Advances in Unconventional Resources Technology: Assessment Methodology

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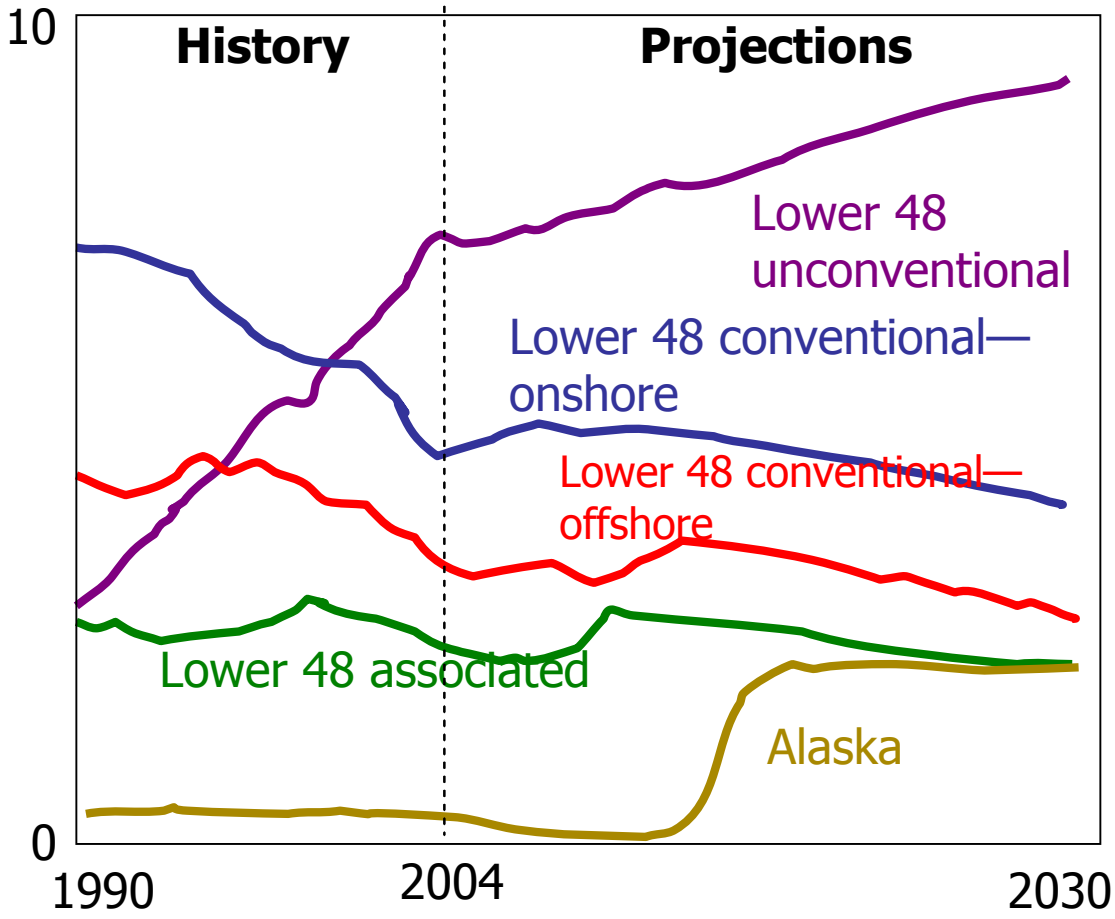
Global Energy Availability Requires Creative Thinking

- We need increasing amounts of energy of right type at right place and right time
- Viability of many alternatives limited by practical considerations
- Unconventional resources play important role for most forecasters
- Improved assessment methodology one key to availability of needed unconventional resources

Unconventional U.S. Gas Production Will Increase



EIA 2006

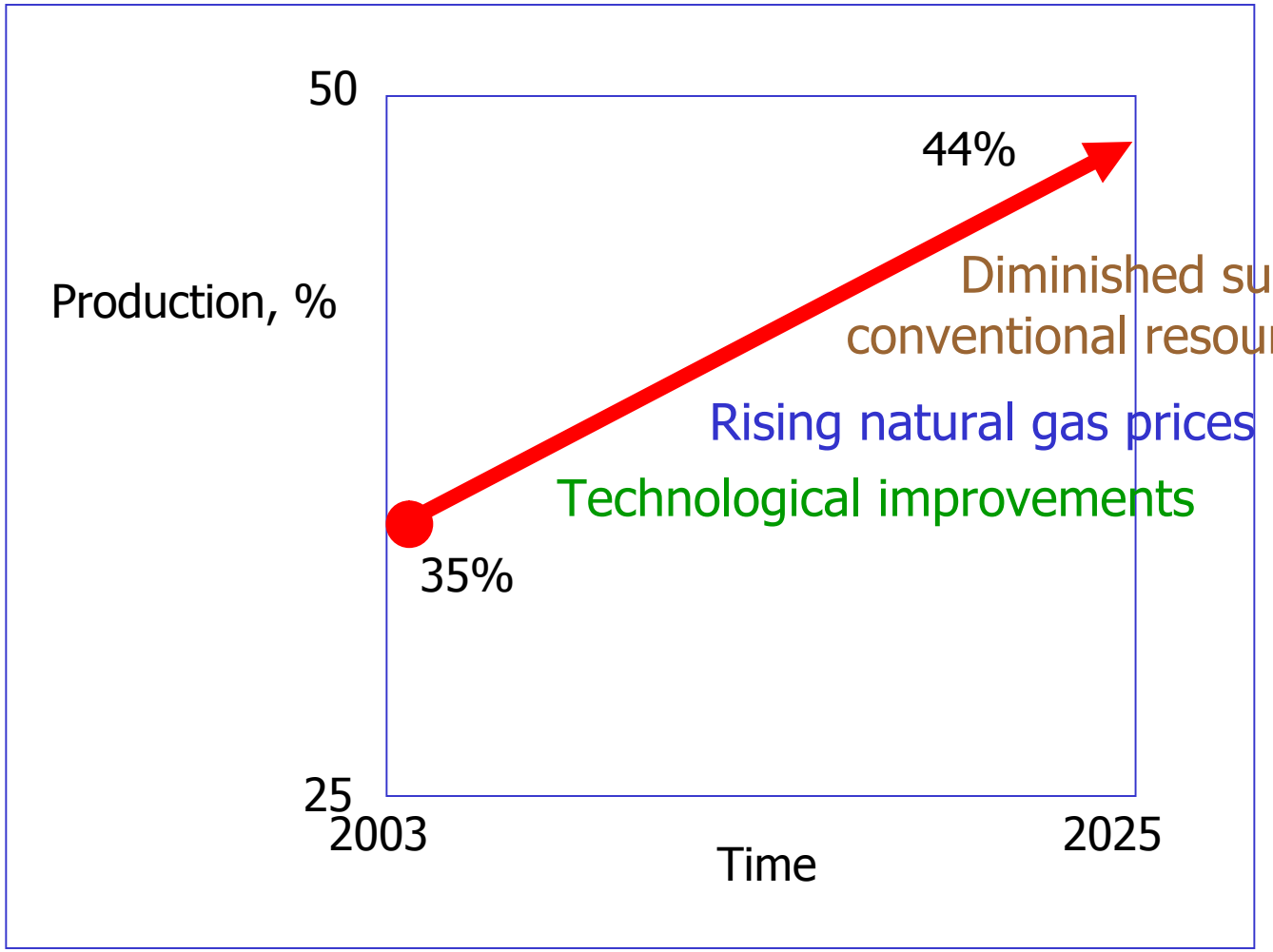
Dependence on Unconventional Resources To Grow in United States

'As a result of technological improvements and rising natural gas prices, natural gas production from relatively abundant unconventional sources (tight sands, shale, and coalbed methane) is projected to increase …

