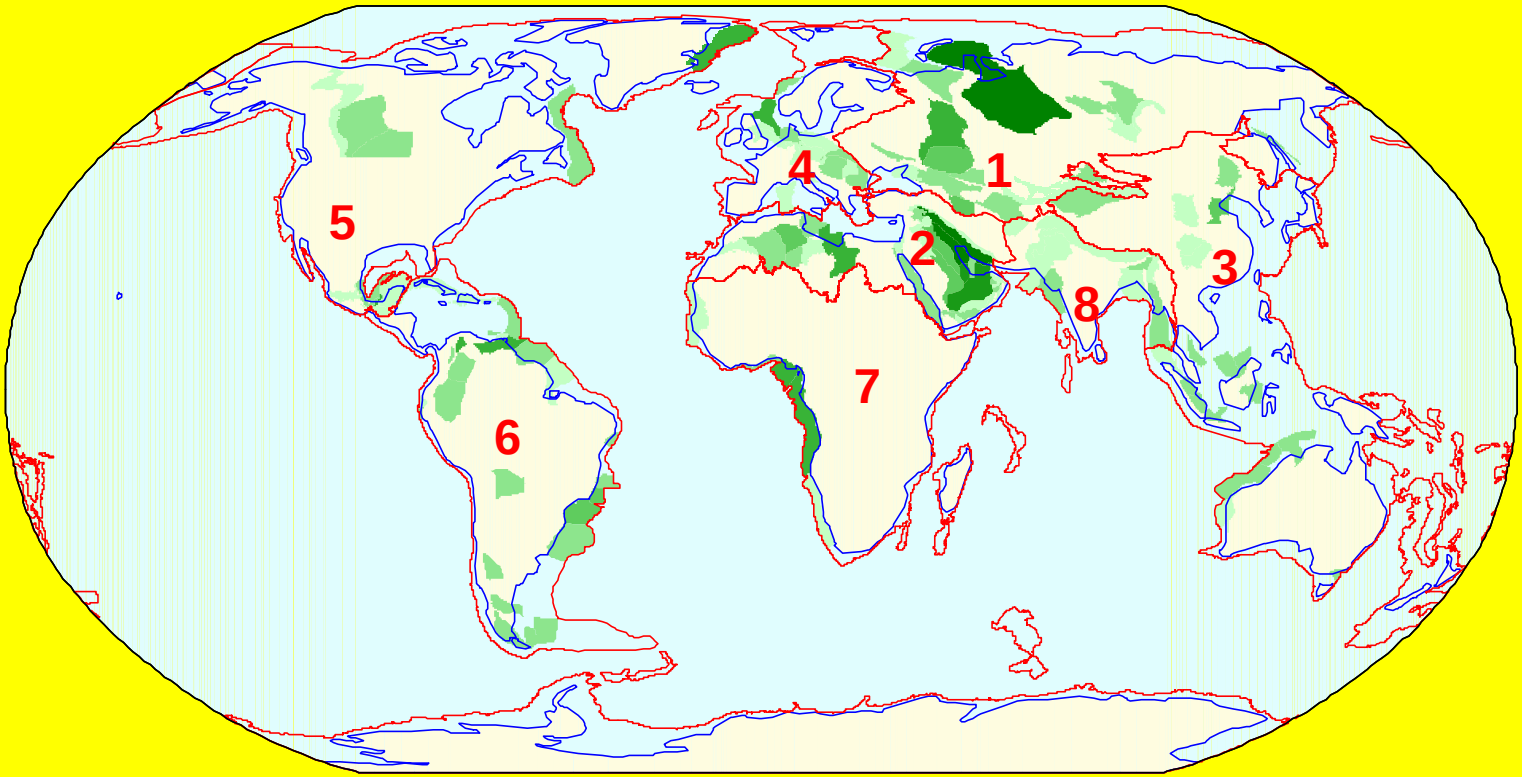
World Petroleum Assessment 2000



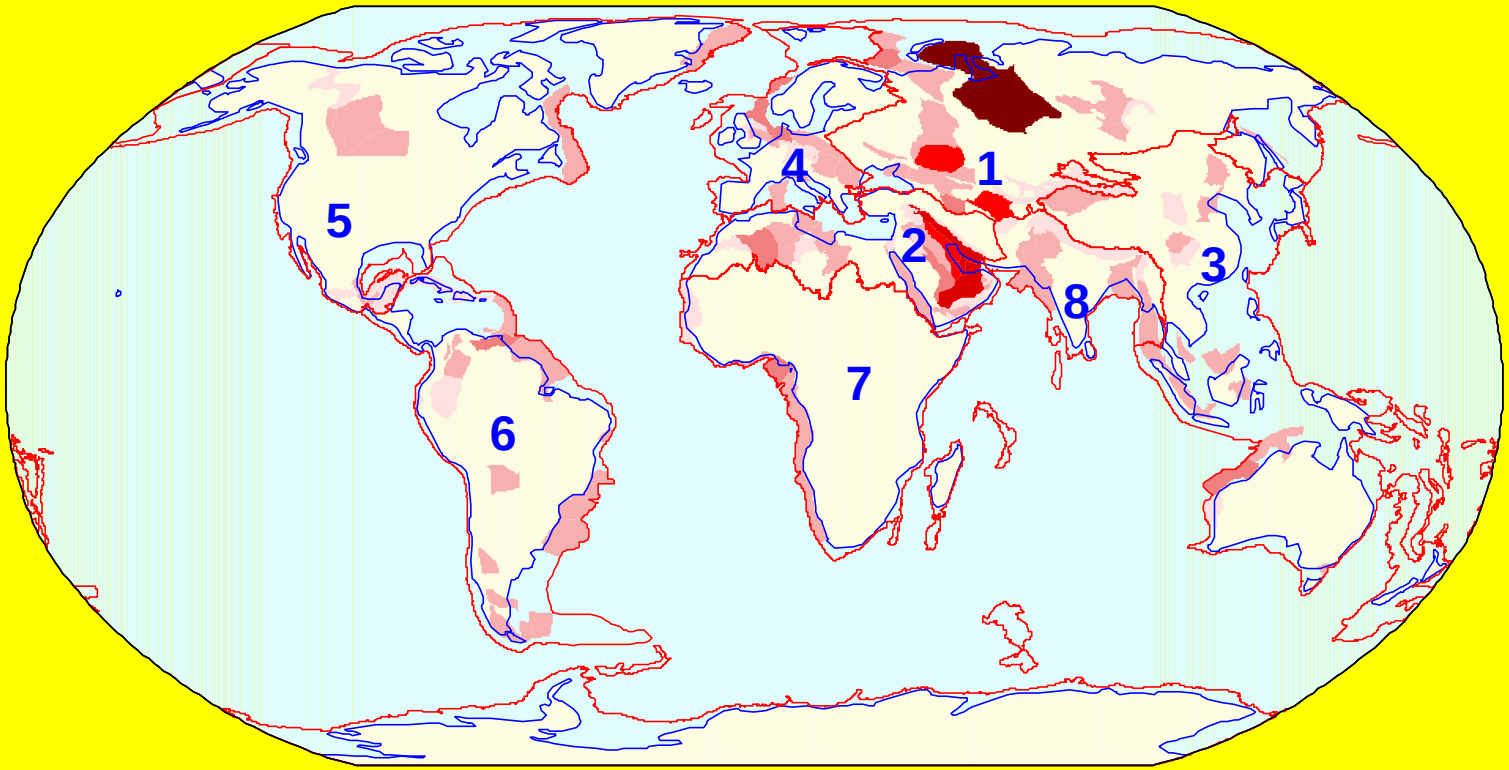
Conventional Oil Endowment of the World

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
- Less than 1 BBO
- 1 - 20 BBO
- 20 - 40 BBO
- 40 - 80 BBO
- 80 - 160 BBO
- Greater than 160 BBO

