Charles A. Sternbach

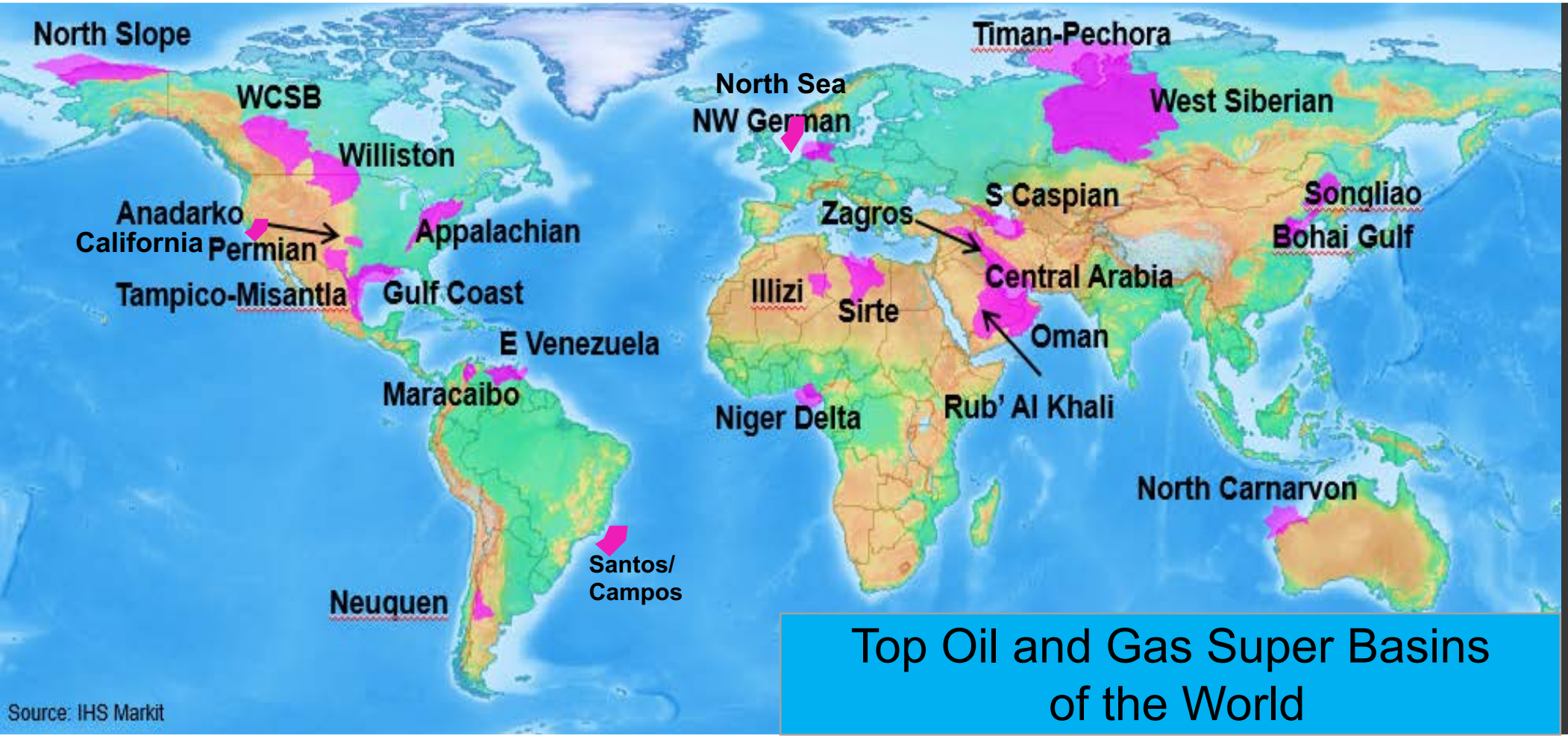
President Star Creek Energy, AAPG Past President 2017-18
And Adjunct Professor University of Houston

Exploration Creativity in the Golden Age of Super Basins -Anticipatory Insights and AAPG Initiatives

AAPG

Top Super Basins-Lessons for all basins

Estimated Technically Recoverable – 860 Bboe



Top Oil and Gas Super Basins of the World

Top global "Super Basins"

Cumulative production and remaining oil and gas both > = 5 billion boe

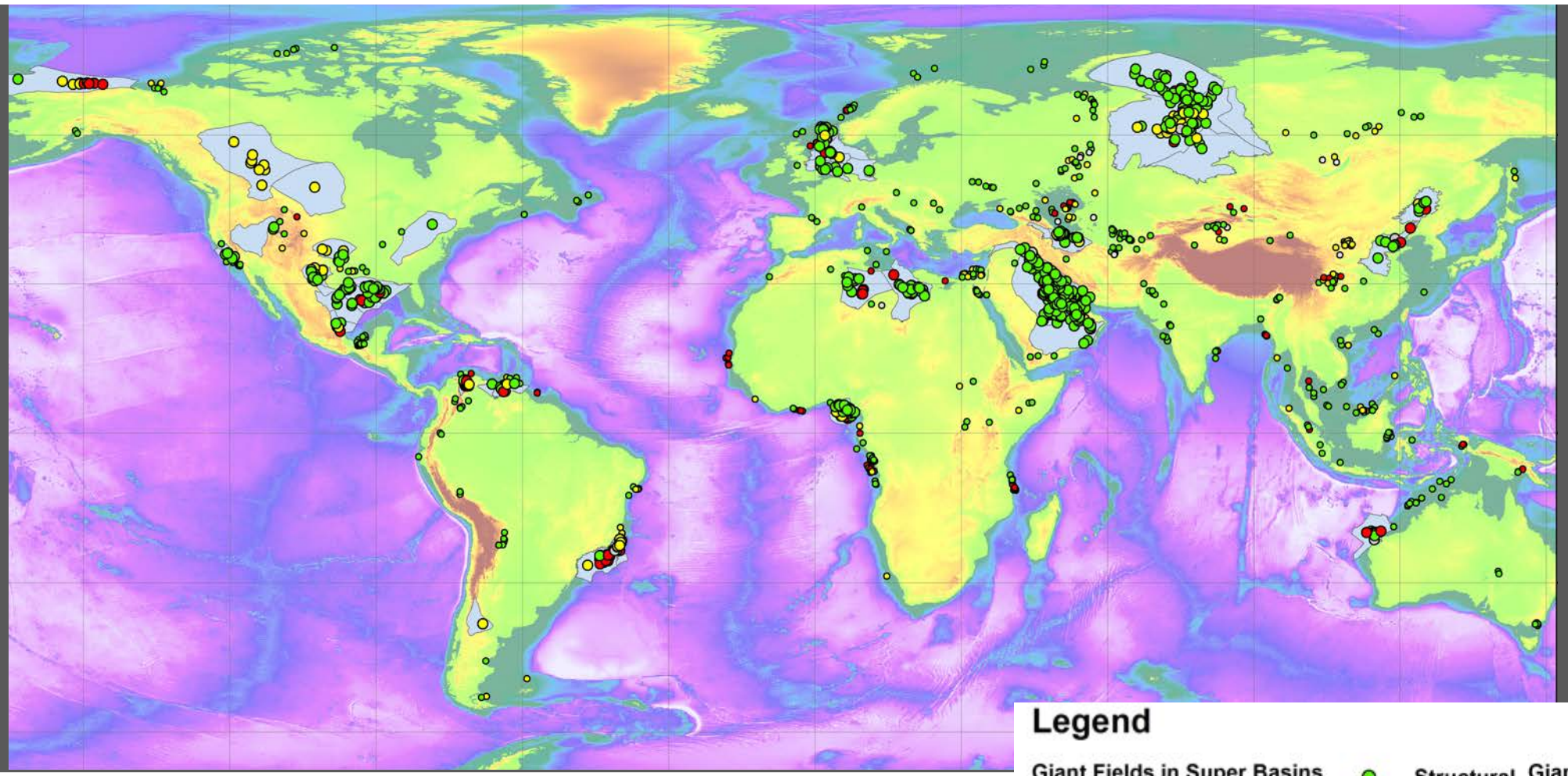
Multiple source rocks / petroleum systems

Infrastructure, services, ecosystems and supply chains

Special Thanks to Bob Fryklund, Pete Stark, IHS

Source: IHSMarkit, *Super Basins – The basins that keep on giving, Sept. 2016.* Leta K. Smith, Pete Stark, Bob Fryklund

Giant Fields by Trap Type and Super Basins



60% of giant fields occur in 5% of the petroleum basins

There are about 1,000 giant fields and just under 1,000 petroleum bearing basins.

How can geoscience attributes like structural setting and source, timing, reservoir, and seal architectures anticipate future energy?

Special Thanks to Lei Sun, and Paul Mann, U of H

Legend

Giant Fields in Super Basins			Giant Fields		
Combination	Structural		Combination	Structural	
Stratigraphic	Unknown		Stratigraphic	Unknown	
				Super Basins	

Why Study Global Super Basins?

“I suggest that the best geologist has seen the most rocks.”

— Herbert Harold Read (Imperial College)

Inaugural AAPG Global Super Basin Leadership Conference

March 2018 Houston

Onshore

- Permian
- Chicontepec Tampico Misantla, Mexico
- Neuquén Basin, Argentina
- GOM onshore
- Western Canada
- Williston Basin
- Appalachian Basin
- Middle East
- West Siberia
- Anadarko Basin

Offshore and Hybrid

- GOM Deepwater
- Brazil Pre Salt
- Norwegian North Sea
- North Sea Rift
- Alaska N. Slope
- North Africa
- Mexico Sur Este

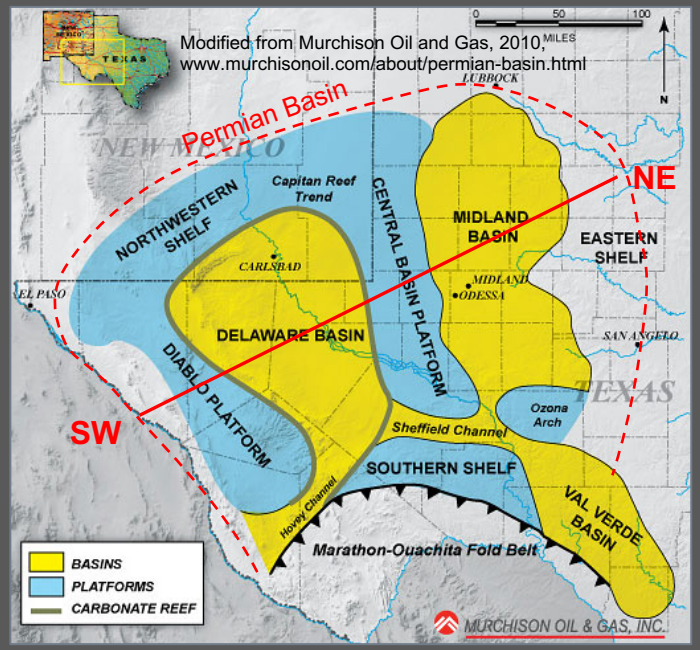
Global Experts on the Largest Basins

Who are the future global experts?

AAPG Super Basin Initiative:

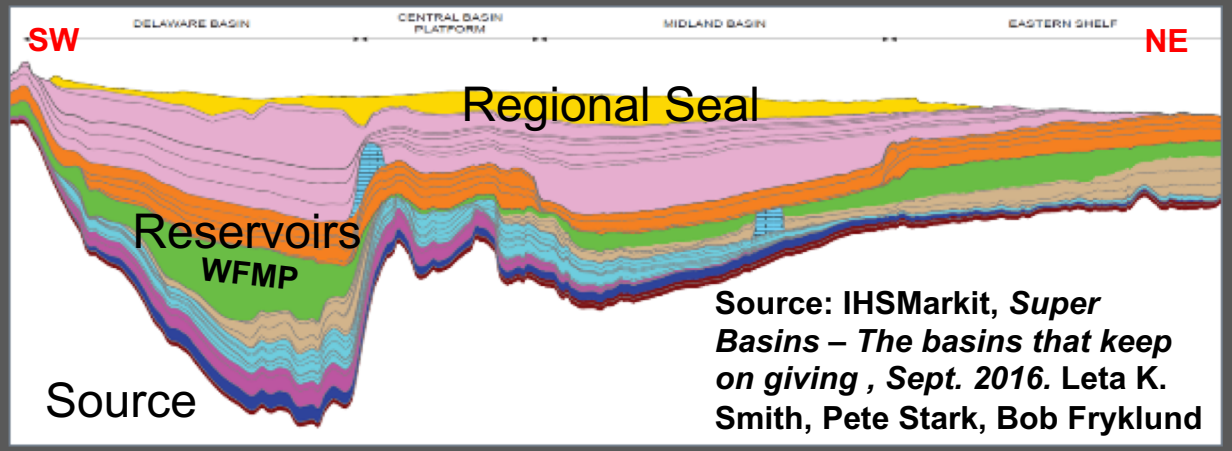
- Architecture: at least one (or more) major petroleum systems (preferably low in stratigraphic section, basin fill and clinoforms, regional seal
- Think 3D: volumetric richness (many stacked targets like Permian, California, Anadarko vs one target plays like Appalachians or Williston); maps and cross sections helpful
- Think 4D (time): critical moment of charge, structural uplifts
- Value Innovation: Progressing from technical mastery to commercial mastery increasing value and reducing costs (supply chain mastery)
- Compare and contrast commonalities for actionable insights for quantum “leap frog” gains

Permian Basin –“super basin” prototype architecture



What is a Super-basin?