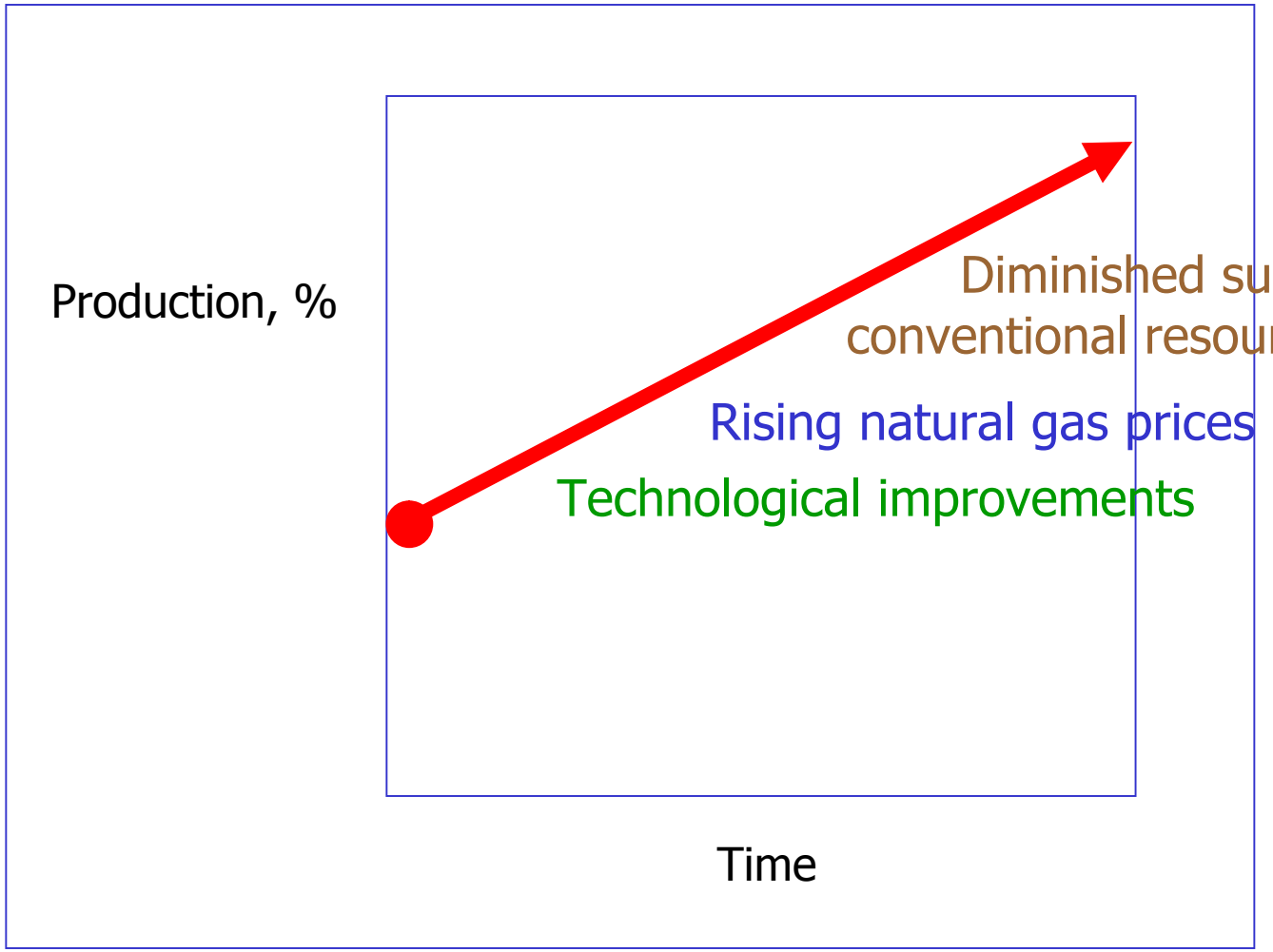
- from **35 percent** of total lower 48 production in 2003
- to **44 percent** in 2025'

EIA Energy Outlook 2005

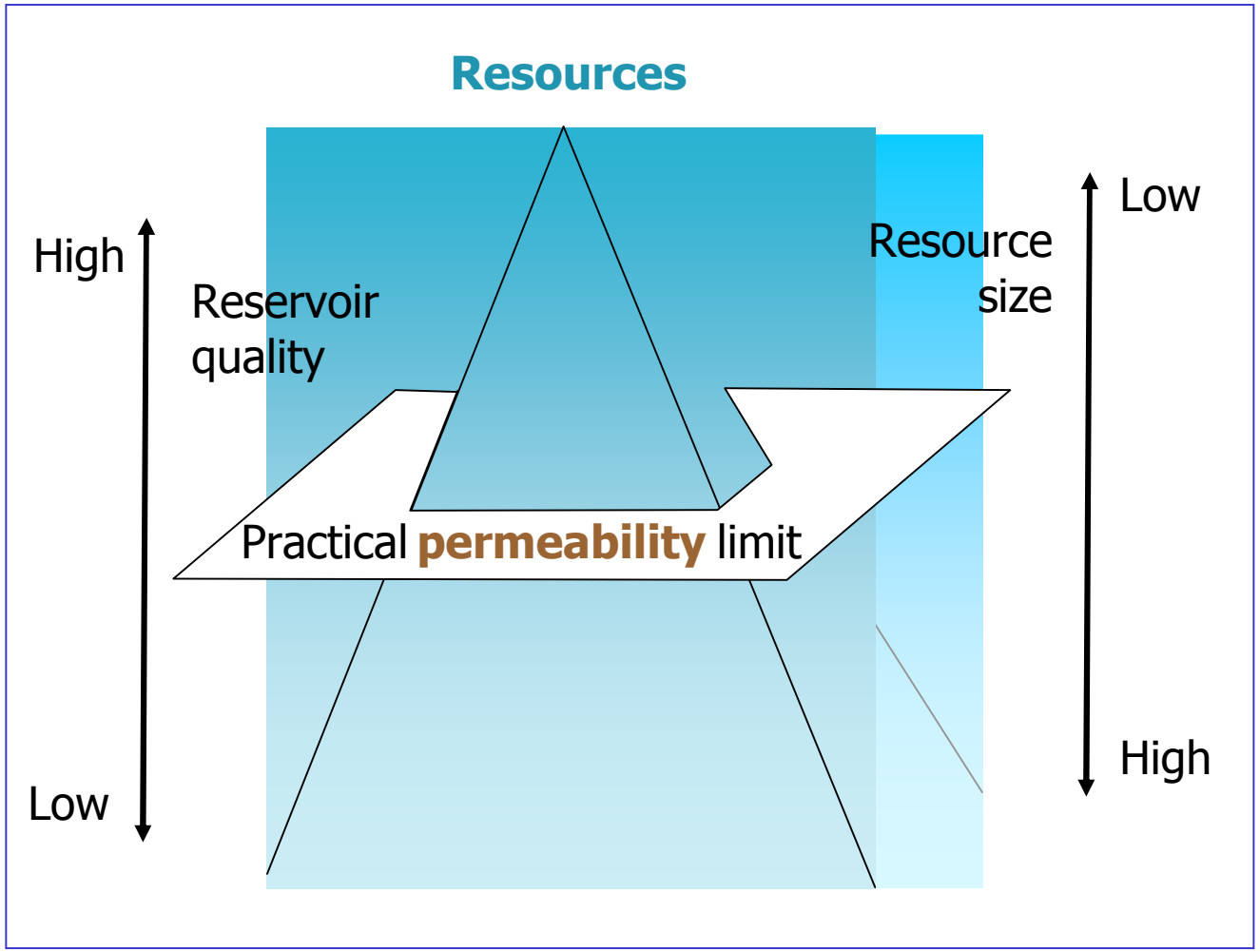
Production From Unconventional Sources Will Increase in U.S.