USGS

World Petroleum Assessment 2000

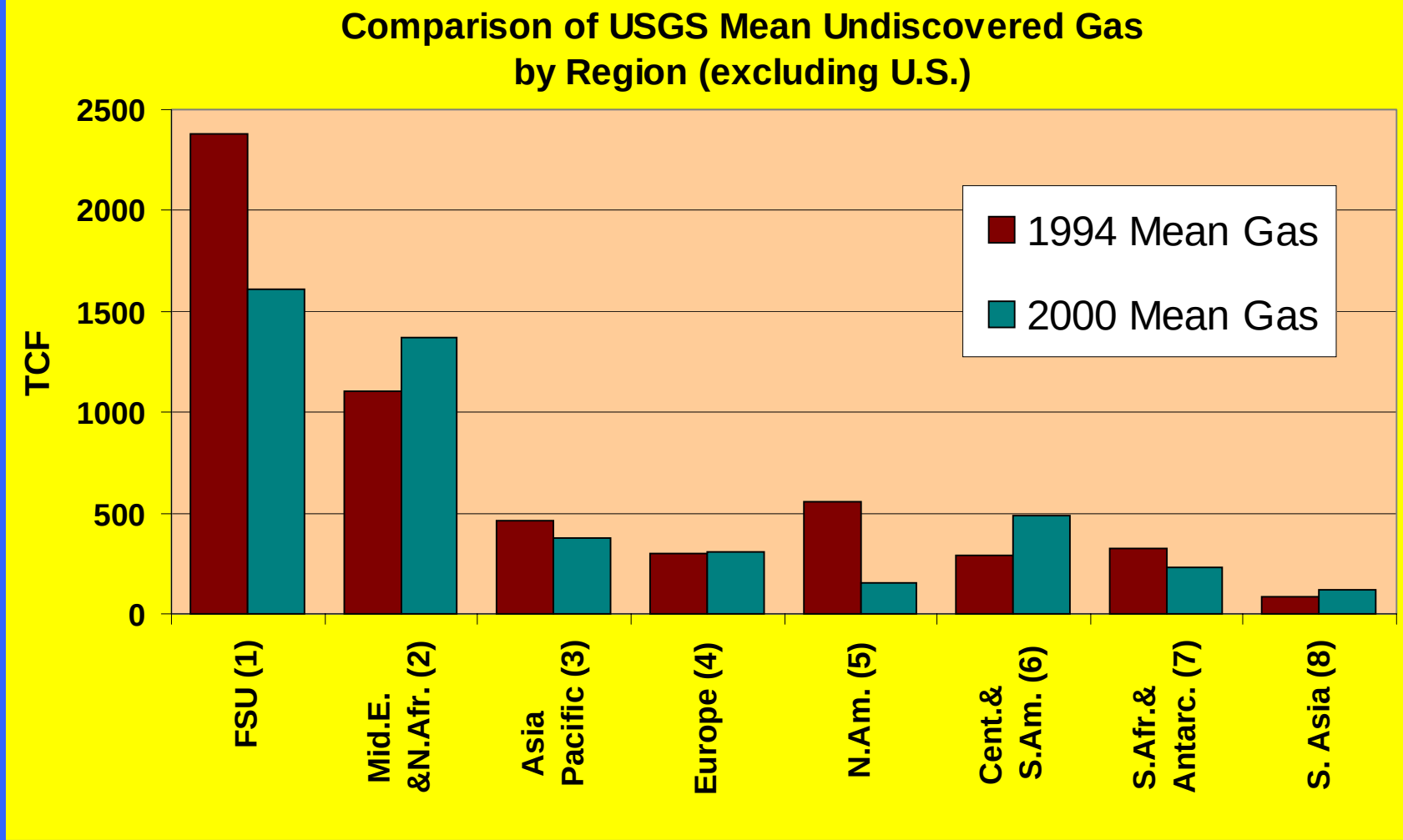


Conventional Natural Gas Endowment of the World

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

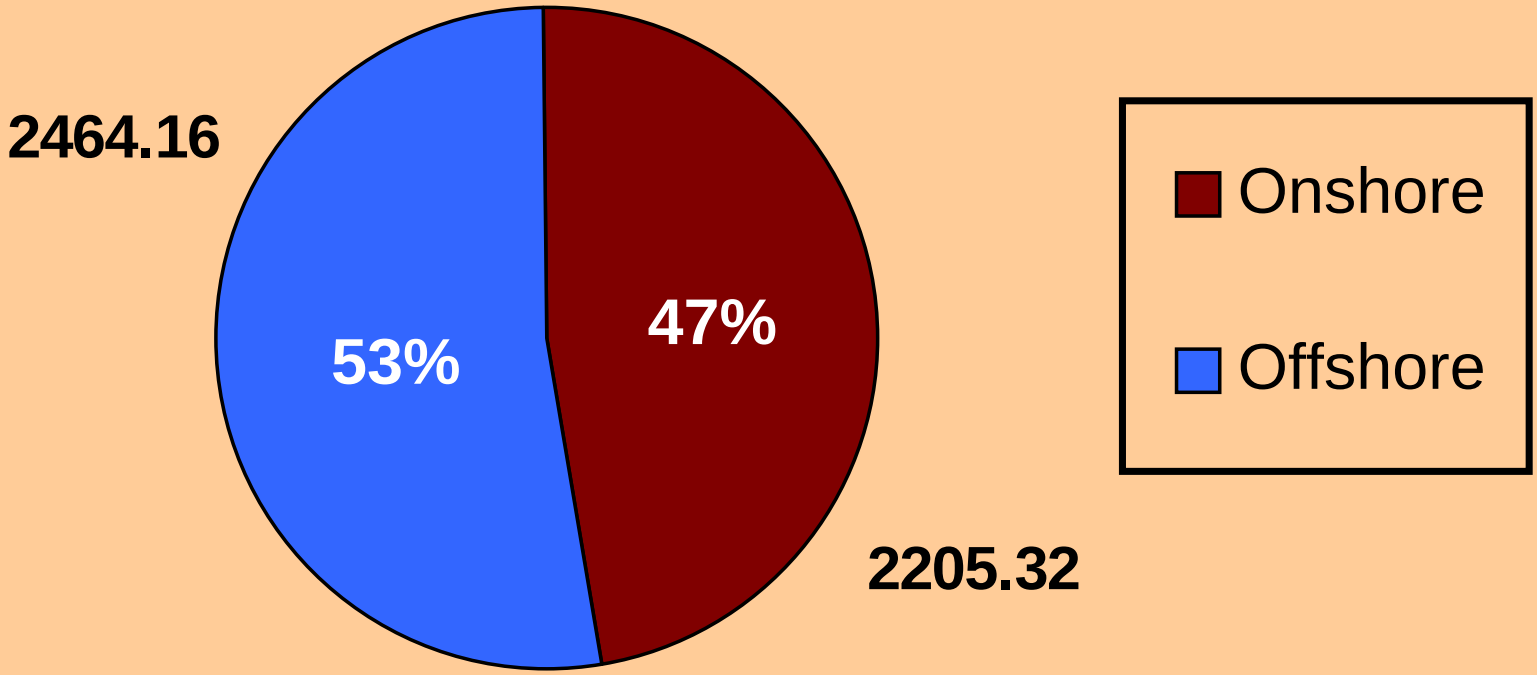
Conventional Natural Gas Endowment in Trillions of Cubic Feet

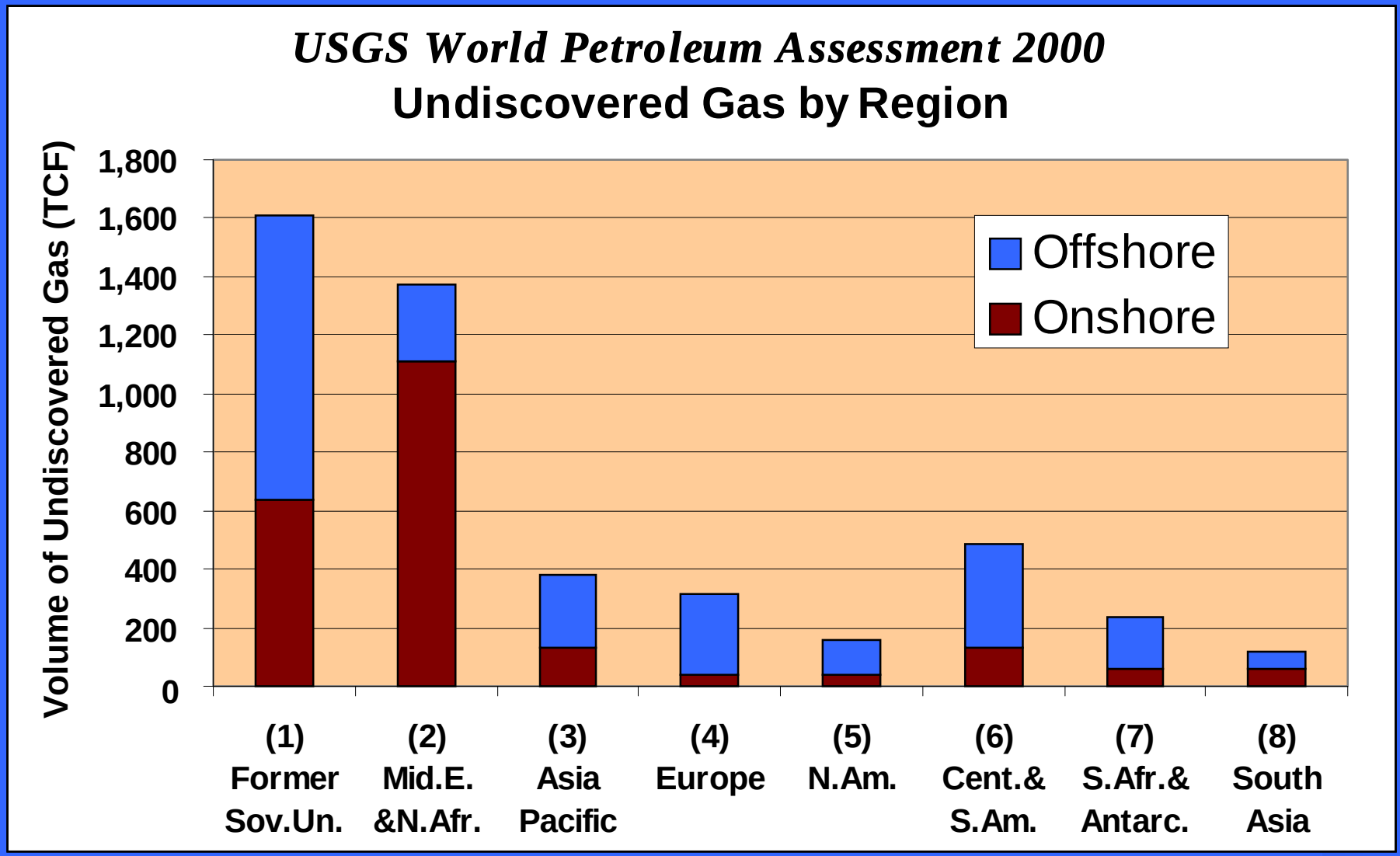
- Less than 6 TCF
- 6 - 120 TCF
- 120 - 240 TCF
- 240 - 480 TCF
- 480 - 960 TCF
- Greater than 960 TCF


Comparison of USGS Mean Undiscovered Gas
by Region (excluding U.S.)
TCF
2500
2000
1500
1000
500
0
1994 Mean Gas
2000 Mean Gas
FSU (1)
Mid.E. &N.Afr. (2)
Asia Pacific (3)
Europe (4)
N.Am. (5)
Cent.& S.Am. (6)
S.Afr.& Antarc. (7)
S. Asia (8)

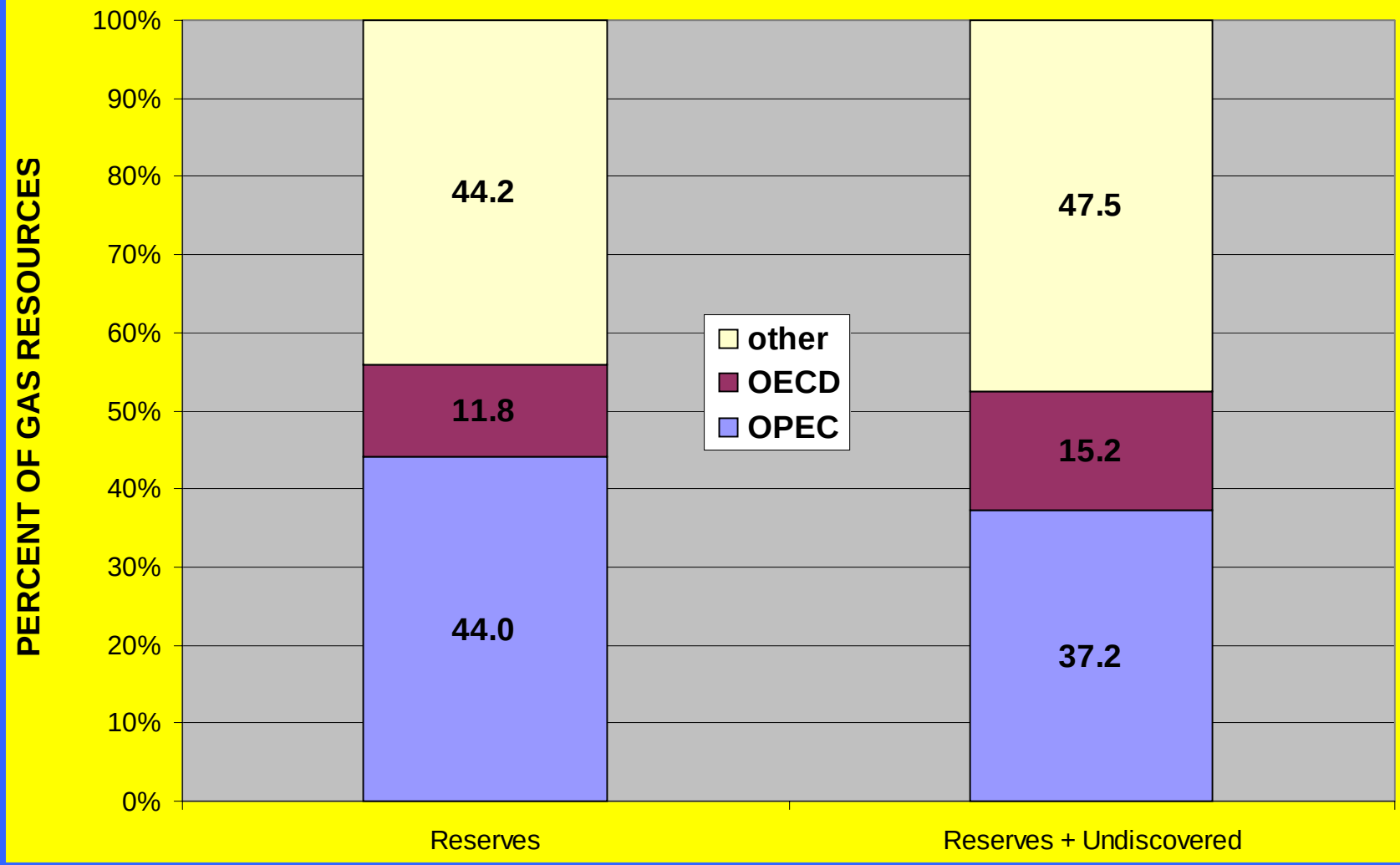
USGS World Petroleum Assessment 2000

Undiscovered Gas (TCF)



