[PS]What is the State of Understanding of Super Basins, The World's Richest Oil and Gas Basins?*

Charles A. Sternbach[1]

Search and Discovery Article #70401 (2020)**
Posted January 20, 2020

*Adapted from poster presentation given at 2019 AAPG Hedberg Conference, The Evolution of Petroleum Systems Analysis: Changing of the Guard from Late Mature Experts to Peak Generating Staff, Houston, Texas, March 4-6, 2019
 DOI:10.1306/70401Sternbach2020

[1]President Star Creek Energy, Past President AAPG (2017-2018), and Adjunct Professor University of Houston (carbodude@gmail.com)

Abstract

As AAPG begins our second century we are seeing an energy renaissance in abundant and affordable energy supply. In addition to exploration in remote and deep water frontiers, new technology such as hydraulic fracturing in horizontal wells and enhanced seismic imaging in "super basins" (the world's most prolific petroleum provinces which possess social license and extensive infrastructure), will sustain us long into the future.

The concept of super basins (The concept and definition of Super Basins were initially developed by Bob Fryklund, Pete Stark, IHS market research paper, 2016.) – a new way of thinking – combines geoscience architecture, commerciality, infrastructure and above-ground issues. Instead of focusing on an individual field, trend or play, the fundamental unit of understanding is a holistic review of entire basins, their petroleum systems, and "yet to find" resources. Comparing and contrasting super basins enables anticipation of new resources by looking for opportunities in all basins.

Each of the world's super basins have at least one active world class petroleum systems. Petroleum modeling can be a powerful predictor of "yet to find resources". It is important to know whether hydrocarbons are being produced from their source beds, in migrated reservoirs, or in a hybrid situation. "Critical moments" of maturation, migration, entrapment and uplift add the fourth dimension of time to 3D stratigraphic architectures. Structural timing of uplifts is important to understand origin of pressure cells. Some basins (e.g. Permian Basin, WCSB, and North Sea) have late structural tilts, creating the possibility for residual oil zones (ROZ).

Super basins are found in many structural settings. Passive margins, rift and continental (intracratonic) basins hold two thirds of world's giant fields (Mann, 2003). Basin infill comparisons show reservoirs and trap commonalities. Highly prolific basins produce from clinoform settings including slope (Anadarko Basin), bottom set (Neuquen Basin, Argentina), or top set strata (North Slope Alaska, W. Siberia). In resource plays, clay mineralogy (smectite/illite), silts, carbonates, silica impact "landing zones" for hydraulic fracturing in horizontal wells. Some super basins

(Arabian Basins, California US) have historically produced from almost all structural traps and few stratigraphic traps, possibly anticipating future exploration opportunities for stratigraphic traps.

In all super basins, infrastructure matters. Each basin creates a community for service companies and operators of various corporate sizes and capitalization. In unconventional onshore basins, early movers tend to be independents. Commercial masters focus on the ability to stack as many vertical resources as possible to enhance value relative to infrastructure investment. Value innovators combine global technical mastery and supply chain commercial mastery. Super basins and giant fields bring resources and incubate technology that benefit basins, fields, and an ecosystem of operators of many sizes.

While there may be more than 100 super basins around the world, review of the top 30 super basins (48 contiguous sub basins) out of 870 petroleum bearing basins, indicate that the top 3-5% of petroleum basins contain about 57% of the of the world's giant oil and gas fields (giant=500 MMBOE, 656 out of 1142). The world's richest super basins contain 10 times the number of giant fields relative to all petroleum bearing basins. Emerging super basins like the north slope of Alaska, north and east Africa, pre-salt Brazil, and offshore Guyana are finding clusters of giant fields.

AAPG has instituted a series of conferences, forums, and publications to assist geoscientists in the super basin energy renaissance. AAPG hosted the inaugural Global Super Basin Leadership Conference (GSBLC) March 27-29, 2018 in Houston. We held a Super Basin Forum at ACE in Salt Lake City on May 21, 2018. This program had more than 500 attendees – the largest attended session. AAPG hosted an invited session for The European Association of Geoscientists and Engineers (EAGE) on June 13, 2018 (Copenhagen, Denmark), featuring Europe and North Africa super basins. Other events included a session on Atlantic conjugate margin basins (Halifax, August 2018), South American Basins (at INGEPET, Peru, October 2018), major company approaches to global basins (October 2018) and African Basins (at ICE, South Africa, November 2018). In addition, publications include the AAPG Bulletin Global Super Basin initiative (March 2018). Global experts on the world's richest basins have been proactively recruited to submit articles to the AAPG Bulletin. These programs are ongoing and receiving great interest and participation.