… And Later in the World

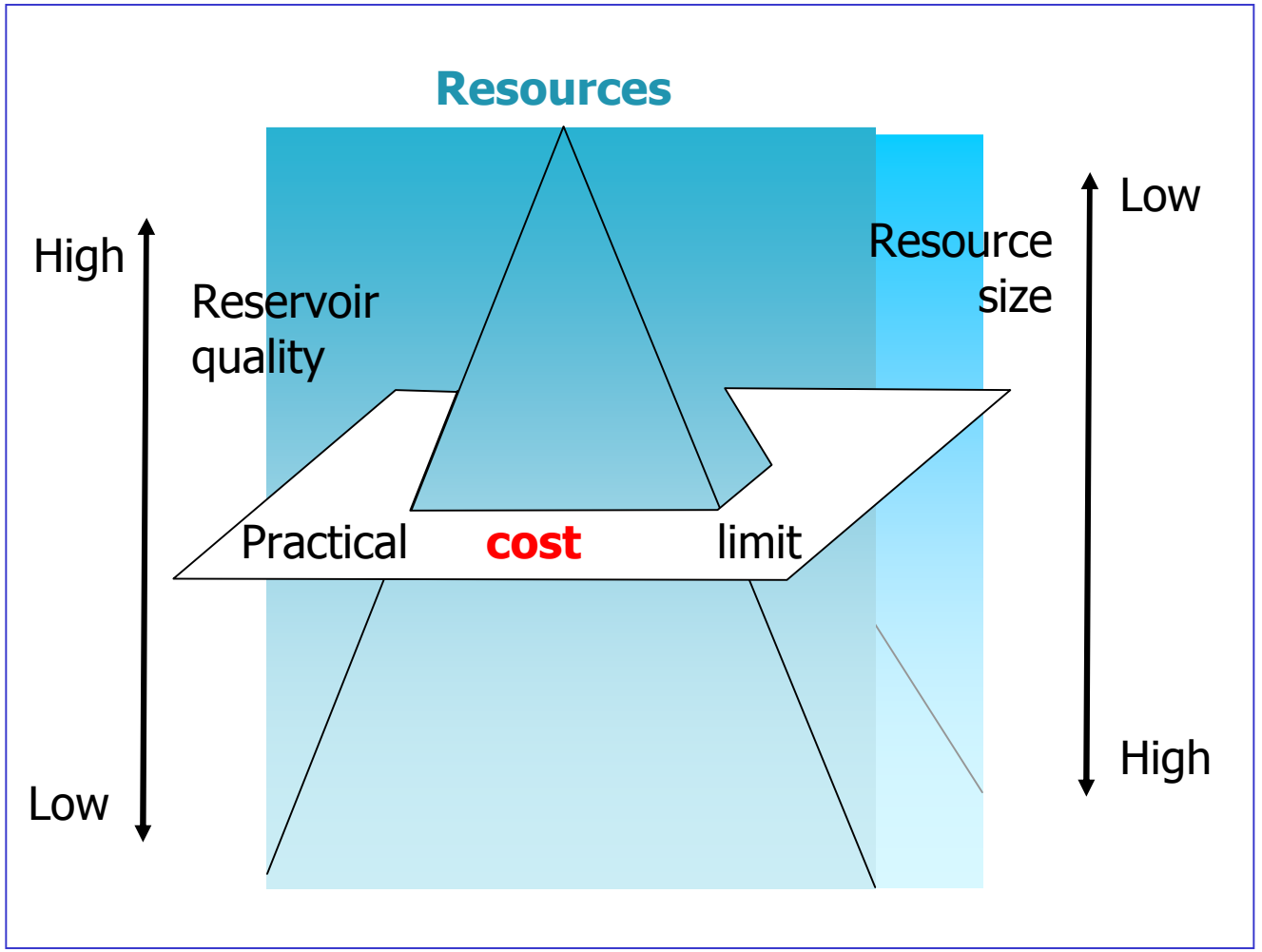


Resource Distribution and Practical Permeability Limit



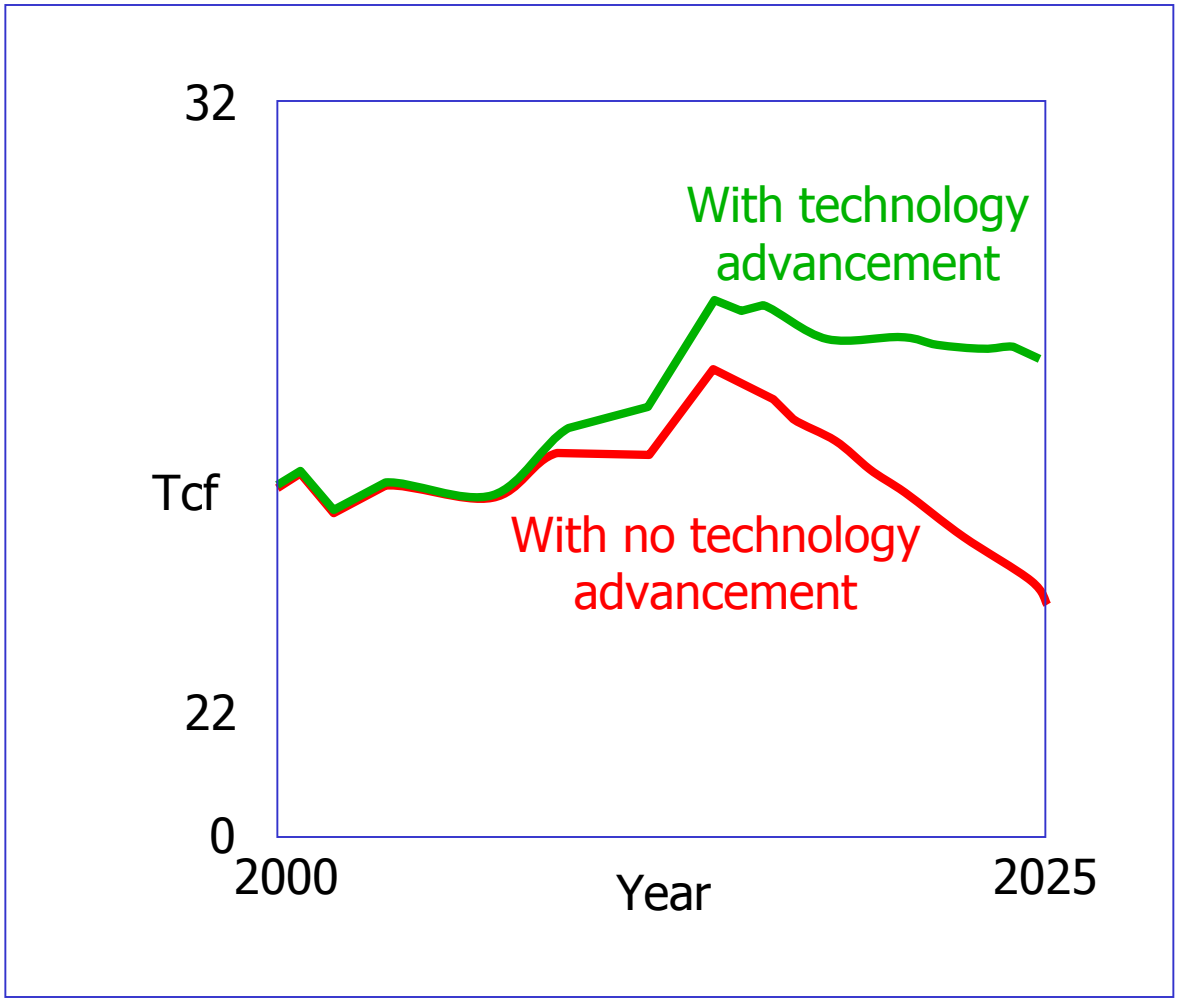
After USGS, 2003

Resource Distribution and Practical Cost Limit



After USGS, 2003

NPC Forecasts Technology Impact on Gas Production



NPC 2003

NPC Model Assumes and Identifies Expected Technology Advances

	Technology Area	Annual, %	25 years, %
↑	Exploration well success	0.53	14
	Development well success	0.41	11
	Ultimate per-well recovery	0.87	24
	Initial production rate	0.74	20
↓	Drilling costs	1.81	37
	Completion costs	1.37	39
	Construction costs	1.18	26
	Fixed operating cost	1.00	22

NPC 2003

Improved Resource Assessment Key to Much Unconventional Resource Development

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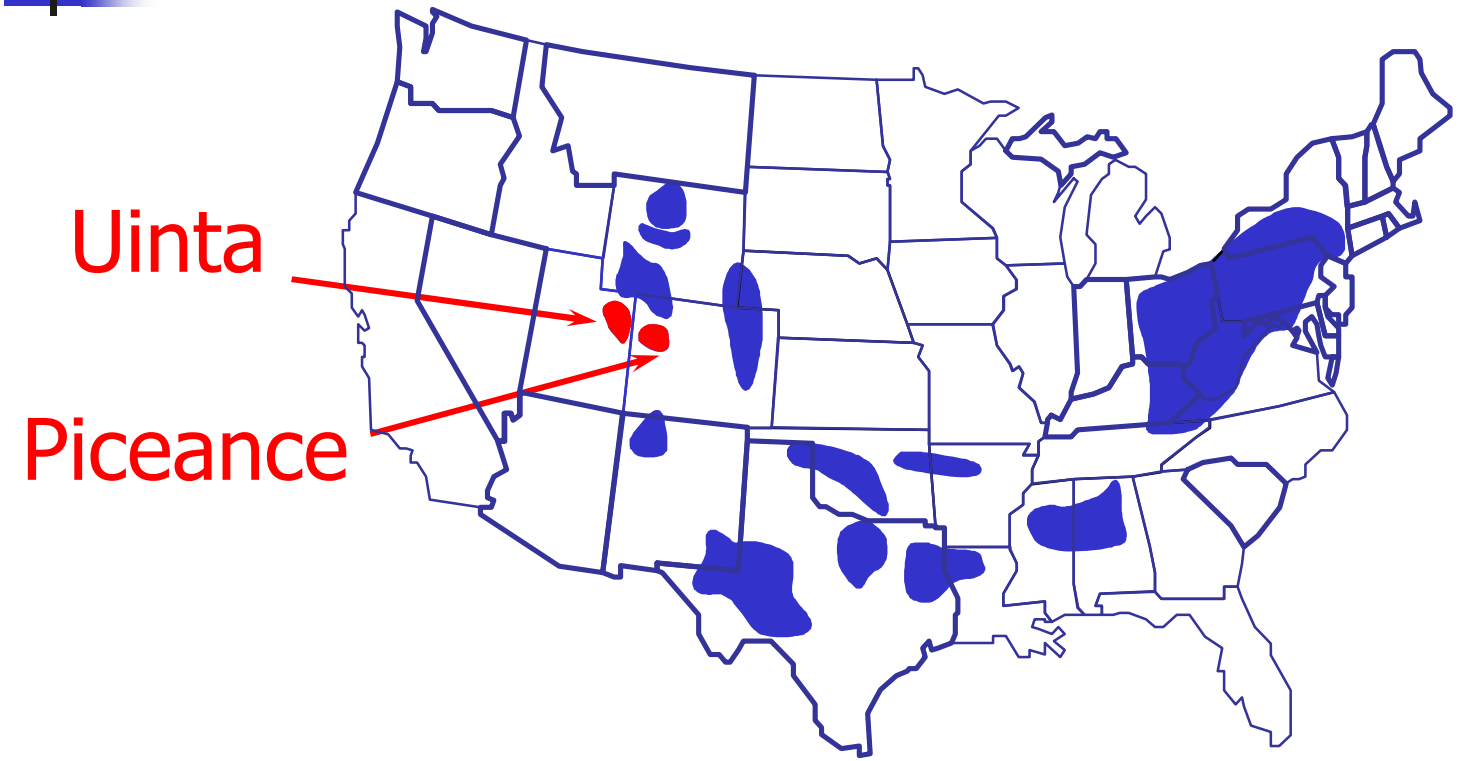
NPC 2003