- **More than 5 billion Boe cumulative production**
- **More than 5 billion Boe remaining production**
- **Multiple source rocks – petroleum systems**
- **An assemblage of conventional, shale (continuous) and tight-non-continuous reservoirs**
- **Stacked pays**
- **Established infrastructure – access to markets**
- **Established service sector & supply chains**

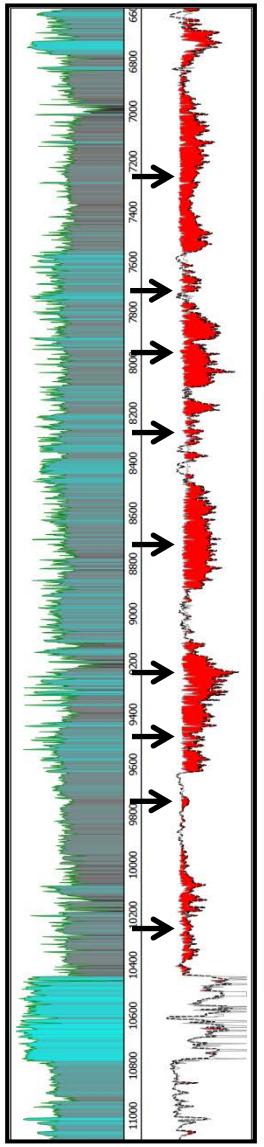


Source: IHSMarkit, *Super Basins – The basins that keep on giving , Sept. 2016.* Leta K. Smith, Pete Stark, Bob Fryklund

1) Four source zones; three low in pile (Simpson, Woodford, Barnett)
2) Maturation due to Permian subsidence for most of basin
3) Late salt seal reduces leakage; Permo-Triassic generation products preserved

THE TWO LARGEST U.S. OIL SHALE PLAYS Commercial efficiency of tall pay columns

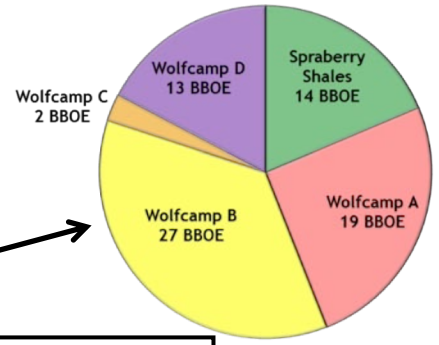
Delaware Basin	Midland Basin
Avalon Shale	Clear Fork
1st Bone Spring	
2nd Bone Spring	M. Spraberry
	JoMill
3rd Bone Spring	L. Spraberry
Wolfcamp A / X-Y Sands	Wolfcamp A
Wolfcamp B	Wolfcamp B
Wolfcamp D	Wolfcamp D "Cline"



Source: PXD

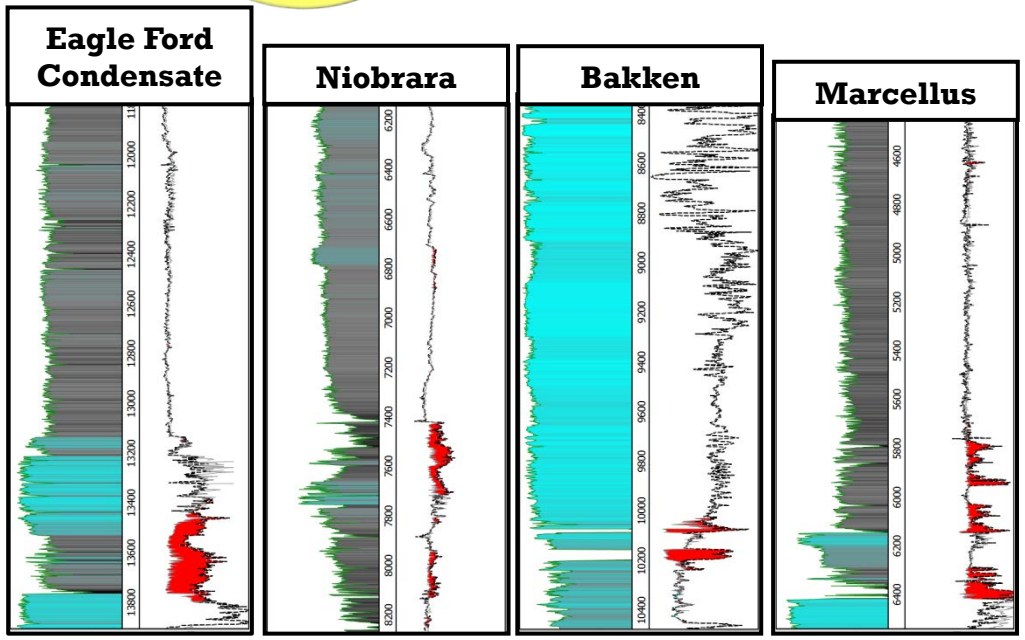
Midland Basin

~75 BBOE recoverable resource potential



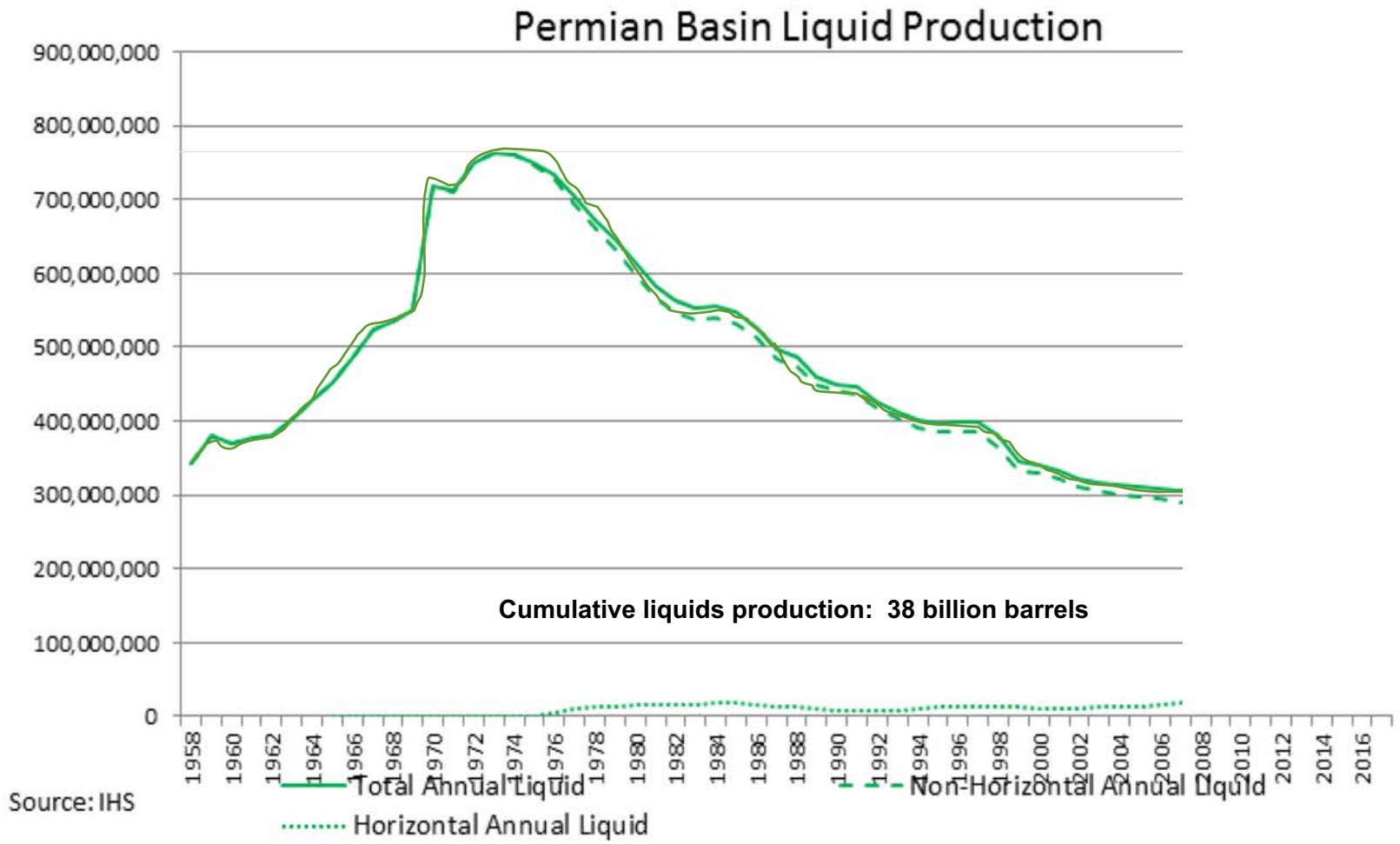
Delaware Basin

Estimates indicate similar resource potential to the Midland Basin



Scott Sheffield, 2018

Onshore Unconventional Analog Super Basin



Source: IHS

Permian Basin Prototype

- **Hydraulic fracturing horizontal wells** of unconventional shale
- **Enhanced seismic imaging** conventional targets previously unrecognizable
- **How do new peaks happen?**

Taking Geoscience to Greater Heights

Permian Basin Innovation: Track Record, Why it happens repeatedly, and toolkit

Critical Factors:

- Community
- Mineral Access
- Information Access
- Infrastructure
- Service Sector
- Regulatory support

Innovative toolkit:

- Associating
- Questioning
- Observing
- Networking
- Experimenting

3D Seismic EOR

Hydraulic Fracturing

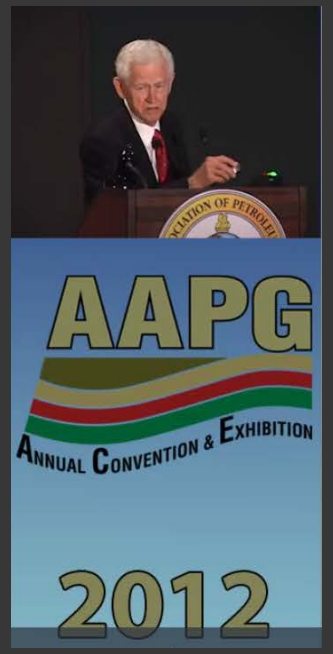
Horizontal Drilling

Horizontal Drilling and Frac

Residual Oil Zone (ROZ)?
Horizontal Drilling + Frac + EOR?
???

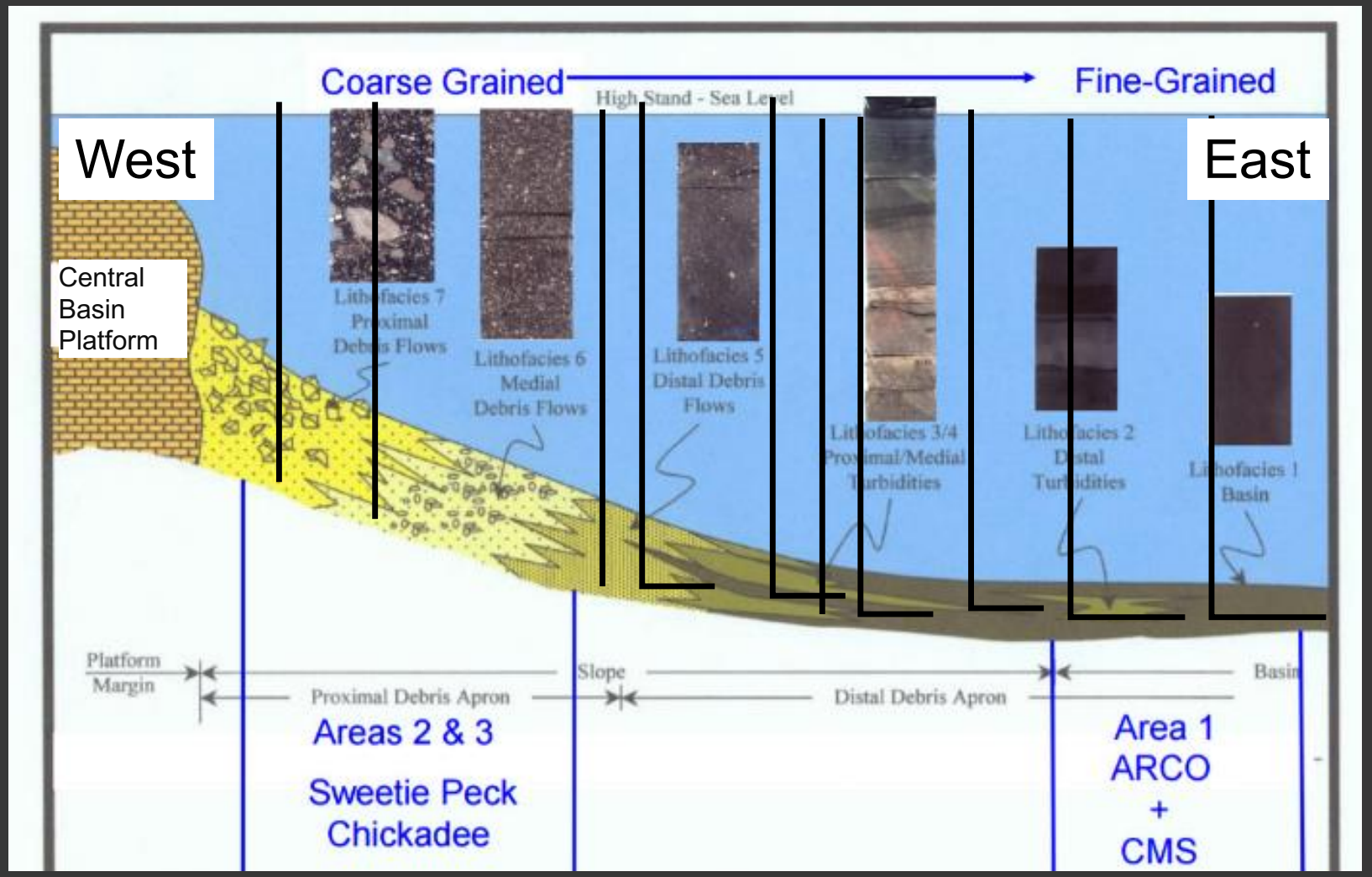
The Innovators DNA: Mastering the five skills of disruptive Innovators
Jeff Dyer, et al, 2011