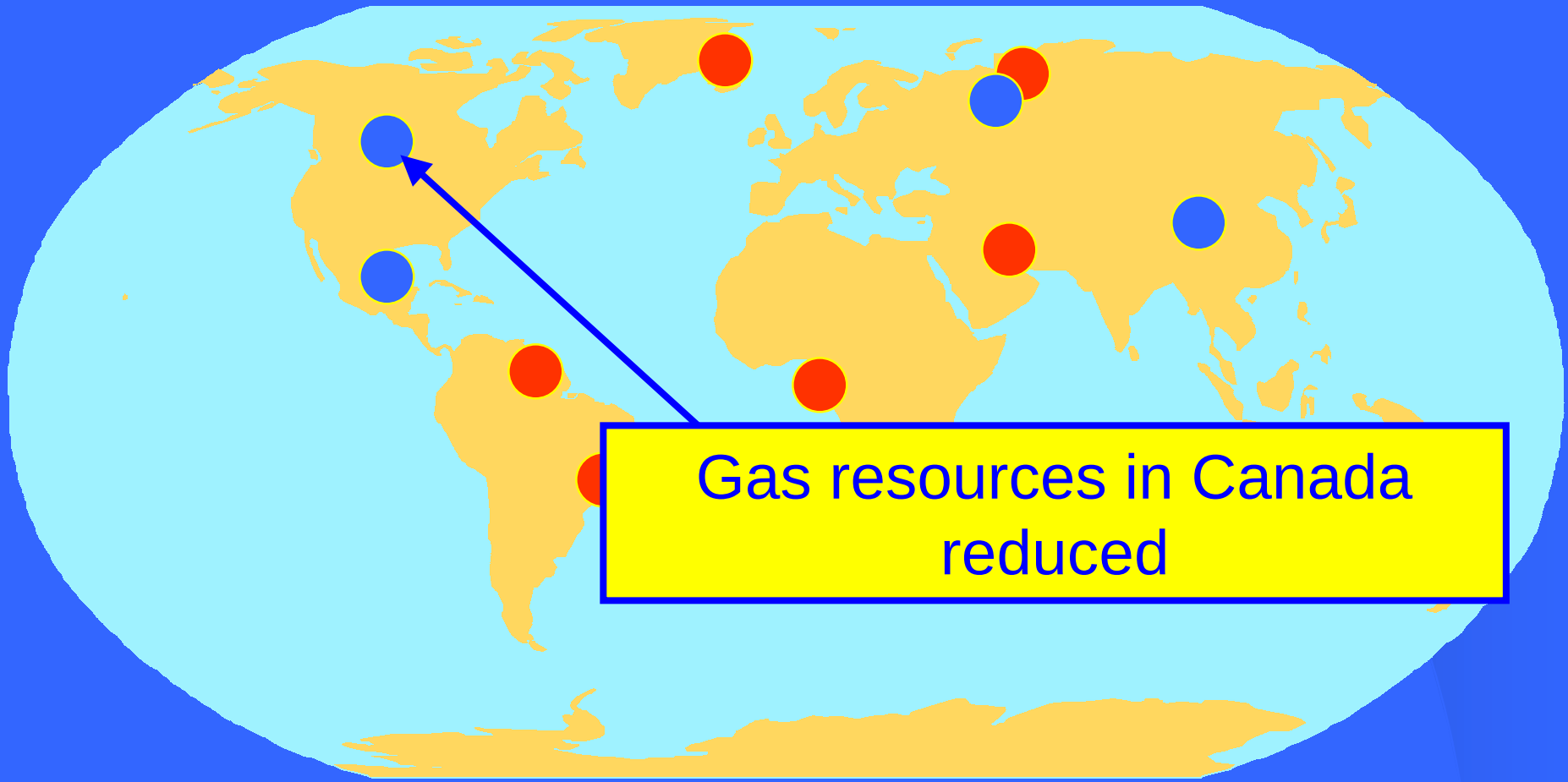

USGS World Petroleum Assessment 2000
Undiscovered Gas by Region
Volume of Undiscovered Gas (TCF)
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
Offshore
Onshore
(1) Former Sov.Un.
(2) Mid.E. &N.Afr.
(3) Asia Pacific
(4) Europe
(5) N.Am.
(6) Cent.& S.Am.
(7) S.Afr.& Antarc.
(8) South Asia

Possible Changes in Organization Share of Gas



Oil and Gas Hotspots and Coldspots

New perspectives from the USGS World Petroleum Assessment 2000



Oil and Gas Hotspots and Coldspots

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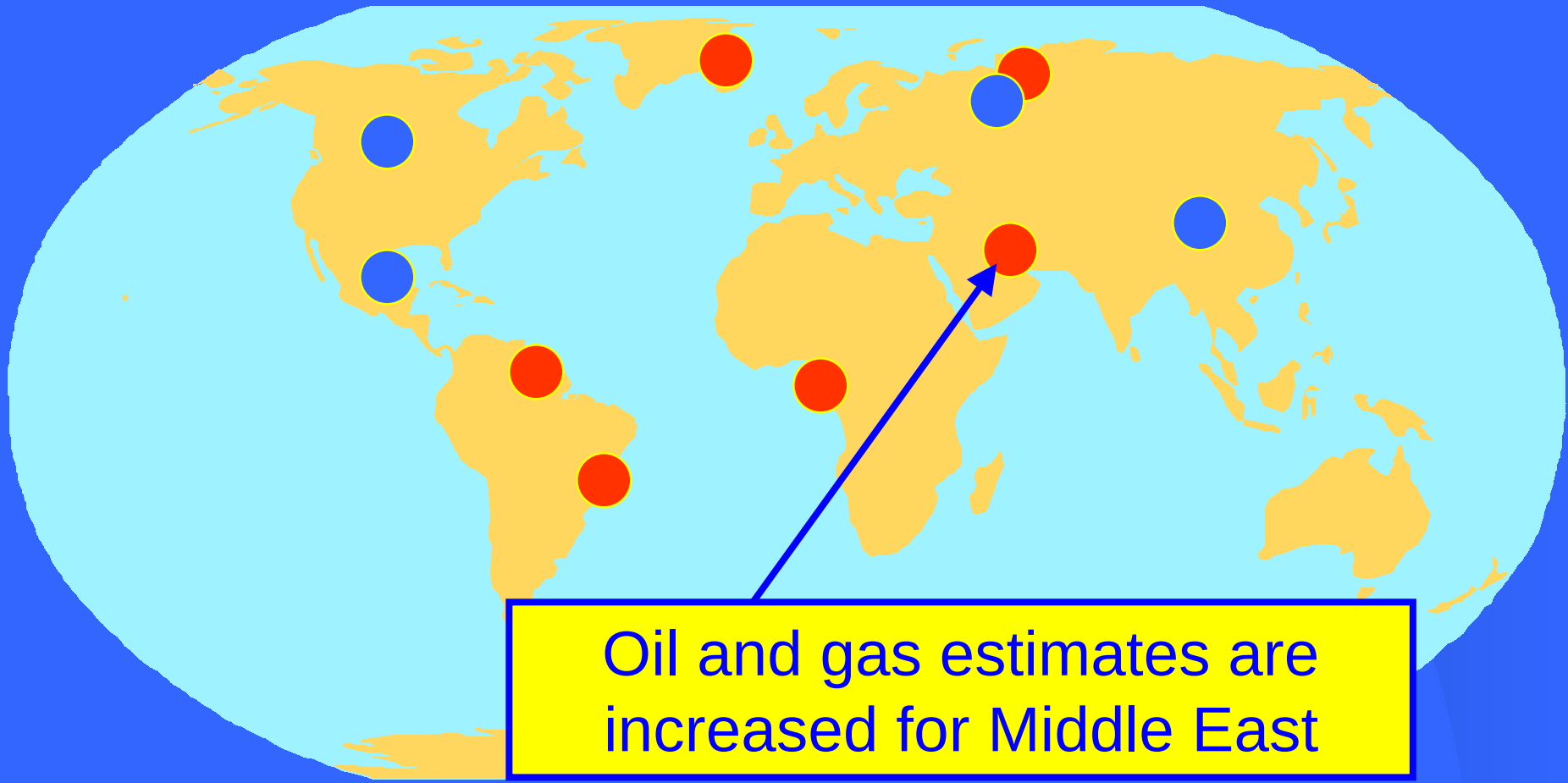
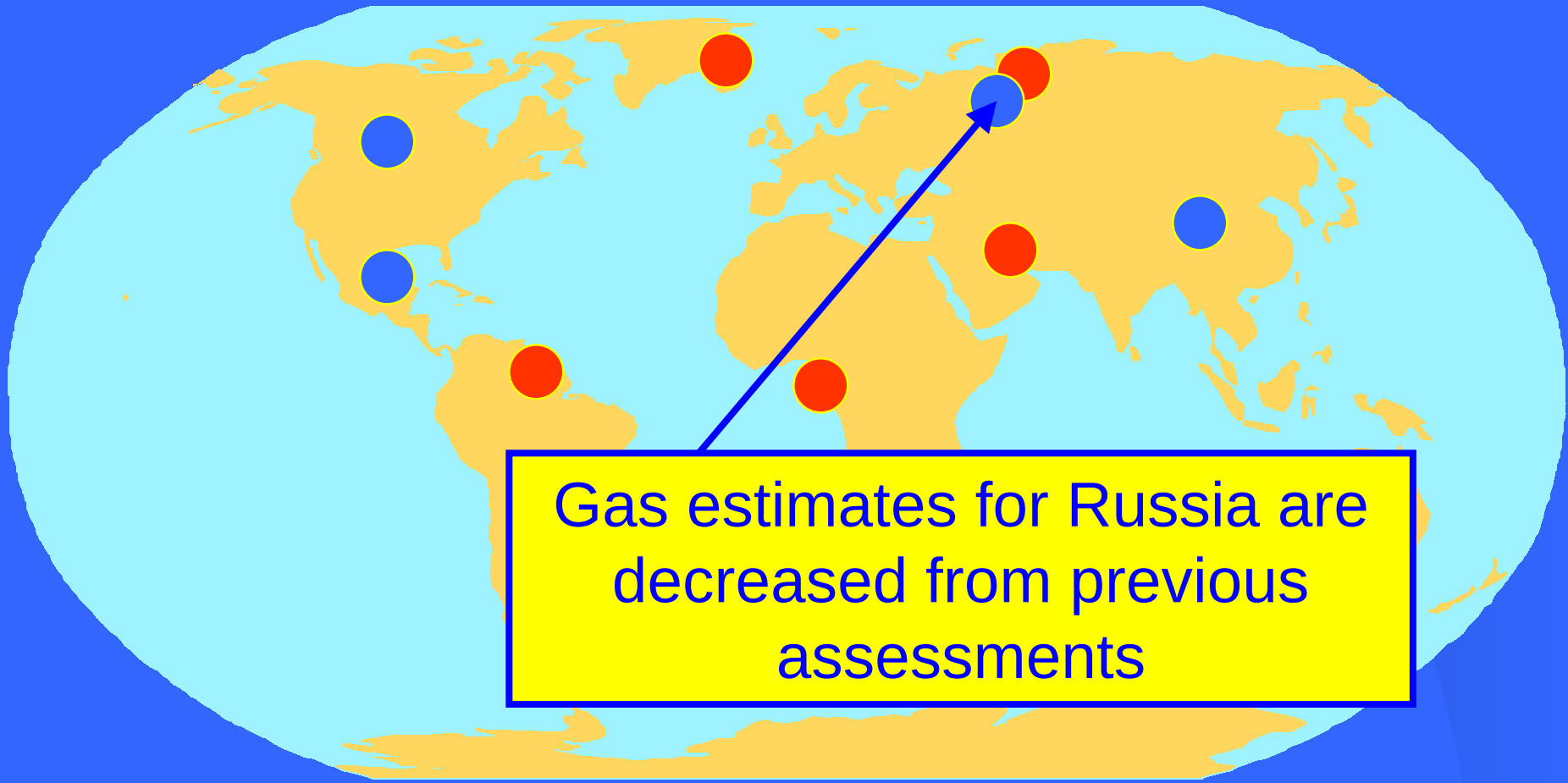