References Cited

Dolson, J., Z. He, and B.W. Horn, 2018, Advances and Perspectives on Stratigraphic Trap Exploration-Making the Subtle Trap Obvious: AAPG 2017 Middle East Region Geosciences Technology Workshop, Stratigraphic Traps of the Middle East, Muscat, Oman, December 11-13, 2017, Search and Discovery Article #60054 (2018). Website accessed January 2020.

Ewing, T.E., 2019, Tectonics and Subsidence in the West Texas (Permian) Basin: A Model for Complex Intracratonic Basin Development: 2018 AAPG Distinguished Lecture Series, Search and Discovery Article #30606 (2019). Website accessed January 2020.

Fryklund, B., and P. Stark, 2016, Super Basins – The Basins That Keep On Giving: IHS Markit, Sept. 2016. https://ihsmarkit.com/solutions/permian-basin.html Website accessed January 2020.

Macellari, C., 2018, The Neuquén Super Basin: The Rebirth of a Mature Basin: AAPG Global Super Basins Leadership Conference, March 27-29, 2018, Houston, Texas.

MacKay, P., 2018, The Western Canadian Sedimentary Basin: A Confluence of Science, Technology, and Ideas: AAPG Global Super Basins Leadership Conference, March 27-29, 2018, Houston, Texas.

Mann, P., L. Gahagan, and M.B. Gordon, 2003, Tectonic Setting of The World's Giant Oil and Gas Fields, *in* M.T. Halbouty (ed.), Giant Oil and Gas Fields of the Decade 1990-1999: AAPG Memoir 78, p. 15-105.

Merrill, R.K., and C.A. Sternbach, editors, 2017, Giant Fields of the Decade 2000-2010: AAPG Memoir 113, ISBN 978-0-89181-393-4, 322 p.

Milikov, A.V., V.N. Vyssotski, and A.S. Bochkov, 2018, West Siberian Super Basin: Learnings from the Past and Insights into the Future: AAPG Global Super Basins Leadership Conference, March 27-29, 2018, Houston, Texas.

Reuber K., and P. Mann, 2019, Control of Precambrian-to-Paleozoic Orogenic Trends on Along-Strike Variations in Early Cretaceous Continental Rifts of the South Atlantic Ocean: Interpretation, v. 7/4, p. SH45-SH69. doi.org/10.1190/INT-2018-0257.1

Skinner, O., L. Canter, M. Sonnenfeld, and M. Williams, 2012, Discovery of "Pronghorn" and "Lewis and Clark" Fields: Sweet-Spots within the Bakken Petroleum System Producing from the Sanish/Pronghorn Member NOT the Middle Bakken or Three Forks!: AAPG Annual Convention and Exhibition, Discovery Thinking Forum, Long Beach, California, April 22-25, 2012.

Sternbach, C.A., 2018, AAPG Bulletin Super Basin Initiative: AAPG Bulletin, v. 102/3, p. vii-viii. doi:10.1306/pn010818

Stoneburner, R.K., 2018, Beyond the North American Mudrock Super Basin Plays: The Unconventional Development of Conventional Reservoirs: AAPG Global Super Basins Leadership Conference, March 27-29, 2018, Houston, Texas.

Yeilding, C., 2018, Gulf of Mexico Offshore Evolution of Past, Present, and Future Plays: AAPG Global Super Basins Leadership Conference, March 27-29, 2018, Houston, Texas.

Zagorski, W.A., 2018, The Appalachian Super Basin: A Discussion of Past, Present, and Future Exploration Trends: AAPG Global Super Basins Leadership Conference, March 27-29, 2018, Houston, Texas.

What is the state of understanding of Super Basins, the world's richest oil and gas basins?