Geoscience Matters—Wolfcamp, Midland Basin

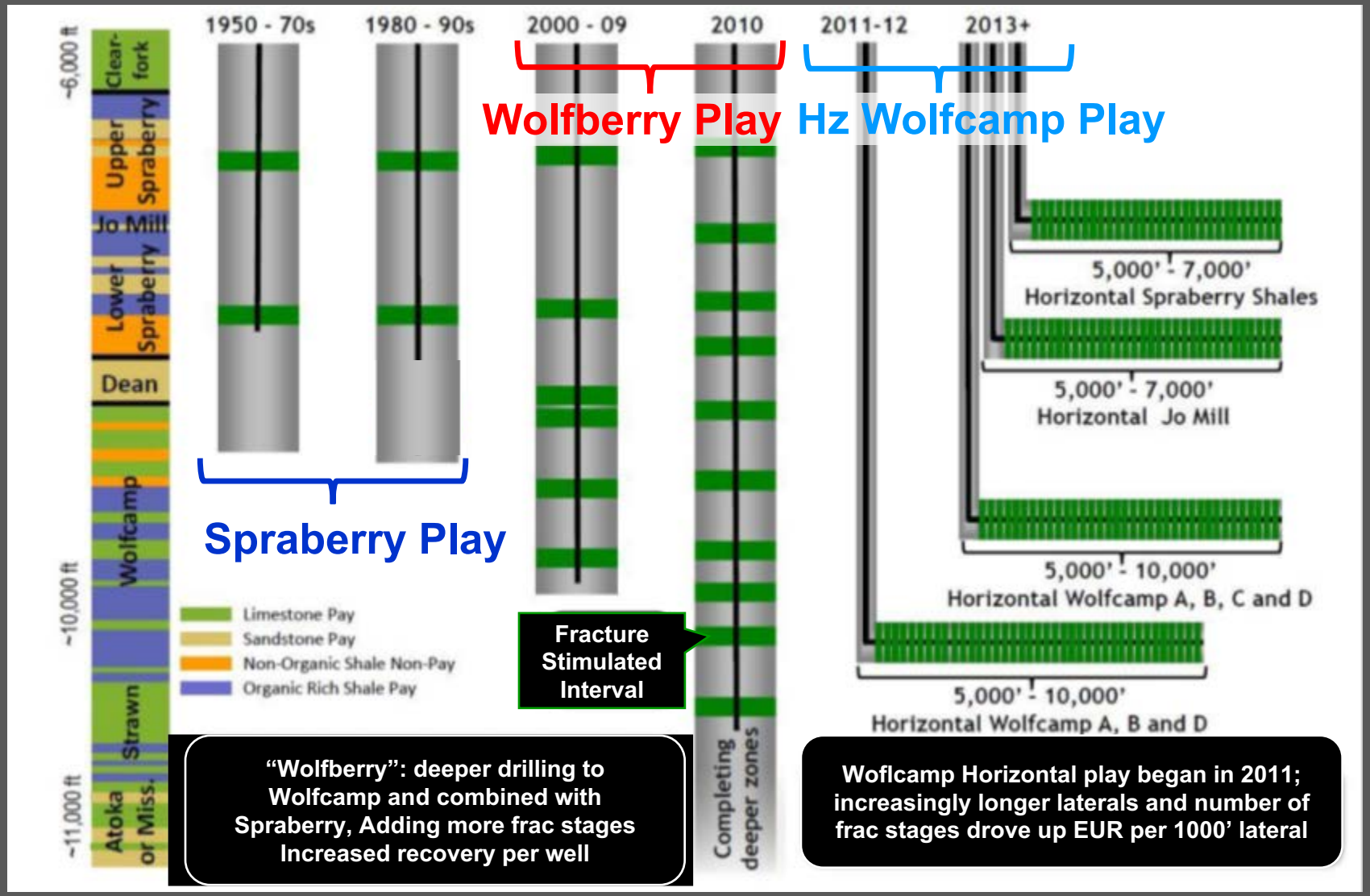


Jim Henry

DT #5, ACE
Long Beach, 2012

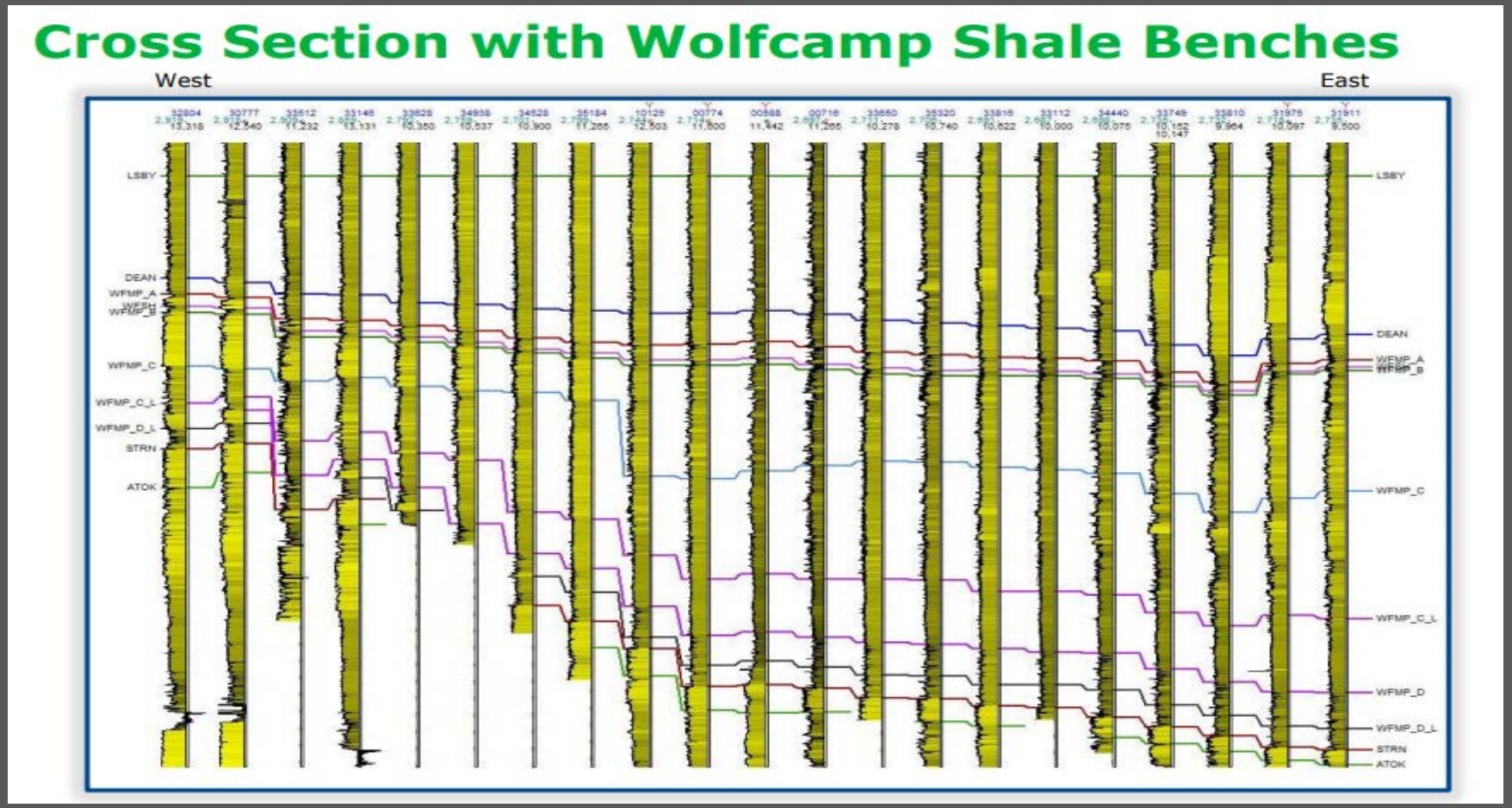


Spraberry to Wolfberry to Horizontal Wolfcamp



Modified from Pioneer Natural Resources (2013) and Blomquist, 2016

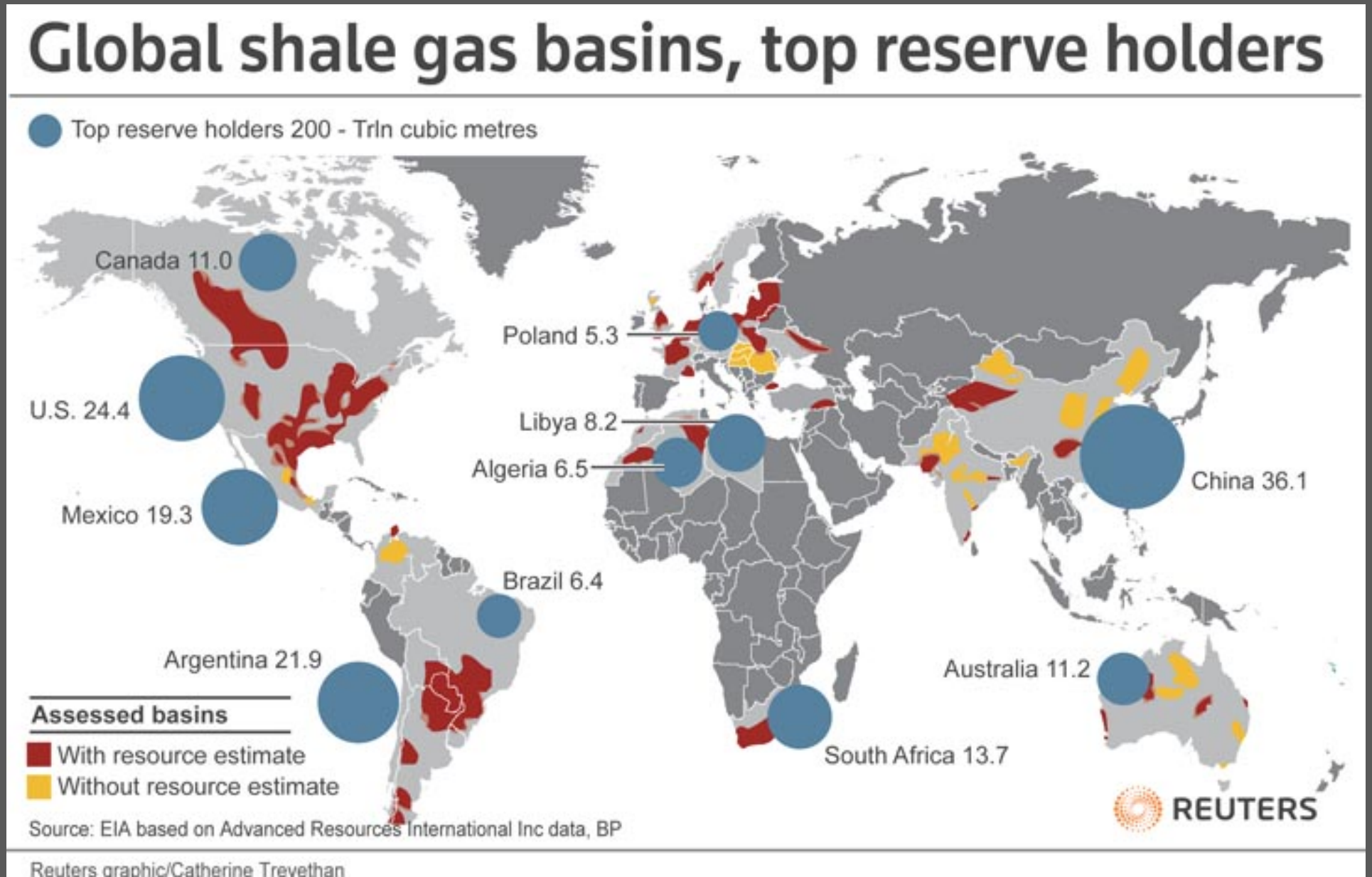
Internal Architecture of Midland Basin Fill



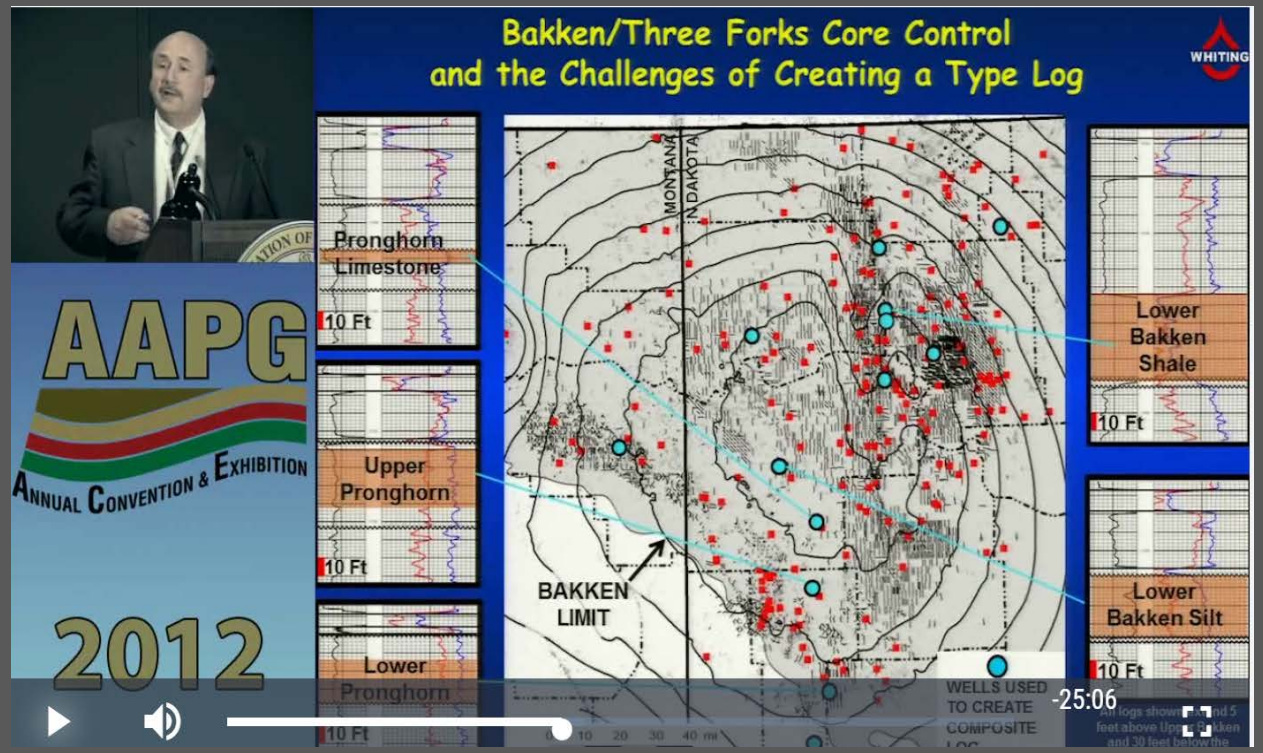
Peter Blomquist, IHS, 2018 Midland Basin, Search and Discovery

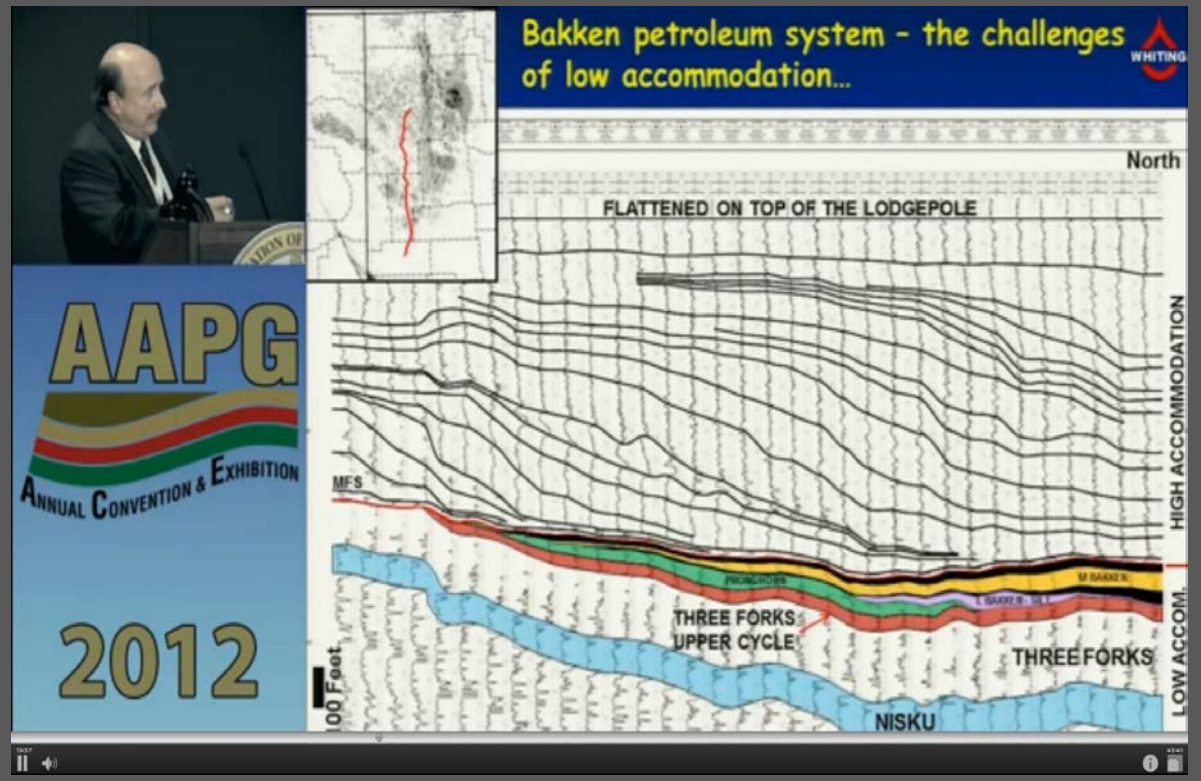
Refer also to Mary Van Der Loop, 2017 for Delaware Basin architecture, Search and Discovery DPA Playmaker video)

