The Petroleum Endowments of the Total Petroleum Systems in the Middle East and North Africa Tethys*

Thomas S. Ahlbrandt[1]

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[1]Falcon Oil and Gas LTD, Denver, CO (tahlbrandt@falconoilandgas.com)

Abstract

The Total Petroleum Systems (TPS) of the Middle East and North Africa represent the dominant oil and liquids (first by significant margins) and natural gas endowments (slightly behind the Former Soviet Union) of the world. 58% of global oil reserves (765 BBO of a total of 1326 BBO exclusive of the U.S. as of 1/1/96) and 44% of the world's known petroleum volume occur in this region. Some estimates suggest that two-thirds of the liquid petroleum potential of the world resides in this region which coincides with Region 2 of the USGS 2000 assessment. Twenty eight TPS were studied in the USGS 2000 global petroleum assessment, and three additional TPS have been evaluated since 2000 in this region.

The petroleum endowment is comprised of four elements; i.e. cumulative production, remaining reserves, reserve growth and undiscovered resources. As of 1/1/96 data, this region had nearly three times the liquid endowment of any other region, and was closely comparable to the Former Soviet Union natural gas endowment, both significantly larger for conventional resources than any other region. Reserve growth data from 1997 to 2003 show that this region dominates additions for oil (85 BBO) and natural gas (over 1100 TCF or 183 BBOE) relative to any other region. Discoveries continue to be impressive in the 2000-2008 time frame with average discovery sizes being 840 MMBOE, 780 MMBOE and 233 MMBOE in Kuwait, Iran and Saudi Arabia (IHS, 2009).

Four mega-TPS dominate the petroleum endowment in this region; i.e. the Infracambrian, Silurian, Jurassic and Cretaceous. All four occur on the Arabian Peninsula with the Jurassic TPS providing over two-thirds of the volume whereas the latter three TPS dominate North Africa, particularly Silurian/Devonian and Cretaceous TPS there. Tertiary TPS contribute in both regions as well. Significant unconventional natural gas resources have been identified or produced in the Silurian TPS in both the Arabian Peninsula (Jordan and

surrounding nations) and North Africa (Algeria) and represent a very large future potential for this richly endowed region. Significant natural gas discoveries in Egypt and the eastern Mediterranean, and oil discoveries in frontier provinces such as the Murzuk Basin, only increase the prospectiveness of this prolific region.

Selected References

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Klett, T.R., J.W. Schmoker, R.R. Charpentier, T.S. Ahlbrandt, and G.F. Ulmishek, 2005, Petroleum systems and geologic assessment of oil and gas in the Southwestern Wyoming Province, Wyoming, Colorado, and Utah; glossary: USGS Digital Data Series, Report # DDS-0069-D, (Web accessed 15 June 2010) http://pubs.usgs.gov/dds/dds-069/dds-069-d/reports.html

THE PETROLEUM ENDOWMENTS OF THE TOTAL PETROLEUM SYSTEMS IN THE MIDDLE EAST AND NORTH AFRICA TETHYS

THOMAS AHLBRANDT
VP EXPLORATION
FALCON OIL AND GAS
(USGS WORLD ENERGY PROJECT CHIEF—1994-2006)

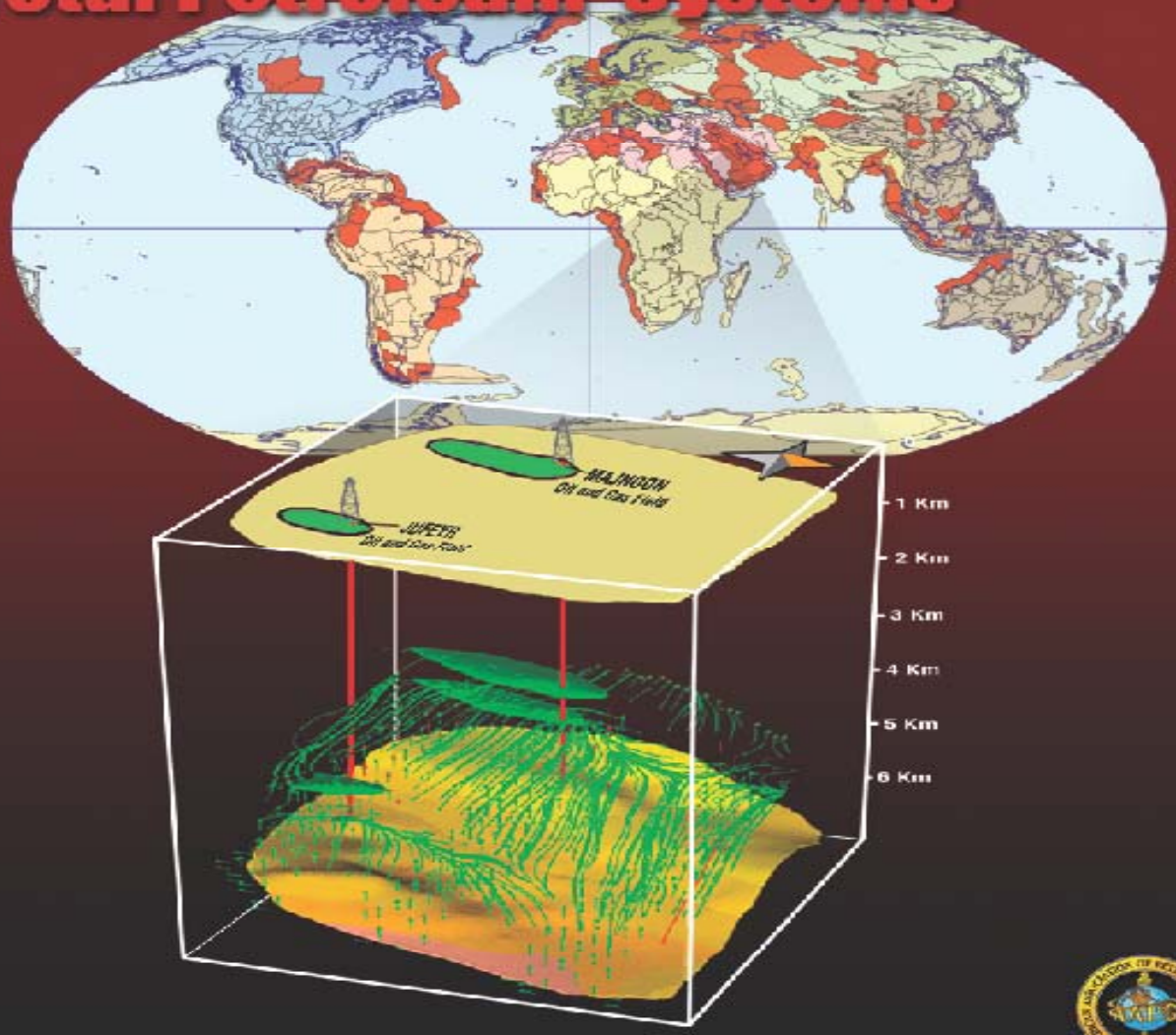
AAPG 2010—New Orleans

Talk Outline

- Global Overview/ Petroleum System Revolution
- Middle East / North Africa Region
  - Conventional Resources (USGS 2000 + Updates)
  - Provinces
  - Total Petroleum Systems
- Unconventional Resources
  - Silurian—Middle East, North Africa
  - Devonian—North Africa
  - Jurassic—Middle East
- New Discoveries, Assessments and Unconventionals (BCGA/BCOA)
  - Murzuk, Hamra (4.7 TCF, 1.7 BBO), Niger Delta, Levant (122TCF, 1.7 BBO),Western Desert, Anah, Euphrates Graben (0.7 BBO), Iran, Reggane, Grand Erg Ahnet, Illizi, 4 Silurian and 1 Jr TPS on Arabian Peninsula
- Summary
- Thanks to IHS, USGS, Falcon

AAPG Memoir 86

Global Resource Estimates from Total Petroleum Systems

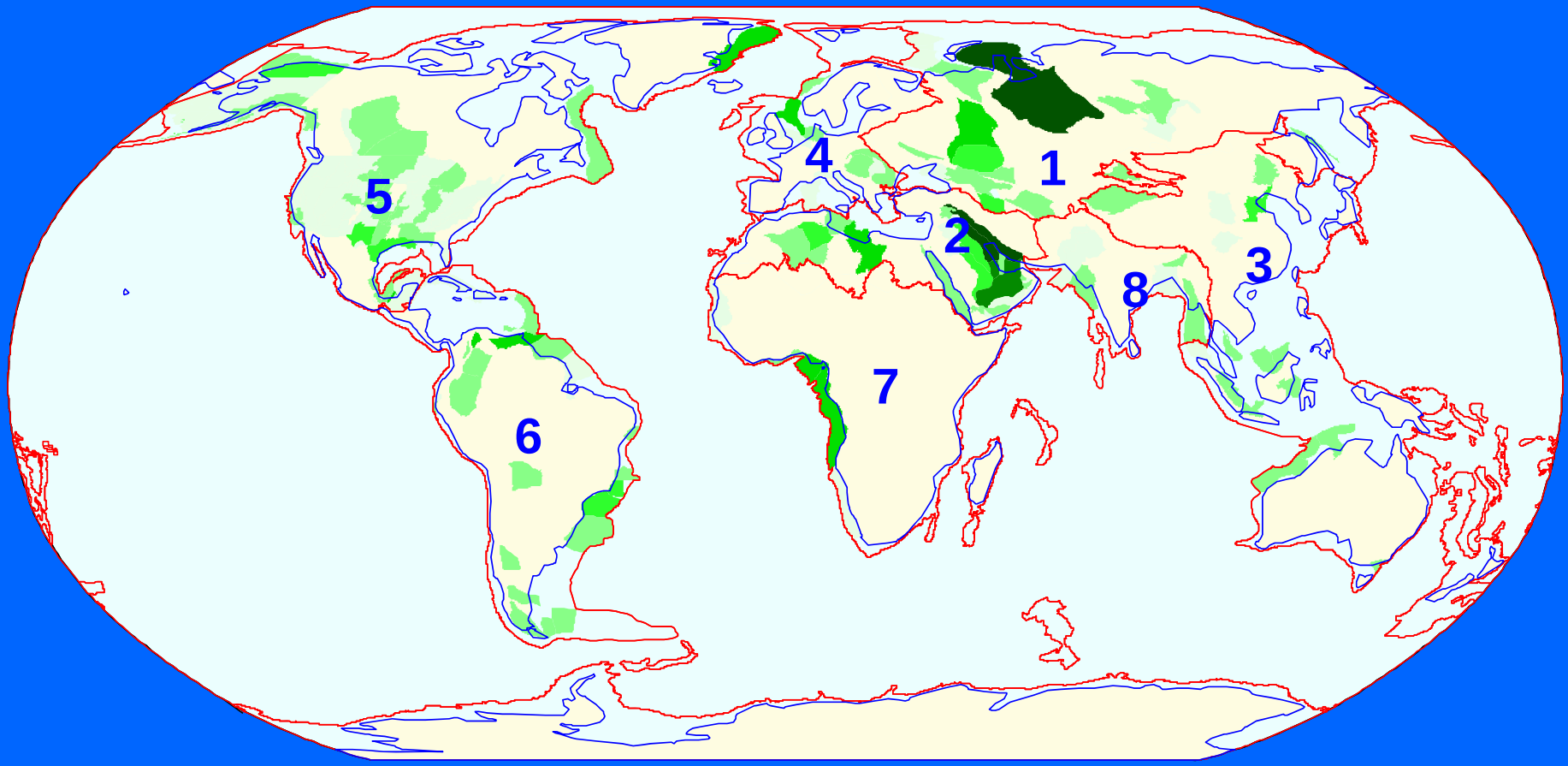


Thomas S. Ahlbrandt, Ronald R. Charpentier, T.R. Klett,
James W. Schmoker, Christopher J. Schenk and Gregory F. Ulmishek

The Petroleum System Revolution

- The Petroleum System world challenges old paradigms
- New technology gives us glimpses of this dynamic petroleum system world
- 3-D, 4-D petroleum migration models must evolve to accommodate PVT (pressure-volume-temperature factors)
- The new view of petroleum prospect/system/basin analysis will likely be Cell based
- Unconventional and conventional resources will be integrated and related to a life cycle
- The revolution in thinking has started (focus on fluids then rocks) integrated models do not exist but elements are evolving towards a unifying model
- Is our greatest petroleum potential behind us or yet to come?