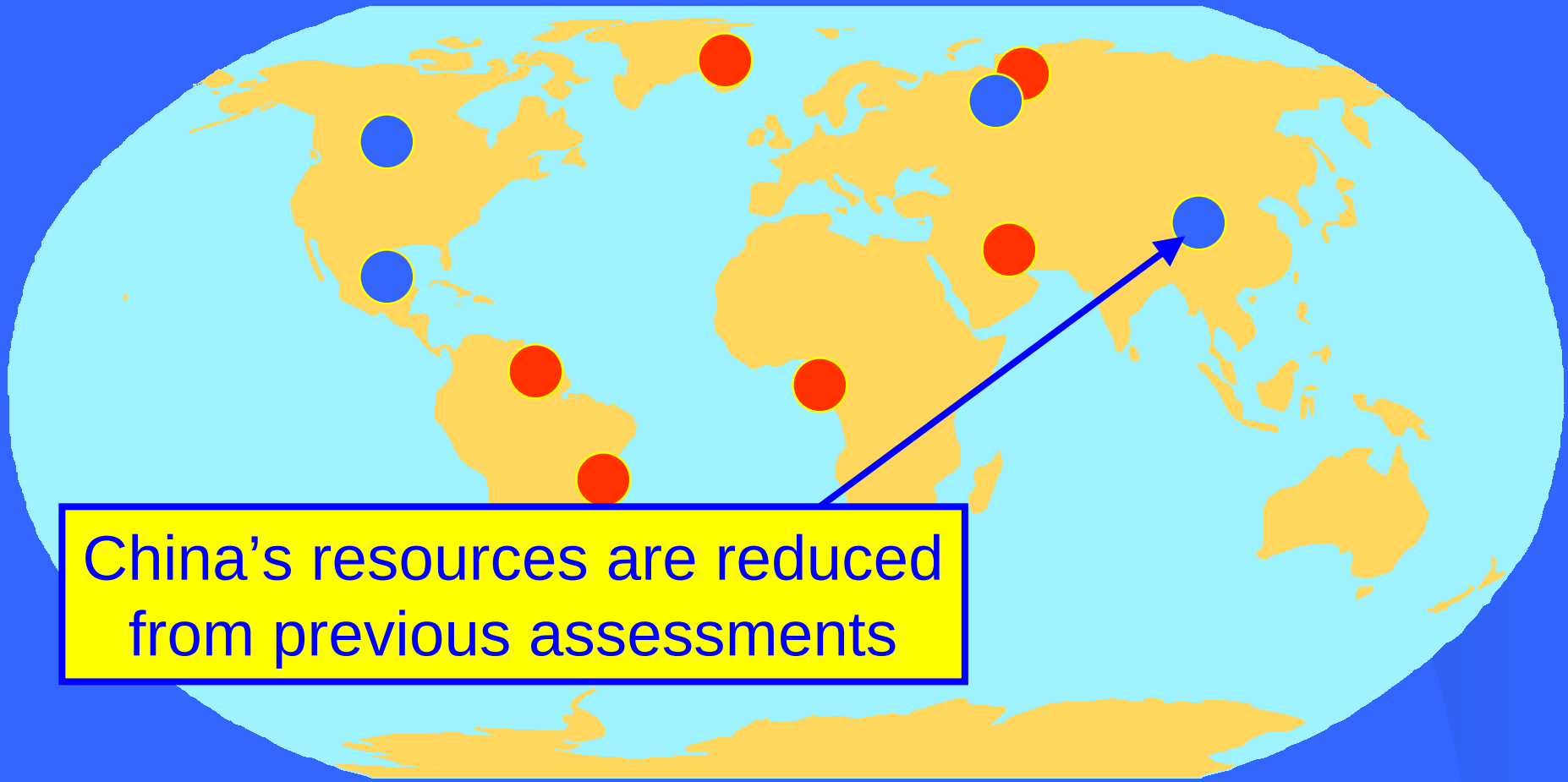
Oil and Gas Hotspots and Coldspots

New perspectives from the USGS World Petroleum Assessment 2000

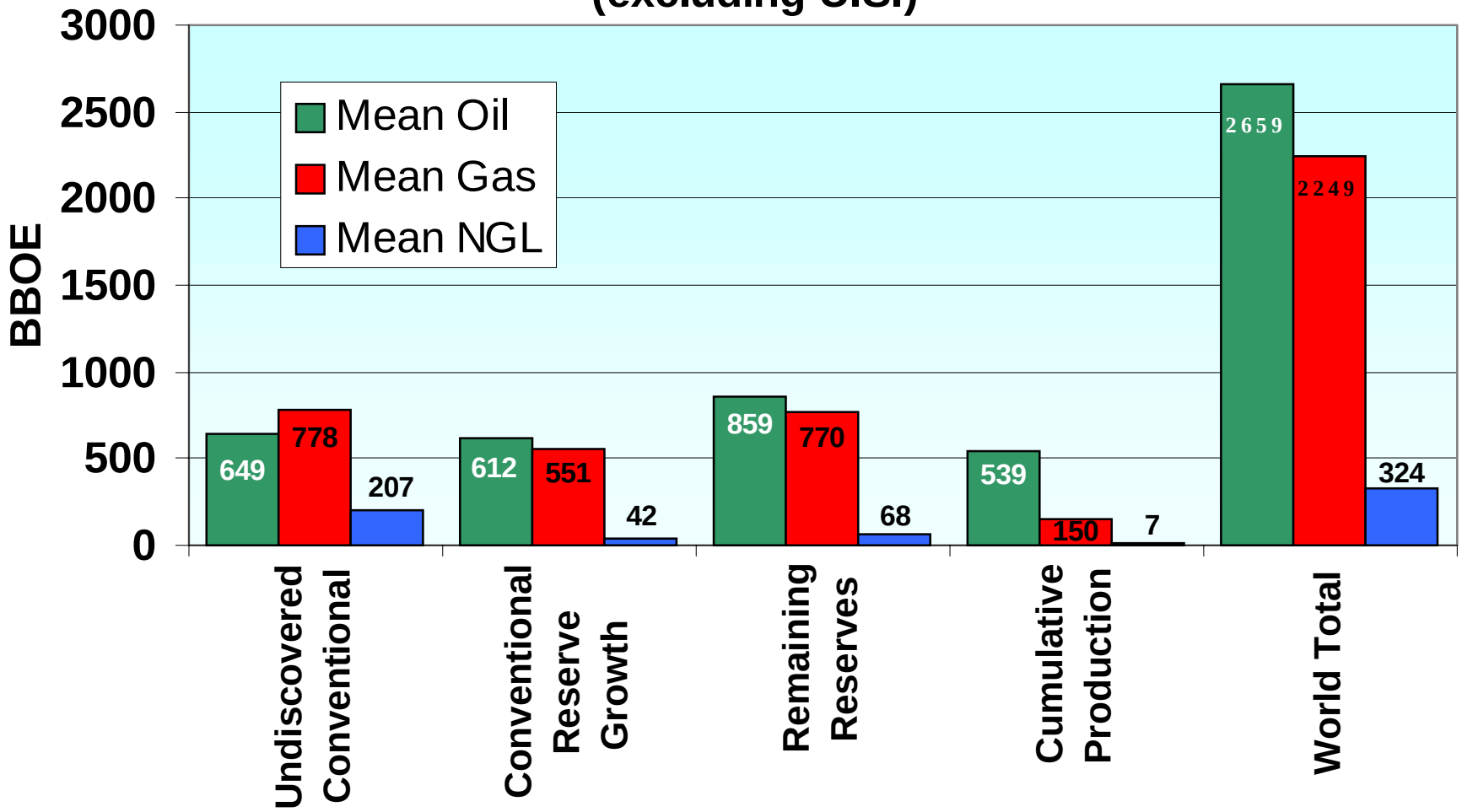


Oil and Gas Hotspots and Coldspots

New perspectives from the USGS World Petroleum Assessment 2000



USGS World Petroleum Assessment 2000
(excluding U.S.)



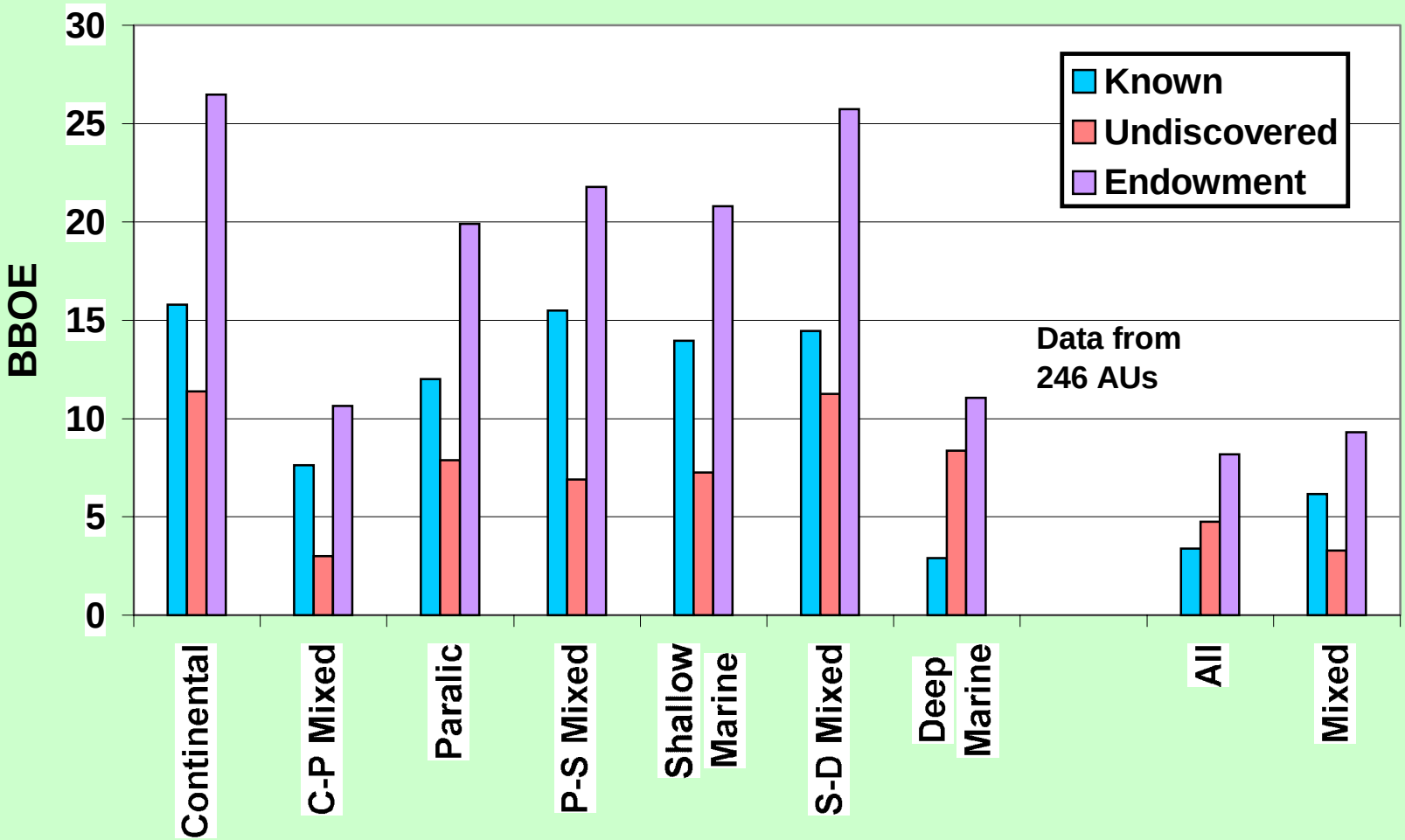
Unresolved Issues

- Impending Crisis Due to Lack Of Discoveries?
- Our Understanding of the Origin, Migration and Accumulation of Petroleum Resources is immature– particularly for Natural Gas
  - Conventional / Unconventional Gas Linkage
  - Isotopic Fractionation, Long Term Preservation
  - Significant volumes of CO2, H2S, Nitrogen