North America selected basin architecture



Bakken, Williston Basin



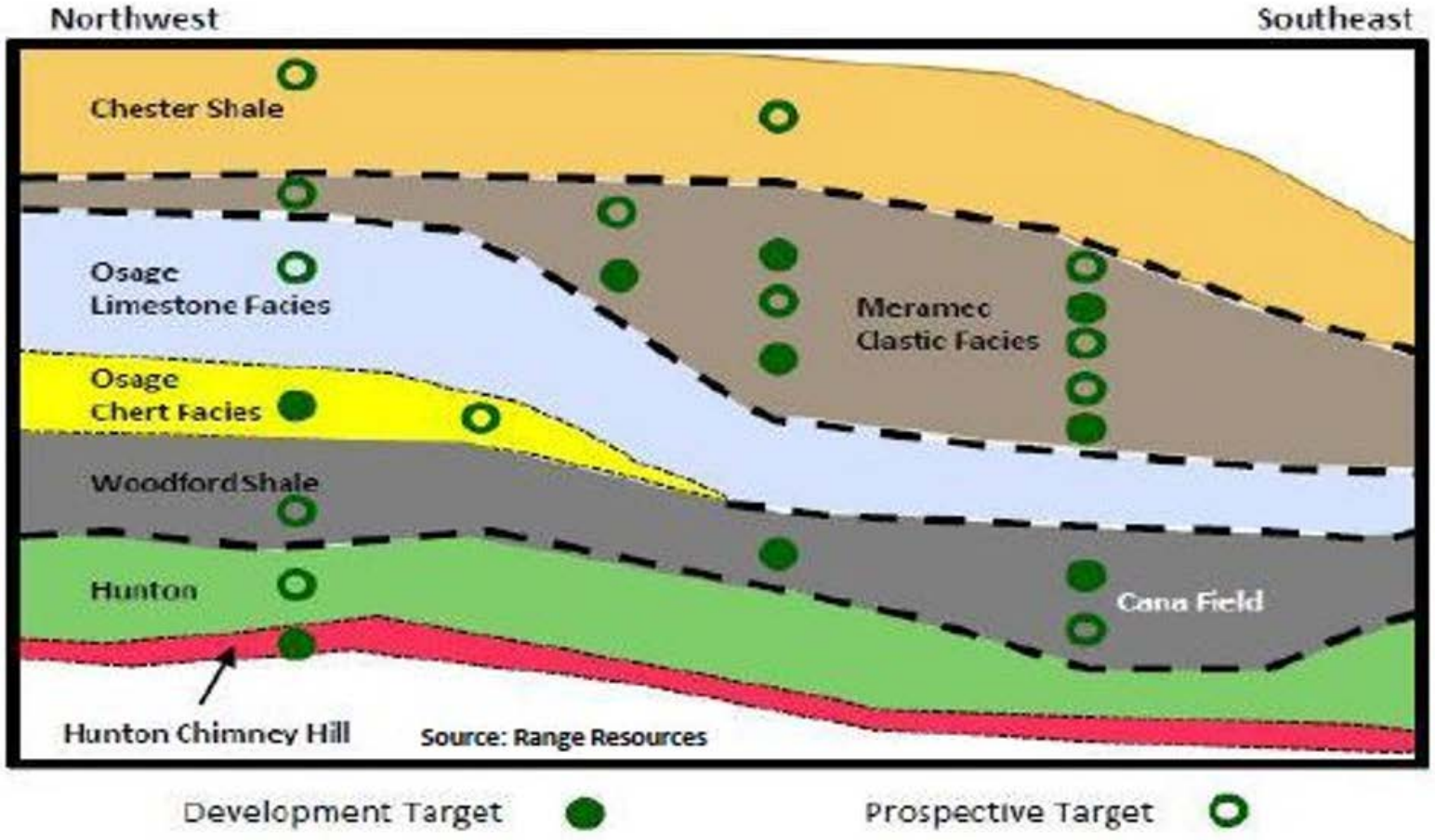


Orion Skinner, Outstanding Explorer,
DT #5, ACE Long Beach 2012

- Open minded to sweet spots factors
- Many benches mean multiple play targets
- Hydraulic Fracturing of Horizontal wells
- Core control key aspect
- Use SEM and core analysis on site
- Lag deposits define key horizons

Anadarko Basin

"Siliceous Is Delicious"—Lindell Bridges

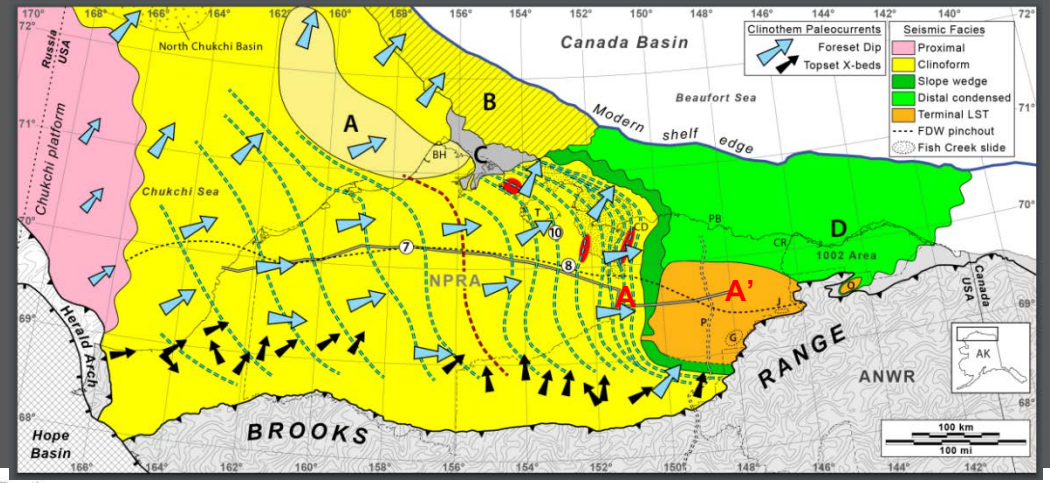


- All of these reservoirs are being developed in the areas commonly referred to as the SCOOP/STACK/MERGE
- The specific facies that is being targeted in the Osage is the chert facies typically developed in the basal Osage section

Stoneburner, 2018

Alaska, North Slope, Nanushuk By Passed Pay Section

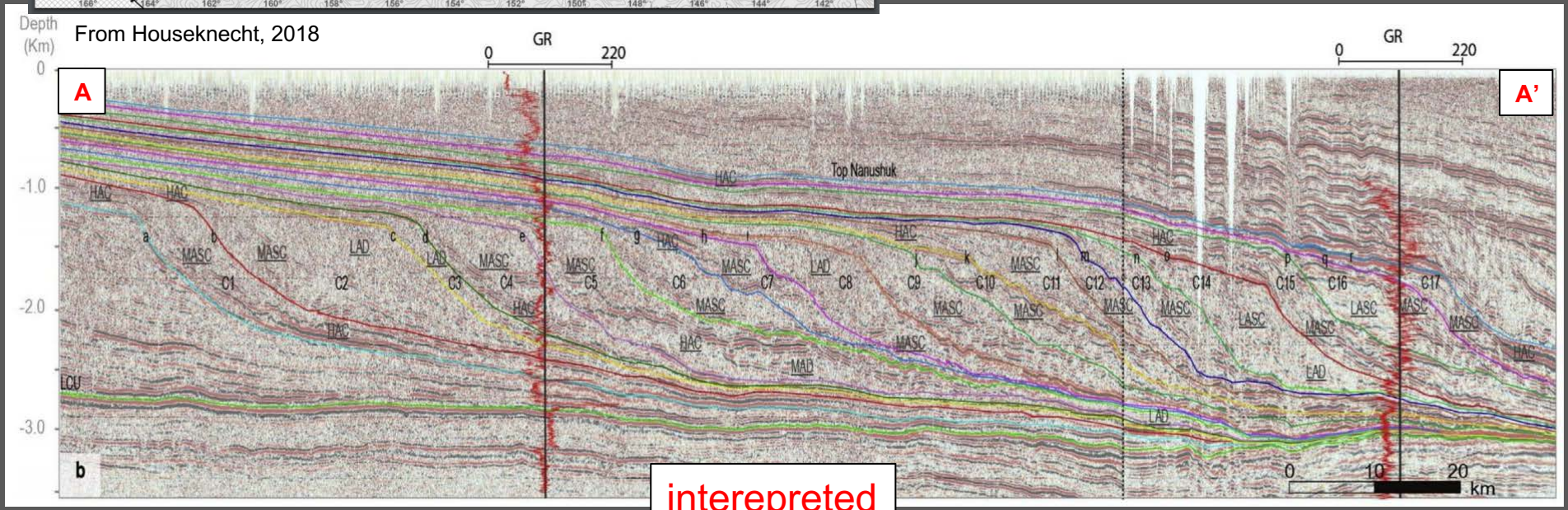
Nanushuk Depositional System: 40-50 Mapable Clinoforms



Clastics shed from ancestral highlands to south and west

Forty-fifty traceable clinoforms, filling basin from west to east:

-Sand-prone topsets
-Muddy slope and sandy turbidites
-Sandy BFF's and condensed shales