USGS World Petroleum Assessment 2000



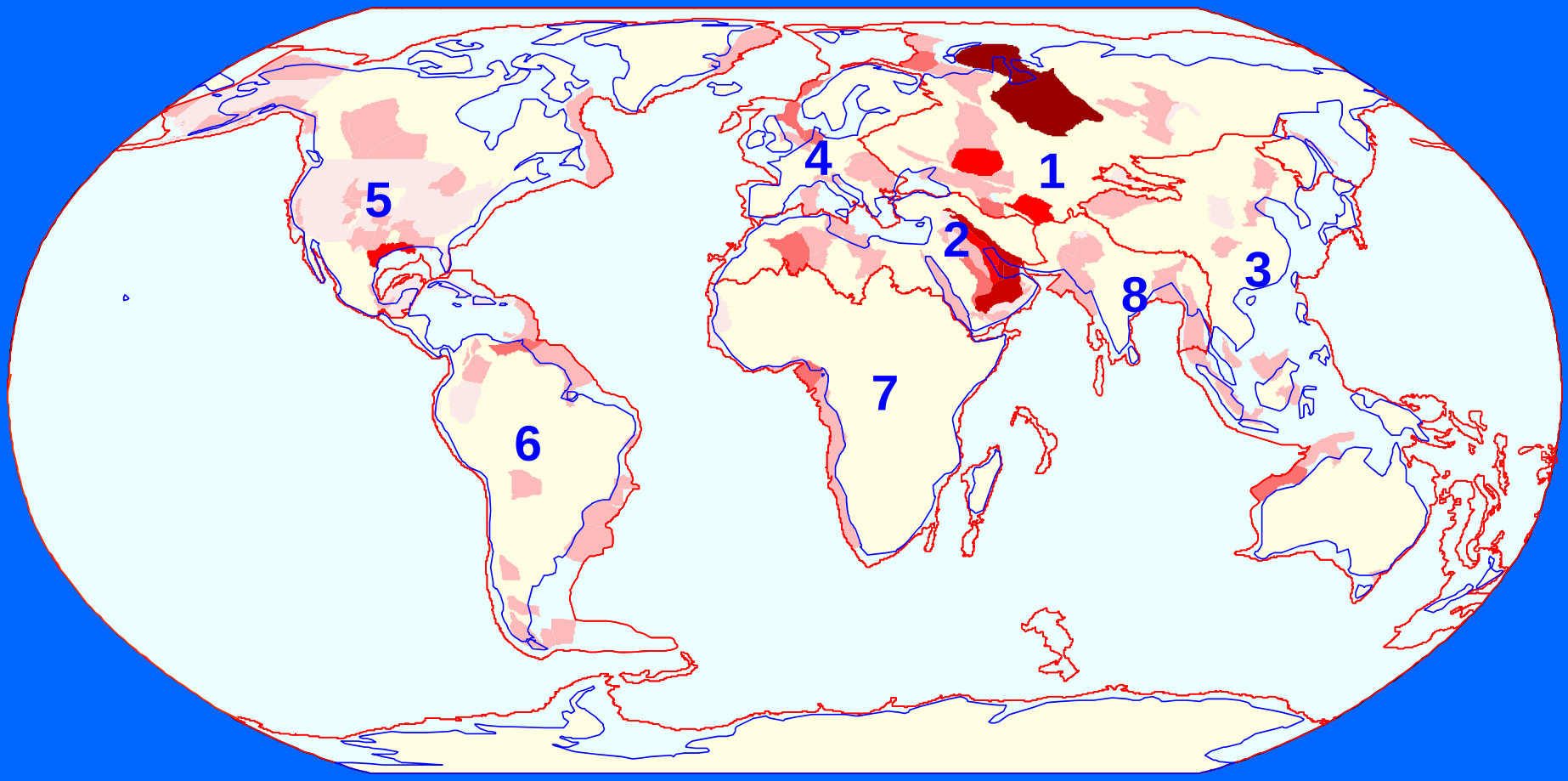
Conventional Oil Endowment of the World

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



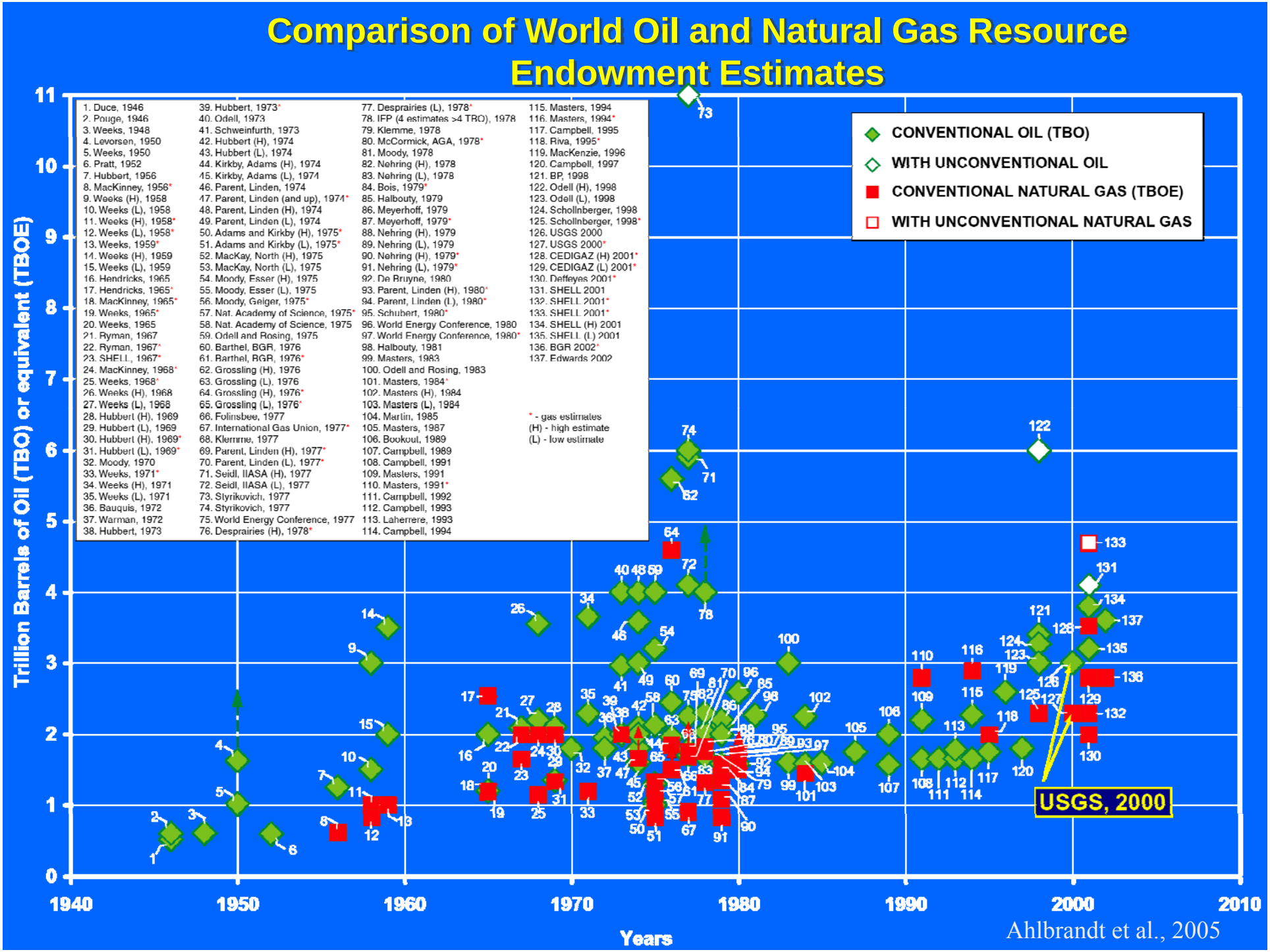
Conventional Natural Gas Endowment of the World

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 World Oil and Natural Gas Resource Endowment Estimates



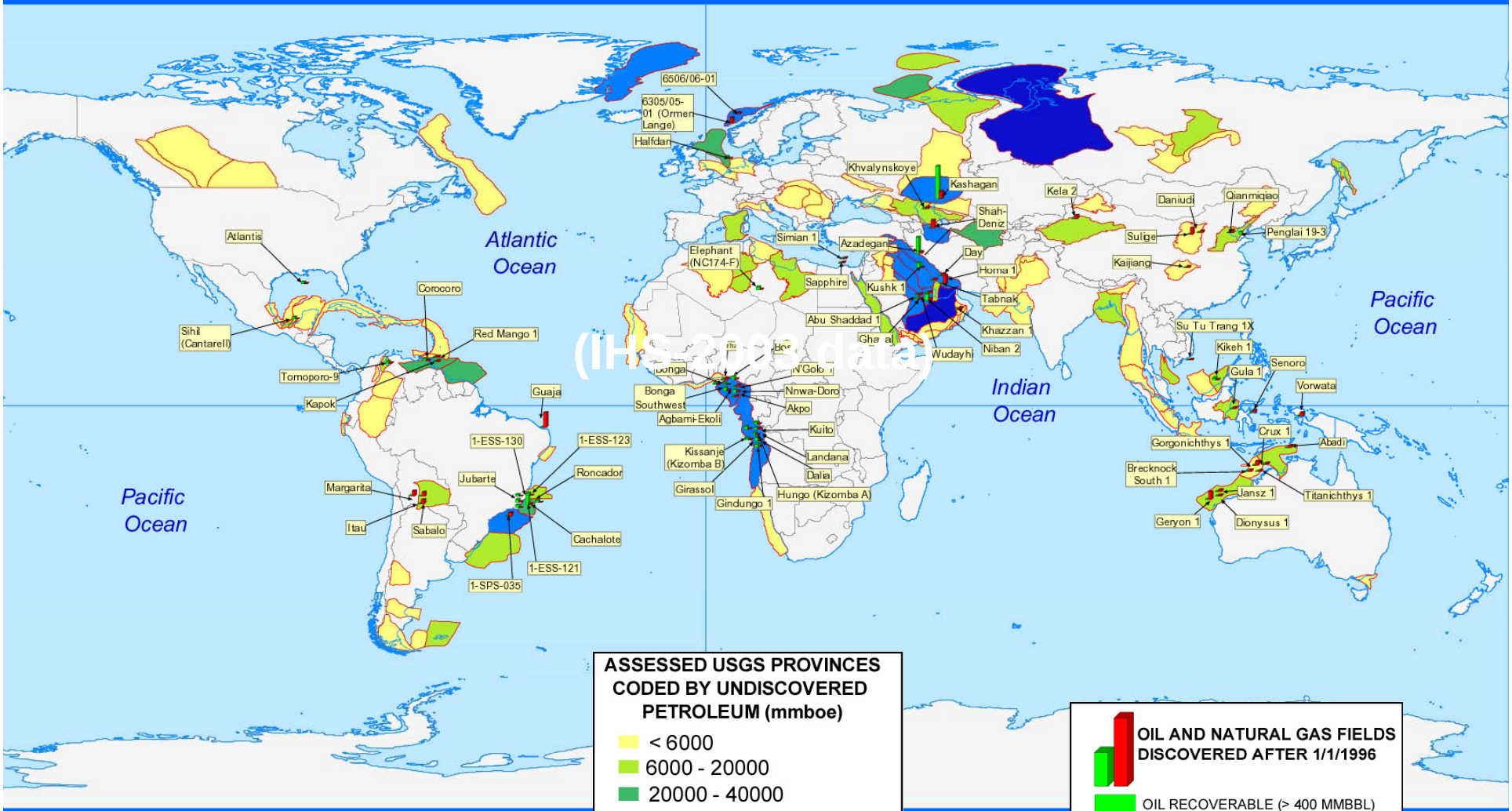
Ahlbrandt et al., 2005

USGS 2000 Calibration In 2003

- 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 rated of reserve additions

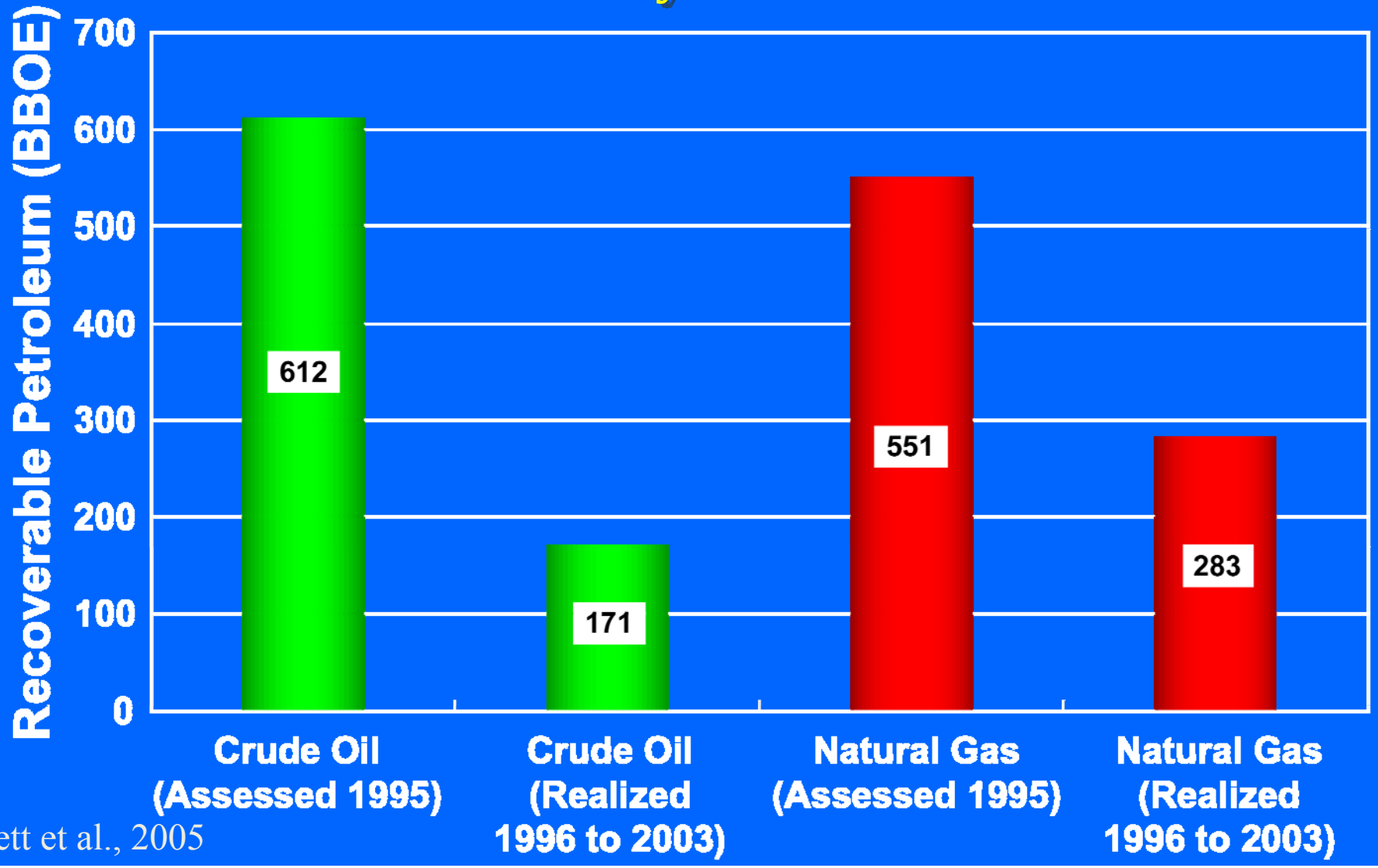
Large New Oil And Natural Gas Fields Discovered After 1/01/1996 And USGS Undiscovered Petroleum (USGS - 2000 DATA) - 70 fields

New Fields with Oil > 400 MMBO or Natural Gas > 2,400 BSCF



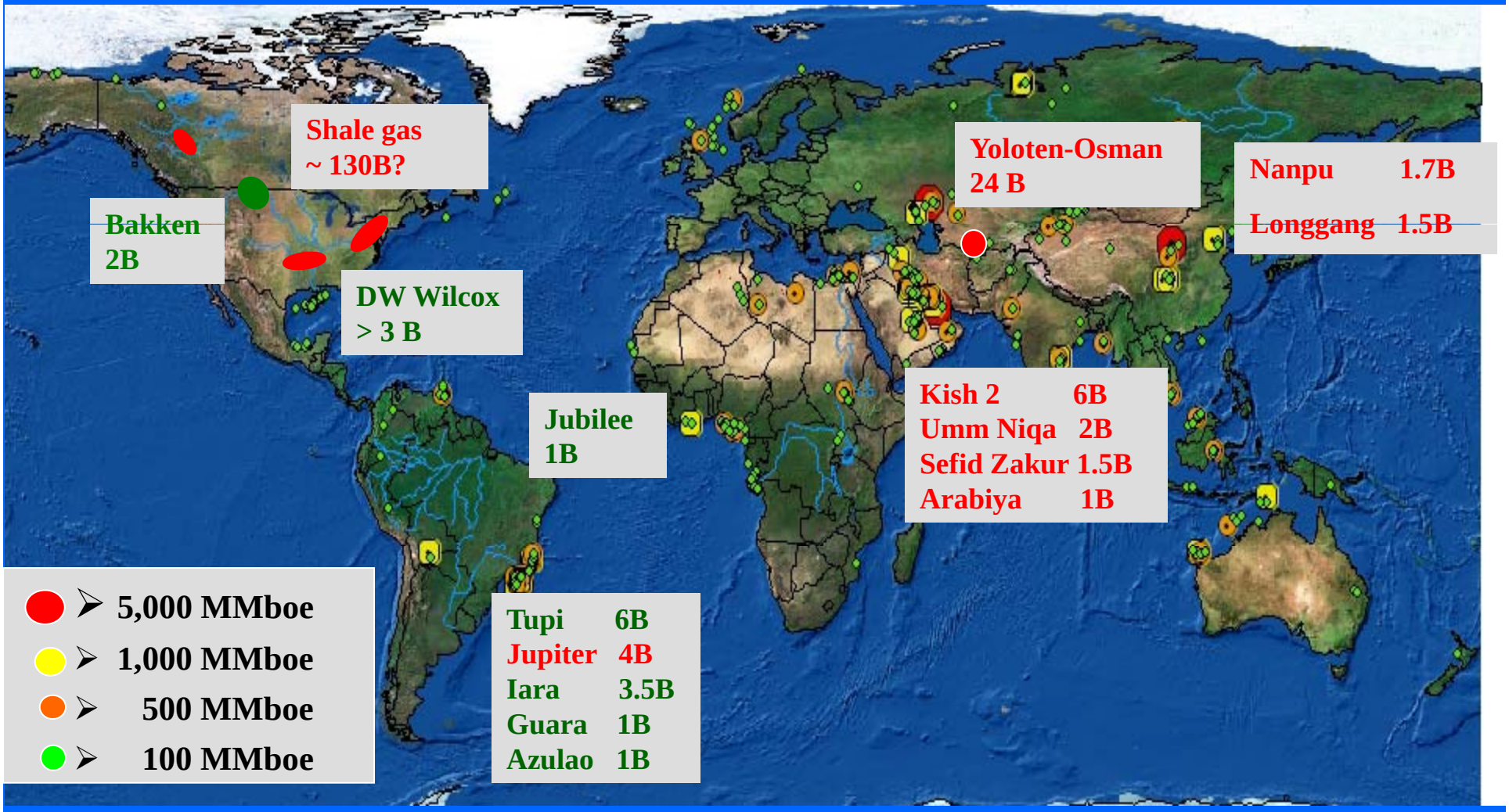
(IHS-2003 data)

Calibration of USGS Oil and Natural Gas Estimates
1st 7 Years of 30 year forecast--2003