Charles A. Sternbach (carbodude@gmail.com) President Star Creek Energy, AAPG Past President,
Adjunct Professor Department of Earth and Atmospheric Sciences, University of Houston

UNIVERSITY of HOUSTON — EARTH AND ATMOSPHERIC SCIENCES

CBTH — Conjugate Basins, Tectonics, and Hydrocarbons — Phase I – 2017-2020

Abstract

Super Basins have been identified as basins with 5 BBOE produced, 5 BBOE yet to produce, multiple pays, multiple plays, at least one major prolific source rock petroleum system, and extensive infrastructure (Fryklund and Stark, 2016 IHS Markit). While there may be technically more than 100 super basins around the world, review of the top 30 super basins (48 contiguous sub basins) out of 870 petroleum bearing basins, indicate that the top 3-5% of petroleum basins contain about 57% of the of the world's giant oil and gas fields (giant=500 MMBOE, 656 out of 1142). In other words, the world's richest super basins also contain 10 times the number of giant fields relative to all petroleum bearing basins.

Beginning with the AAPG Super Basin Initiative of 2018 (March AAPG Bulletin), AAPG and industry are teaming up to take stock of our collective knowledge of the top petroleum basins on the planet. What is the state of understanding of the world's top 30 basins (light blue outlines, Figure 1)? Ongoing research includes: what is the extent of geoscience literature on super basins, what are the key Arc GIS layers that can contribute to a betting understanding of oil and gas production in super basins, how well do we understand the architecture of source rocks, petroleum systems, reservoir, seals, fracture and permeability fabrics, pressure cells, timing of migration, uplift, structural setting, structural tilts producing residual oil zones (ROZ) and other factors including above ground issues. Petroleum modeling and source global source rocks are key drivers.

The goal is to stimulate discussion on the world's biggest basins. Do you have burial history and source rock maturation profiles for one or more of the world's super basins? Can you discuss the state of knowledge on estimates of source rocks generation potential and actual found volumes? Can basin super basin petroleum system histories be grouped by tectonic setting into meaningful categories to help us draw insights on past and future potential?

Super basins are important because many have undergone an energy renaissance within the last 10 years resulting from 1) hydraulic fracturing of unconventional resources in onshore basins (Permian Basin, Texas plus 7 other North American Basins and the Neuquen Basin, Argentina), 2) enhanced seismic imaging (e.g Sub Salt Gulf of Mexico, Campos and Santos Basins of Pre Salt Brazil), 3) natural gas basins and LNG (Carnarvon, NW Australia) and 4) tar sandstone resources (e.g. Canada and Russia).

We are identifying classes of super basins that are representative centers of excellence that can help us develop anticipatory insights in other super basins and basins around the world. We are developing strategies to find stratigraphic and structural trap populations, similarities and differences in basins, ways to prioritize both conventional and unconventional production suitability, and ways to leverage the collective knowledge of global super basins. Data management and "Big Data" have an important role to play in onshore basins and in offshore basins.