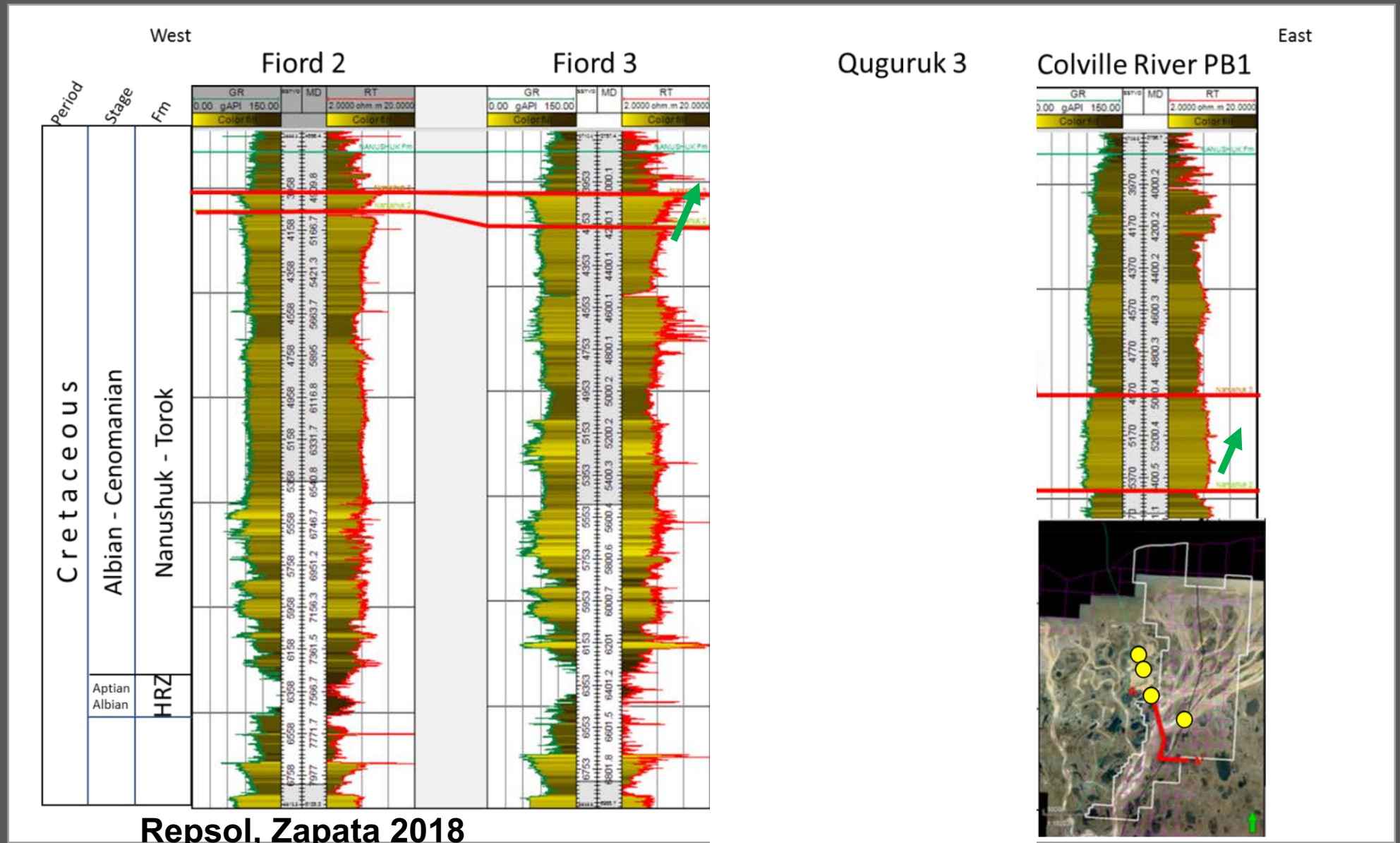


Ramon-Duenas et al, 2018

Repsol, Zapata, 2018

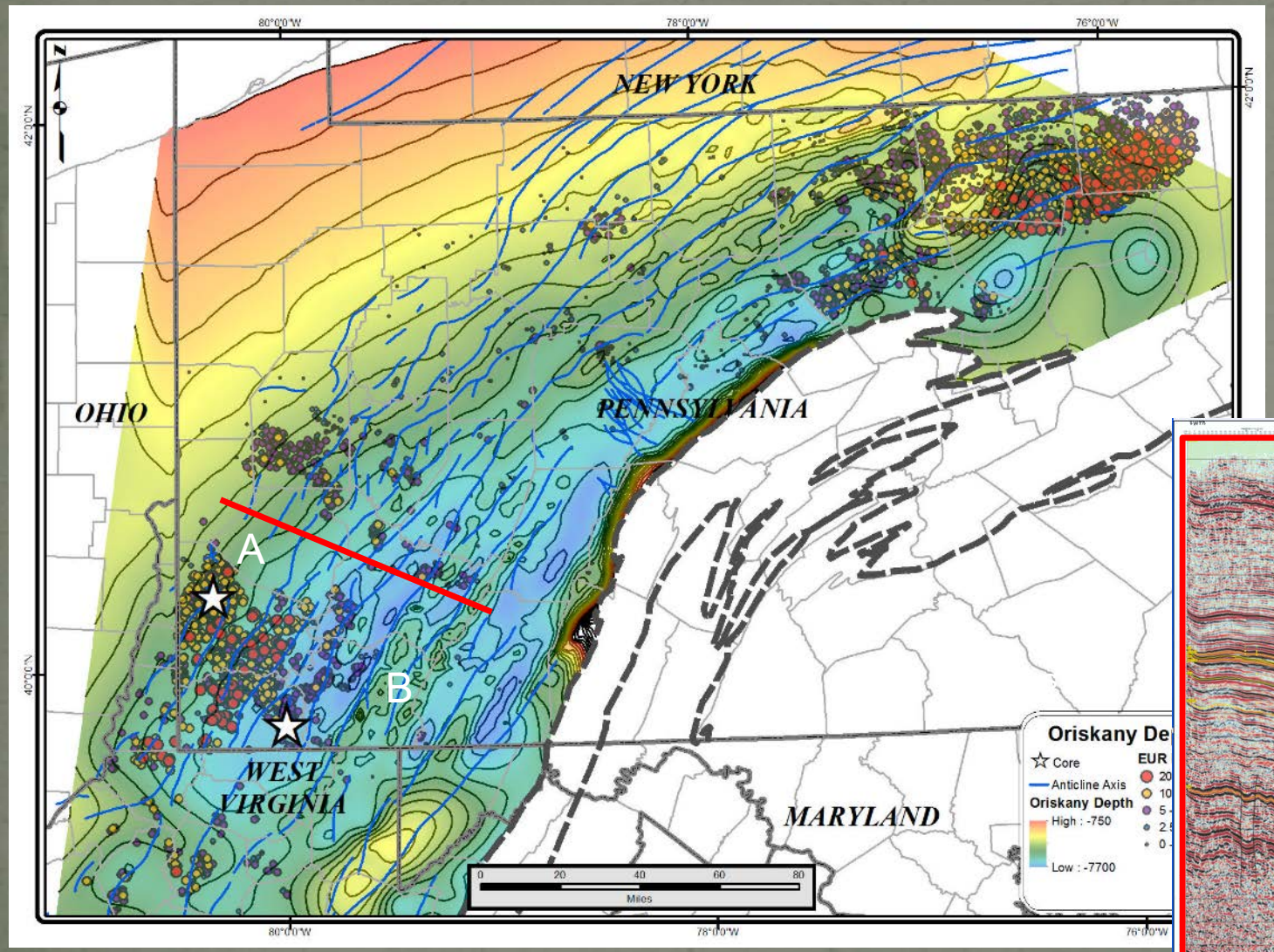
Alaska, North Slope, Nanushuk By Passed Pay Section

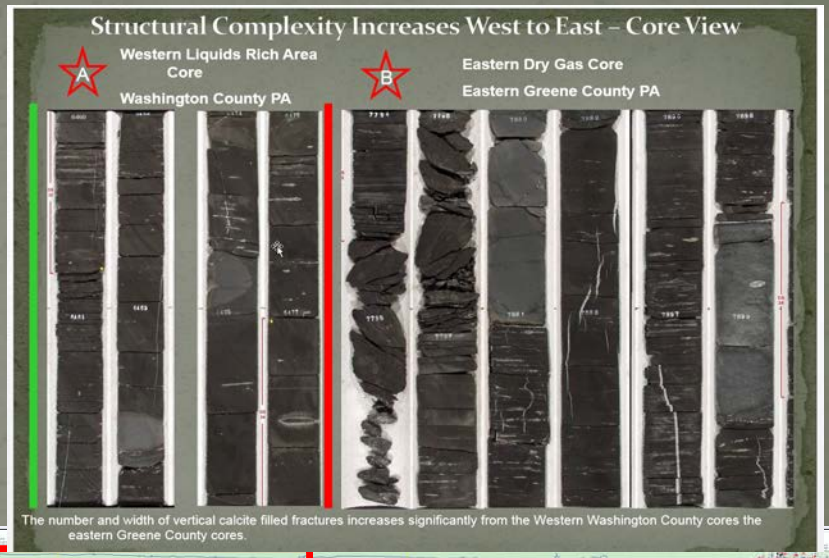
NW | Proximal 1994 | Proximal 1995 | Delta Front 2013 | Distal Pro-Delta 1993 | SE

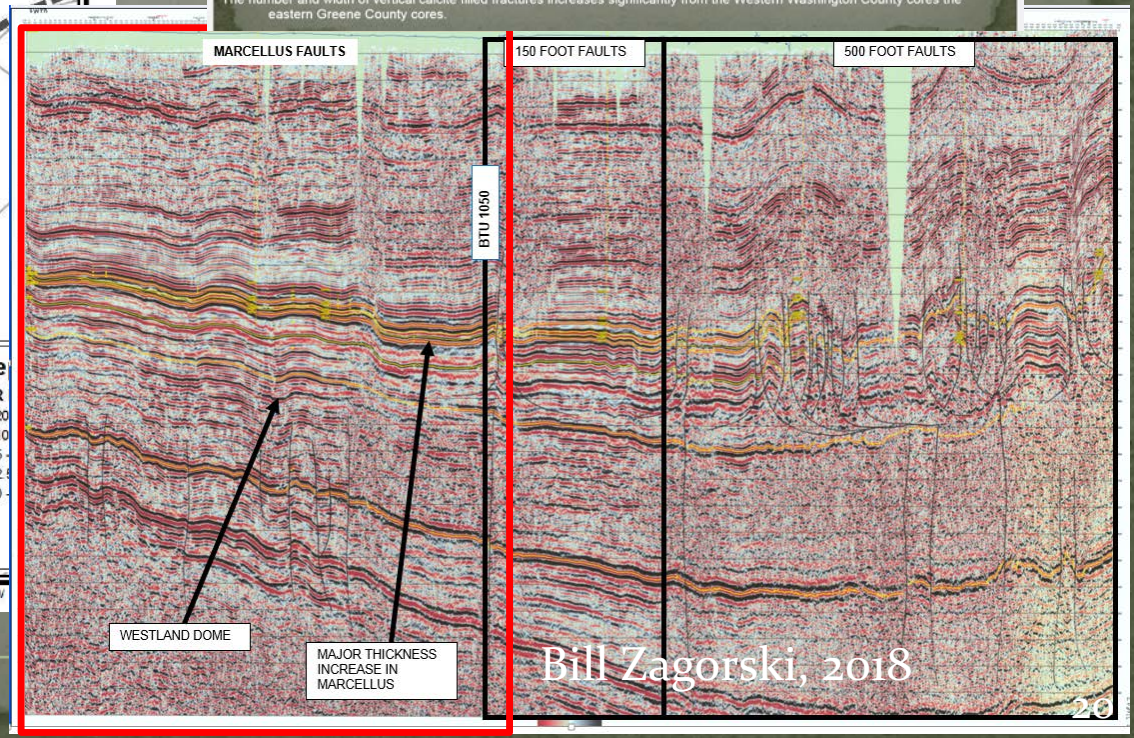


Repsol, Zapata 2018

Appalachian Baisn, Marcellus
Structural Complexity Increases West to East



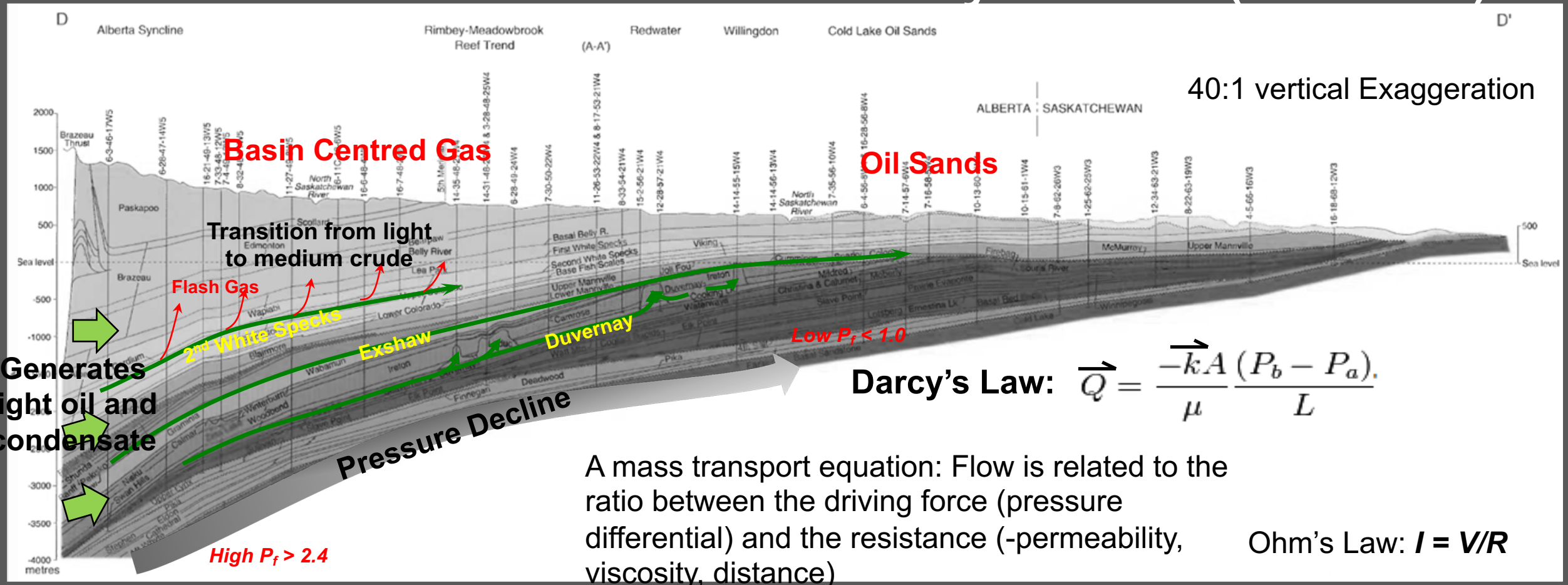




In SW PA the "core" area of the Marcellus is in the western less structurally complex region.

Bill Zagorski, 2018

Western Canada Sedimentary Basin (WCSB)



Mackay 2018

The Great Migration:

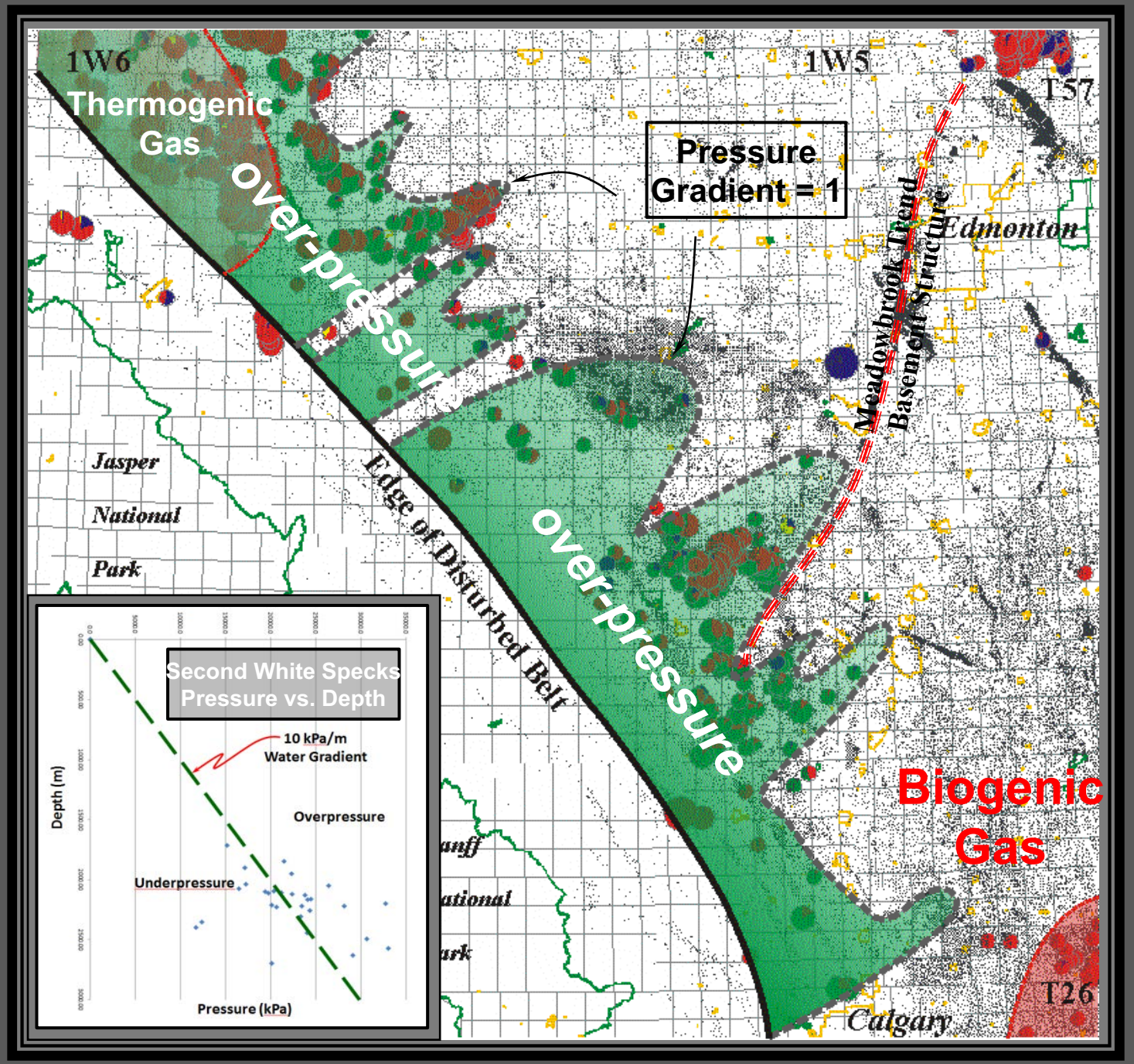
1:1 vertical Exaggeration

West Canada

Pressure Gradient Second White Specks

(source rock for Cardium)

Pressure gradient of one equivalent to hydrostatic pressure



Paul Mackay 2018

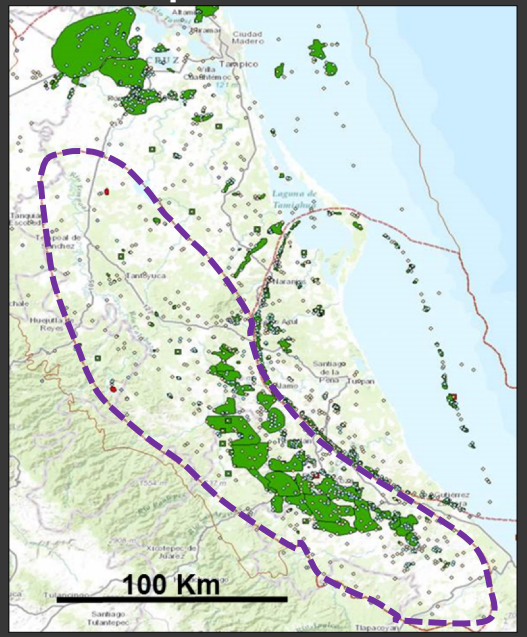
Comparison Of ChicontepecTampico Misantla Basin Mexico with Midland Basin US