Klett et al., 2005

Discoveries > 100 MMboe 2000 –2008
> 1000 MMboe 2005-2008 Annotated

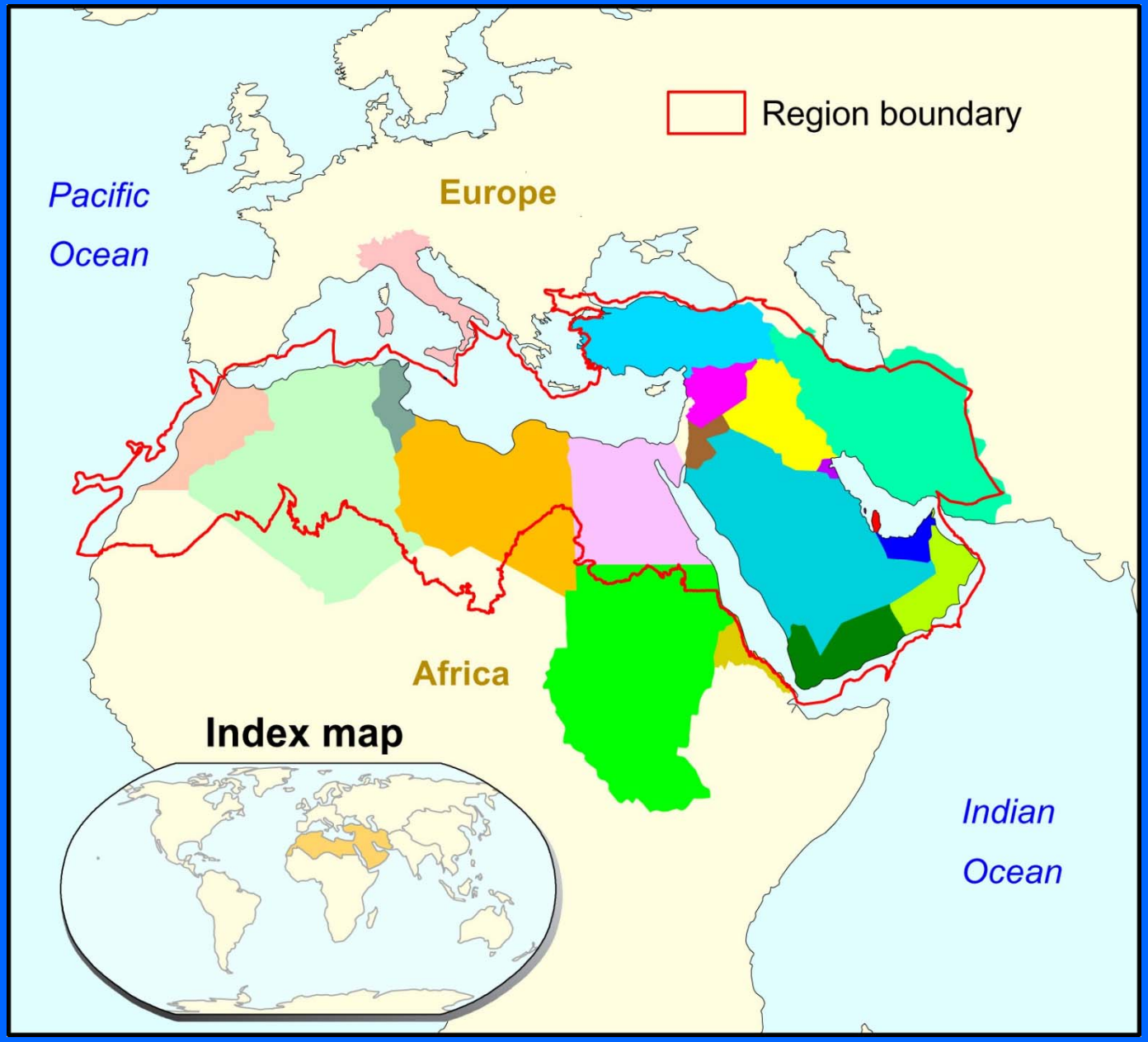


IHS, 2009

Middle East / North Africa Region

- Regional Comparisons
- Province
- Total Petroleum System
- Unconventional (Continuous) Resources
  - Silurian (Middle East)
  - Devonian (North Africa)
  - Jurassic (Middle East)

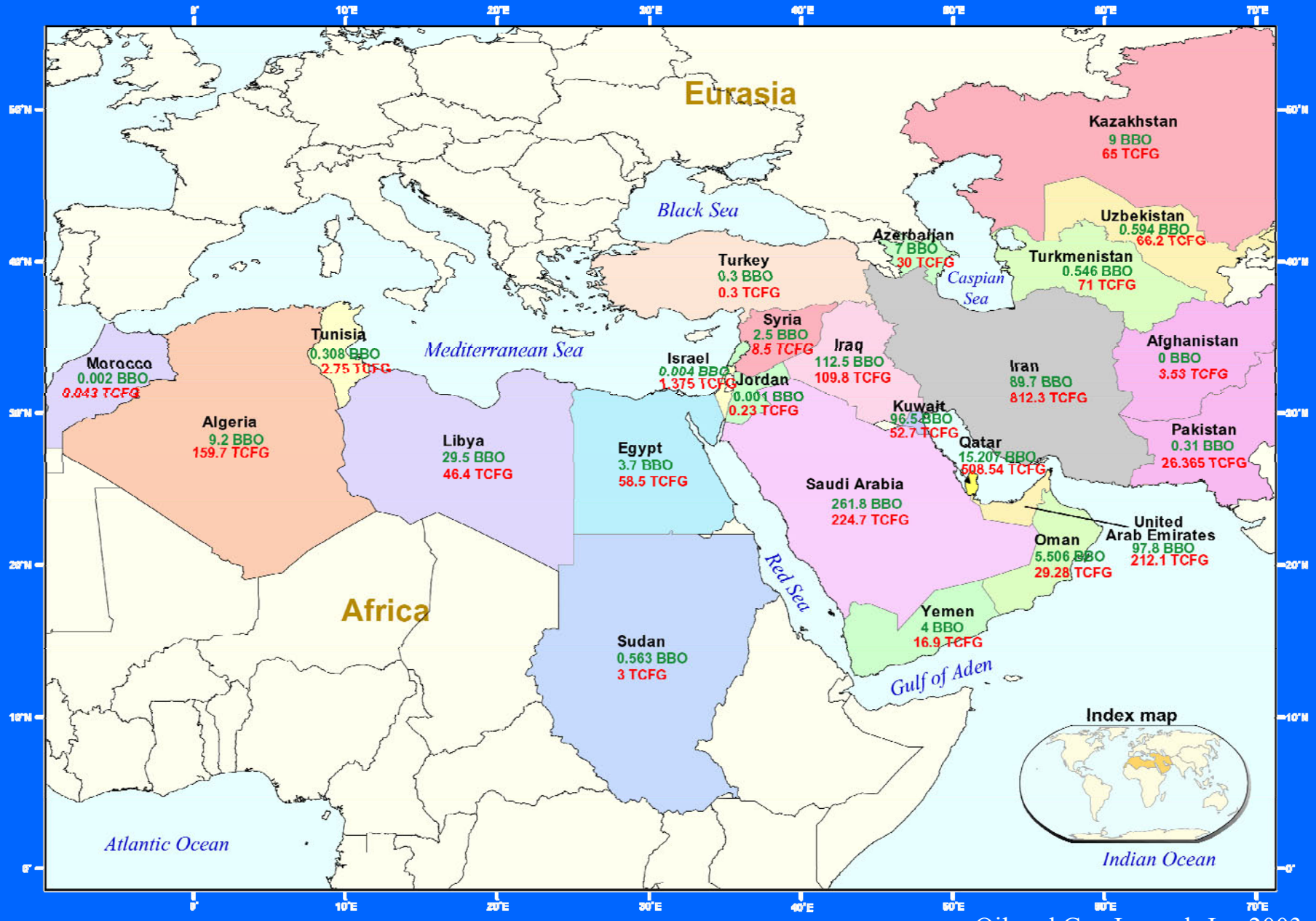
Middle East and North Africa Region 2



Countries with assessed resources in Region 2

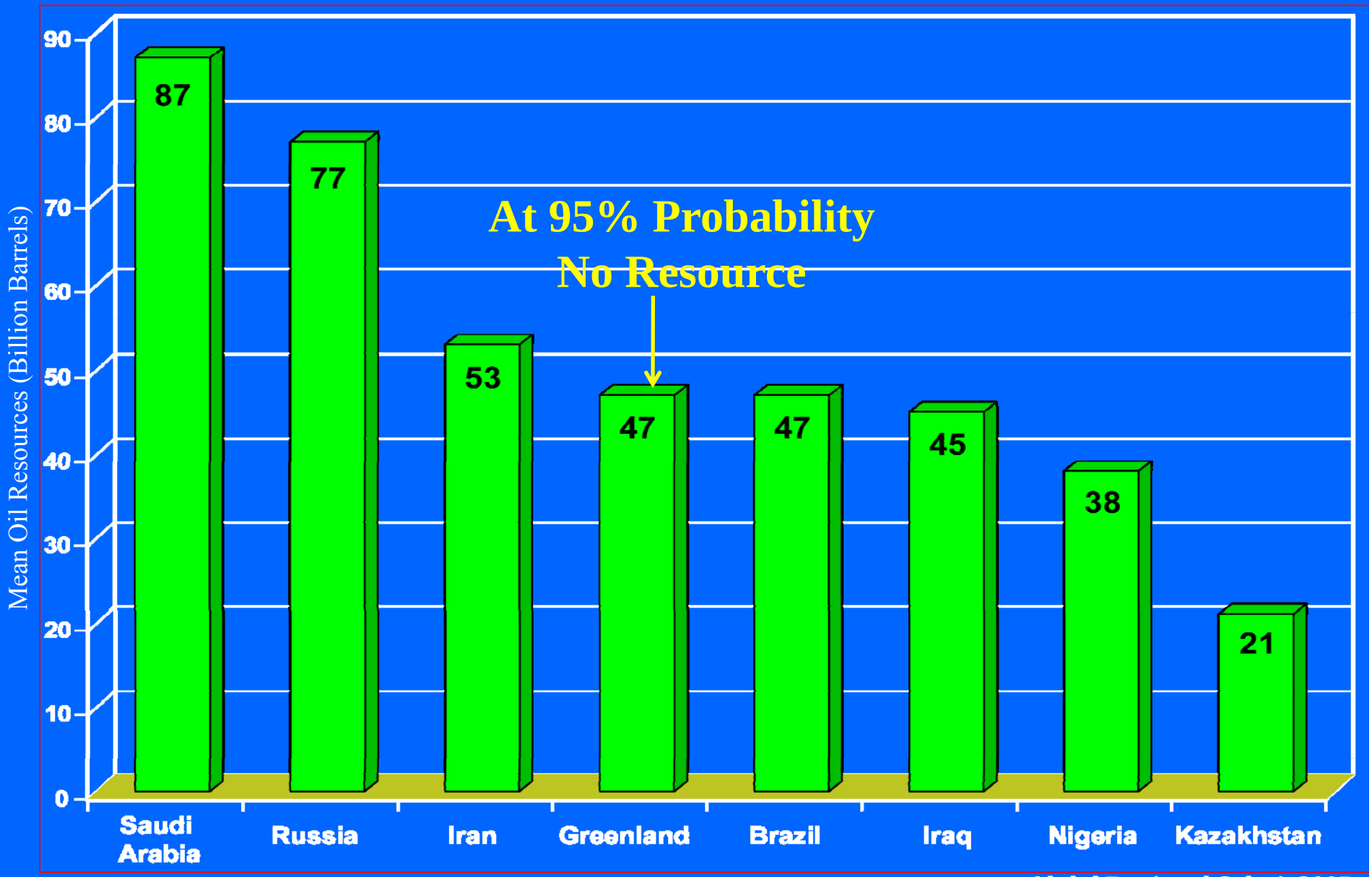
- Algeria
- Bahrain
- Egypt
- Eritrea
- Iran
- Iraq
- Italy
- Jordan
- Kuwait
- Libya
- Malta
- Morocco
- Oman
- Qatar
- Saudi Arabia
- Sudan
- Syria
- Tunisia
- Turkey
- United Arab Emirates
- Yemen

North Africa and Middle East Provinces (Region 2)
Crude Oil and Natural Gas Known Reserves



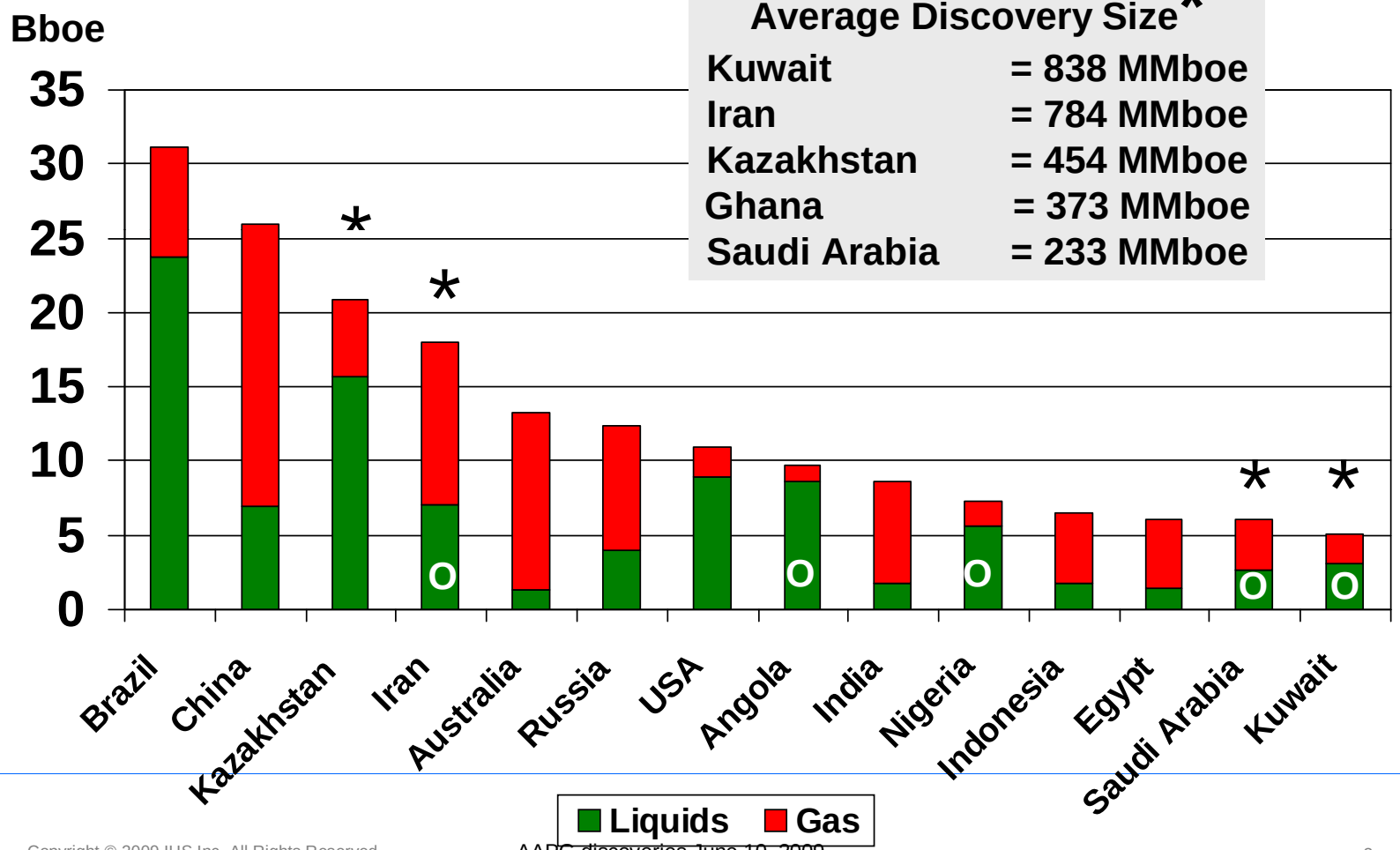
Oil and Gas Journal, Jan 2003

US Geological Survey 2000 Estimate of Top 8 Regions of Undiscovered Recoverable Oil Resources