Active Projects in Resource Assessment

- Quantifying uncertainty in unconventional gas resource assessments in North America

- Estimating unconventional gas resources outside of North America

USGS Applied Methodology for Undiscovered Resources in 2003

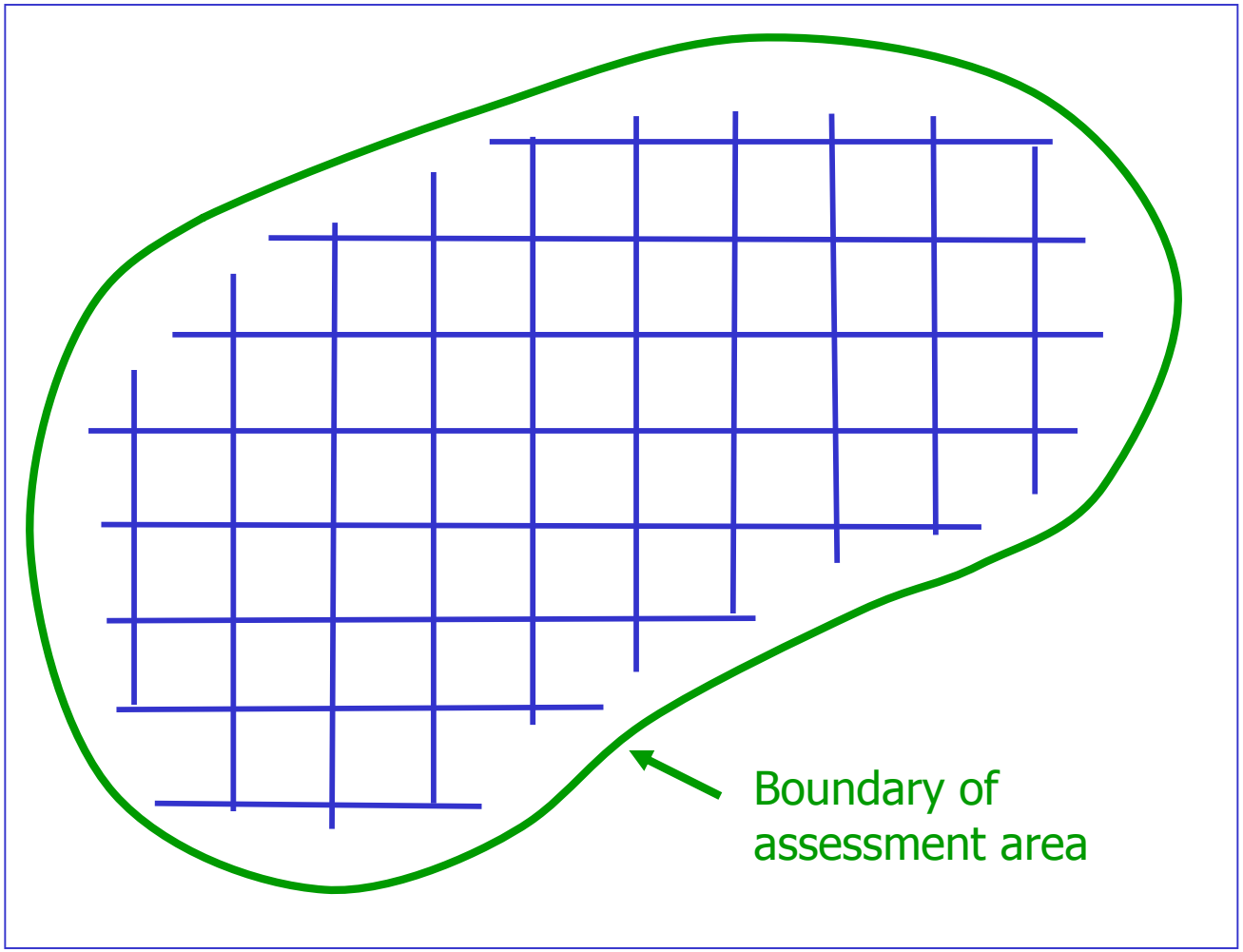


SAH97.165

Resource Assessment Methodology

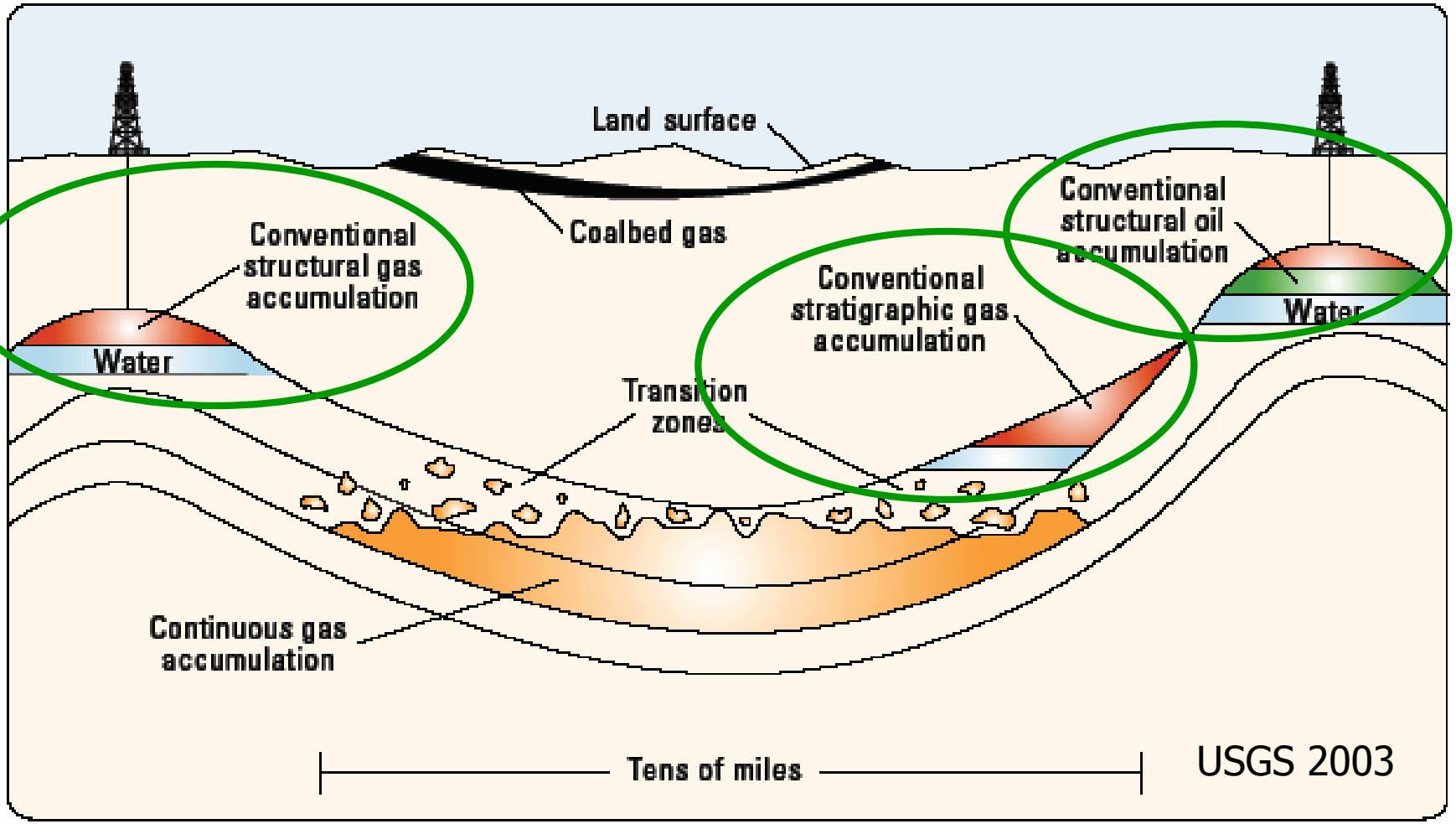
- Identify areas within petroleum province that are 'total petroleum systems'
  - Hydrocarbon source rocks
  - Reservoir rocks
  - Hydrocarbon traps