Permian basin
Midland sub basin

Alfredo Guzman 2018

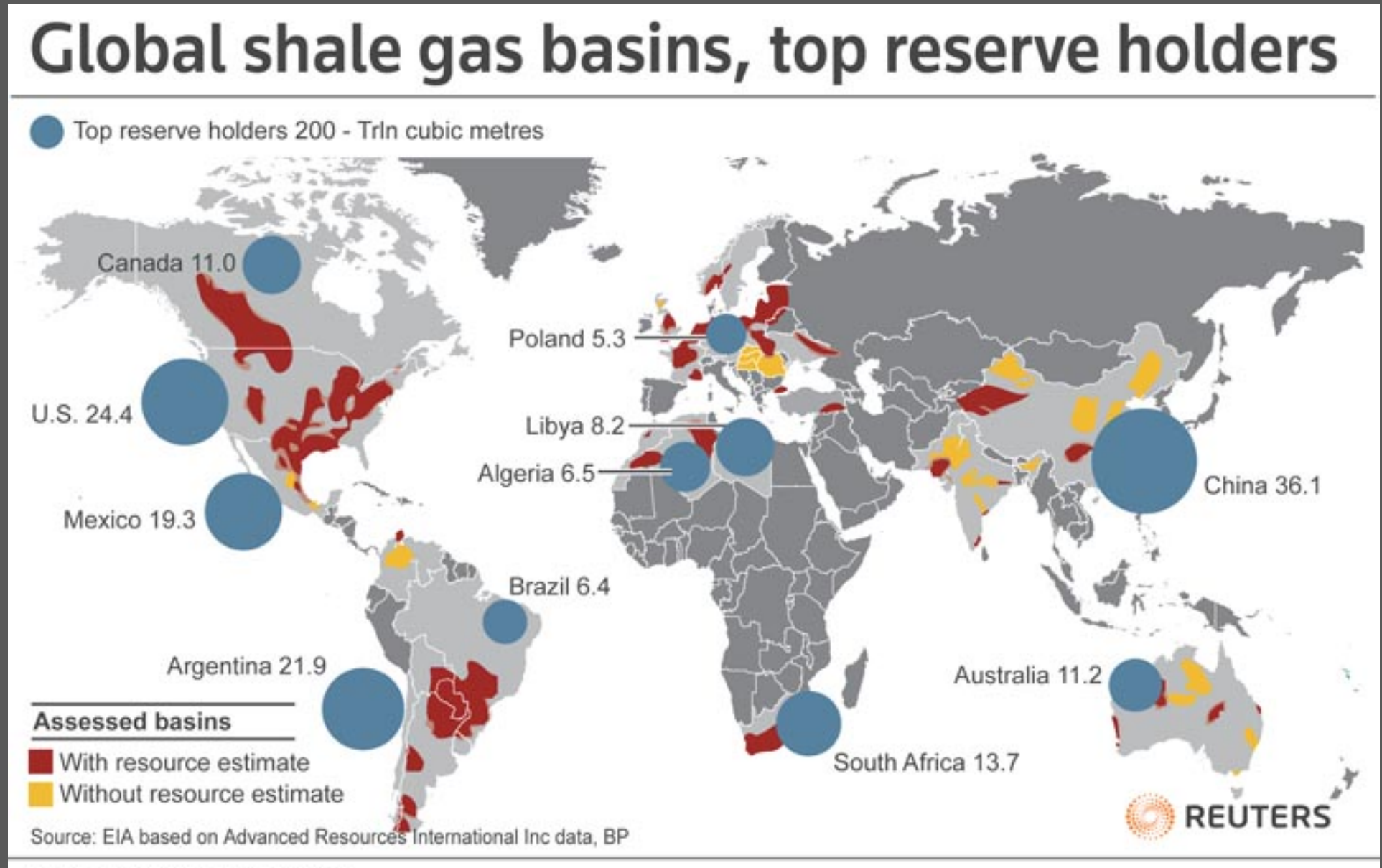
Permian basin	Tampico – Misantla basin
Cum. prdn. 35 Bboe	Cum. prdn. 7 Bboe
OOIP ? Bboe	OOIP 107 Bboe
Recoverable oil 150 Bboe	Recoverable oil 42 Bboe
Production 3 MMbod	Production 0.1 MMbod
Midland sub basin	**Chicontepec sub basin**
Recoverable oil 75 Bboe	Recoverable oil 41 Bboe
Production 1.9 MMboe/d	Production 0.05 MMboe/d
Cum. Prdn. > 2 Bboe	Prdn Acum. < 0.3 Bboe.
Total wells > 500,000	Total wells < 3,000
EIA / Pioneer	Pemex / CNH

Tampico – Misantla basin
Chicontepec sub basin

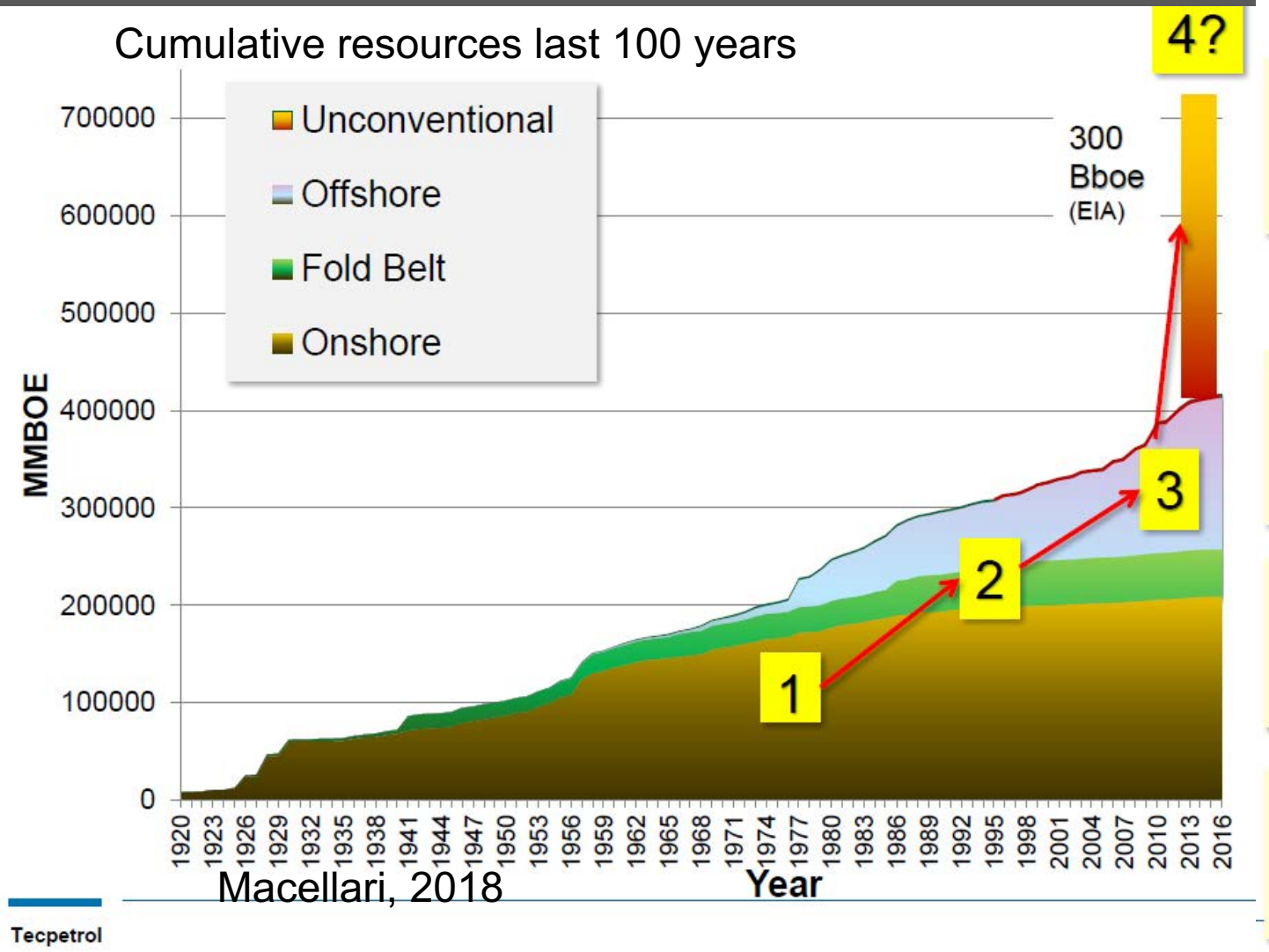


It is very important to note that the 41 Bboe just refer to the Tertiary sub basin and do not consider the recoverable tight oil resources in the Mesozoic.

South America, Africa and other global architectures

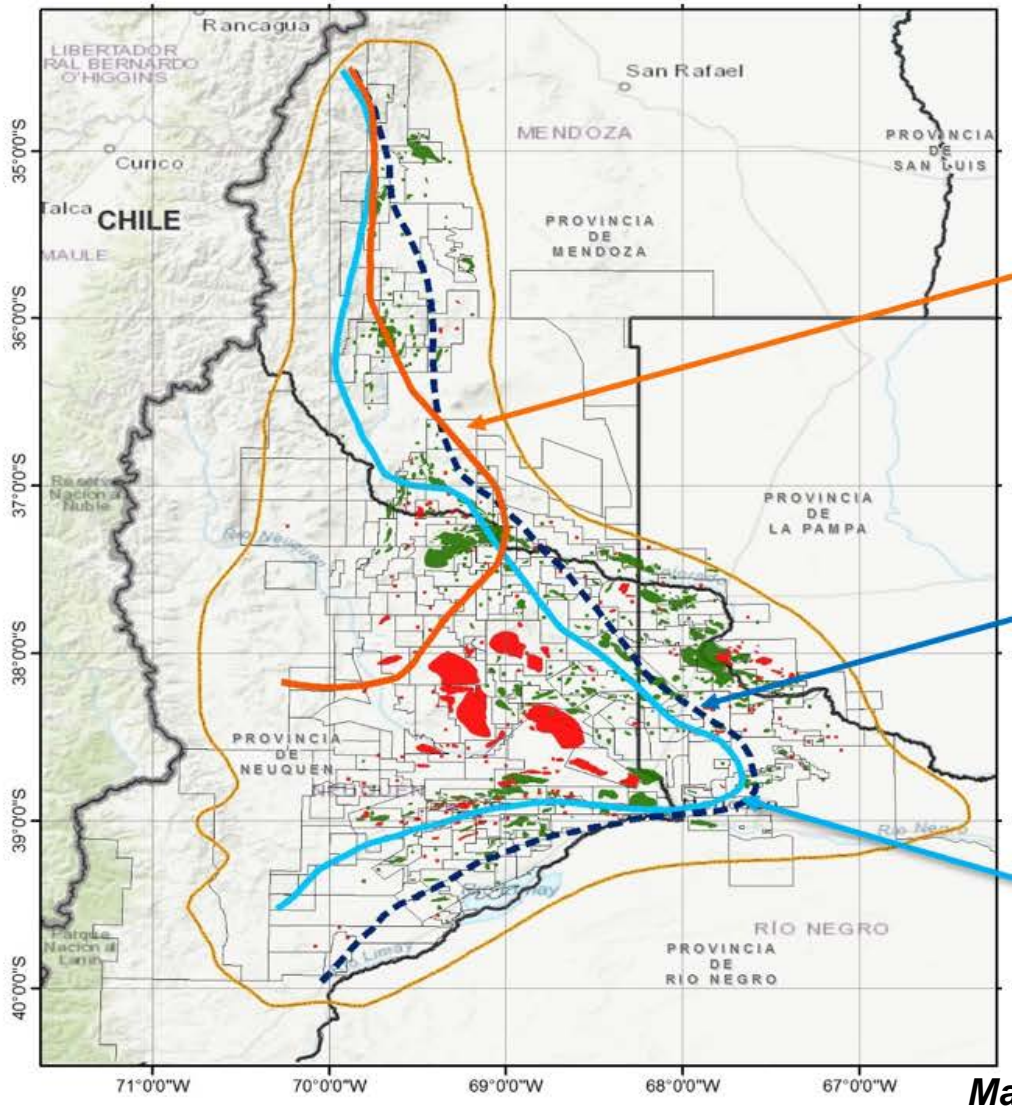


South American Basins



Macellari, 2018

Neuquen Basin, Argentina



AGRIO

Organic-rich shales.

Thickness: 50 to 400 m

TOC: 2-5%

Kerogen Type: II to II-III

Source Quality/Maturity: mostly oil-prone

VACA MUERTA

Organic-rich shale and marls.

Thickness: 25 to 700 m

TOC: 3-17%

Kerogen Type: I/II; locally restricted type II-S facies

LOS MOLLES

Organic-rich shales - initial sag stage of the basin.

Thickness: 100 to 800 m.

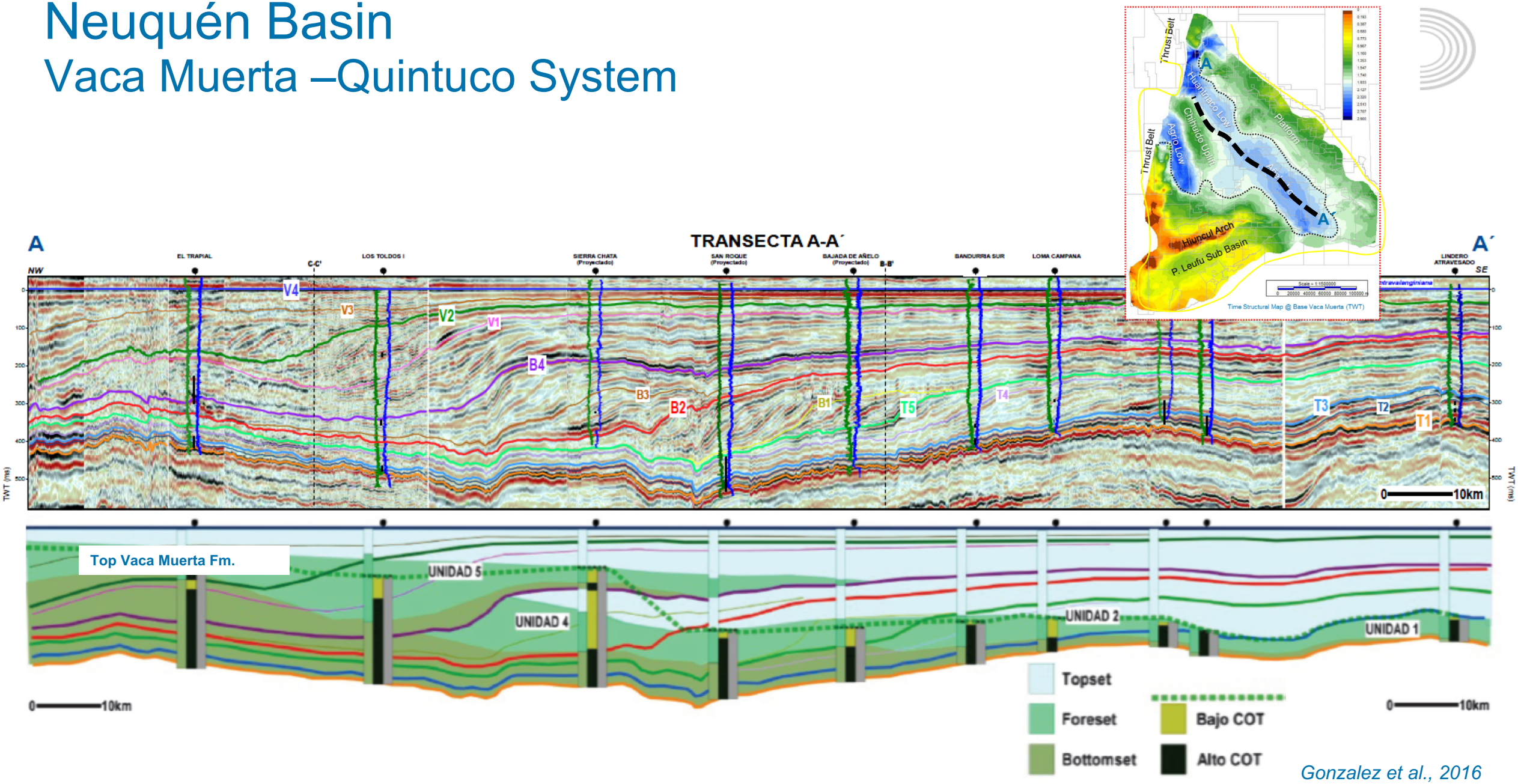
TOC: 1-5%

Kerogen Type: II-III.