Reservoirs

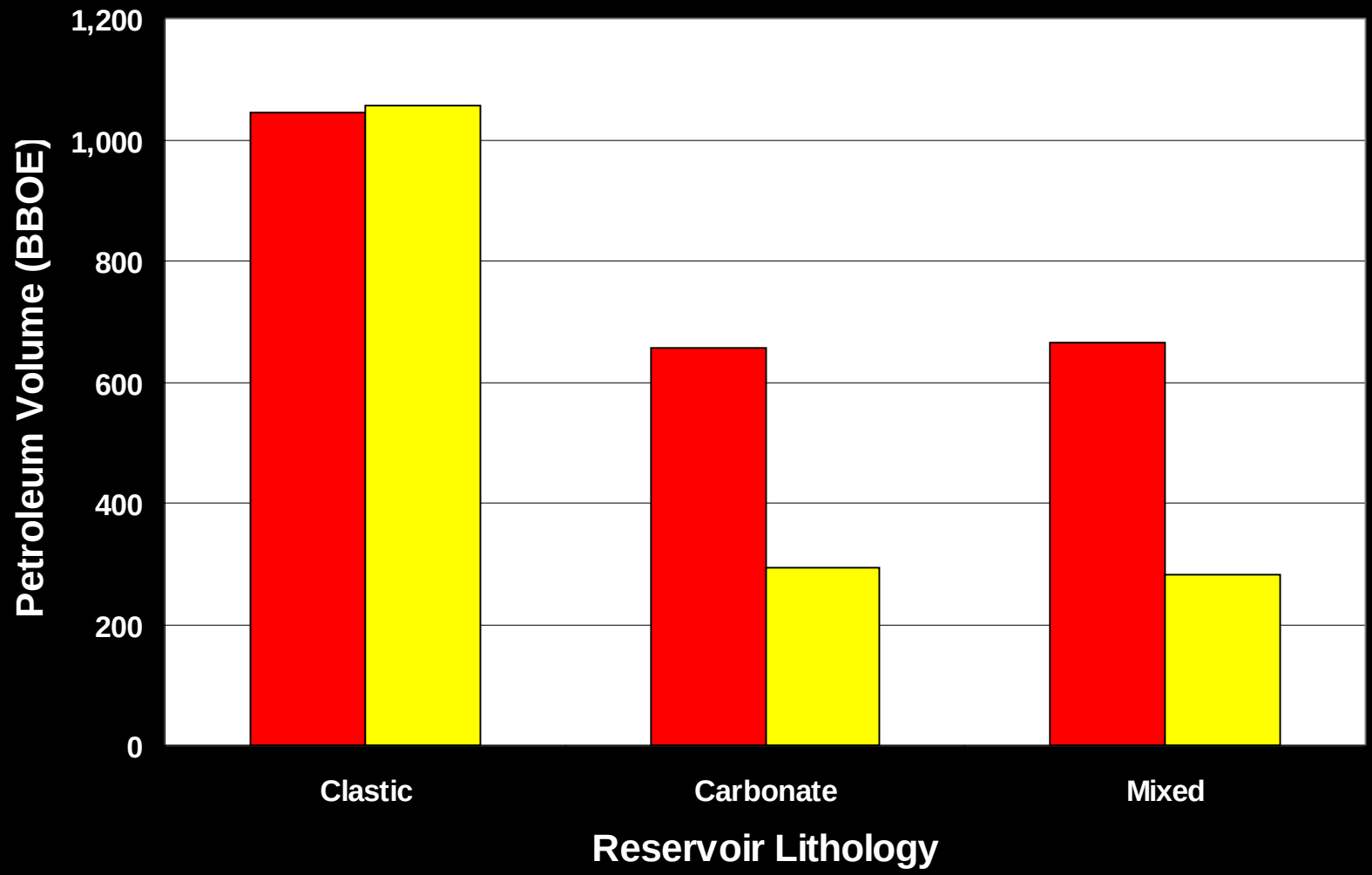
- Despite enormous recent discoveries in deep-water deposits they are the least significantly volumetrically
- Continental clastics are the dominant reservoir
- Future discoveries will be dominated by clastics
- Mega-cycles at Era boundaries—why?

Mean Resource by Reservoir Rock Depositional Environment

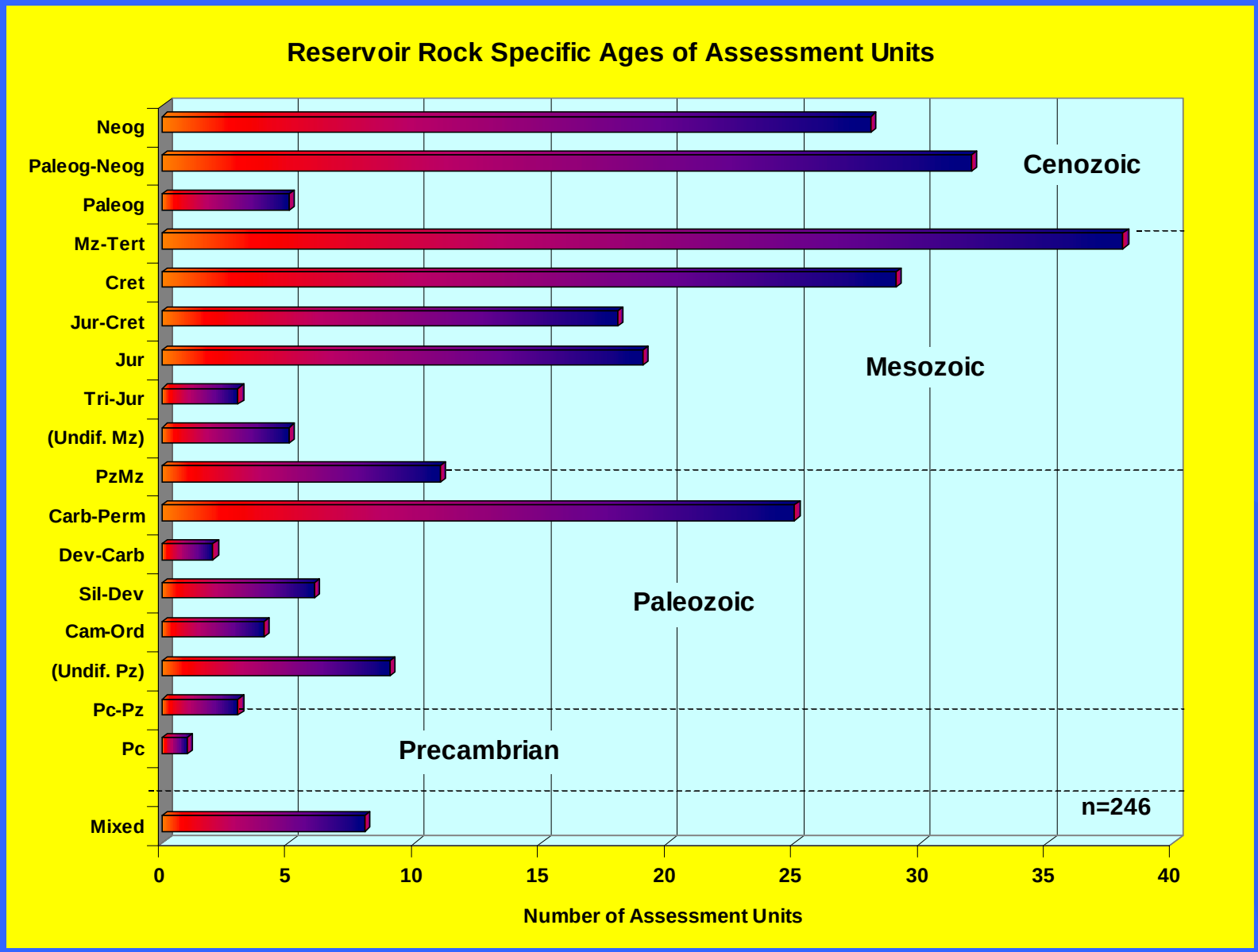


USGS

Petroleum Volumes by Reservoir Lithology



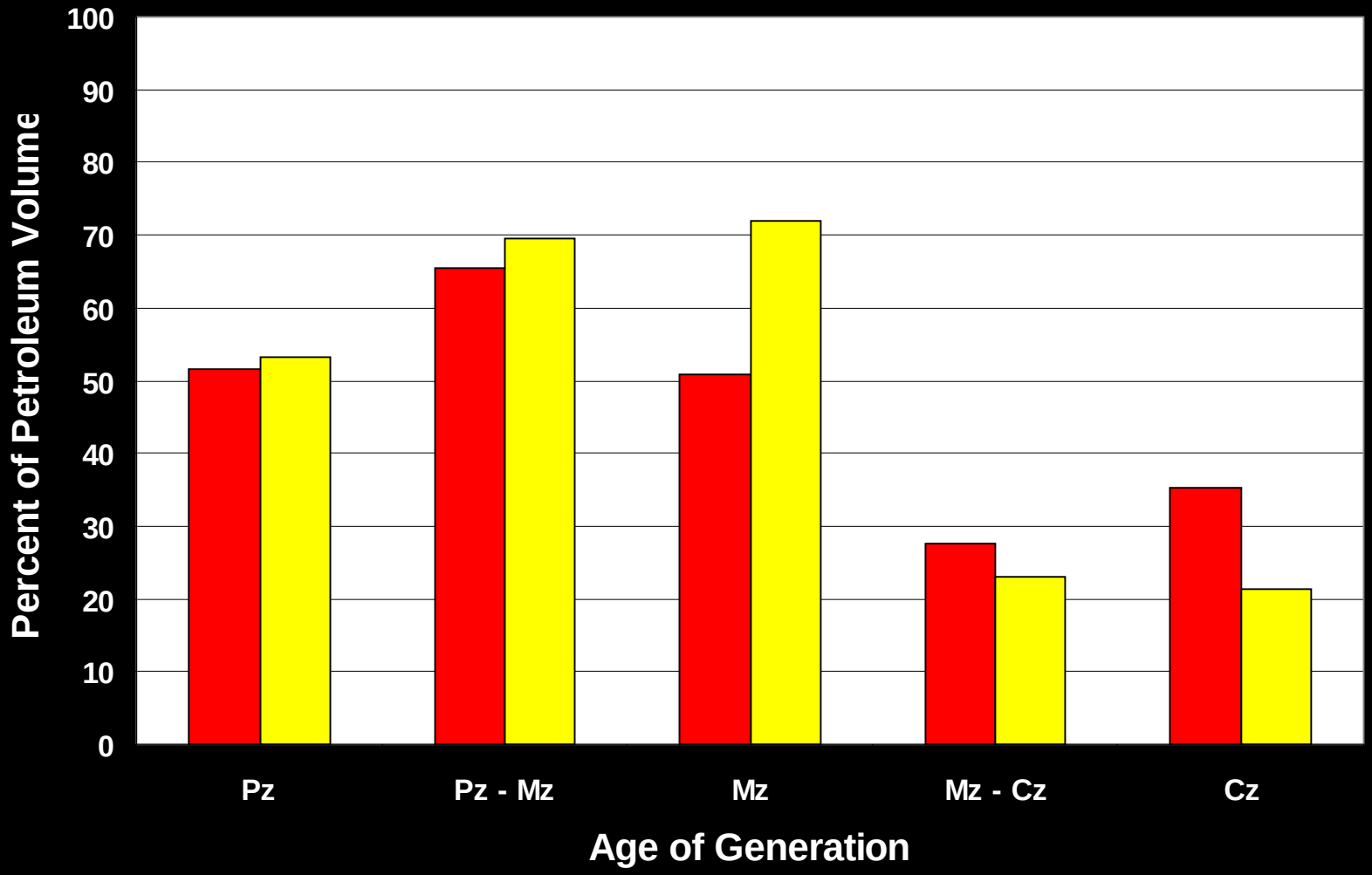
USGS


Reservoir Rock Specific Ages of Assessment Units
Neog
Paleog-Neog
Paleog
Mz-Tert
Cret
Jur-Cret
Jur
Tri-Jur
(Undif. Mz)
PzMz
Carb-Perm
Dev-Carb
Sil-Dev
Cam-Ord
(Undif. Pz)
Pc-Pz
Pc
Mixed
Cenozoic
Mesozoic
Paleozoic
Precambrian
n=246
0
5
10
15
20
25
30
35
40
Number of Assessment Units