Analyze 'Assessment Area' (Play) – About 700 in North America

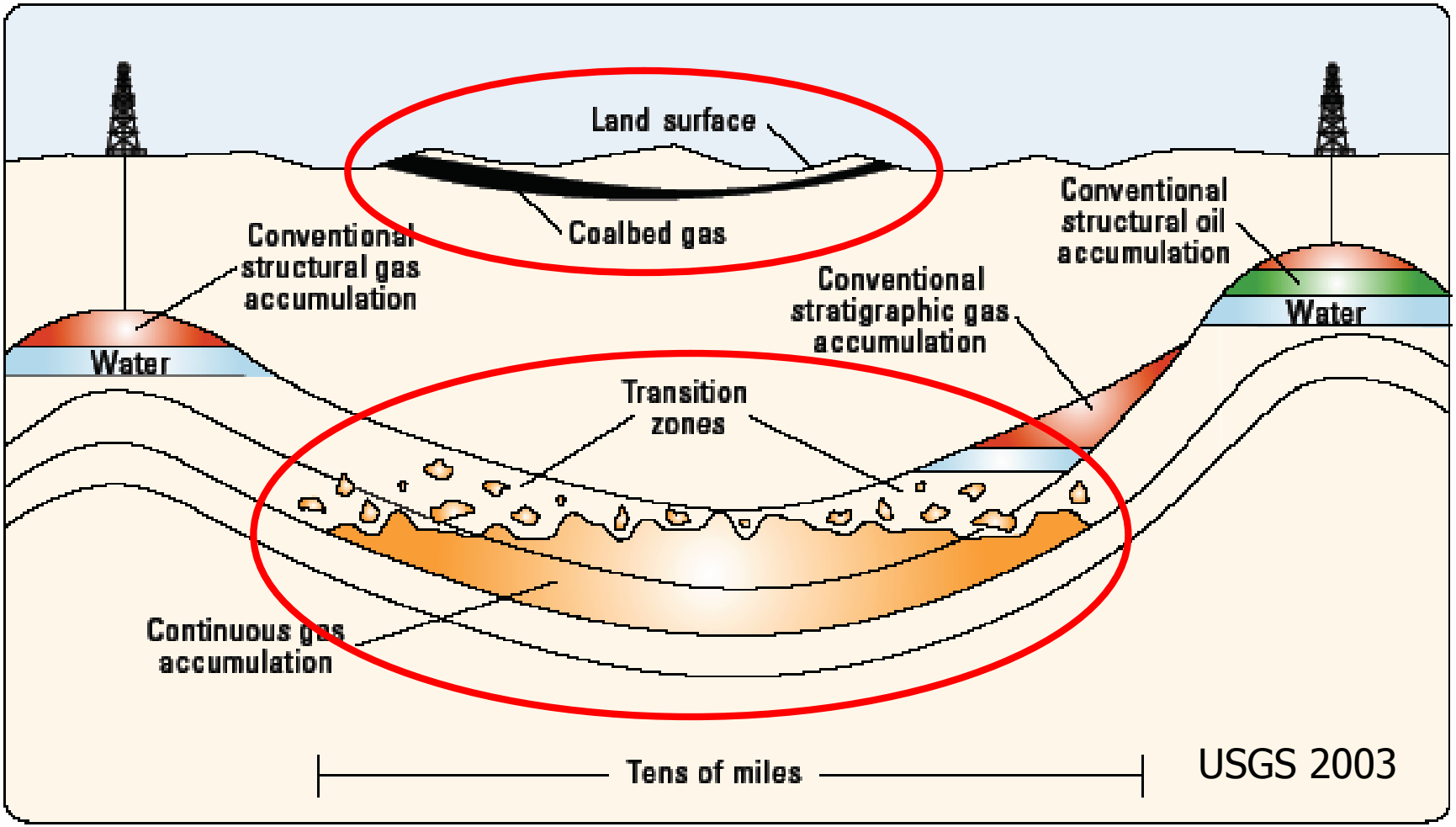


USGS 2003

Classify Petroleum Systems as Conventional …



...or Continuous



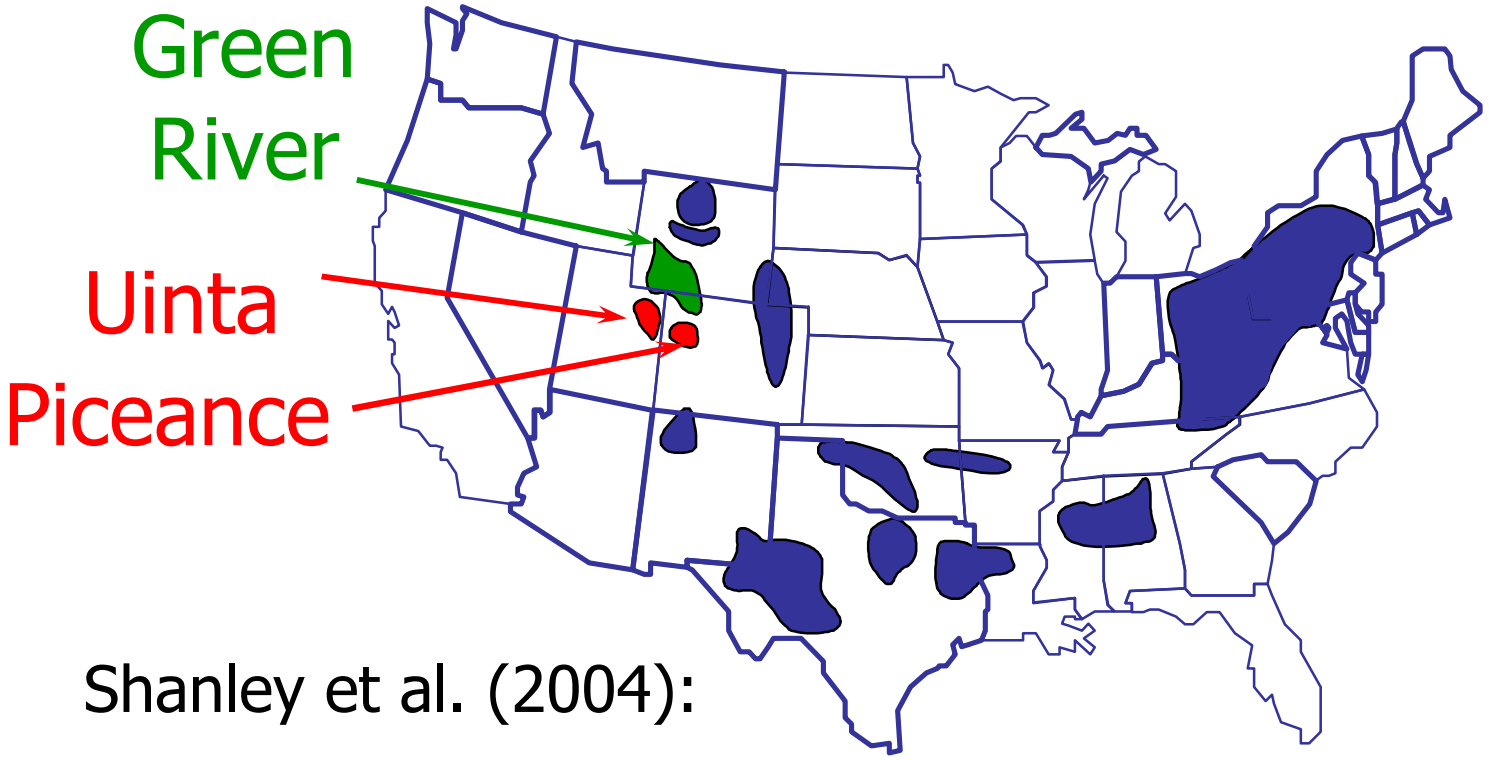
Characteristics of ‘Conventional’ Accumulations

- Relatively high matrix permeability
- Obvious seals and traps
- High recovery factors

Characteristics of 'Continuous' Accumulations

- Regional in extent
- Diffuse boundaries
- Low matrix permeabilities
- No obvious seals or traps
- No hydrocarbon/water contacts
- Abnormally close to source rocks
- Low recovery factors
- Includes tight sandstones, coalbed gas, oil and gas in fractured shale and chalk