Source Quality/Maturity: mixed for oil and gas.

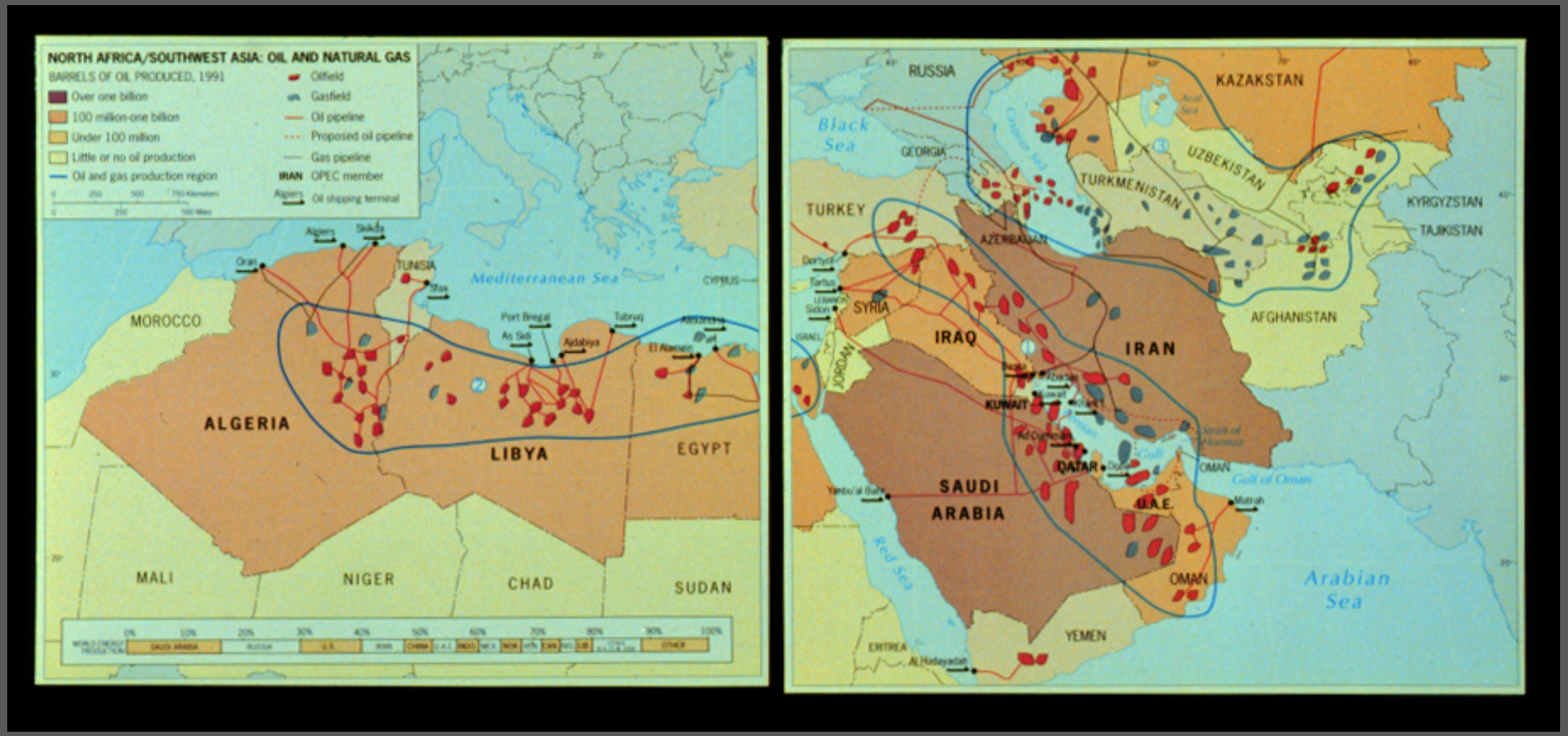
Macellari 2018

Neuquén Basin
Vaca Muerta –Quintuco System



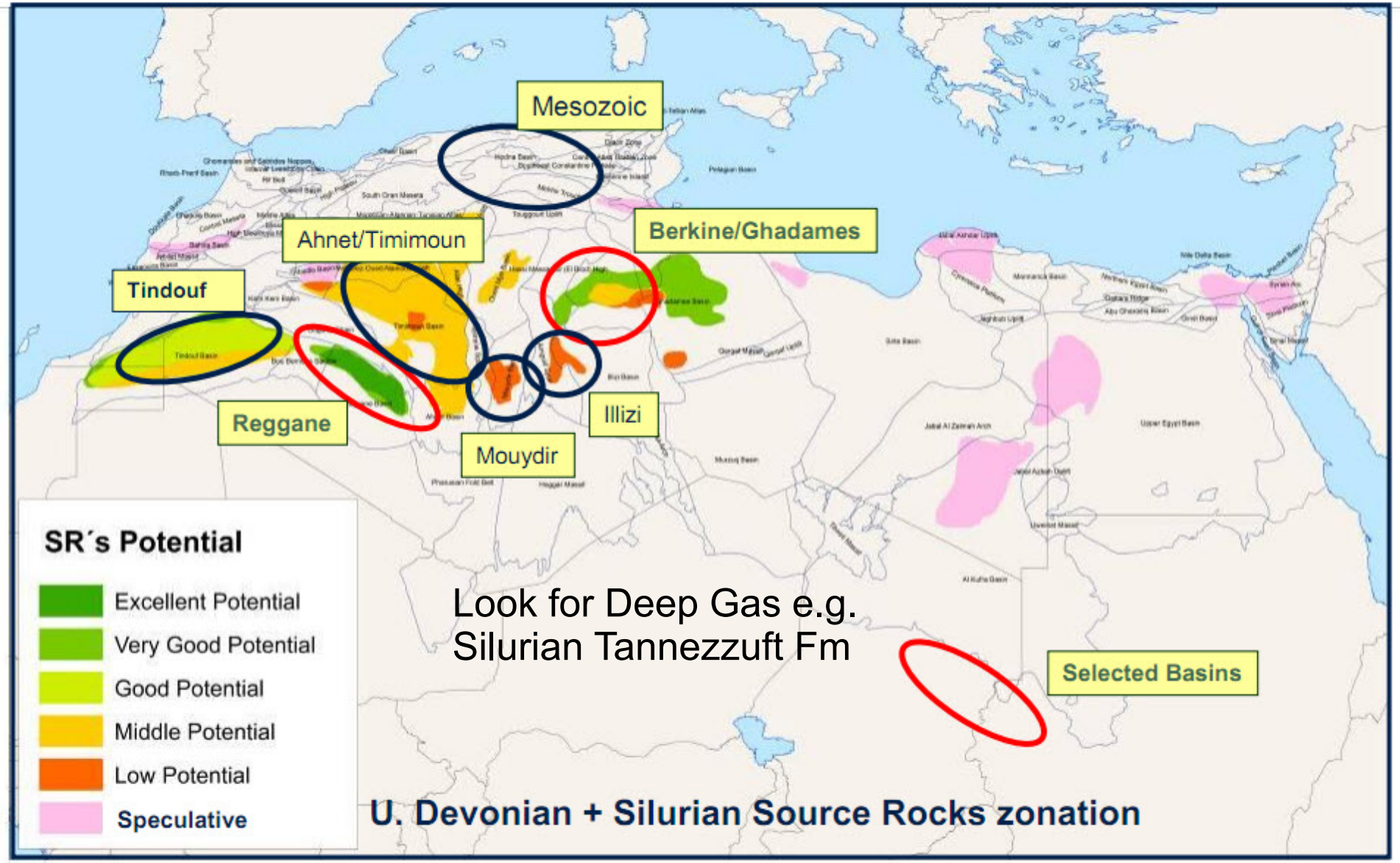
Gonzalez et al., 2016

North Africa and Middle East



North Africa

Algeria Shale Gas Potential



020610

South Africa

USGS Sub-Saharan P50 assessments

In inland Karoo

- 23.5 TCF shale gas in Karoo Basin (Whitehill-Collingham and Prince Albert sources) **Permian Age (and Devonian source rocks), Permian Basin 2.0??**
- 8 TCF CBM outside strict Karoo (foreland) Basin (Botswana-Zambia-etc.)

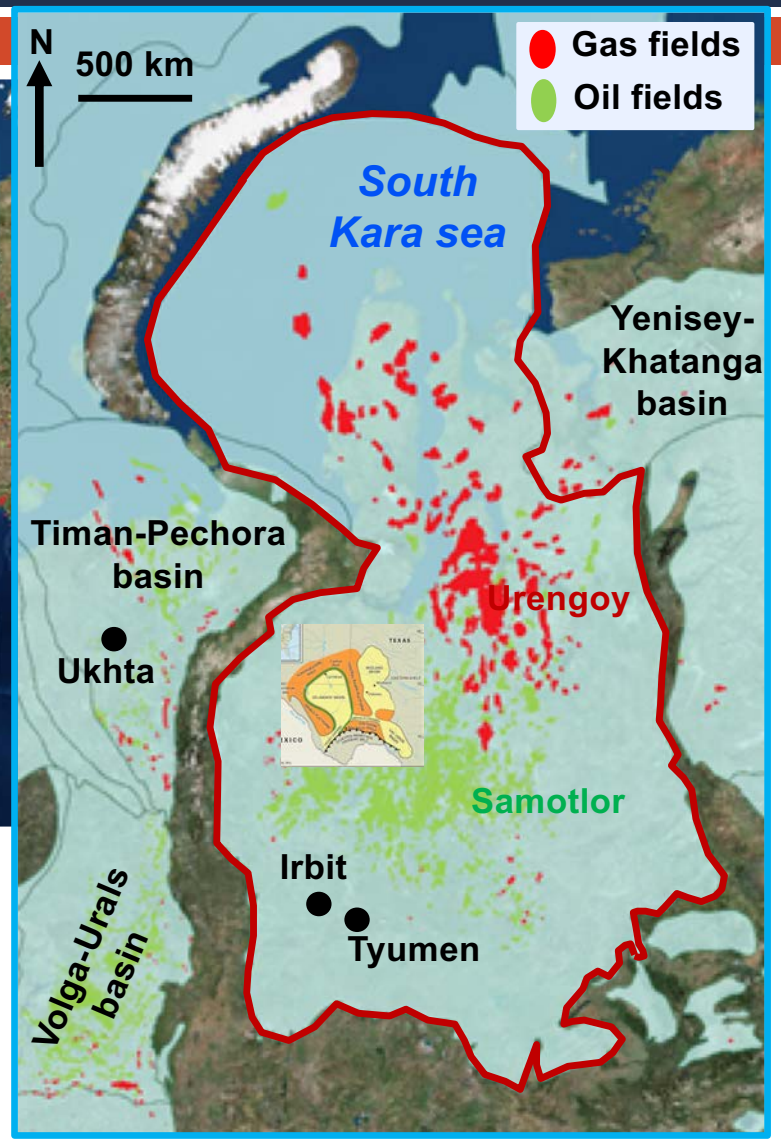
Jim Granath et al, 2017

Other Potential Basins of interest include intracratonic sags like The Congo Basin

Upper Jurassic Stanleyville Group and Lower Cretaceous Loia Group have up to 25% TOC and 900mg HC/gCorg Type 1 and Type 1 & 2 kerogens, respectively;

Sachse et al 2012 AAPG Bulletin

West Siberian Super Basin

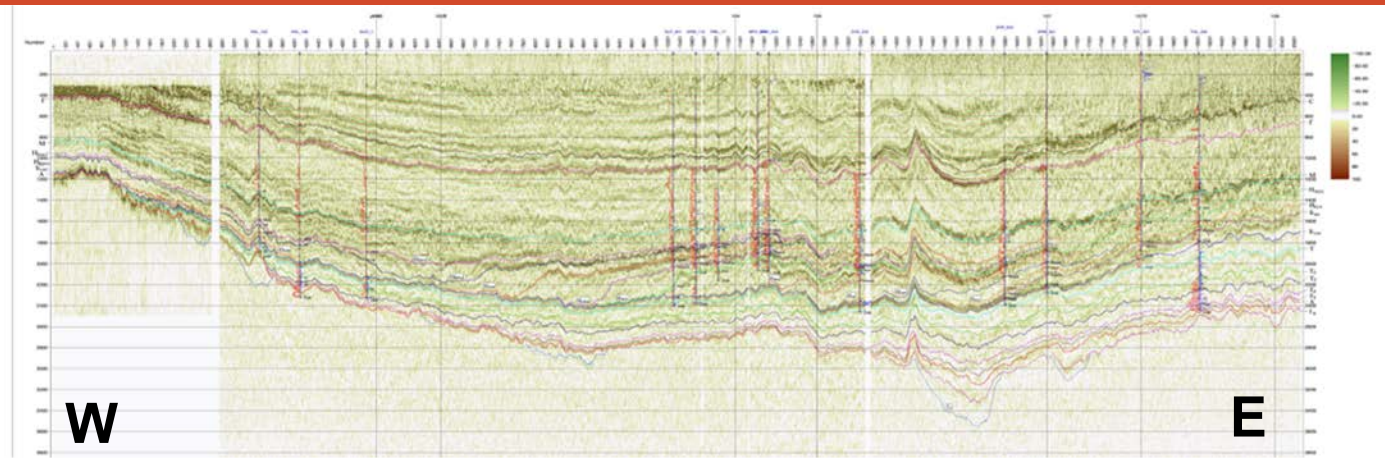


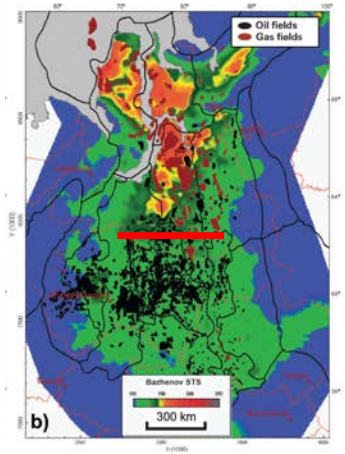
Data and maps from IHS as of January, 2018