Abdul Baqi and Saleri, 2005

Leading Countries
Discovery Bboe 2000 – 2008



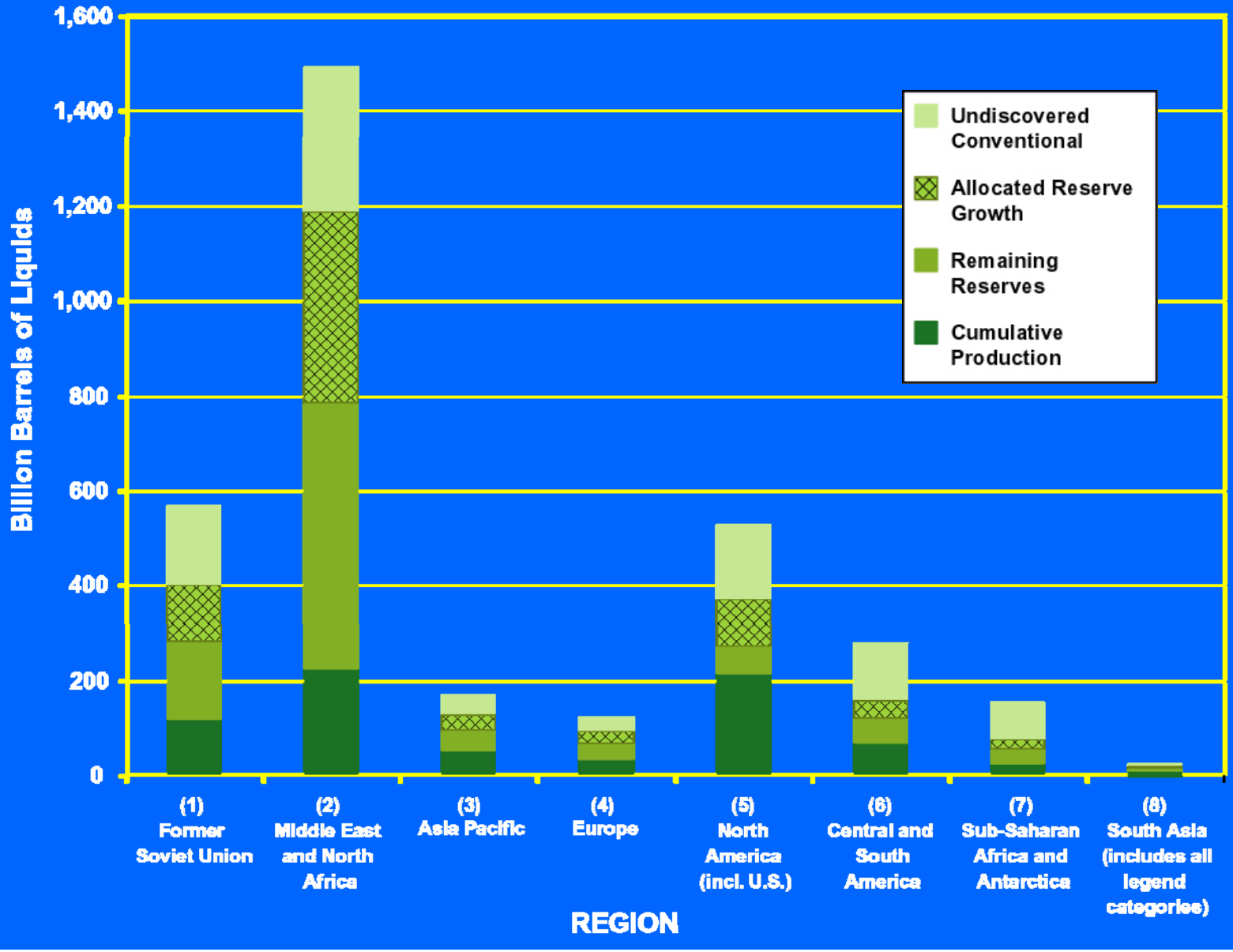
Average Discovery Size*

Kuwait	= 838 MMboe
Iran	= 784 MMboe
Kazakhstan	= 454 MMboe
Ghana	= 373 MMboe
Saudi Arabia	= 233 MMboe

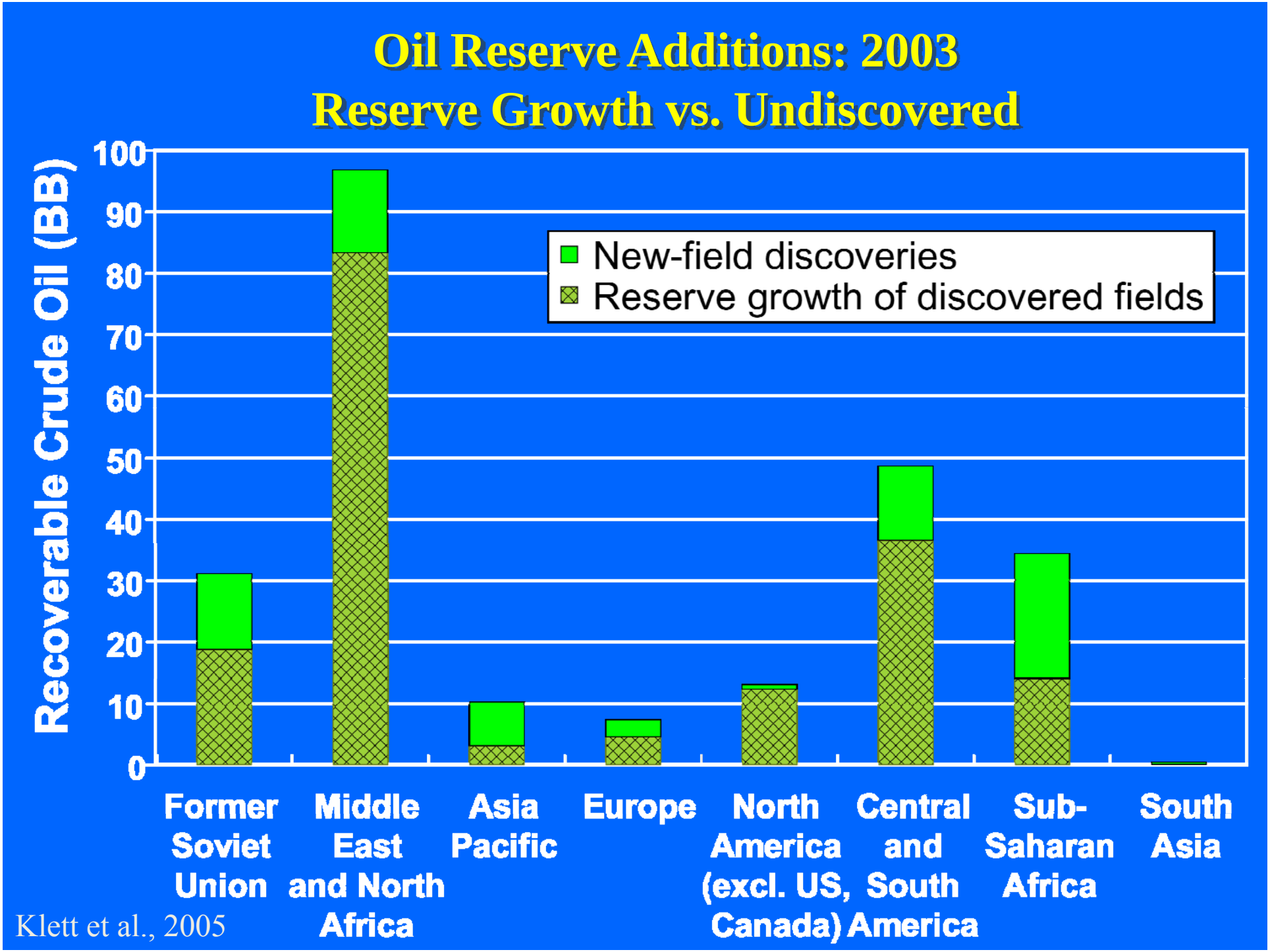
Middle East / North Africa Region

- 84 Assessment Units in 24 Total Petroleum Systems in 31 provinces were analyzed in USGS 2000 (11 of 16 Priority provinces)—3 provinces (Hamra, Murzuk, Levant), 2 TPS and 8AU added subsequently
- ~80 BBOE of new conventional resources added in 2000-2008
  - ~55 BBOE of new discoveries added from 2000-2008
  - ~24 BBOE of new undiscovered added from 2000-2008
- Regional Oil Rankings (1/1/96;USGS 2000)
- 45% of World Oil Endowment (w/US); 58% (wo/US)
  - 1st in cumulative oil production—219 BBO
  - 1st in oil reserves—529 BBO
  - 1st in reserve growth—363 BBO
  - 1st in undiscovered resources—230 BBO
  - 1st in total endowment (765 BBO/1326 BBO wo/US)

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



Oil Reserve Additions: 2003
Reserve Growth vs. Undiscovered

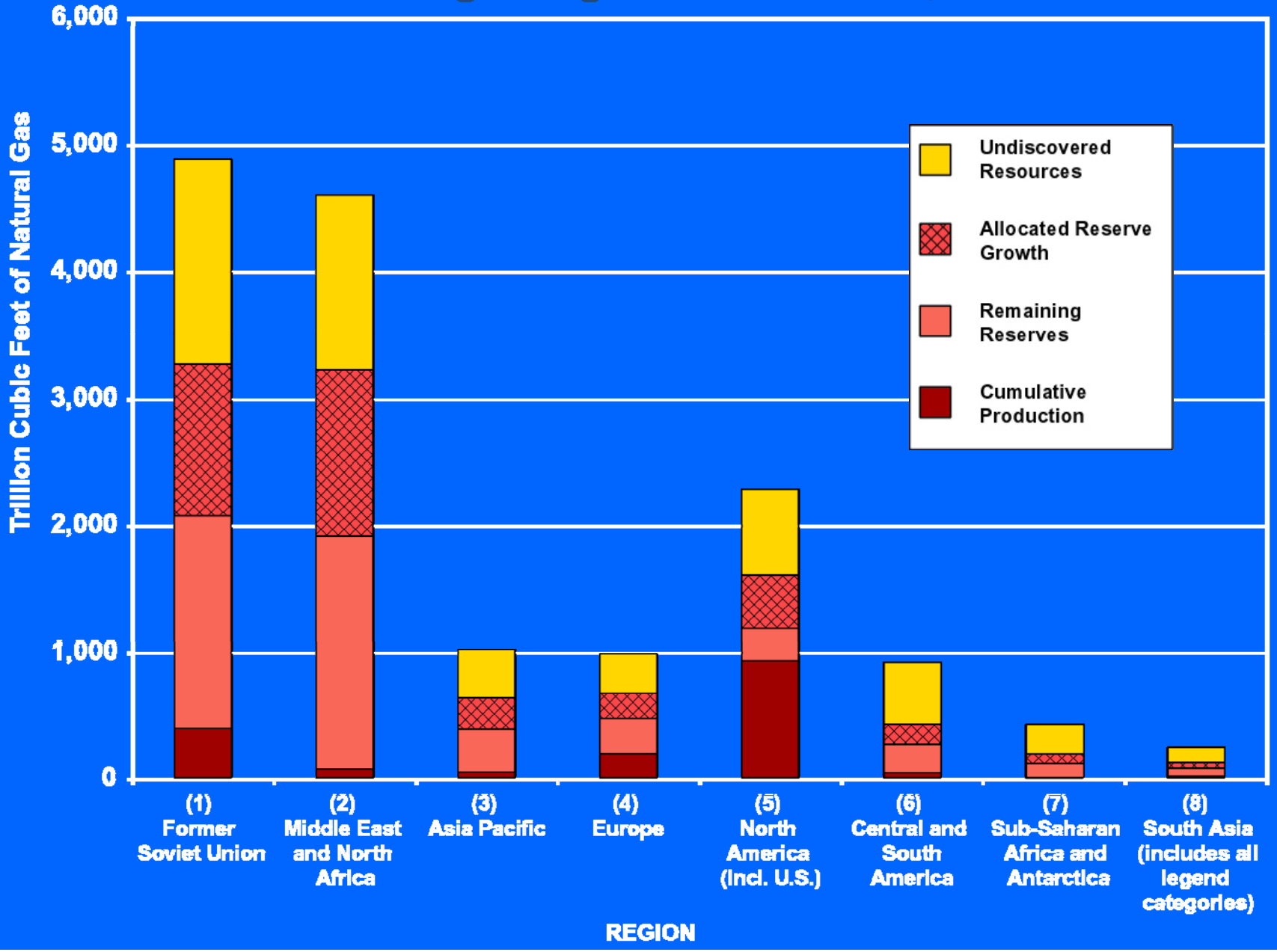


Klett et al., 2005

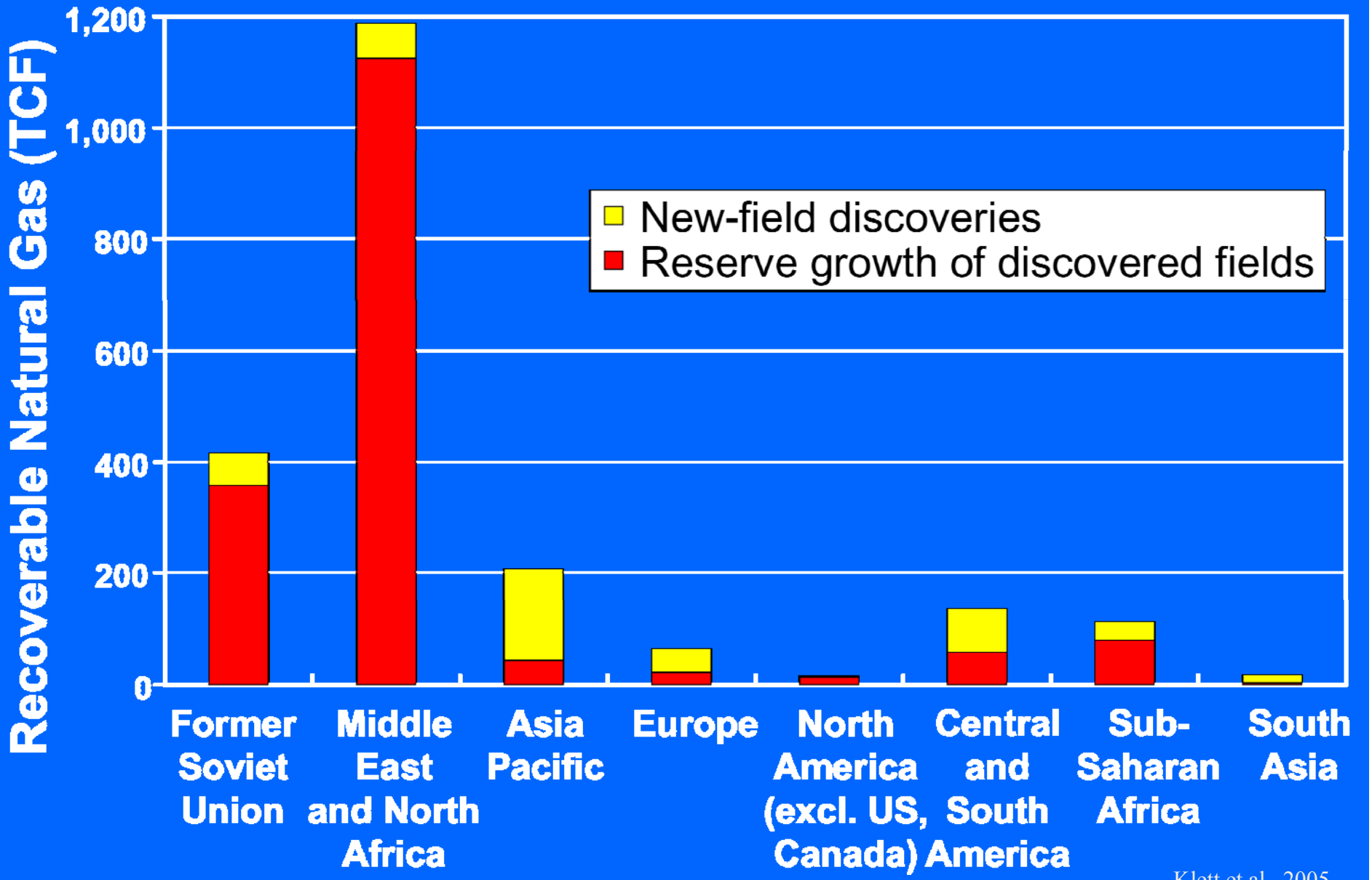
Middle East / North Africa Region

- Regional Natural Gas (30% of world as of USGS 2000)
- Most reserve additions and estimates increases are in natural gas (~48 BBOE of 80 BBOE) from 2000-2008
  - 4th for Cumulative Production 73 TCF; U.S.-1st 939 TCF
  - 1st for Reserves—1836 TCF, FSU—1683 TCF
  - 1st for Reserve Growth—1313 TCF
  - 2nd for Undiscovered Resources—1370 TCF
  - 2nd for Endowment-4592 TCF; FSU-4887 TCF
- 1st for Natural Gas Liquids (43% of world)
  - 140 BBNGL