Some Don't Accept USGS Model for Unconventional Resources

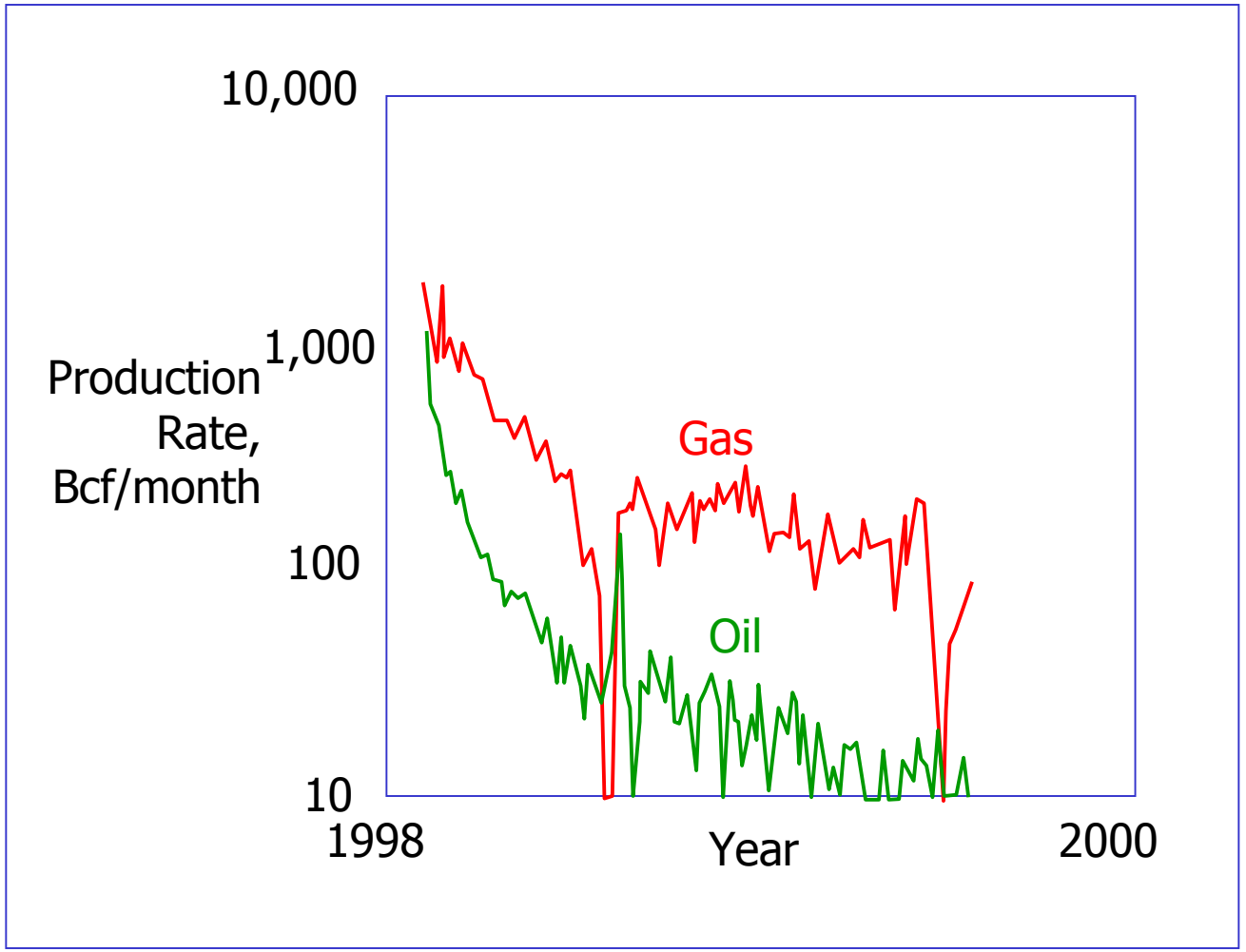


Shanley et al. (2004):

Some low-permeability gas fields occur in poor-quality rocks in conventional traps

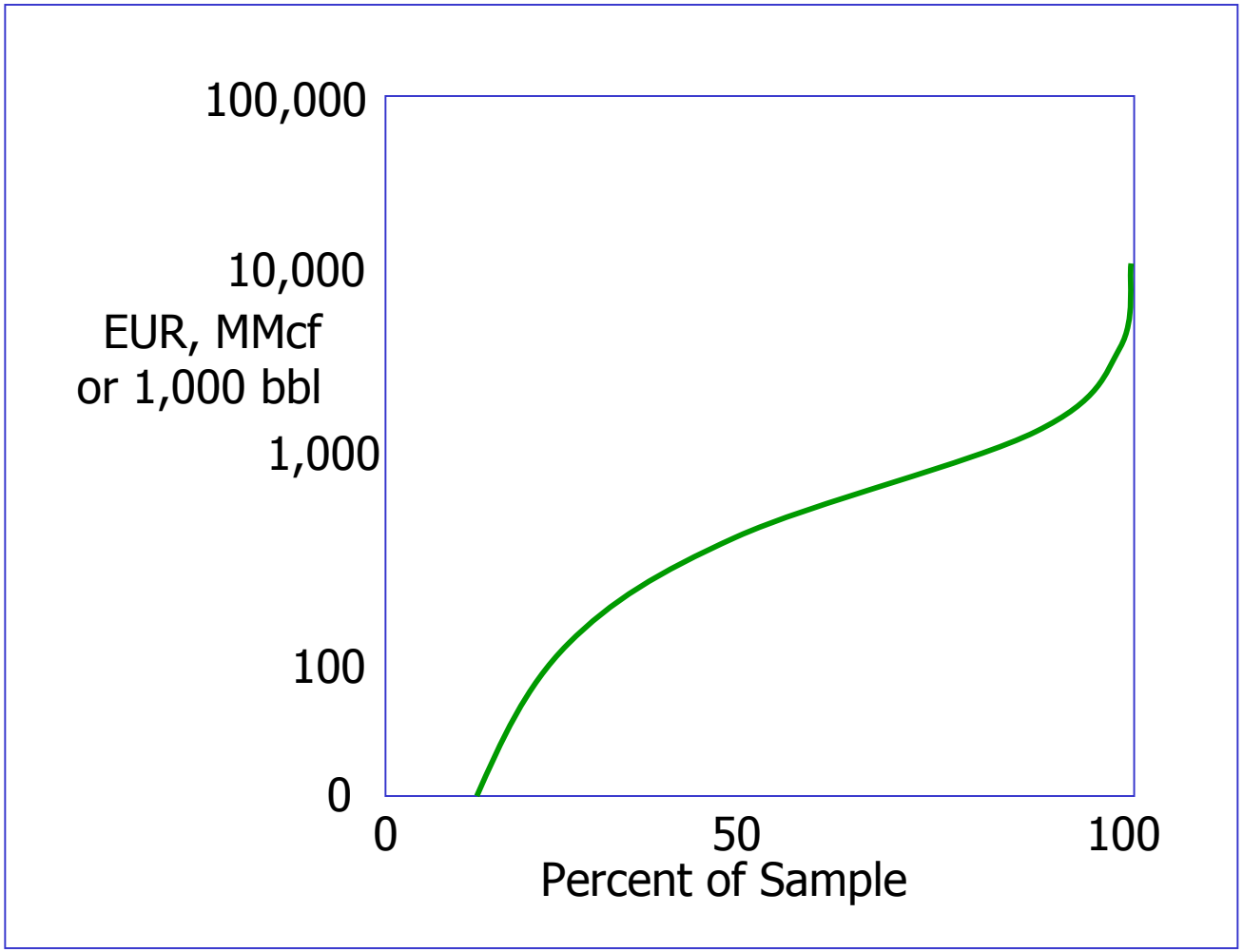
SAH97.165

Production Decline Curves Used to Predict EUR



USGS 2003

EUR Distribution for Continuous Accumulation



USGS 2003

USGS Undiscovered Oil and Gas Estimates for Uinta-Piceance Province, Utah-Colorado

Resource Type	Oil, MMSTB		Gas, Bscf	
Conventional	P95	7.15	P95	63.71
	P50	18.47	P50	191.12
	Mean	**20.39**	**Mean**	**213.12**
	P5	40.44	P5	436.01
Continuous	P95	31.99	P95	12,145.49
	P50	37.57	P50	20,121.27
	Mean	**38.78**	**Mean**	**21,211.03**
	P5	56.84	P5	33,978.81

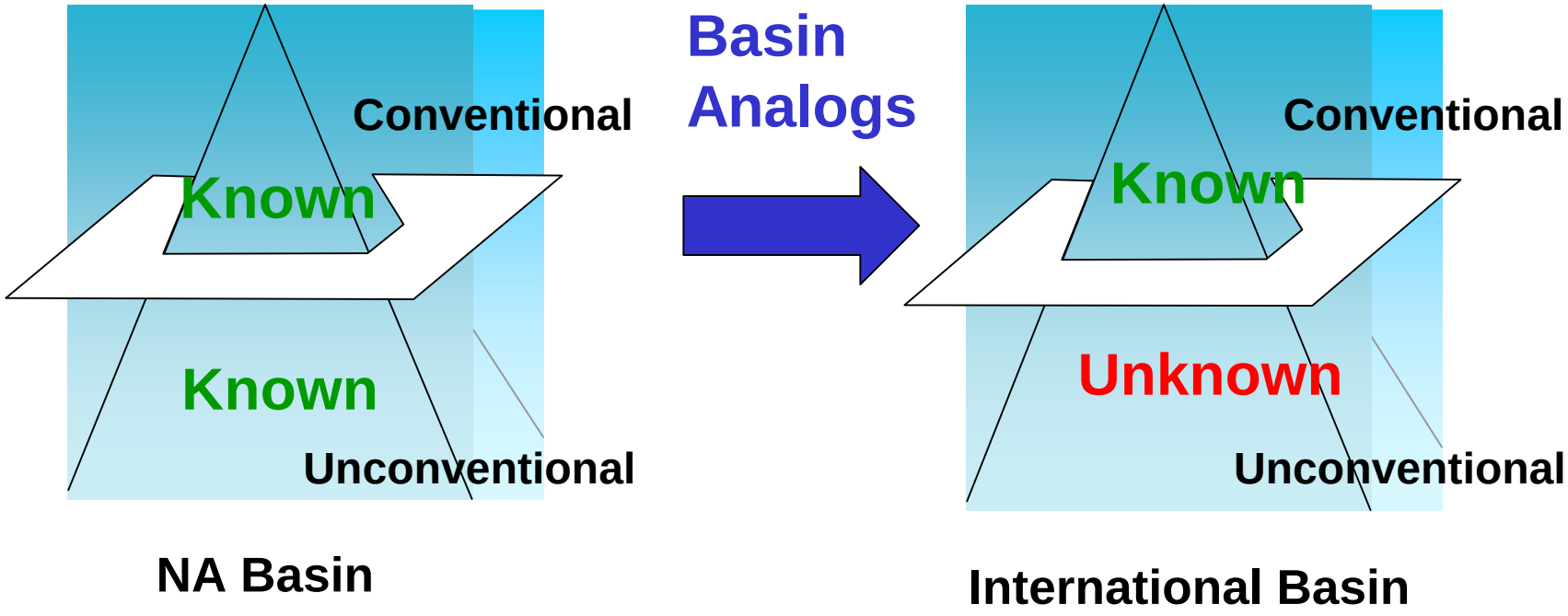
Observations

- USGS Methodology yields probability distribution of undiscovered resource
  - Previous presentations simply most likely, high, low cases
- Virtually all undiscovered resource in USGS model ‘continuous’ gas
  - Validity of continuous model critical
- Range from P5 to P95 quite narrow
  - Analysis indicates narrow, subjective input data