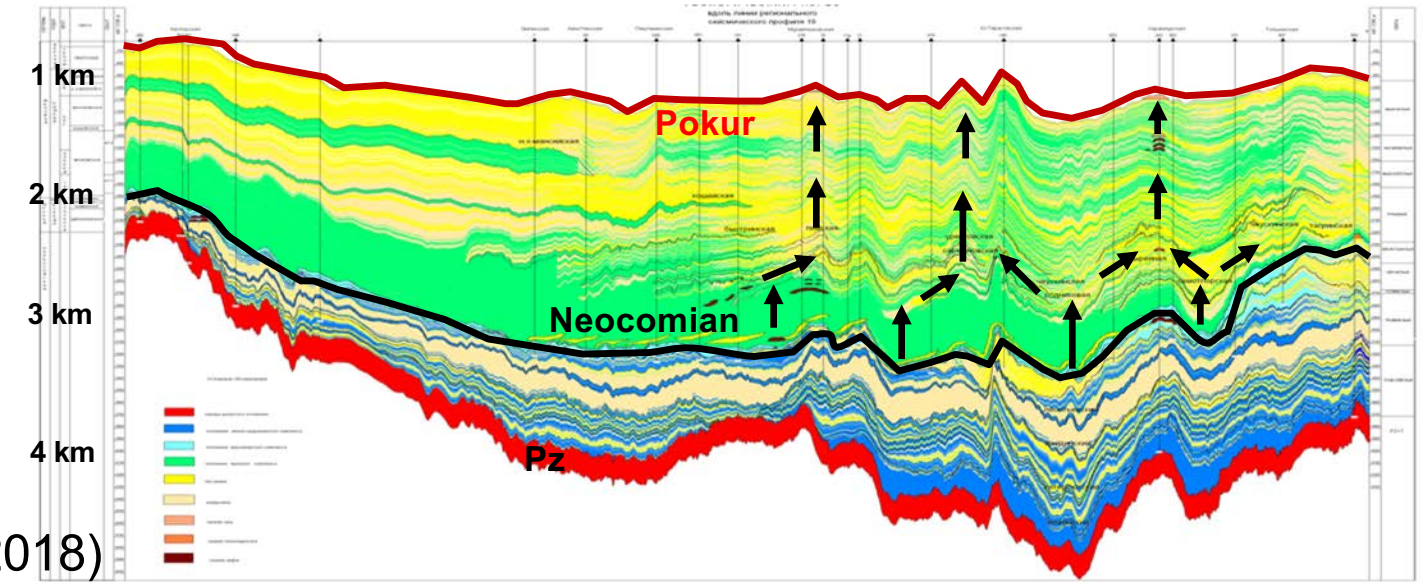
Milkov (2018)

- Total area 1.1 million mi^2:
  - 85% onshore.
- 906 oil and gas fields.
- ~488 billion boe 2P reserves discovered.
- ~220 billion boe produced.
- As large as 45 minimum Super Basins combined.
- Many giant fields!

Representative W-E cross-section







Milkov (2010, 2018)

Simple Geology = Super Basin

Mega-regional seal

Large simple anticlines

Sandstone reservoirs

Rich mature source

Other source rocks

Other plays

History and Plans For Super Basin Events

- March 27-29, 2018 Inaugural AAPG Global Super Basin Leadership Conference (275)
- May 21 2018 Super Basin Forum at AAPG (ACE) Salt Lake City, Utah (500)
- June 13 2018 EAGE: European Basins, North Sea and North Africa super basins (350)
- August 22, 2018 Conjugate Margins Conference, Halifax CA (200)
- Sept. 11 2018 HGS Africa Conf., Super Basins African Perspective (225)
- Oct. 3, 2018 INGEPET, Lima Peru, Super Basins Latin America Basins (800)
- Oct 30, 2018 Houston, Super Basin views by Exxon, Chevron, BP and Anadarko, Global Women's Leadership Forum, Center's of Excellence (800)
- Nov. 7, AAPG (ICE) Africa and Middle East Basins, Cape Town South Africa (100)
- **January 22-24, 2019, AAPG, Permian Super Basin, Houston, TX (290) TOTAL 3540 Attendees**
- March 3-5 2019 Hedberg: Petroleum Systems, state of knowledge on super basins, Houston TX
- August 27-30, 2019 AAPG (ICE), Buenos Aires, Argentina, Latin American Super Basins
- March 2020, GEO Bahrain, Middle East Basins
- Interest expressed for events in China, SE Asia, Australia

Thanks to 3500 Attendees!

Resources for Explorers: AAPG Bulletin Articles

AAPG Bulletin *Super Basin Initiative*

Charles A. Sternbach, President of AAPG (2017/2018)

The *AAPG Bulletin* introduces a new initiative for its second century—the super basin series. The inaugural publication features an overview of the super basin concept by Bob Fryklund and Pete Stark (IHS Markit). AAPG plans to roll out new super basin papers regularly in the months ahead. Together with AAPG Editor, Barry J. Katz, our plan is to build a legacy of foundational papers of the world's top petroliferous areas that continue to produce prodigious amounts of energy (Figure 1). We anticipate that these papers will be revisited as a valuable resource in the years and decades ahead. The authors of these papers will be invited and acknowledged for their expertise in their particular basin or region. It is also envisioned that super basins will be an important component of AAPG conferences and technical events.

These publications will show the importance of geoscience as these basins continue to have new life breathed into them by innovative geoscientists using new technology and how rocks tell the story. This series will frame the geoscience architecture of the world's most petroliferous basins including an understanding of their petroleum systems, richness, distribution, and position in the stratigraphic column of the source rocks and their maturity and an appreciation of the reservoirs, seals, and structural configuration. For example, the Permian Basin will be included in this series. It is endowed with multiple rich source rocks (Simpson, Woodford, Barnett, and Permian/Pennsylvanian) deep within the sedimentary section that contains many reservoir seal pairs, all within the oil and gas window, a shallow regional evaporite seal and a structural evolution that prevent leakage to the surface, abundant surface infrastructure, open access to mineral rights, and favorable regulation.

AAPG Memoir 74: Petroleum Provinces of the Twenty-first Century (Marlan Downey, Jack Threet, and William Morgan, 2001) was a landmark publication for frontier exploration. The super basins concept is a dramatically different focus—a return to established mature basins where resources are known to be present, and will be a key resource for tomorrow's oil and gas supplies.

Super basins, as defined by Fryklund and Stark, are established producers with at least 5 billion BOE produced and 5 billion BOE remaining recoverable, two or more petroleum systems or source rocks, stacked reservoirs, existing infrastructure/oil field services, and access to markets. Horizontal drilling and multistaged horizontal fracturing and their unconventional resource potential are driving the onshore super basin renaissance. Improved seismic imaging, particularly below salt (or obscured layers), is driving offshore super basins rejuvenation. The Permian Basin, Gulf of Mexico, and Middle East basins are prototype oil and gas prone super basins.

Energy is where you find it. In many cases, the most promising reserves for today and tomorrow are in areas that have long been productive. The total petroleum systems concept guides our approach. Much has been said and written about peak oil. Peak oil is a concept defined by a population of energy accumulations known, detectable, and producible at a particular time and place. When there are "multiple" peaks to a basin historical hydrocarbon production, each peak represents new technology and ideas that resurrect a maturing or declining petroleum province. Many of the super basins that will be featured in this series discuss basins that only recently were thought to be played out but are now experiencing production peaks and in some cases exceeding production peaks of previous decades, such as in the Permian Basin. The super basin series will also discuss the new technology driving this rejuvenation and the sharing of best practices of these new technologies that can be applied in various super basins.

[1]Star Creek Energy Company, Houston, Texas; carbondude@gmail.com

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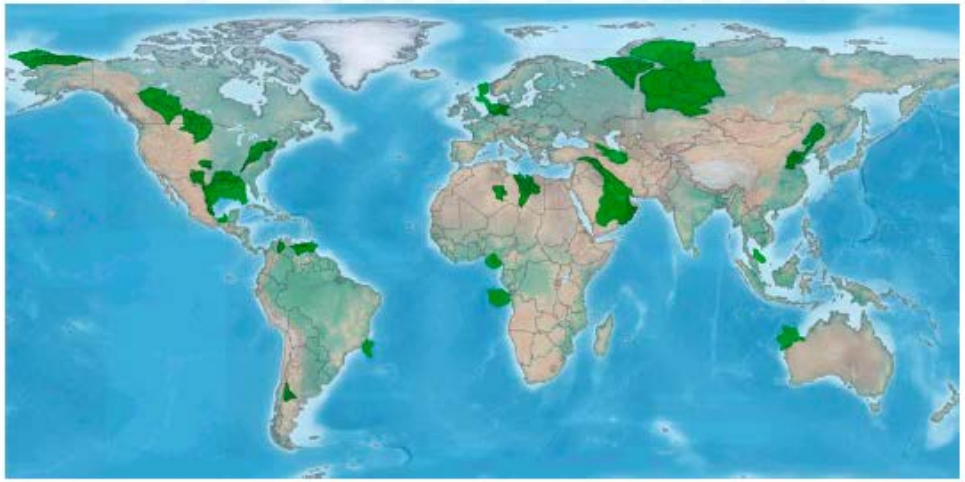


Figure 1. Map of top 25 super basins (courtesy IHS Markit).

Topics the papers will address include

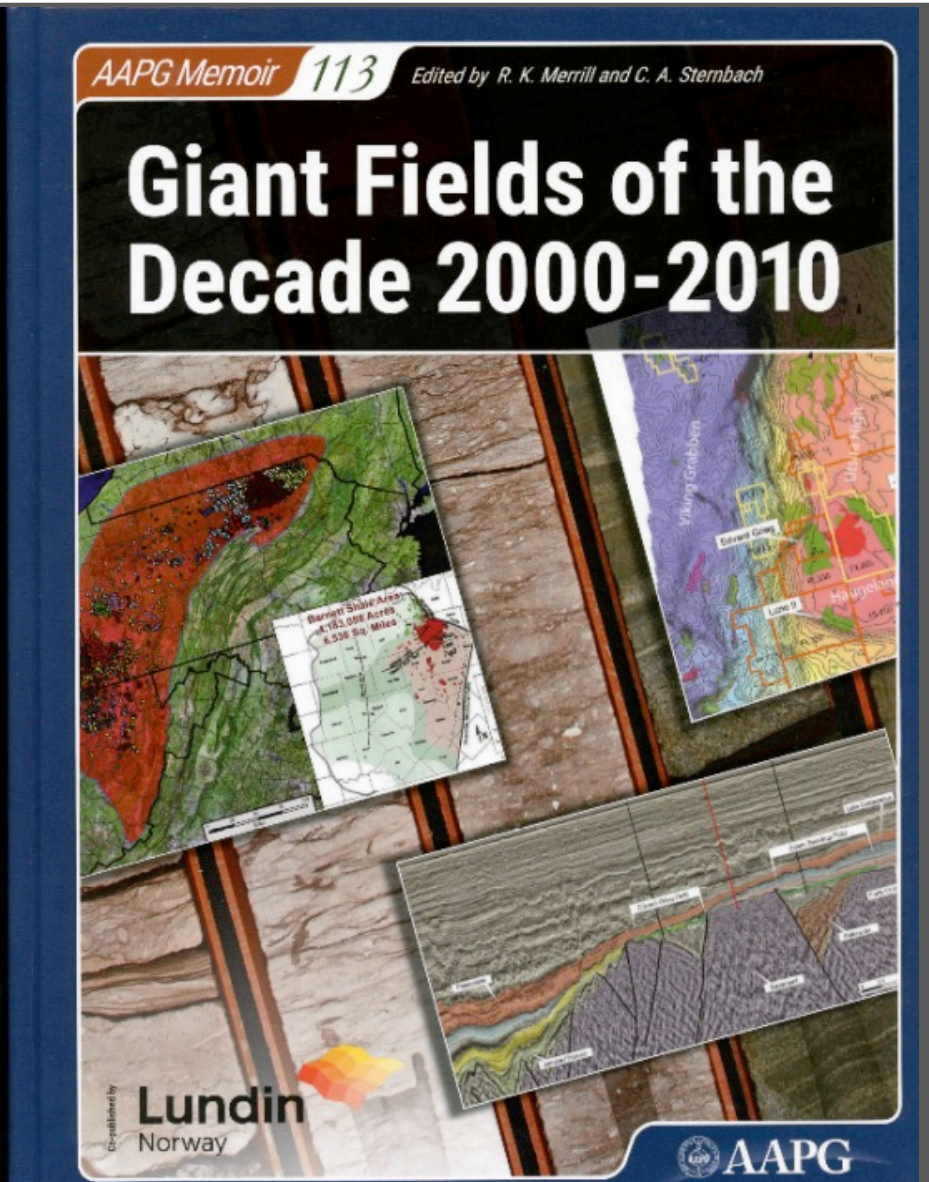
- What makes a super basin special and unique and what can we learn from them?
- What are the critical geoscience elements that contribute to success?
- What is the exploration/production history, and what are the major plays with remaining potential—conventional, unconventional, and field growth.
- What are key innovations in each super basin like: adoption of horizontal drilling, hydraulic stimulation, completion and drilling techniques, and seismic imaging that helped unlock the potential and what is needed to grow it further?
- How do "above ground" issues like politics, access, mineral ownership, and geography influence realizing the full resource potential of each super basin?
- Will the basin be a regional or global disrupter?

In addition to their geologic energy endowment, super basins have large scale and infrastructure to incubate new technology. Technology nurtured and proven in super basins has great relevance and application to basins of all sizes. Thus, super basin papers will have widespread value to energy producers not just in super basins. Super basins are creating valuable contributions to our energy, economy, and environment. We will continue to enjoy abundant and affordable energy due to super basins. In addition, super basins will have a great impact on sustainability, security, and geopolitical factors.

We believe that (1) our energy industry has made major contributions to global prosperity, (2) this prosperity will grow far into the future, and (3) professional societies like AAPG will continue to play a key role in preparing men and women to provide this energy and prosperity long into our next century. Thus, we begin the super basins initiative for the *AAPG Bulletin*.

March 2018 AAPG Bulletin

New AAPG Book on Giant Fields; Another AAPG Publication to Feature Giant Fields 2010-2020!



Planning to have a paper on Midland and Delaware Basins in upcoming volume!

Appalachian Super Basin

Williston Super Basin

Gulf of Mexico Super Basin

Geoscience Matters

Communicating the case to Industry Leaders

Advancing our science and profession

Summary

- Technology transfer—The World is watching the Permian Basin
- Networking, lateral thinking, anticipatory insights
- Communicate: geoscience matters!
- Thanks to you, the energy finders, for providing abundant and affordable energy to make the world a better place