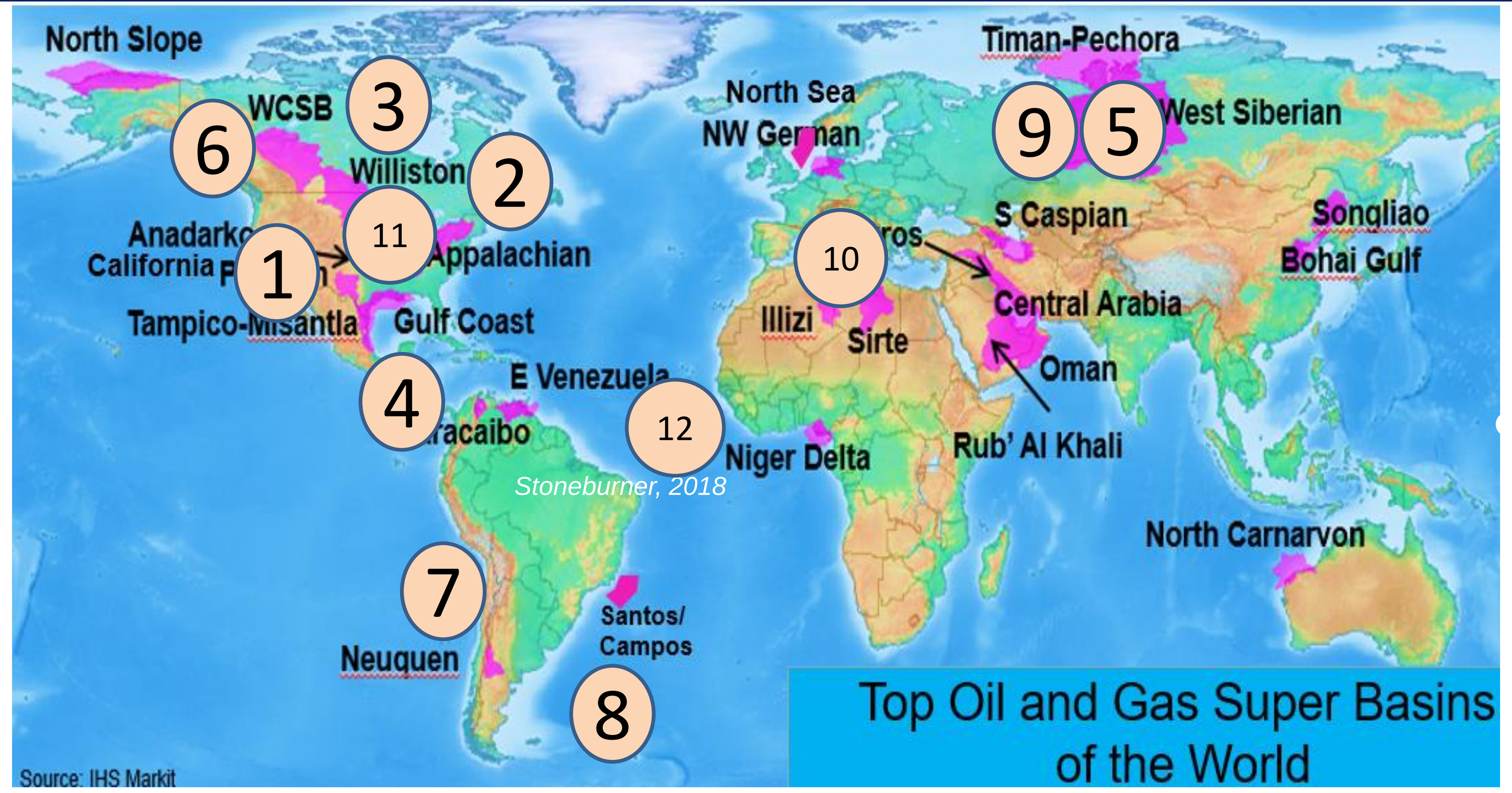
As we understand the world's greatest basins and giant fields, we gain insights to the entire ecosystem of basins and fields of all sizes.

Super Basin Event History and Plans (attendance)