Seals

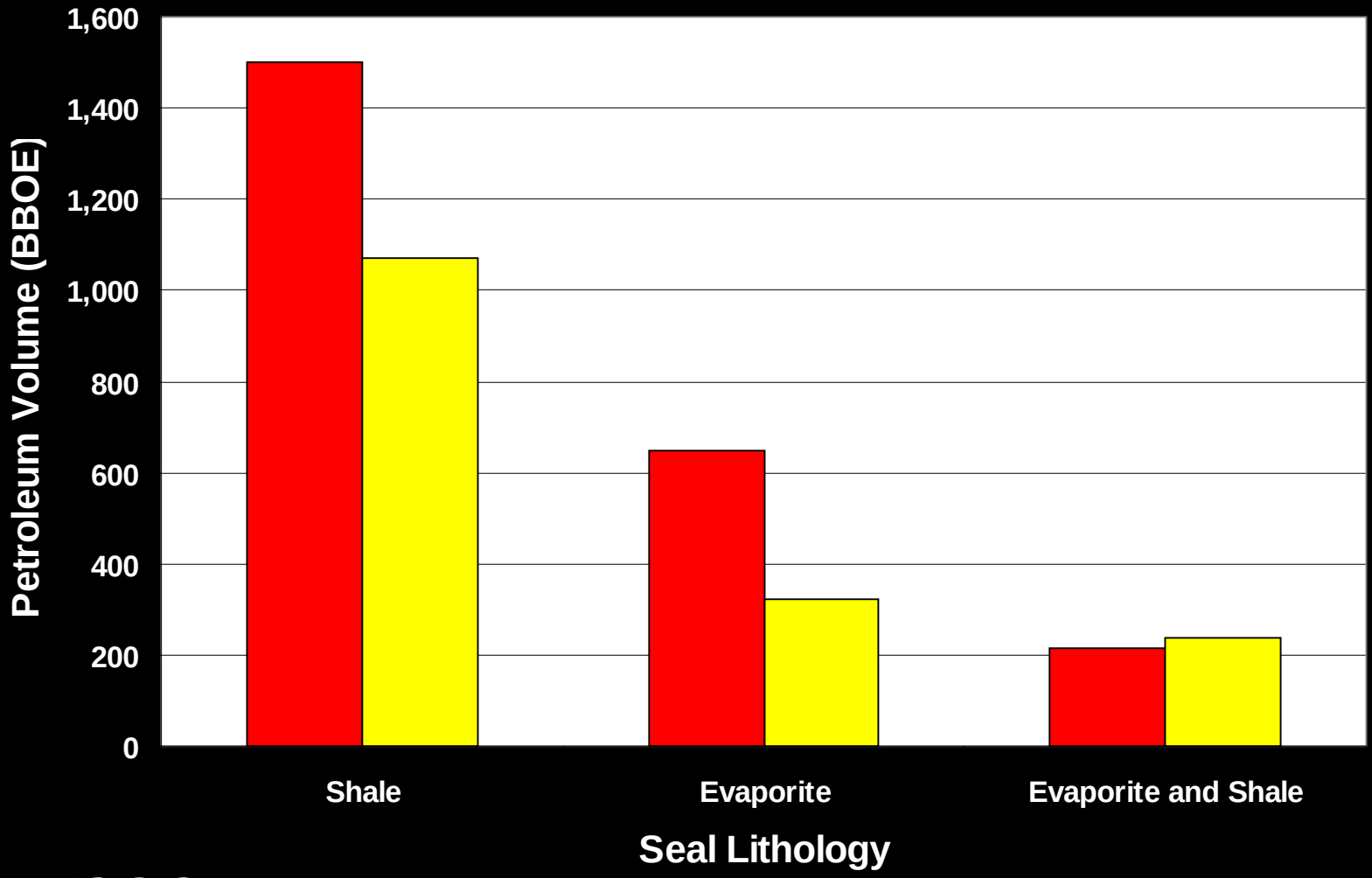
- Only salts (evaporites) form effective long term seals; long term trapping of gas not clearly understood
- Much (if not most) petroleum has been lost to the surface—most seals are clastic and leaky
- Seals for unconventionals are perhaps are the most important and least understood

Percent of Volume with Evaporite Seals



USGS

Petroleum Volumes by Seal Lithology

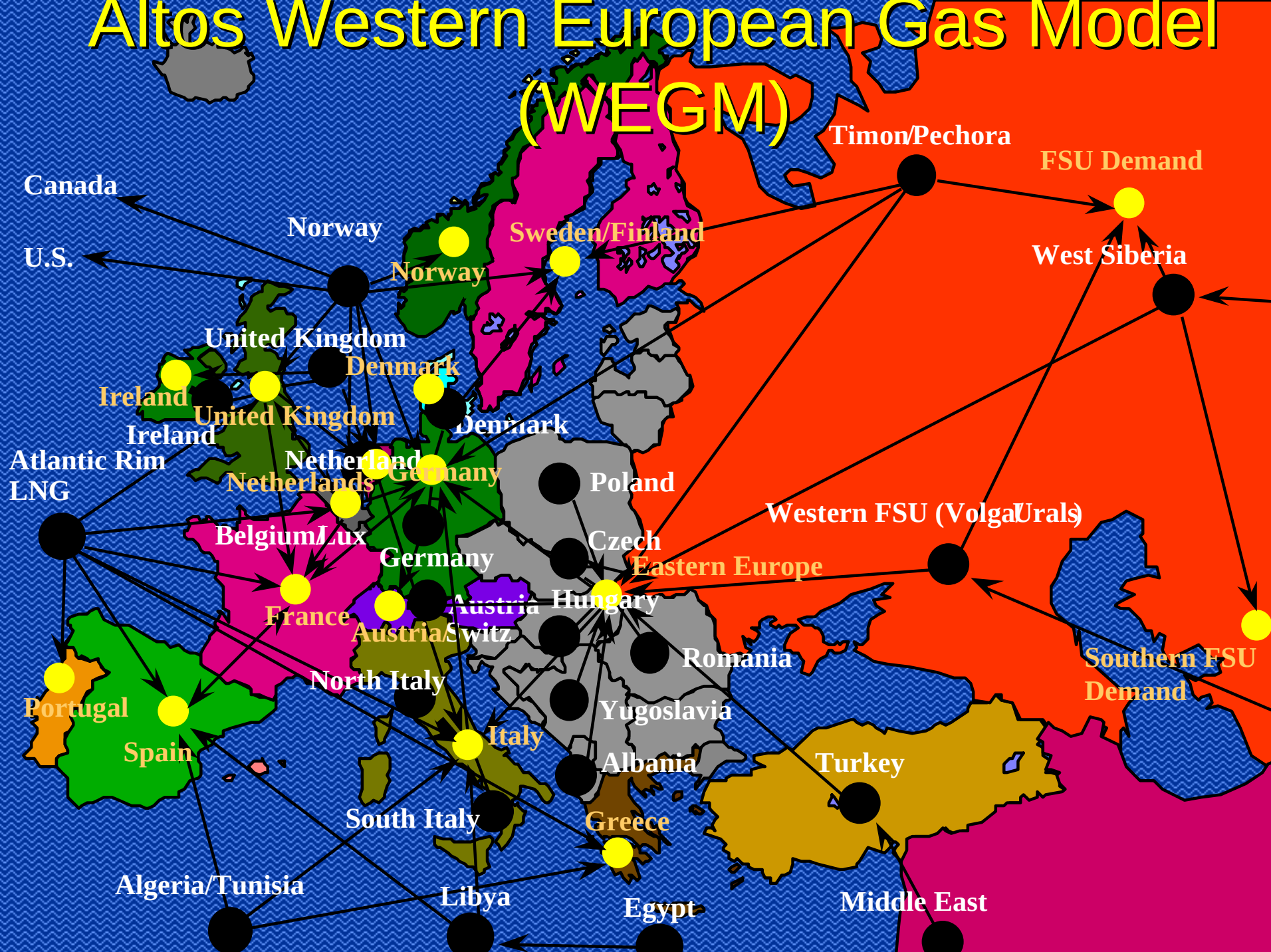


USGS

Resource Assessments as Inputs to Economic, Infrastrucutre Decisions

North Sea—importance of technology and reserve growth for gas supply

Arctic Resources—The next frontier—major gas resource potential


Altos Western European Gas Model
(WEGM)
Timon/Pechora
FSU Demand
Canada
Norway
Sweden/Finland
U.S.
Norway
West Siberia
United Kingdom
Denmark
Ireland
United Kingdom
Ireland
Denmark
Atlantic Rim
LNG
Netherland
Germany
Netherlands
Poland
Western FSU (Volga/Urals)
Belgium/Lux
Czech
Germany
Eastern Europe
France
Austria
Hungary
Austria/Switz
Romania
Southern FSU
Demand
North Italy
Portugal
Yugoslavia
Spain
Italy
Albania
Turkey
South Italy
Greece
Algeria/Tunisia
Libya
Egypt
Middle East

The Resource Base Has Expanded Substantially

Volumes are double what they were in 1995.