North American and Non-North-American Basins Selected for Further Study

- North American basins studied will probably include frontier areas in Travis Peak and Barnett Shale
- Non-North-American basins will include Neuquen and Cuyo basins (Argentina) and Sichuan basin (China)

Estimating Non-North American Unconventional Gas Resources



Objectives and Challenges

- Objectives
  - Develop methodology for identifying analogous basins
  - Estimate potential resources in selected basins
- Challenges
  - No public literature available
  - General lack of data availability
  - Large number of basins in North America
  - Which parameter to use? What criteria?

Data Collection

	Neuquen	Cuyo
Basin Type	Foreland & Extensional	Foreland
Fill Thickness	3500 - 12000 m	
Source Rock:		
- Age	Lower Jurassic, Upper Jurassic - Lower Cretaceo	
- Depth	2800-840	
- Type	Mudston (calcareo	
- Kerogen		
- Ro (reflectivity)		
- Thickness	100-500m	
- Formation	Los Molle	
Reservoir:		
- Age	Lower Cr Lower Cr	
- Depth	2500-670	
- Thickness	900-2500	
- Source Rock HC Type	Oil & Ga	
- Porosity		
- Permeability		
- Depositional System/Facies	Mainly A and mud coast to	
Traps Type	Structura	
Deforming Stress Type		
Seals		
Migration:		
- Distance		
- Direction	Vertical and Horizontal	

Build database of reservoir properties

- ✓ Define criteria to find analog basins
- ✓ Include characteristics of international basins
- ✓ Build expert system to compare NA basins to international basins

Analog basin progress

All NA basins:

60 - 70 basins

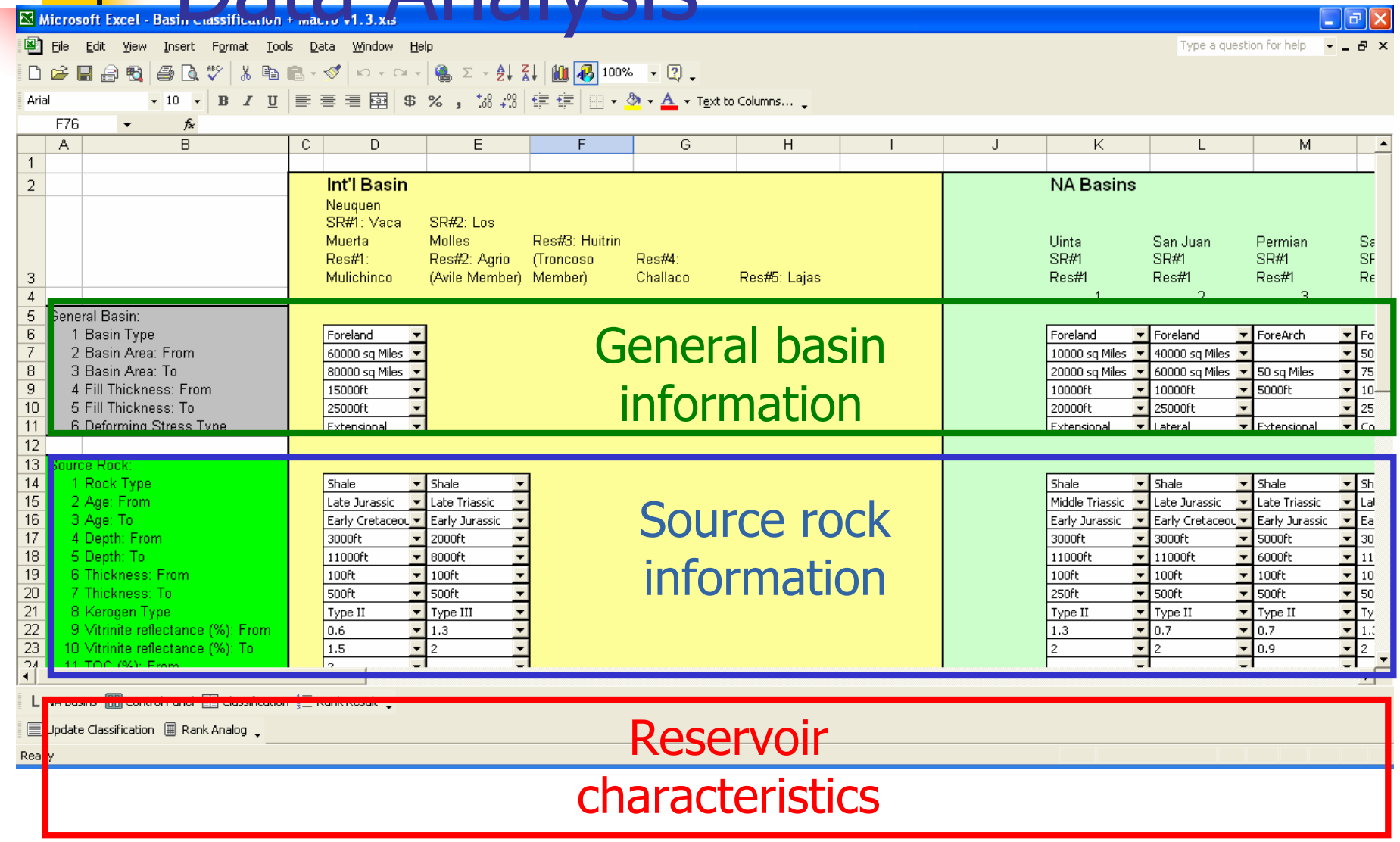
NA basins with unconventional gas potential