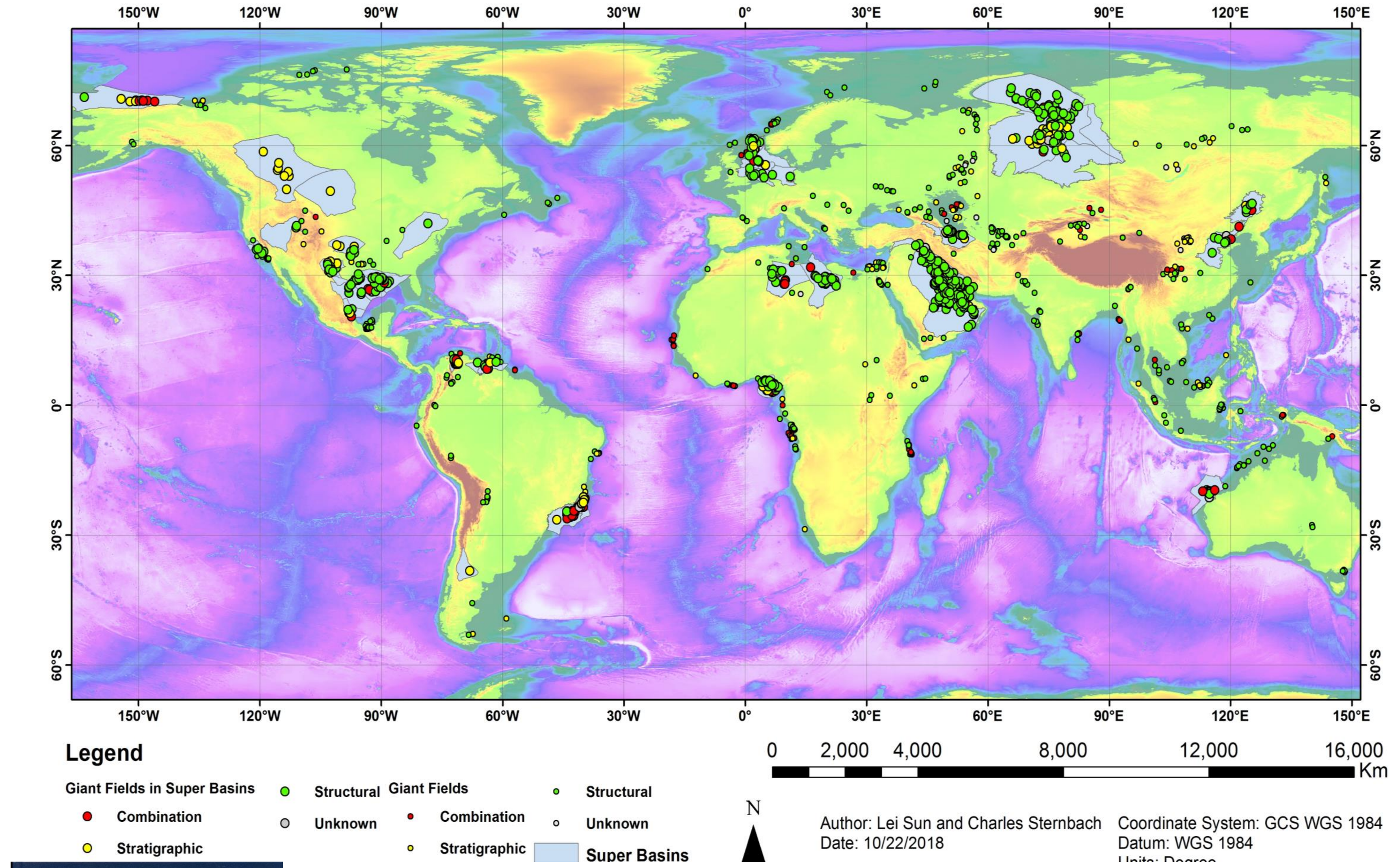
- March 27-29, 2018 Inaugural AAPG Global Super Basin Leadership Conference (275)
- May 21 2018 Super Basin Forum at AAPG (ACE) Salt Lake City, Utah (500)
- June 13 2018 EAGE: European Basins, North Sea and North Africa super basins (350)
- August 22, 2018 Conjugate Margins Conference, Halifax CA (200)
- September 11 2018 HGS Africa Conf., Super Basins African Perspective (225)
- October 3, 2018 INGEPET, Lima Peru, Super Basins Latin America Basins (800)
- October 30, 2018 Houston, Super Basin views by Exxon, Chevron, BP and Anadarko, Global Women's Leadership Forum, Center's of Excellence (800)
- November 7, AAPG (ICE) Africa and Middle East Basins, Cape Town South Africa (100)
- January 22-24, 2019, AAPG, Permian Super Basin, Houston, TX (301)
- February 5, 2019, UT Energy Week, Panel discussion, Super Basin Initiative (200)
- **March 3-5 2019 Hedberg on Petroleum Systems, Houston TX (80)**
- TOTAL 3,820 Attendees to this point.
- August 27-30, 2019 AAPG (ICE), Buenos Aires, Argentina, Latin American Super Basins
- February 19-21, 2020 AAPG Global Super Basin Leadership Conference 3.0, Houston TX
- March 16-20, 2020, GEO Bahrain, Middle East Basins
- Interest expressed for events in China, SE Asia, Australia

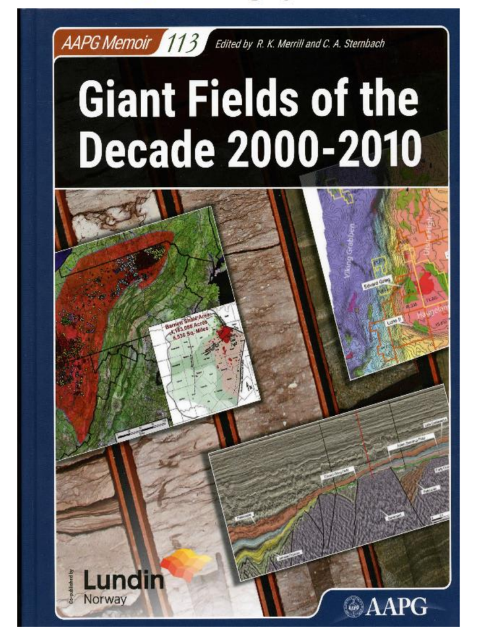
Thanks to 3,800+ participants in the Super Basin Energy Conversation