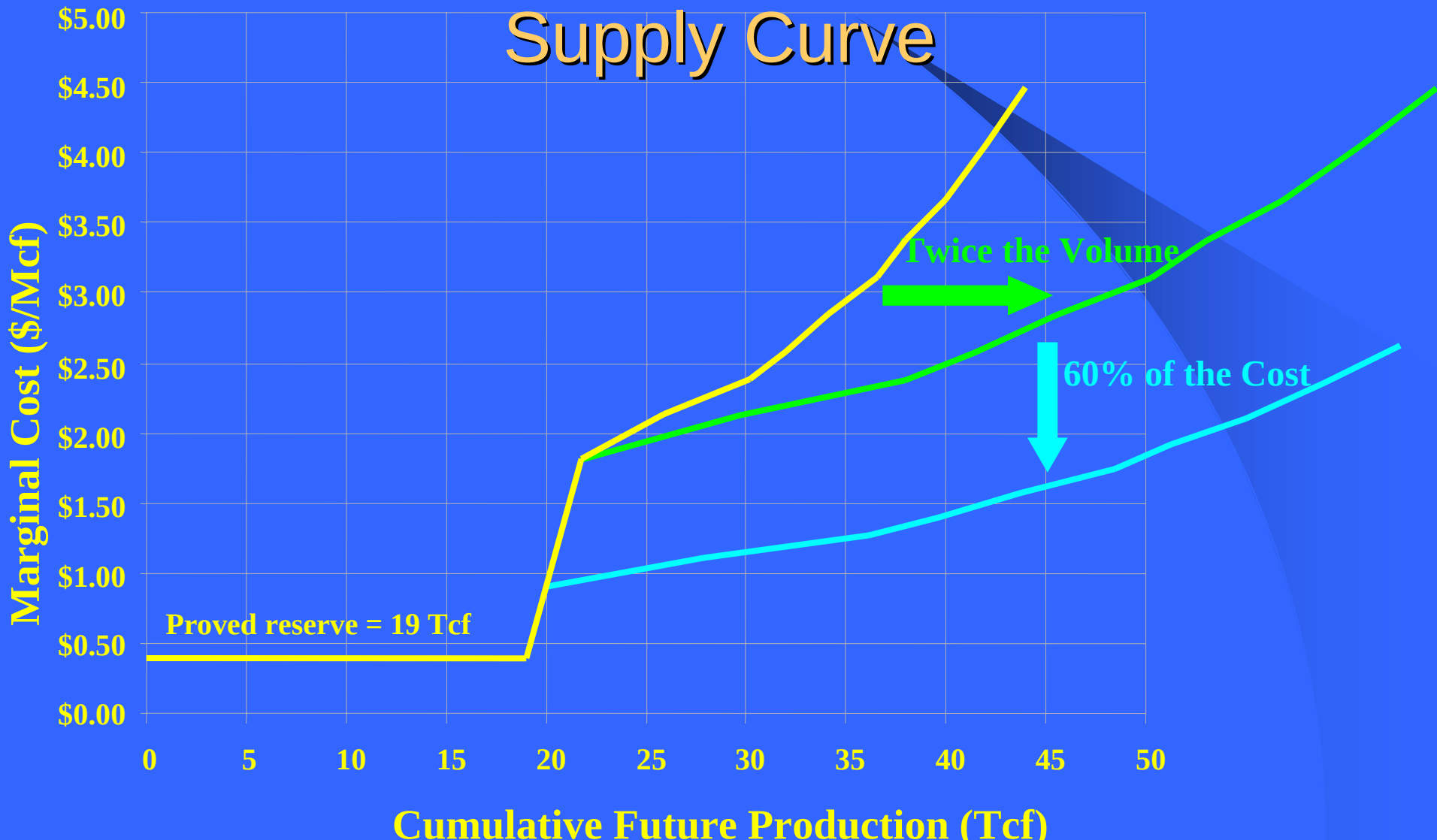
Costs are 50-60 percent of what they were in 1995.

Because of

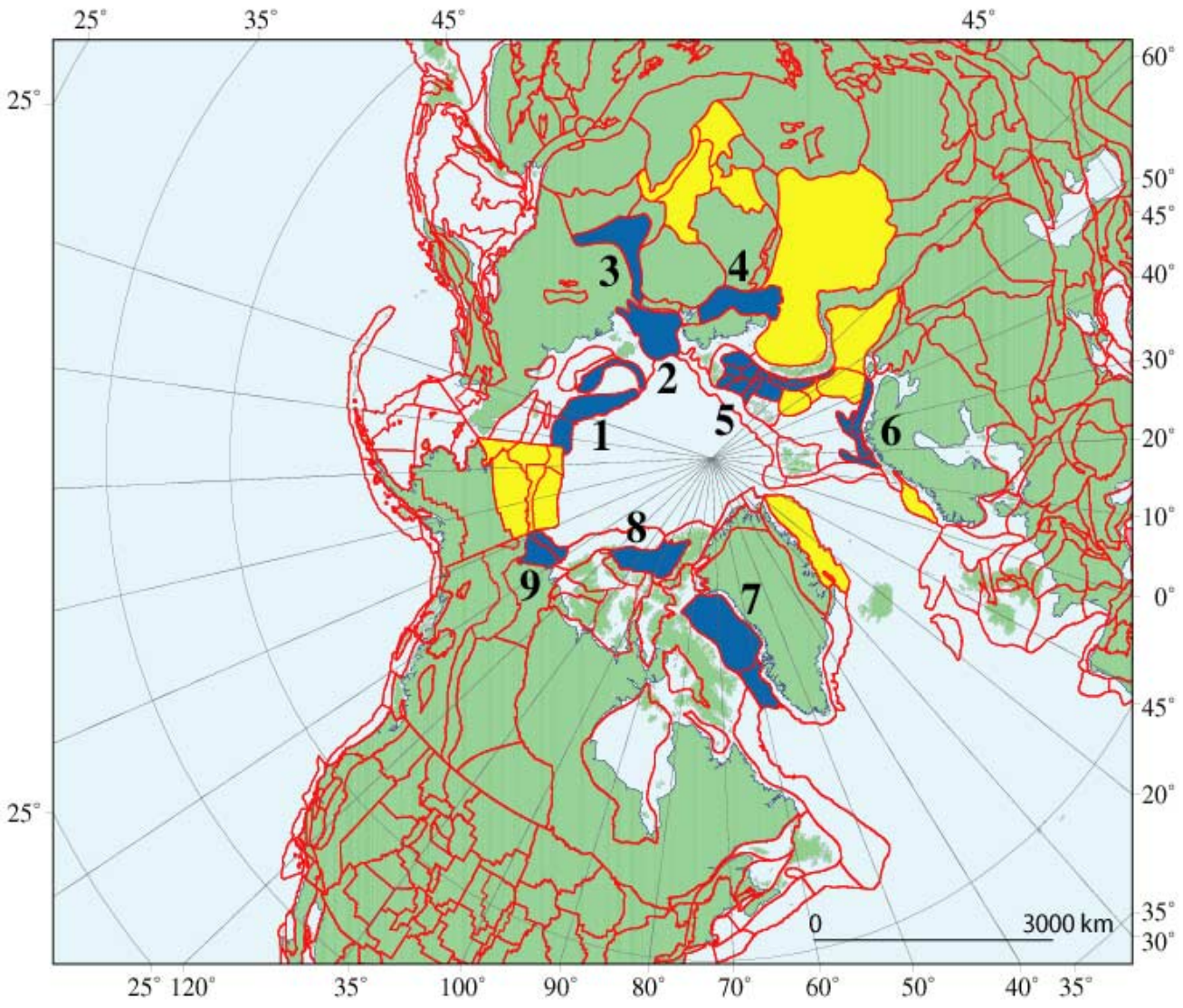
- Continued discovery success
- Undiscovered fields (USGS World Energy Project)
- First estimates of future reserve growth

Nobody has talked about deep water drilling yet!

Old Versus New United Kingdom/Southern North Sea Gas Supply Curve



Arctic Provinces for Study in 2002



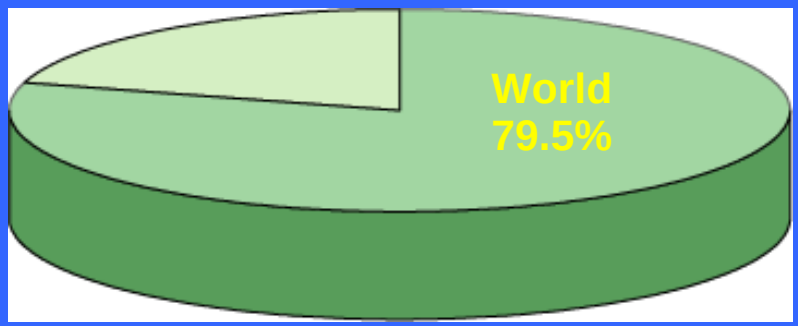
1-Vilkitsky
2-Laptev Sea
3-Vilyuy
4-Khatanga
5-North Kara Sea
6-West Barents
7-West Greenland
8-Sverdrup
9-Beaufort-Mackenzie