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

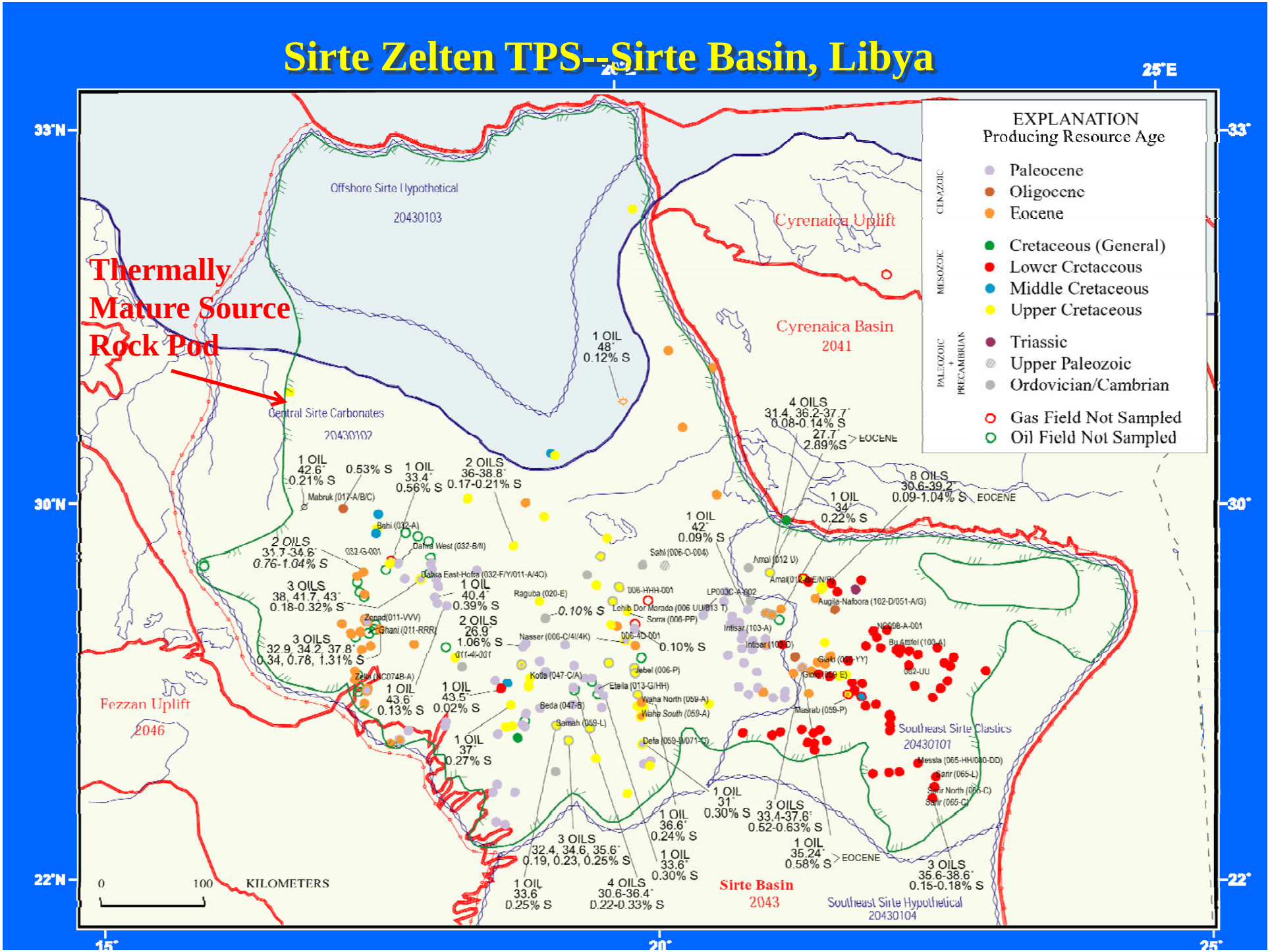


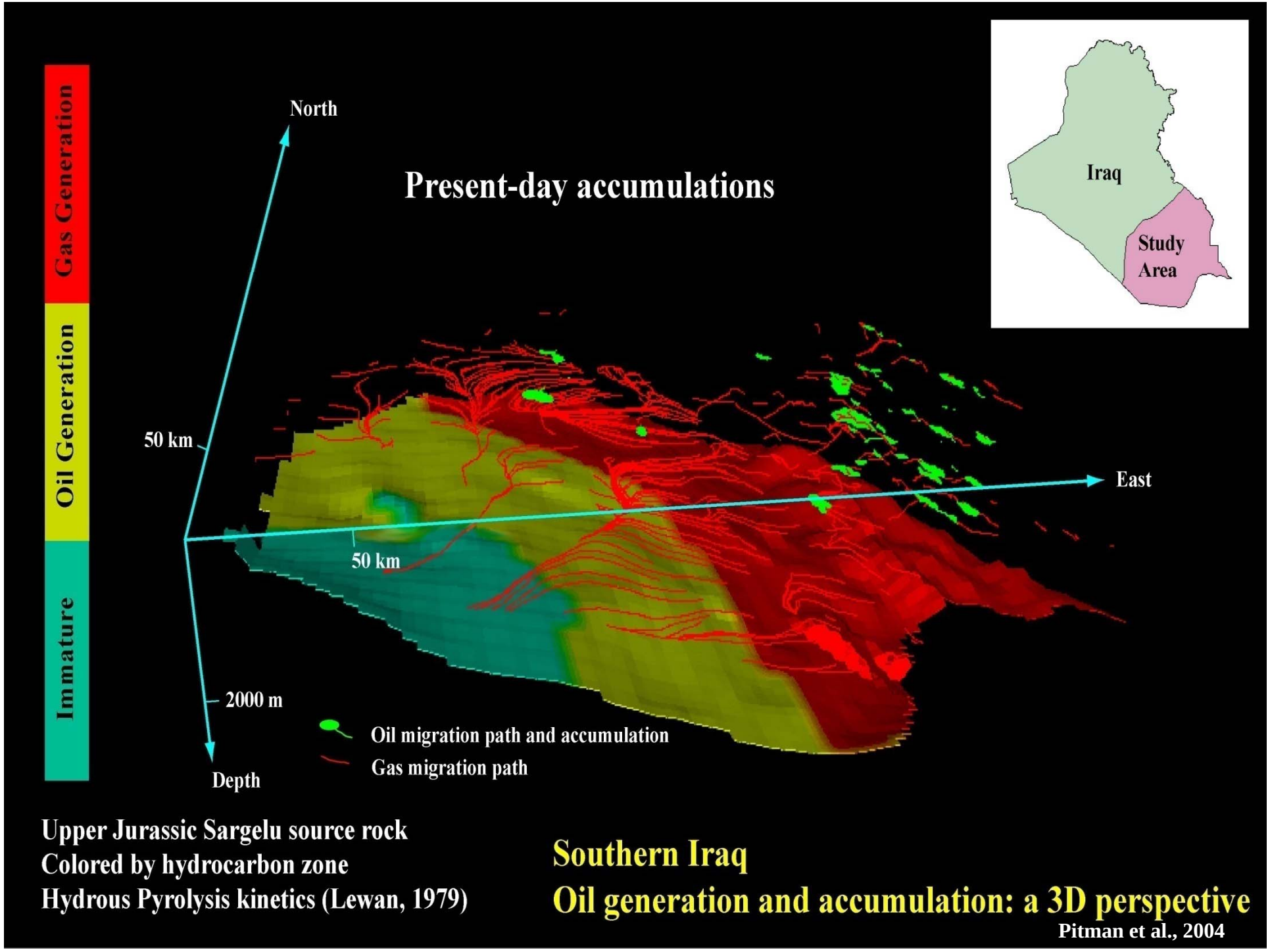
Natural Gas Reserve Additions: 2003
Reserve Growth vs. Undiscovered



Klett et al., 2005

Sirte Zelten TPS--Sirte Basin, Libya



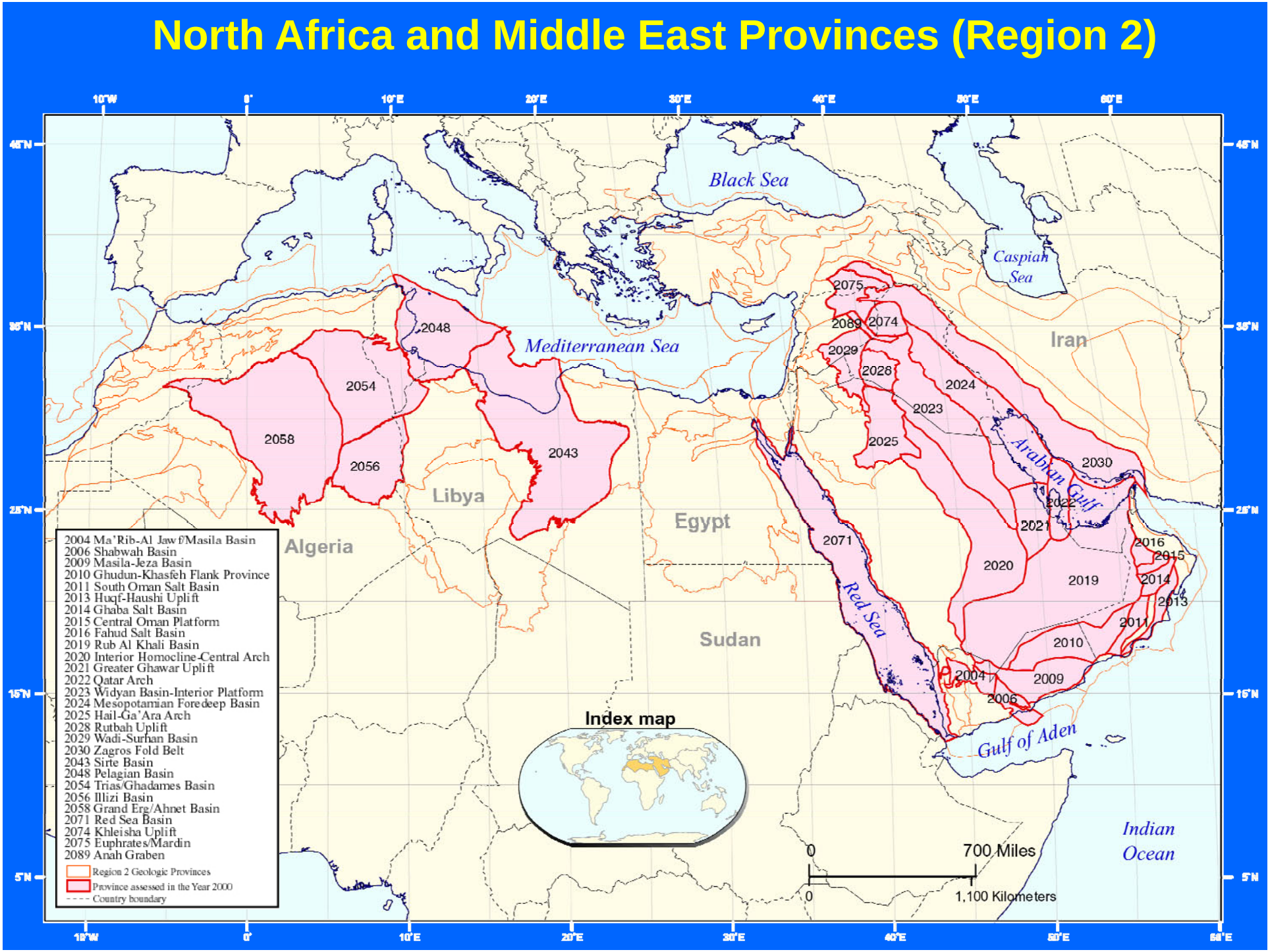


Upper Jurassic Sargelu source rock
Colored by hydrocarbon zone
Hydrous Pyrolysis kinetics (Lewan, 1979)

Southern Iraq
Oil generation and accumulation: a 3D perspective

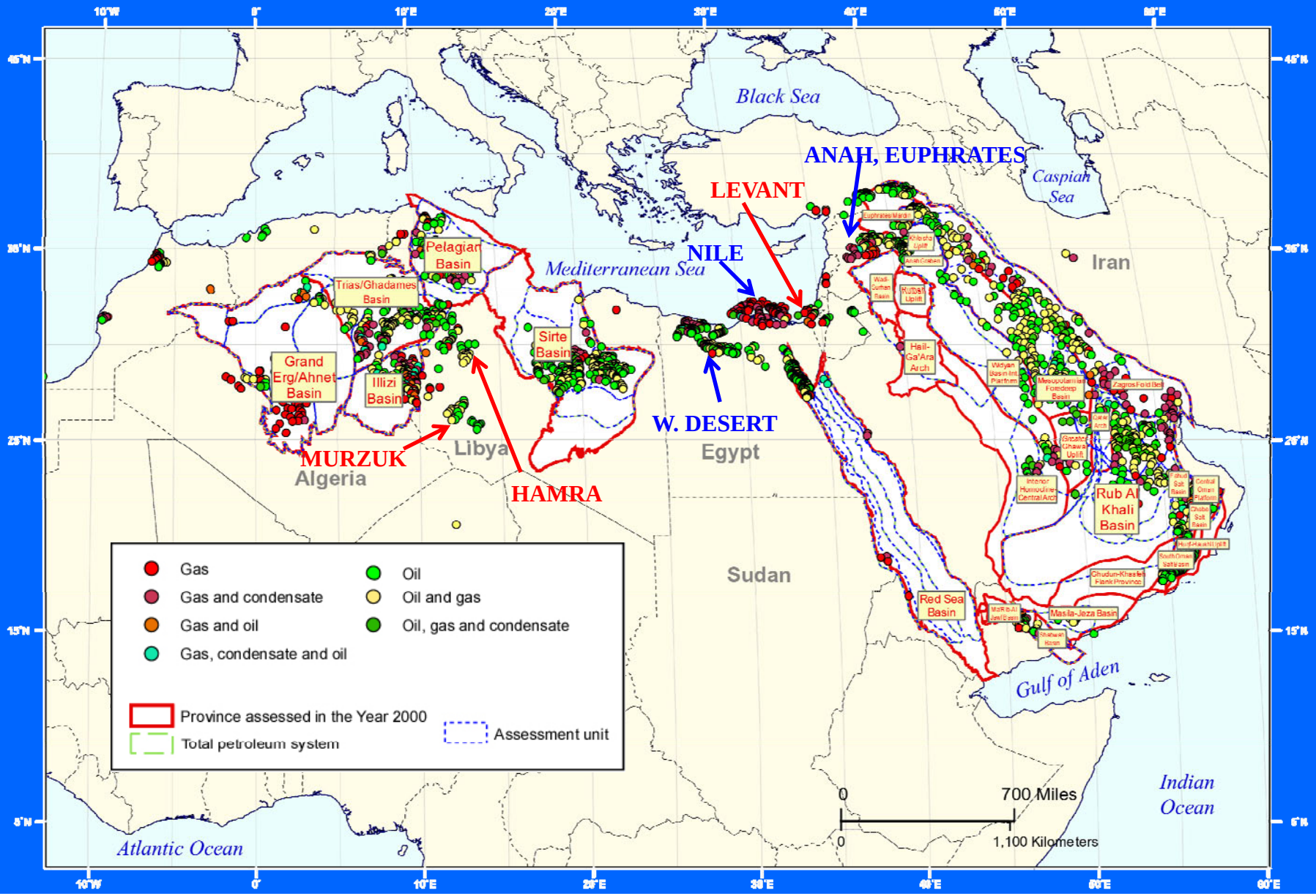
Pitman et al., 2004

North Africa and Middle East Provinces (Region 2)