31 basins

Analog score

Final Analog Basins

Data Analysis



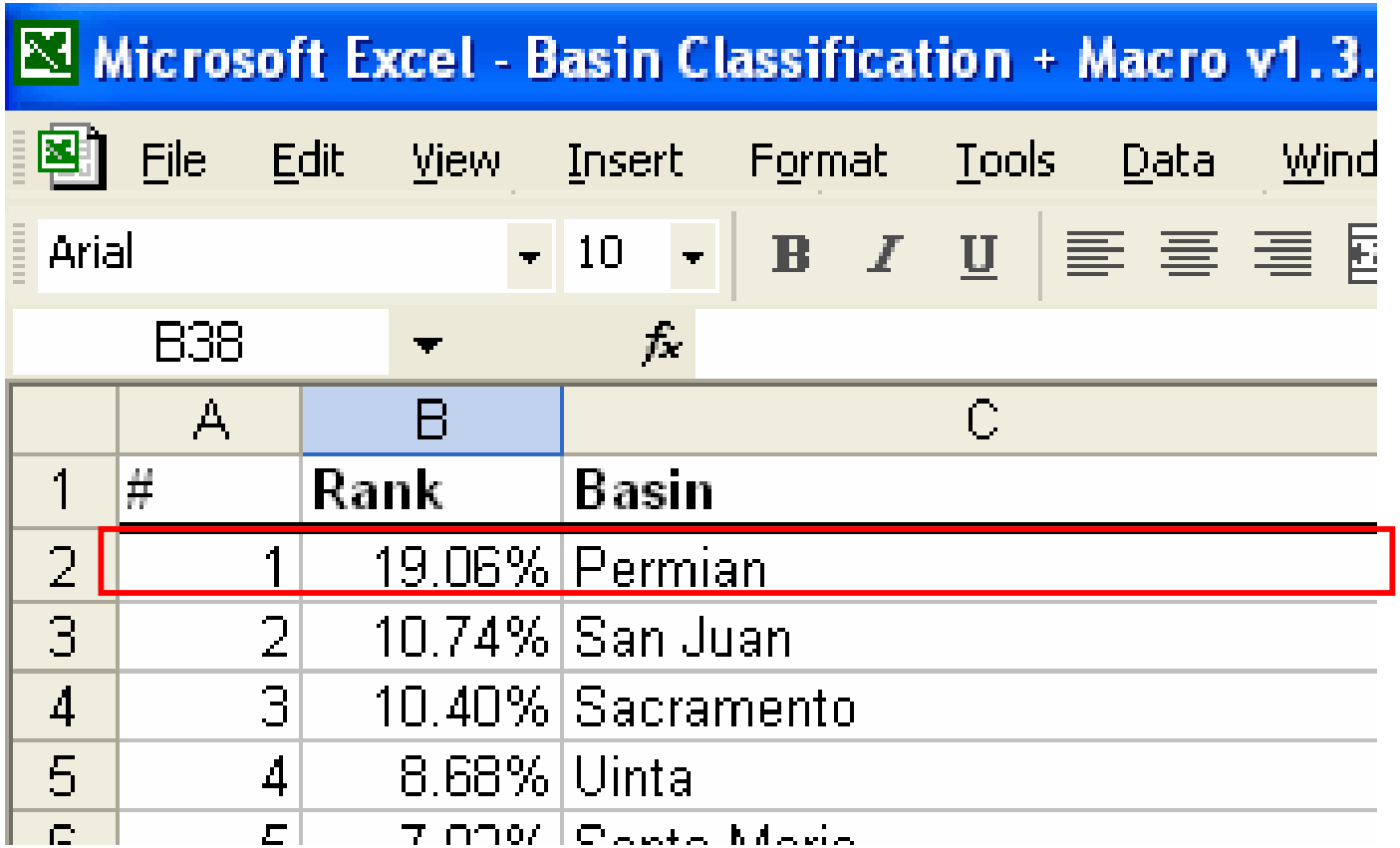
Point Calculation

	General Basin:	Int'l Basin	NA Basins 1	NA Basins 2
5				
6	1 Basin Type	Foreland	Foreland	Foreland
7	2 Basin Area: From	60000 sq Miles	10000 sq Miles	40000 sq Miles
8	3 Basin Area: To	80000 sq Miles	20000 sq Miles	60000 sq Miles
9	4 Fill Thickness: From	15000ft	10000ft	10000ft
10	5 Fill Thickness: To	25000ft	20000ft	25000ft
11	6 Deforming Stress Type	Extensional	Extensional	Lateral
		$1 \times WF_1$	$1 \times WF_1$	$1 \times WF_1$
		$1 \times WF_2$	$0.1 \times WF_2$	$0.8 \times WF_2$
		$1 \times WF_3$	$0.1 \times WF_3$	$0.75 \times WF_3$
		$1 \times WF_4$	$0.7 \times WF_4$	$0.7 \times WF_4$
		$1 \times WF_5$	$0.8 \times WF_5$	$1 \times WF_5$
		$1 \times WF_6$	$1 \times WF_6$	$0 \times WF_6$
		Total Pts	Basin 1	Basin 2

Nearness of match, not relative values

Highest scores most likely analogs

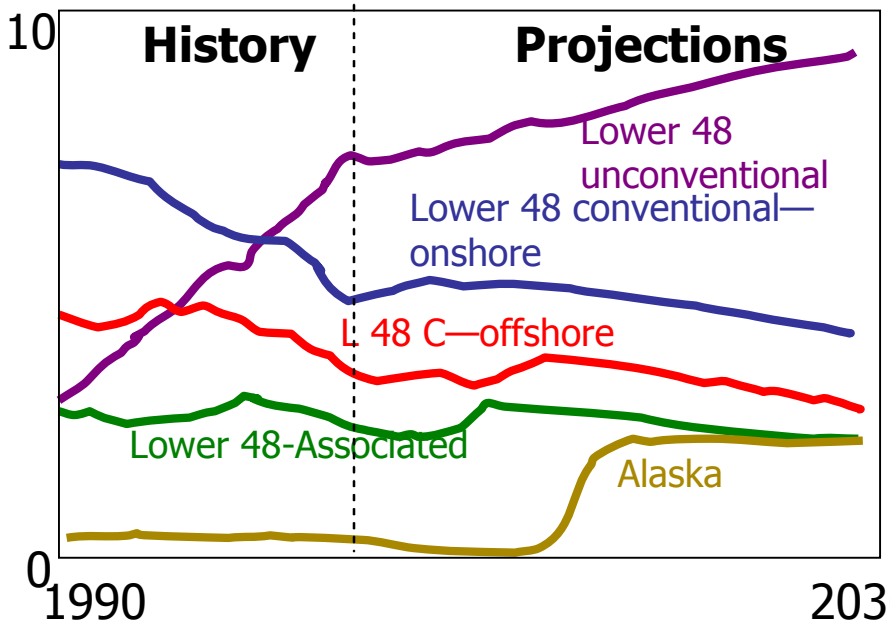
Rank Result Sheet



	A	B	C
1	#	**Rank**	**Basin**
2	1	19.06%	Permian
3	2	10.74%	San Juan
4	3	10.40%	Sacramento
5	4	8.68%	Uinta

Summary Comments

- Unconventional resources, especially gas, to play leading role in North American energy supply in next 25 years



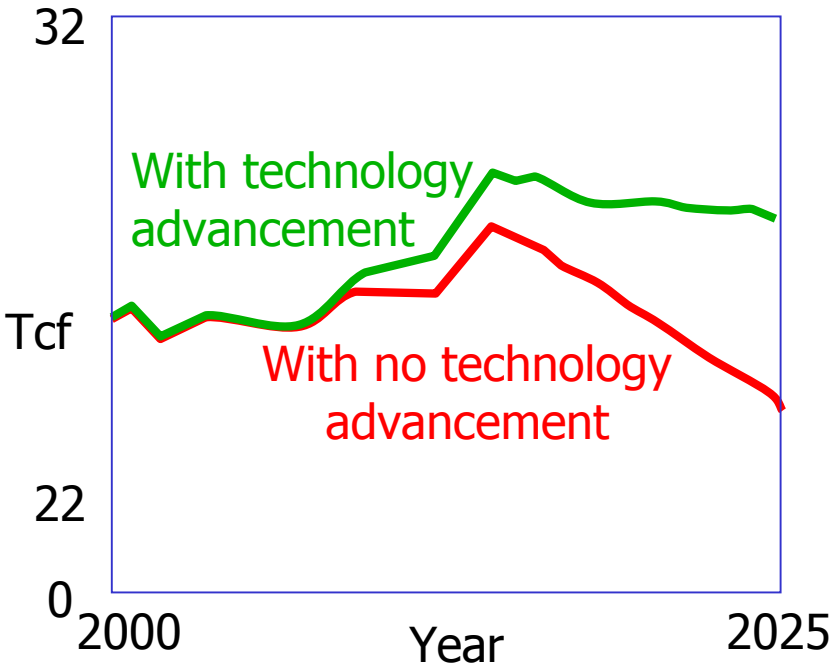
EIA 2006

Summary Comments

- Unconventional resources also to play increasingly important role in world energy supply in coming decades

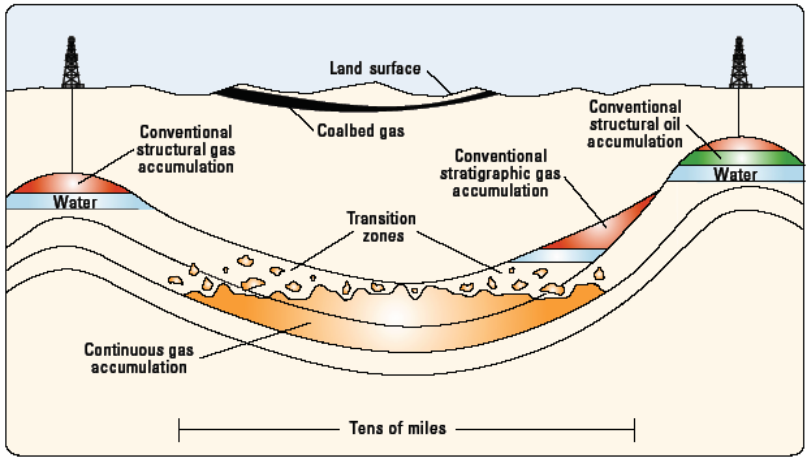
Summary Comments

- Advances in technology key to developing potential of unconventional resources



Summary Comments

- Ability to access resources better, quantify uncertainty important part of technology development

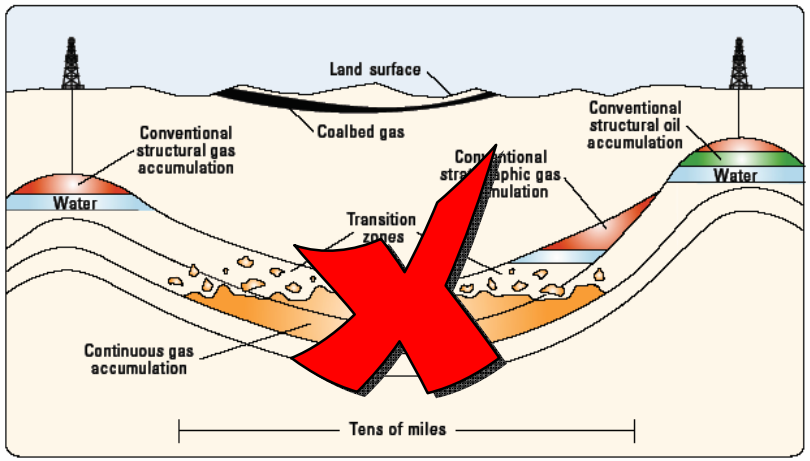


Summary Comments

- USGS methodology for resource assessment good starting point

Summary Comments

- Widespread applicability of continuous gas accumulation model questioned



Summary Comments

- Final modified model to be applied in North America, other continents to identify broad potential, specific target areas

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