Assessed Arctic provinces

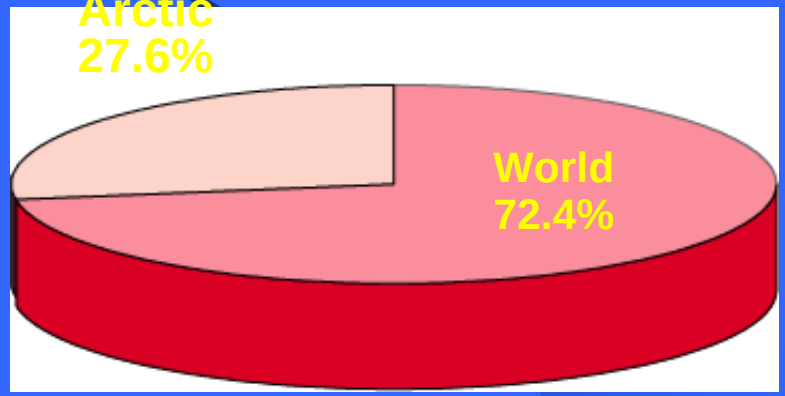
Potential Arctic provinces

ARCTIC SHARE OF UNDISCOVERED PETROLEUM

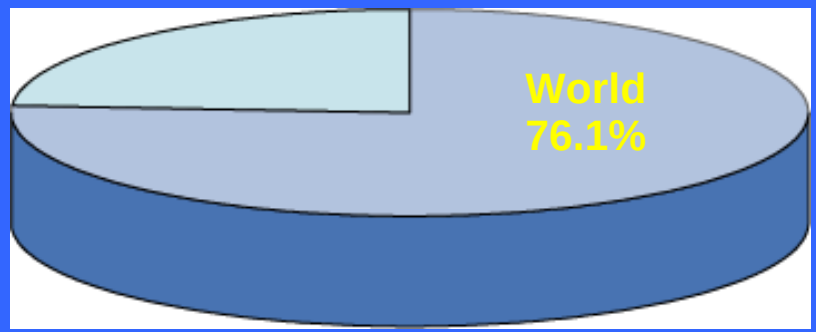
OIL & NGL



GAS



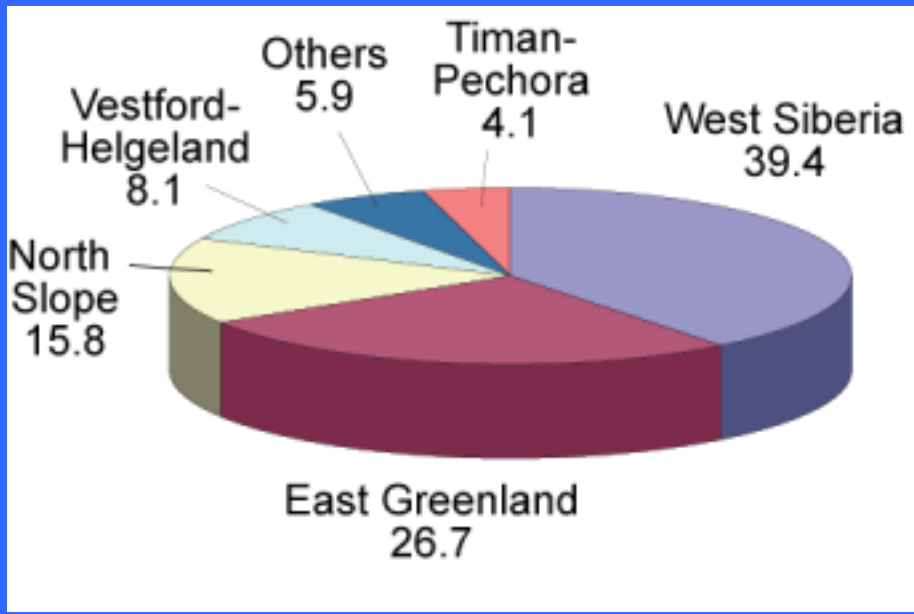
BOE



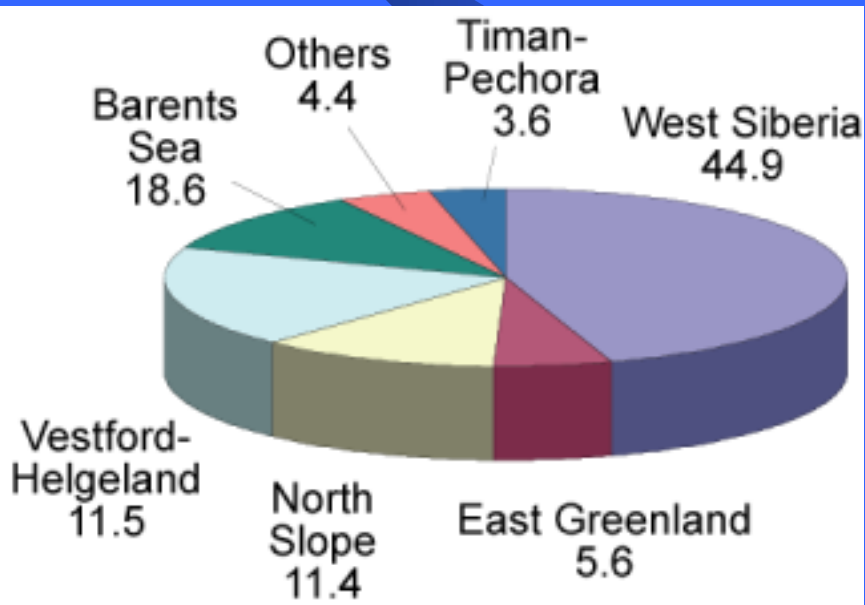
USGS
science for a changing world

DISTRIBUTION OF ASSESSED UNDISCOVERED RESOURCES IN ARCTIC

OIL & NGL, %

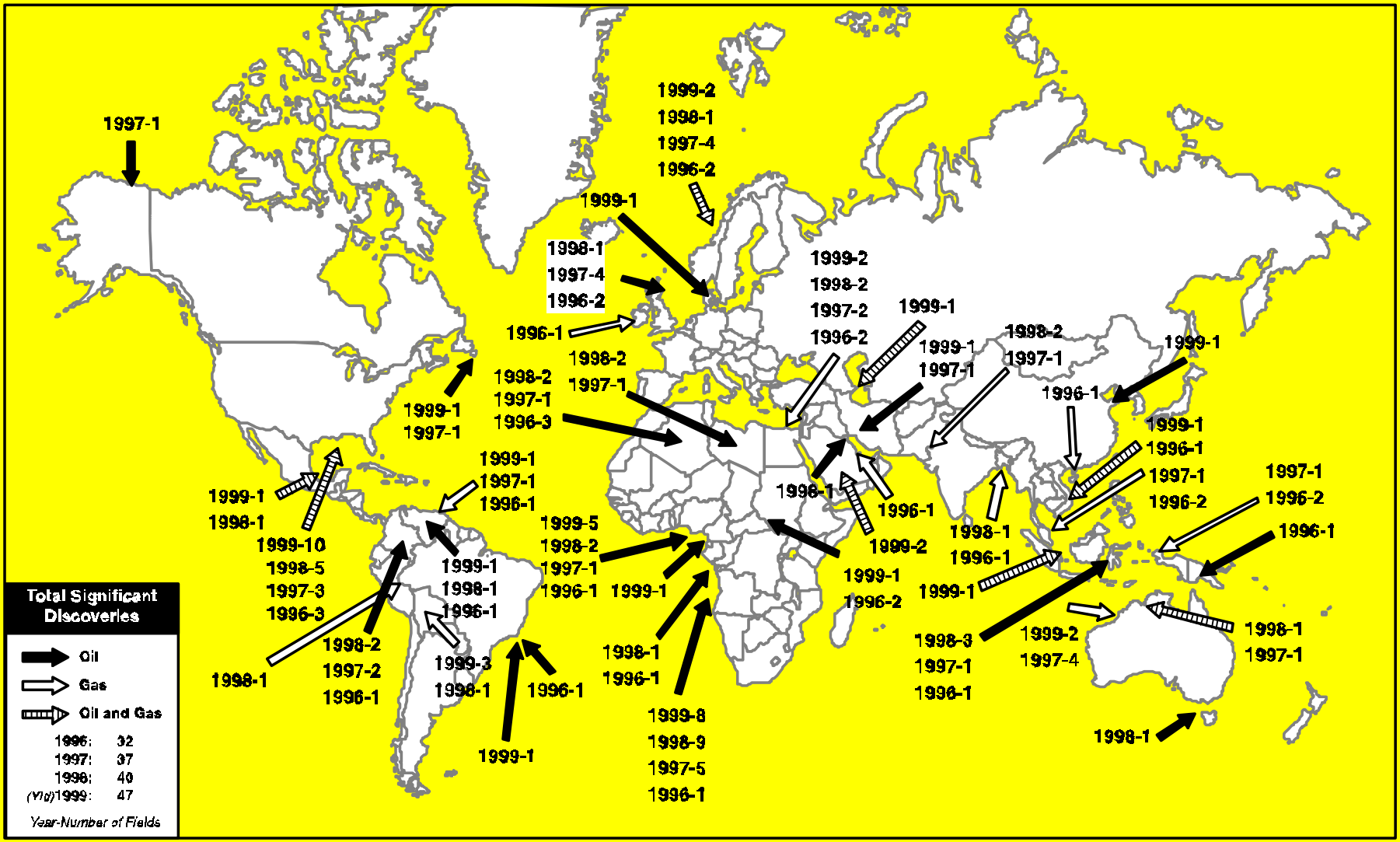


GAS, %



1996-1999 Significant Discoveries

(larger than 100 million barrels, 1 trillion cubic feet)



Source: Cambridge Energy Research Associates.

January 2000

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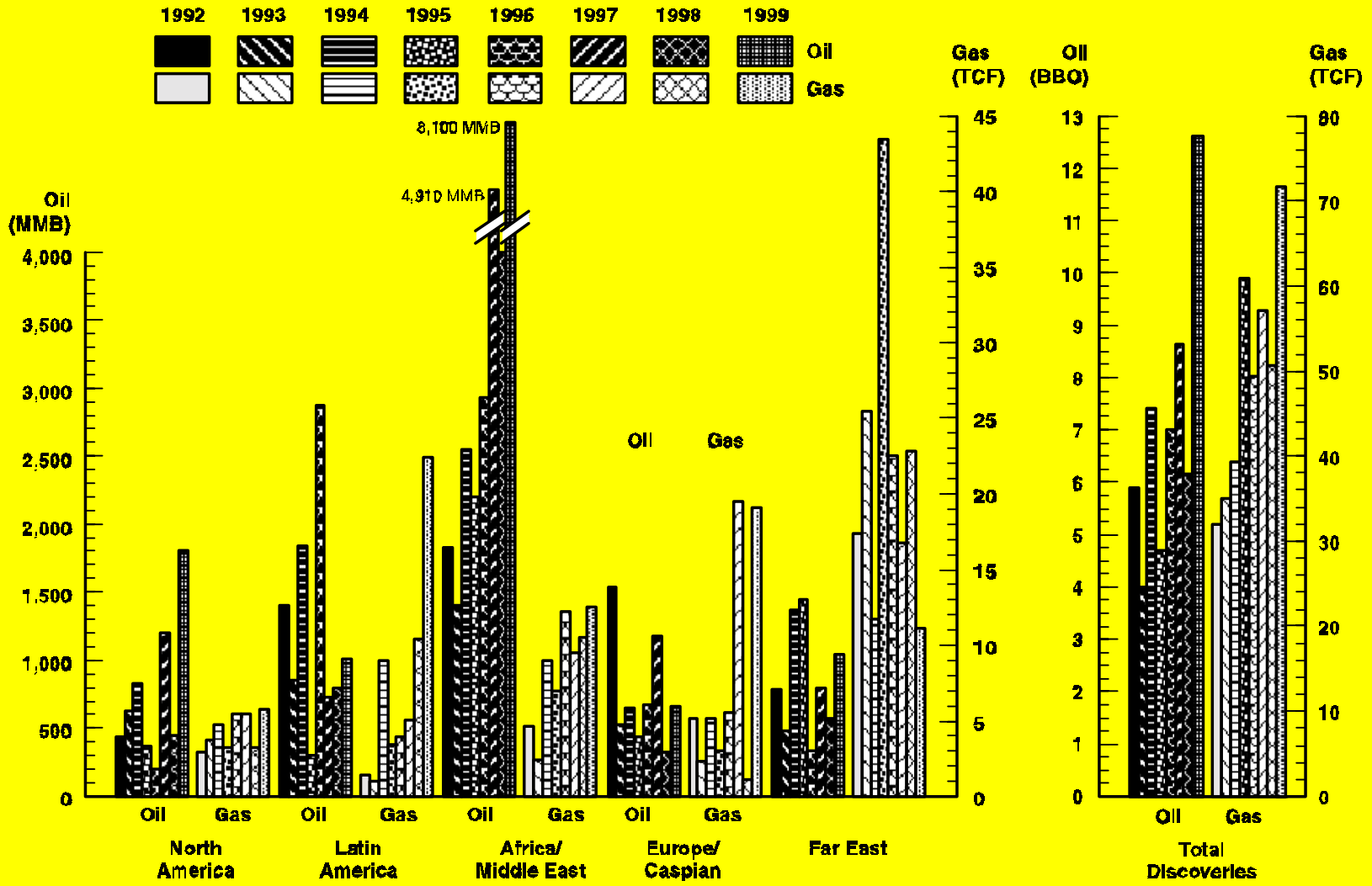
CERA

World Oil and Gas Discoveries, 1992–1999



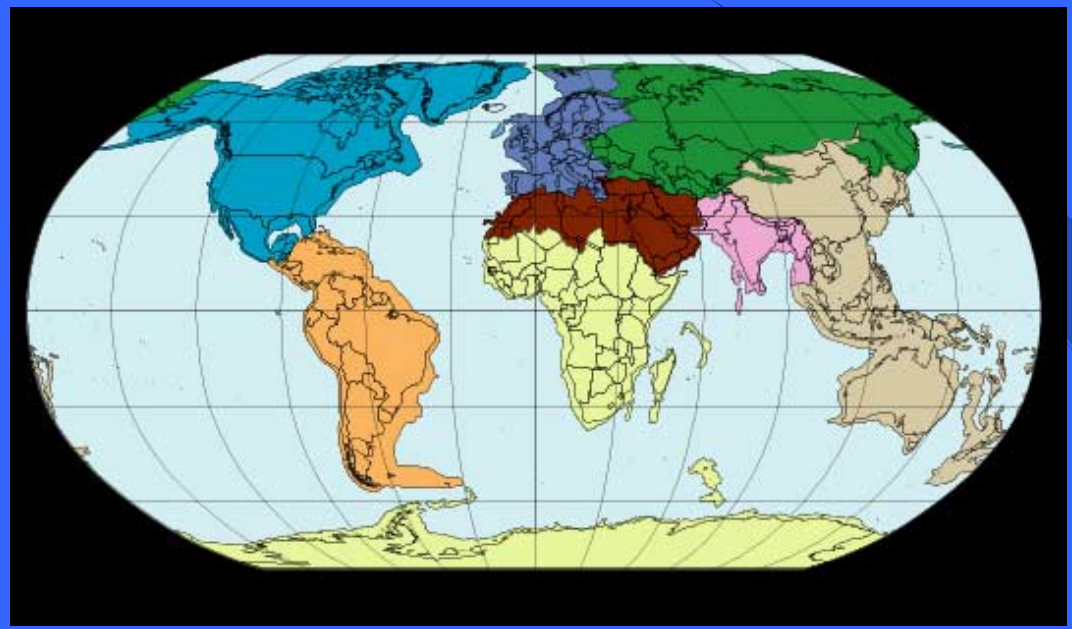
Source: Cambridge Energy Research Associates.

Updated April 2000

Summary

- Estimates of Undiscovered Petroleum are up (+9.5% overall; oil +24.3%, gas –10.4%, NGL +104%) relative to 1994 USGS estimates
- **Field Growth** is 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
- 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**.
- U.S. Reserves—surprising ~12% of world endowment, but **troubling recent U.S. downturn and problems for Canadian Gas**.
- Our understanding of petroleum systems is just beginning, many challenges to our preconceptions and needed research into gas systems, unconventional (continuous resources)

For additional information:



USGS DDS-60

or

http://energy.cr.usgs.gov