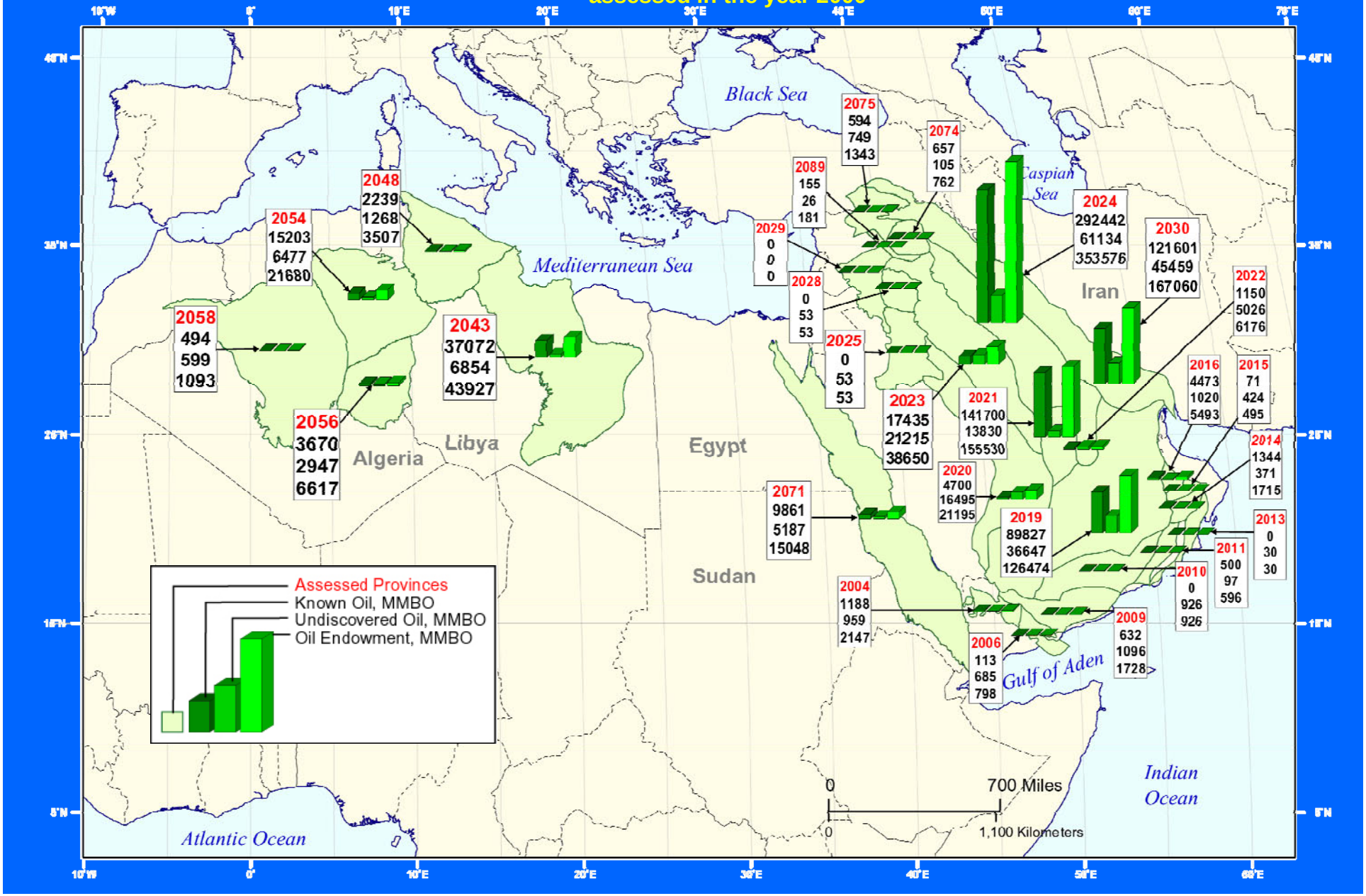
Oil and gas fields centerpoints (IHS data) of the North Africa and Middle East Provinces

to present day



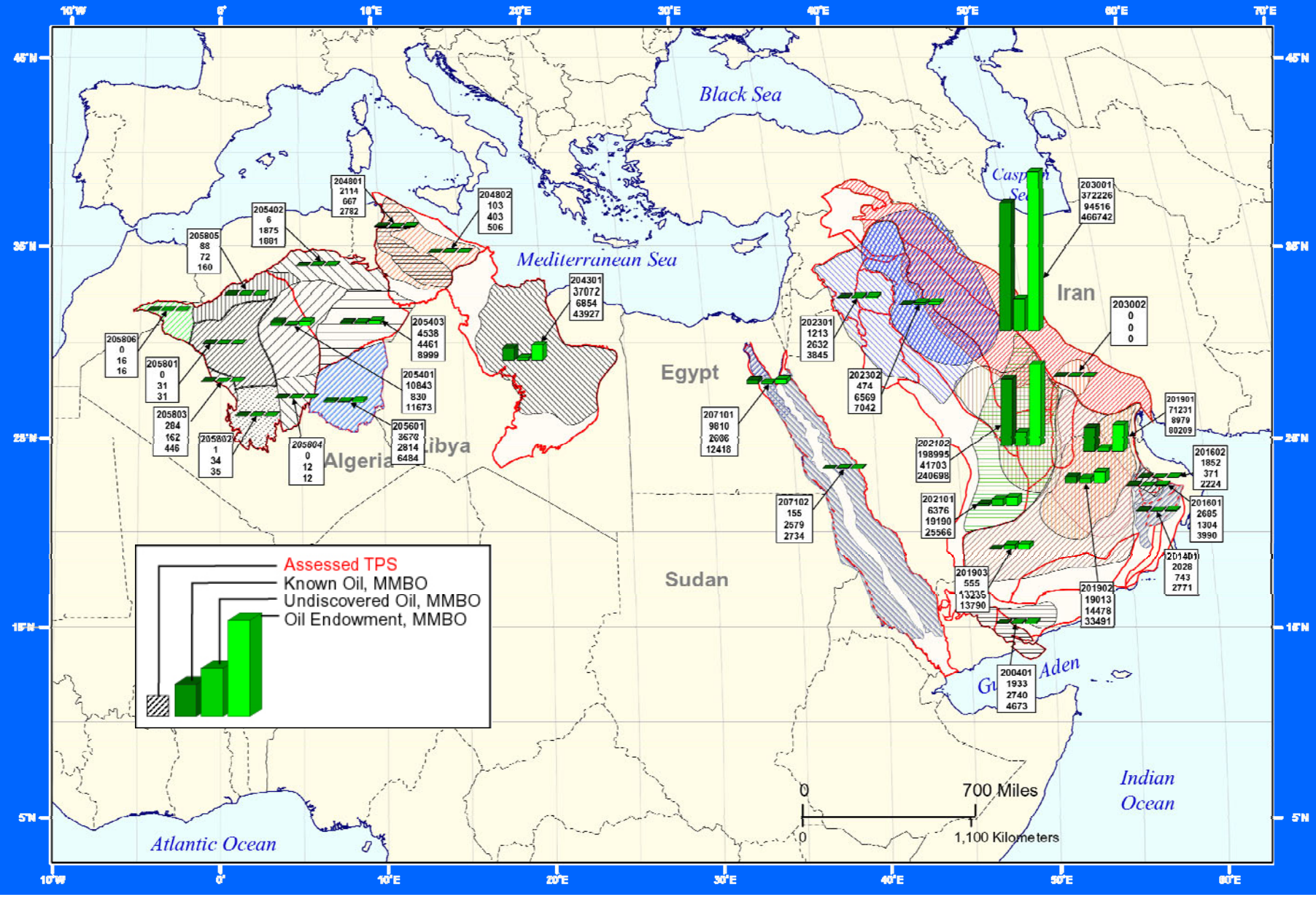
Known, Undiscovered, and Endowment Oil for the North Africa and Middle East Provinces

assessed in the year 2000



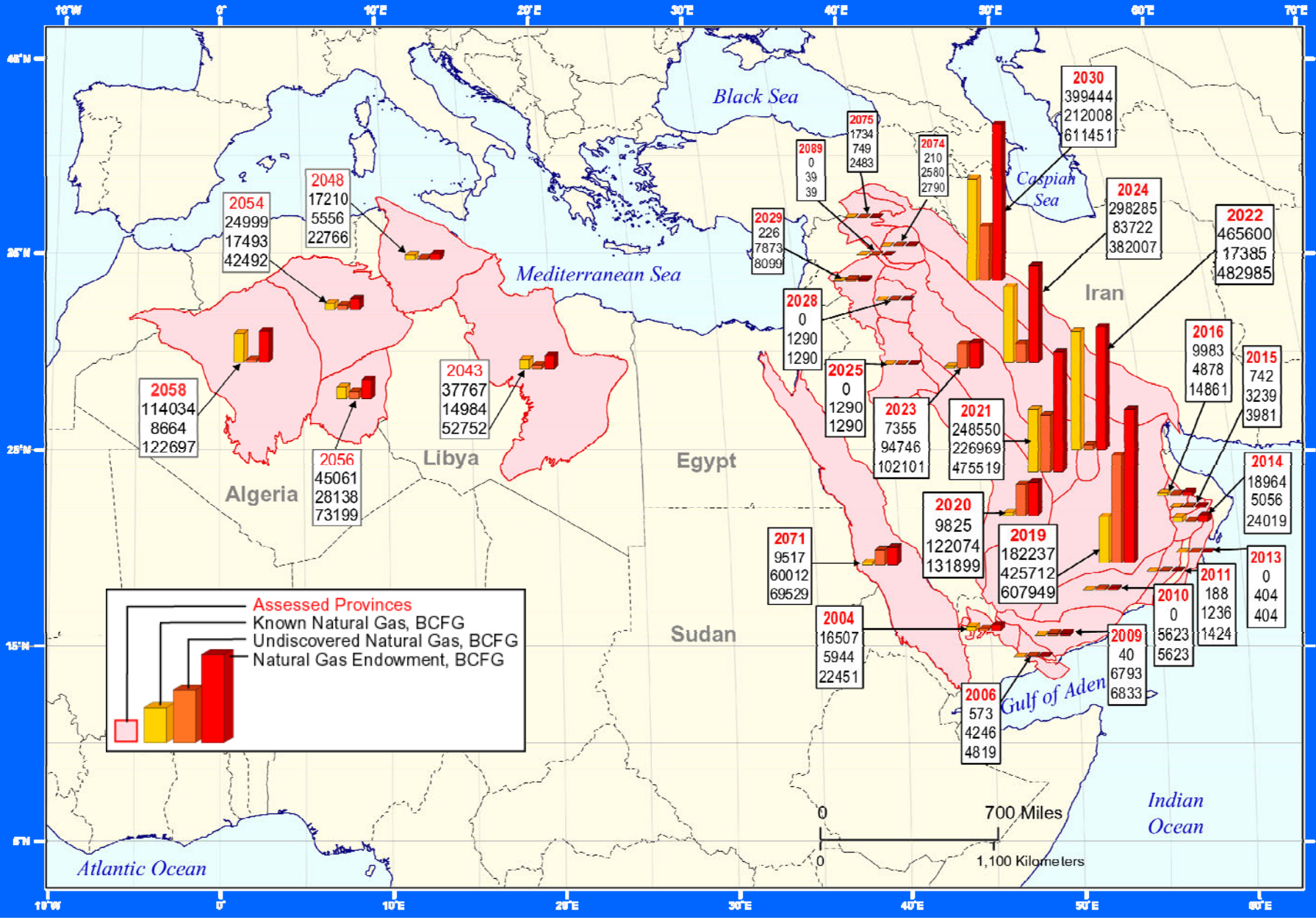
Known, Undiscovered, and Endowment Oil for the North Africa and Middle East TPS

assessed in the year 2000



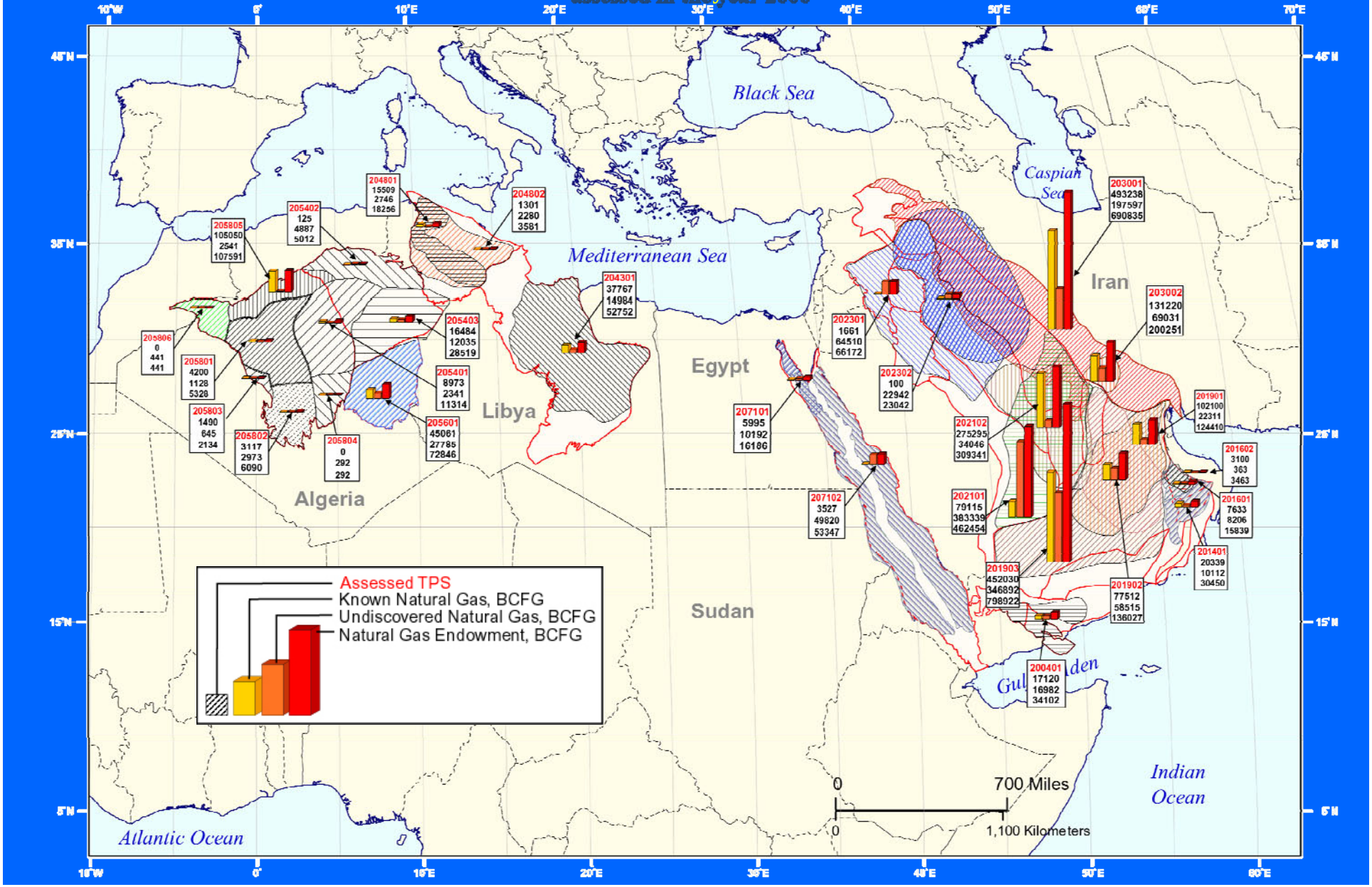
Known, Undiscovered, and Endowment Natural Gas for the North Africa and Middle East Provinces

assessed in the year 2000

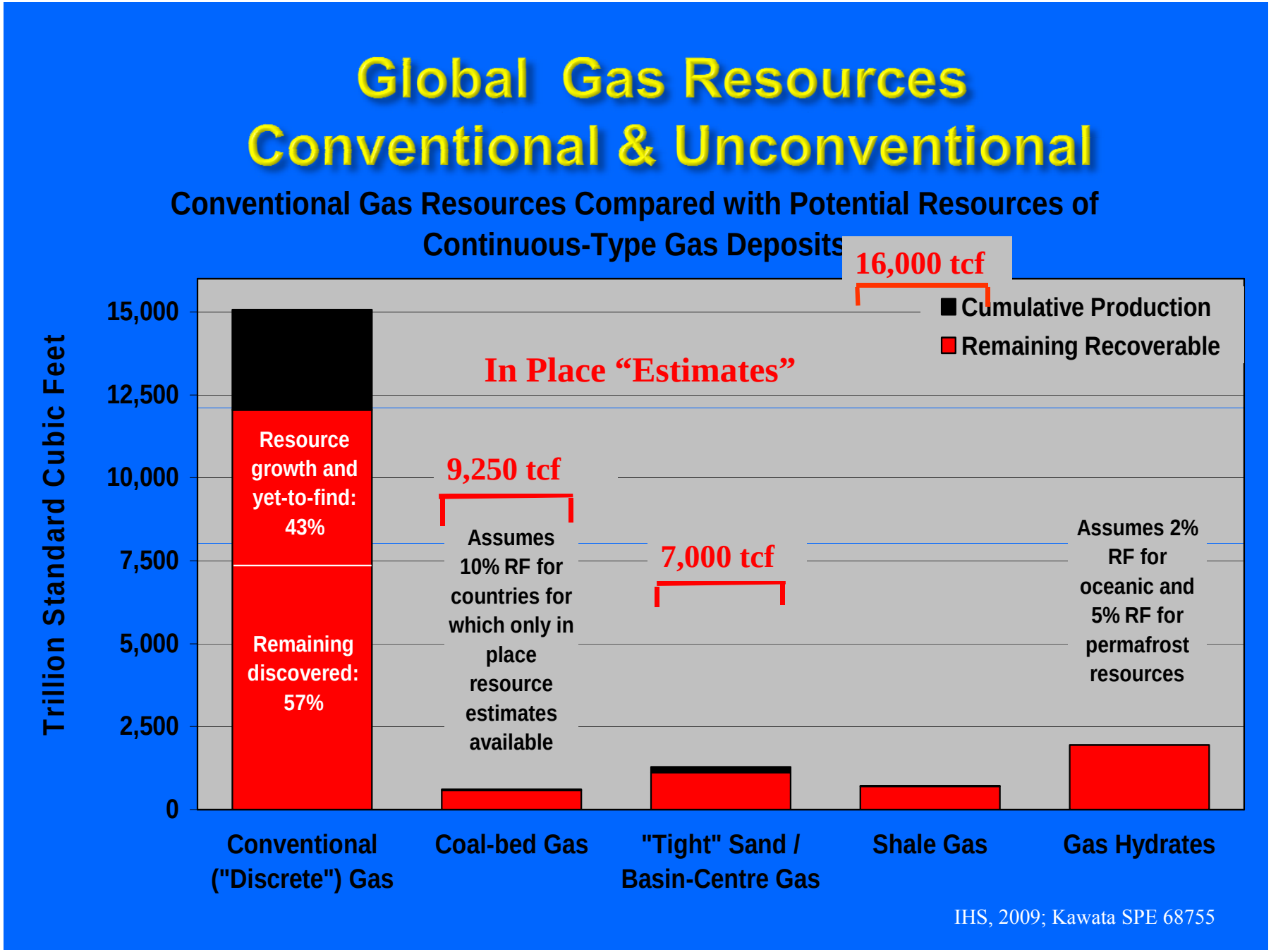


Known, Undiscovered, and Endowment Natural Gas for the North Africa and Middle East TPS

assessed in the year 2000

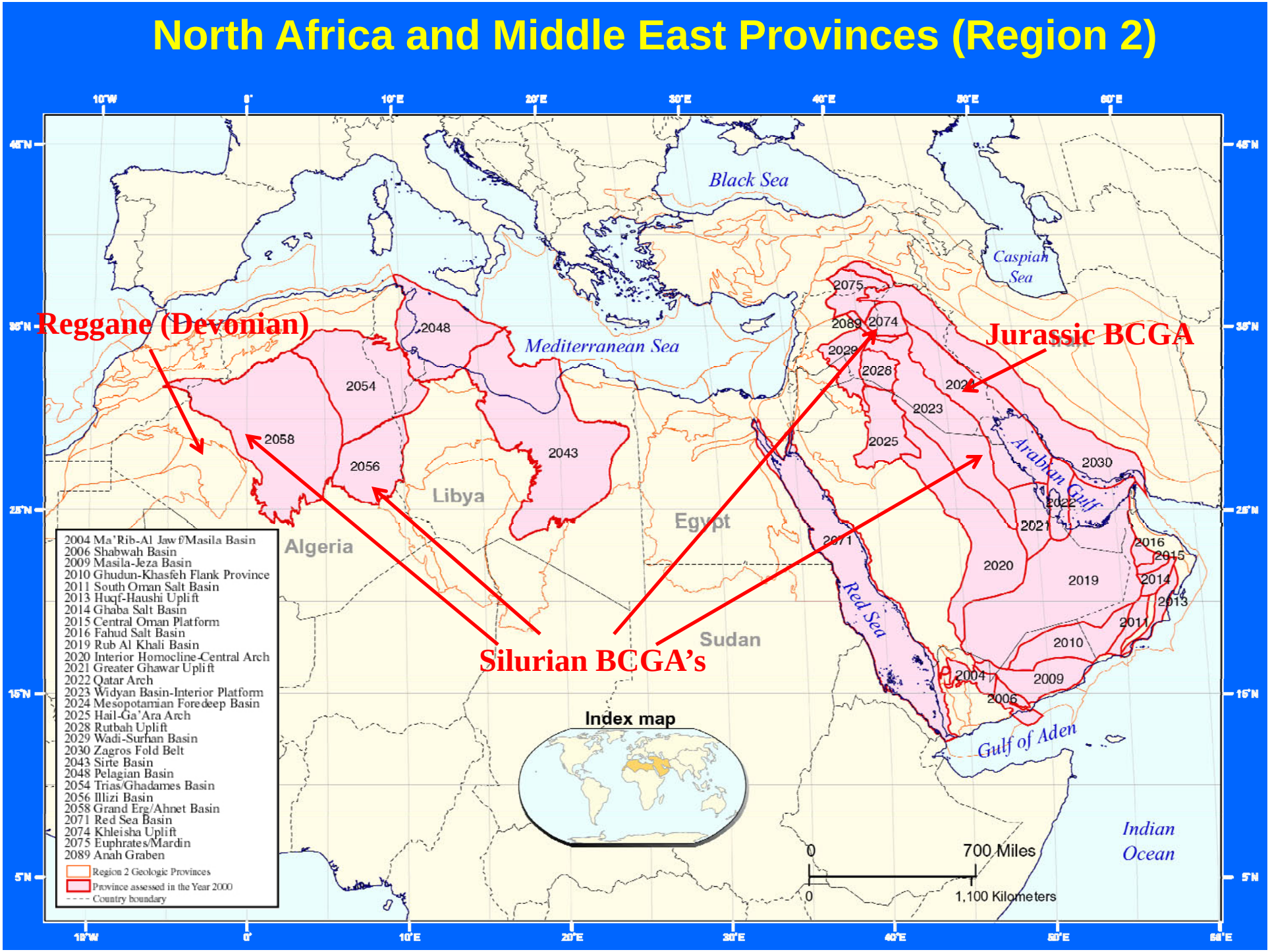


Global Gas Resources
Conventional & Unconventional



Notes by Presenter: With the exception of the gas hydrates, for which arbitrary low recovery factors have been selected, recovery factors for the non-conventional gas resources are typically 10% or less. Considerable potential therefore exists to increase recoverable resources from the large in-place resources that exist.

North Africa and Middle East Provinces (Region 2)



MIDDLE EAST SILURIAN TPS

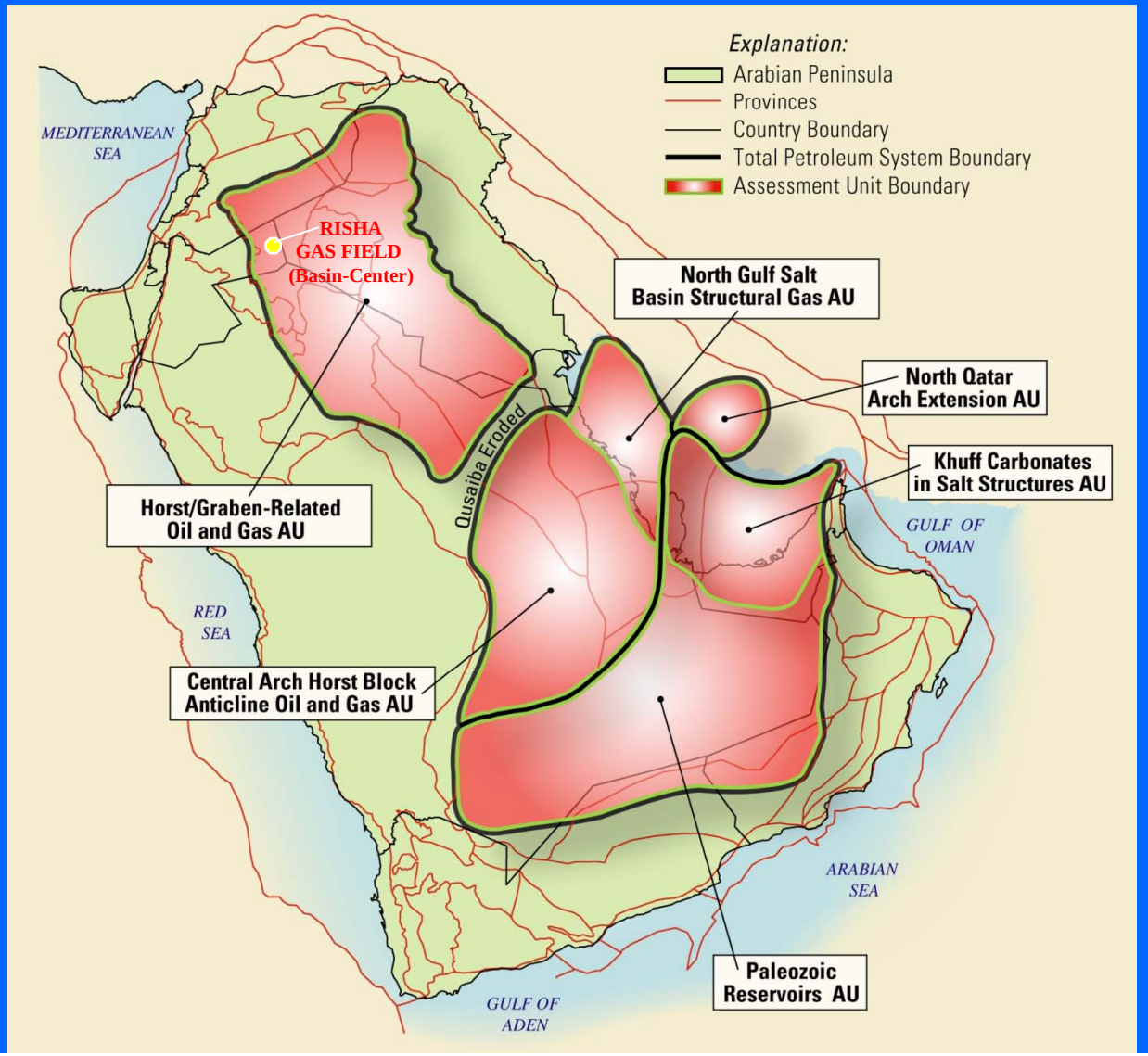
- THE FOUR PALEOZOIC (SILURIAN CHARGED) GAS TPS REPRESENT THE LARGEST UNDISCOVERED CONVENTIONAL GAS RESOURCES POTENTIAL (808 TCF) IN THE WORLD (USGS, 2000)—MUCH IS BASIN CENTER GAS (CONTINUOUS) ACCUMULATION AS EVIDENCED BY RISHA FIELD, JORDAN

- RESERVOIRS AT RISHA FIELD ARE LOW POROSITY (<8%), LOW PERMEABILITY (<50mD), UNDERPRESSURED AND SUSCEPTIBLE TO FORMATION DAMAGE; FRACTURES AND SECONDARY POROSITY ARE CRITICAL TO COMMERCIAL PRODUCTION.

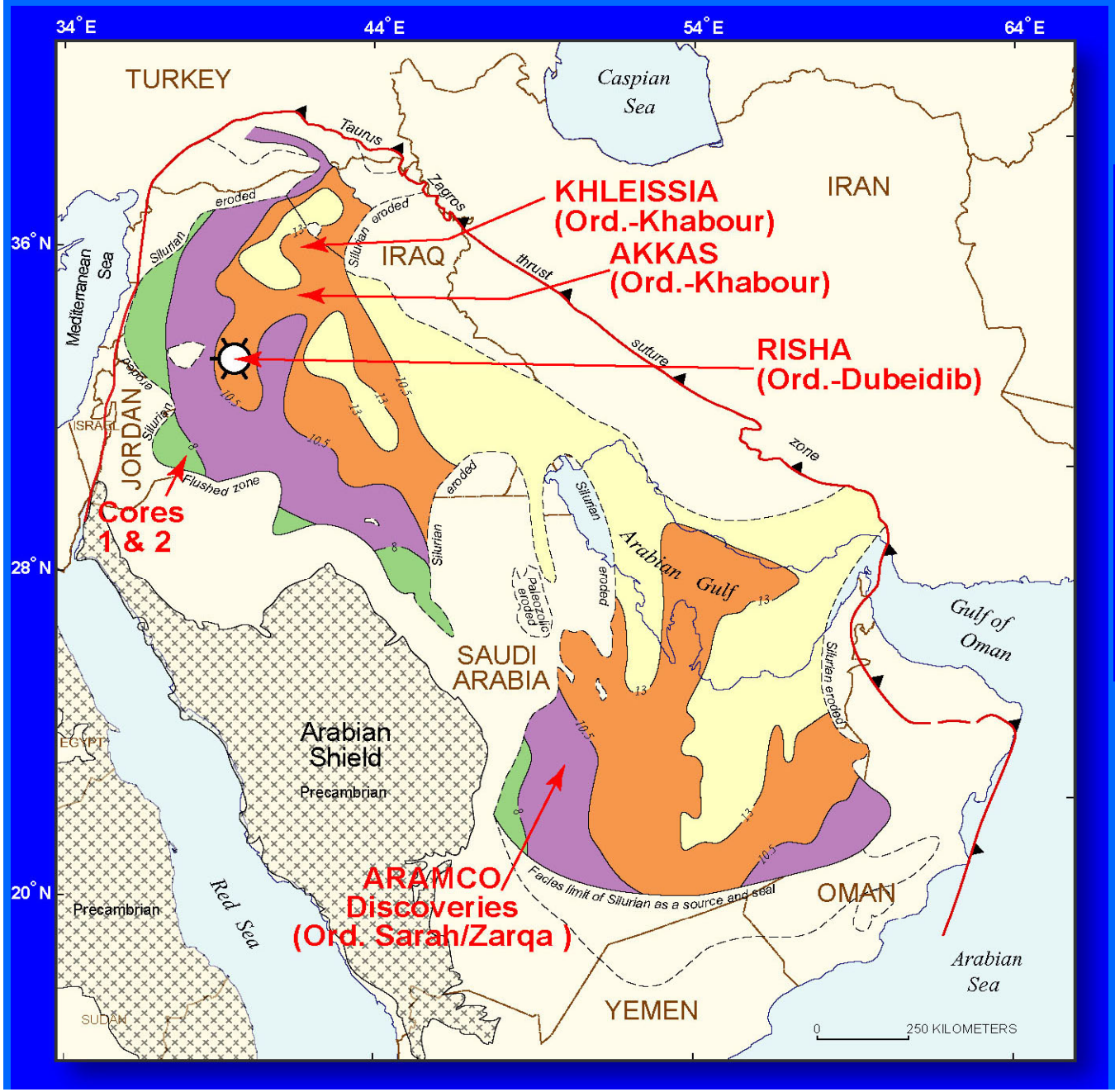
- THE BASIN-CENTER (“TIGHT”) GAS RESOURCES ARE EASILY OVERLOOKED PARTICULARLY IN AREAS OF LARGE CONVENTIONAL GAS ACCUMULATIONS

- THE CONTINUOUS GAS RESOURCE IS LARGE IN AREA AND IN VOLUME, BUT CURRENTLY NOT FORMALLY ASSESSED. RISHA FIELD IS CURRENTLY VIEWED AS A ONE HALF TCF FIELD AND IS ECONOMICALLY VIABLE SUGGESTING ADDITIONAL GAS POTENTIAL FOR THE ARABIAN PENINSULA.

Undiscovered Conventional Oil and Gas Resources of Lower Silurian Qusaiba-Paleozoic Total Petroleum Systems and Assessment Units (AU), Arabian Peninsula

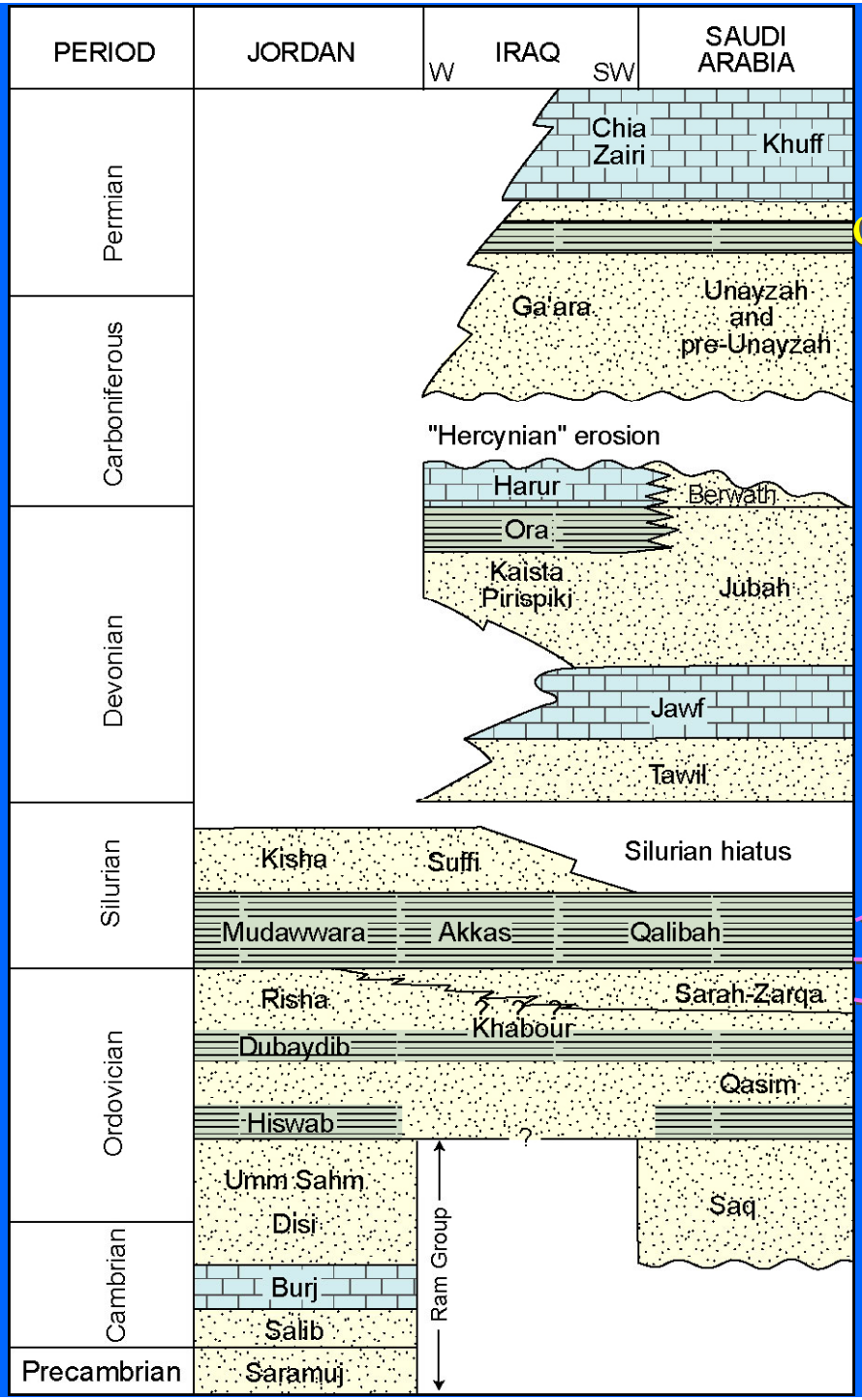


Thermal Maturity and Extent of Silurian Source Rocks & Seal



(Modified from Bishop, 1995)

Paleozoic stratigraphic column of Jordan, the Southwestern Desert of Iraq and northern Saudi Arabia



EXPLANATION

- Carbonate
- Shale
- Sandstone

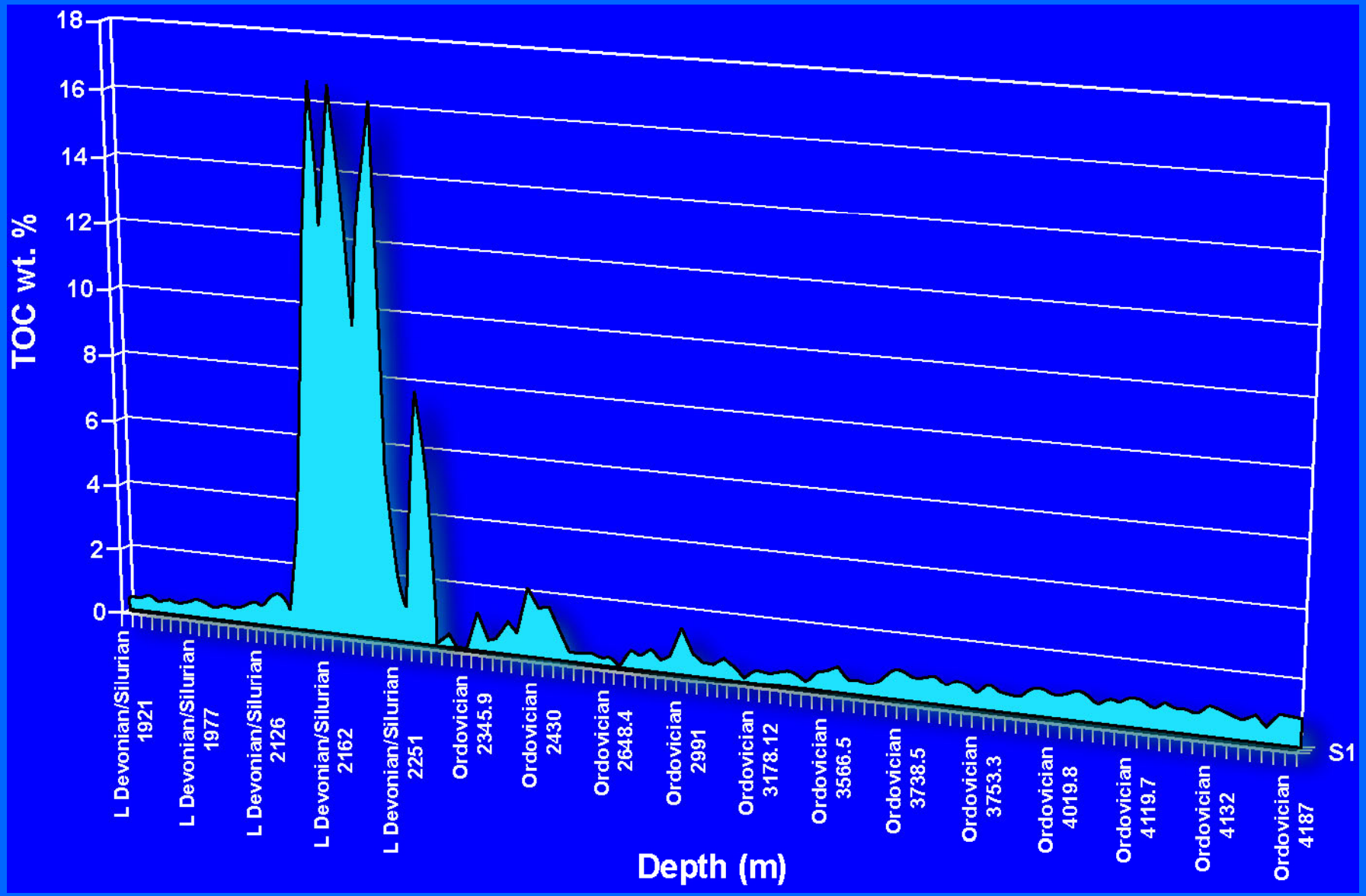
SOURCE ROCK

"HOT SHALE"

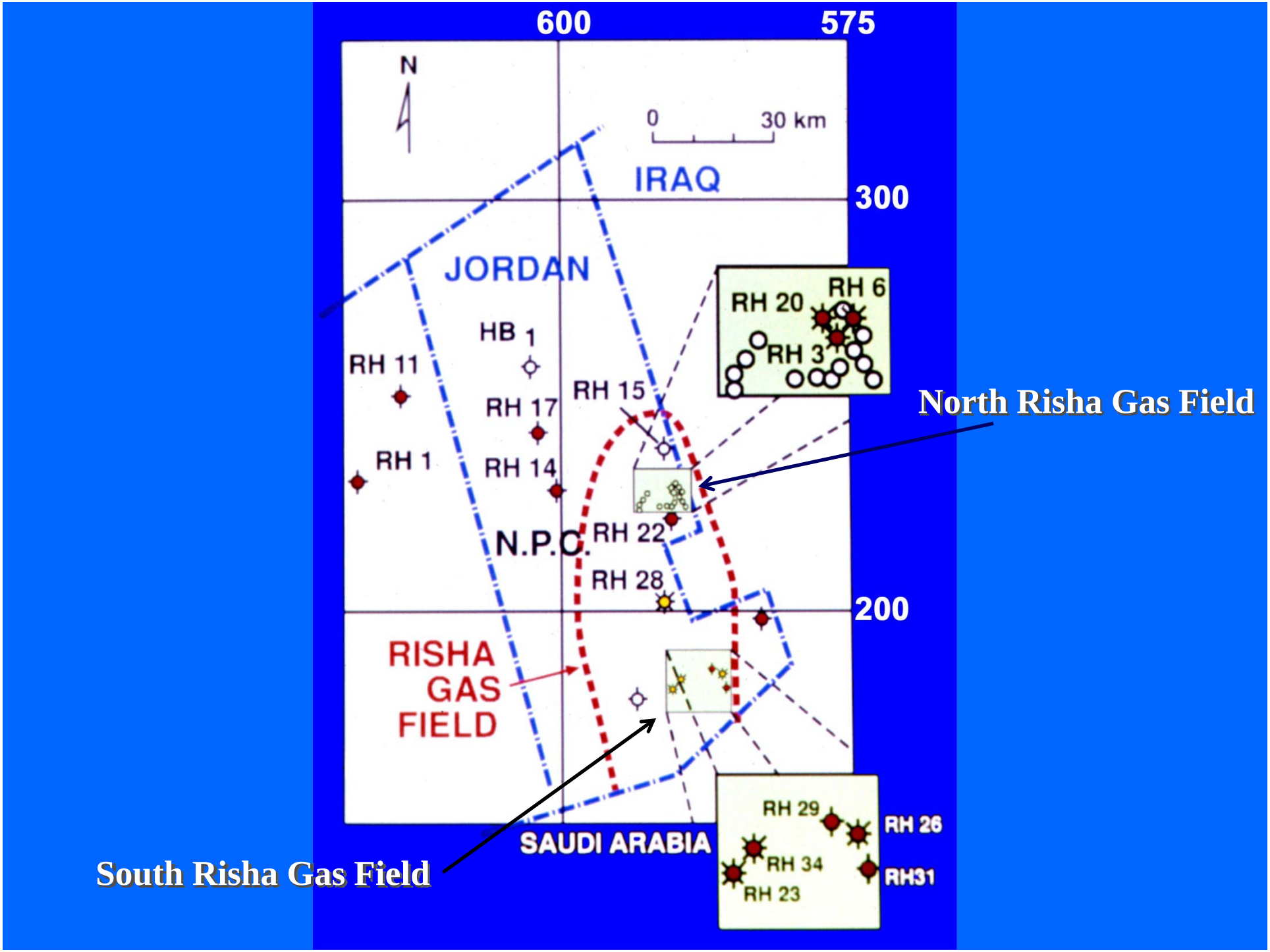
RESERVOIR ROCK

(Modified from Agrawi, 1998)

Akkas Well, Western Iraq



(From GeoDesign, 1997)


600
575
N
0
30 km
IRAQ
300
JORDAN
HB 1
RH 11
RH 17
RH 15
RH 1
RH 14
RH 20
RH 6
RH 3
North Risha Gas Field
N.P.C.
RH 22
RH 28
200
RISHA
GAS
FIELD
RH 29
RH 26
RH 34
RH 23
RH31
SAUDI ARABIA
South Risha Gas Field

NORTH RISHA GAS FIELD, JORDAN

DISCOVERY WELL RH 3 - 7/87

- Depth: -1737M Subsea
  - 2611M Drill (8600')
- Reservoir:
  - Risha Member (Dubiedib Fm.)-Unit III
  - Upper Ordovician (Cardoc-Ashgill)
  - Thickness - 105M
    - Unit I- 53M SS
    - Unit II-21 M Siltstone
    - Unit III-31 M SS
  - Slightly Underpressured .39 psi/ft
  - Low Porosity (6-8%); one streak-13%
  - Fractured
  - Clay: Chlorite
- Production:
  - P 15 MMCF/D; 3407 psi
- Reserves:
  - Initial Estimate (Consultants)--0.5 BCF
  - Initial NRA Estimate--11.5 BCF
  - Production by 4/94 (RH3 &6)--27 BCF
    - Est. 70% RH3

SOUTH RISHA FIELD HISTORY

RH 28-5/93 (50KM South of RH3/RH20)

Depth: -1773M Subsea
2702M Drill (8,885')

Reservoir:
Risha Member (Dubeldib Fm.)-Unit 1
Thickness: Risha Member 85.5M
Unit 1- 22M SS
Unit 2 - 24M Siltstone
Unit 3 - 39.5M SS
Slightly Underpressured -.38 psi/ft
Porosity: 8-8%; 1 streak to 11.5%
BHT-300 F
RW -.035
Fractured
Clays- Kaolinite/Smectite

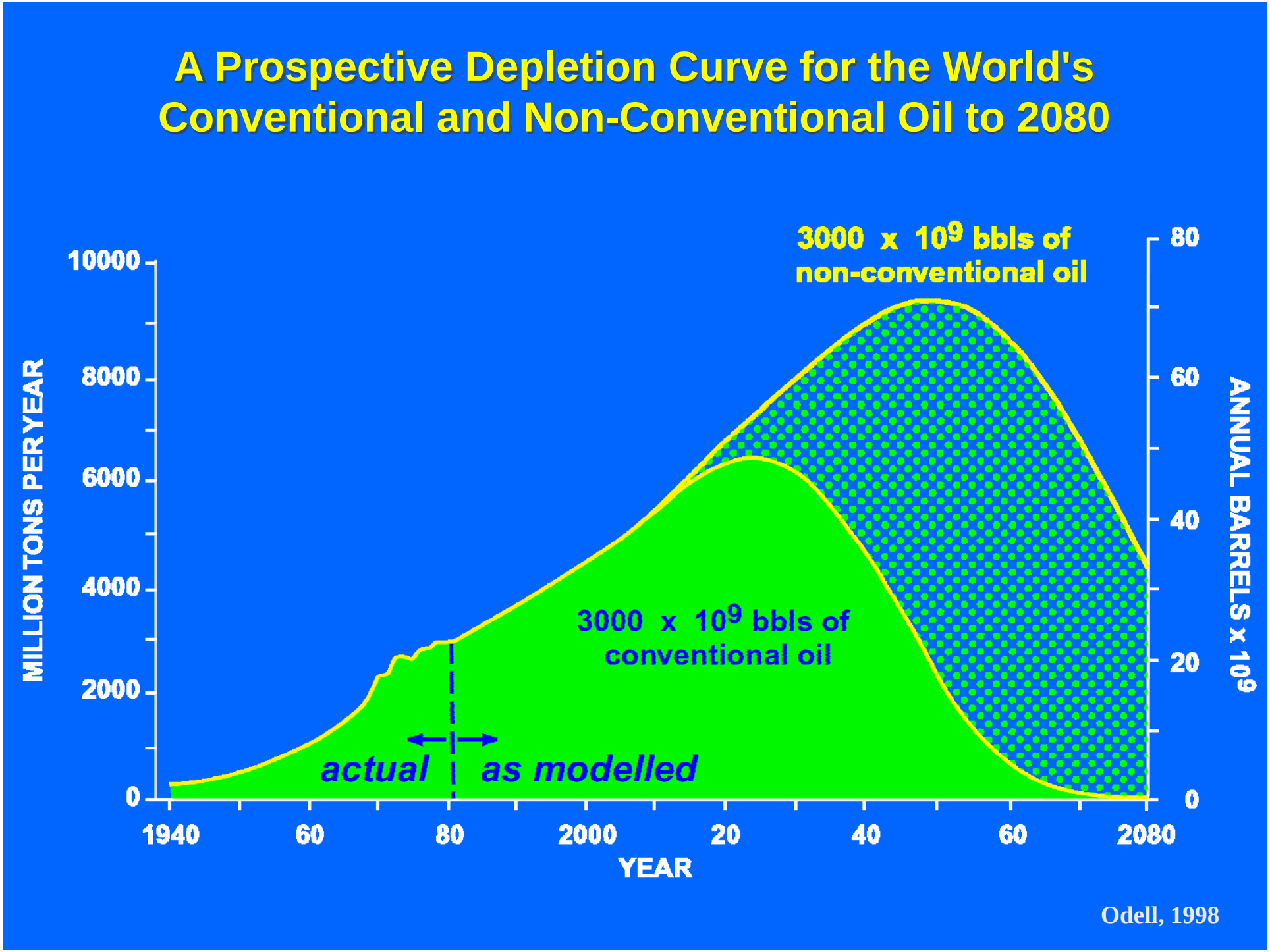
Production: IP 4MMCF/D, 3407 psi
C1-90.5%; C02-8.5%; N02-0.95%

Reserves:

NRA (North Risha)	200 BCF
Petroconsultants (1995)	215 BCF
Petroconsultants (2002)	333 BCF (233 BCF Recoverable 70% Rec. Factor)
Arab O&G Dir. (8/95)	535 BCF

7 wells producing 30MMCF/D North and South RIsha;10% Electrical Power of Jordan, 3 power plants 31 wells drilled in entire area.

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



Odell, 1998

SUMMARY

- The Tethys (Middle East—North Africa) is the dominant oil and natural gas liquids region and will remain so; barely 2nd in conventional gas in USGS 2000 (1/1/96 data)
- New discoveries & increased estimates from 2000-2008 are significant (~80 BBOE); some major new provinces demonstrate more conventional resource potential here (i.e. USGS 2000 estimates using 1/1/96 are conservative)
- The petroleum systems of this region, already dominant in conventional resources, will likely become the dominant unconventional resource plays for both gas (BCGA) and oil (BCGO)
- The petroleum system revolution is coming to the Tethys