Super Basins, Giant Fields, and Prototype Centers of Excellence: Architectural elements, anticipatory insights and opportunity for global onshore and offshore energy revitalization



World Giant Fields by Trap Types



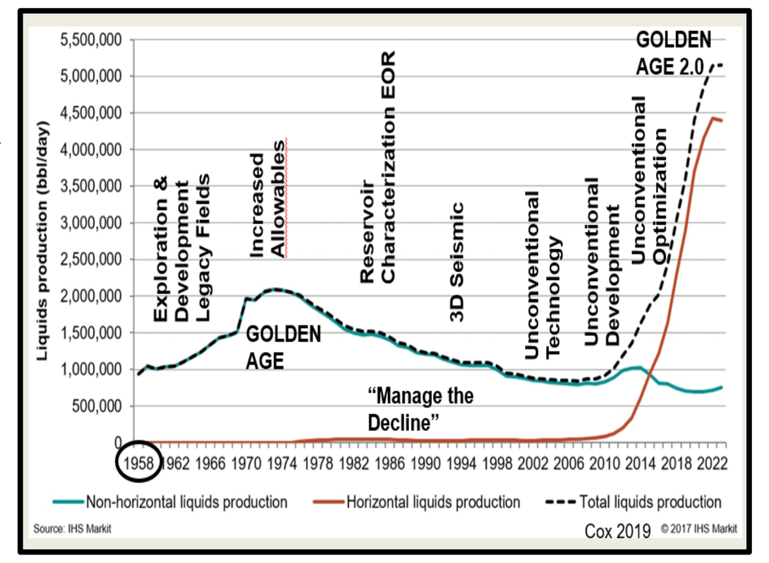


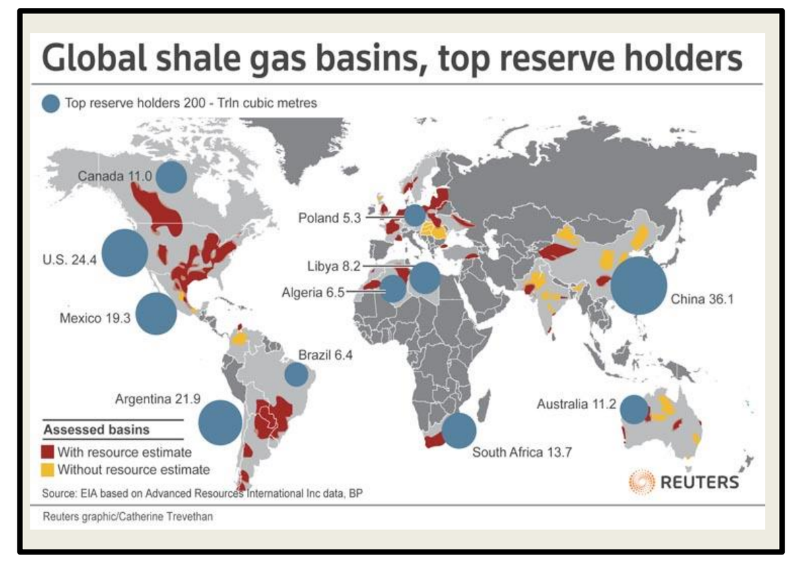
CALL TO ACTION: Papers Needed for giant fields books and articles for the AAPG Bulletin Super Basin Initiative

CONCLUSION: What can we learn from super basins? Each has at least one active world class petroleum systems where petroleum modeling can be a powerful predictor of "yet to find resources". Prototype architecture consists of rich source rocks buried by a thick sedimentary section (commonly clinoforms), capped by a regional seal or series of seals, in a non-leaky setting. Thus, passive margins, rift and intra-cratonic basins hold two thirds of world's giant fields. Prototype basins are a cradle of technology. Some super basins have many structural traps but few stratigraphic traps. This study compares insights from top basins for actionable intelligence applicable to the global ecosystem of all basins.

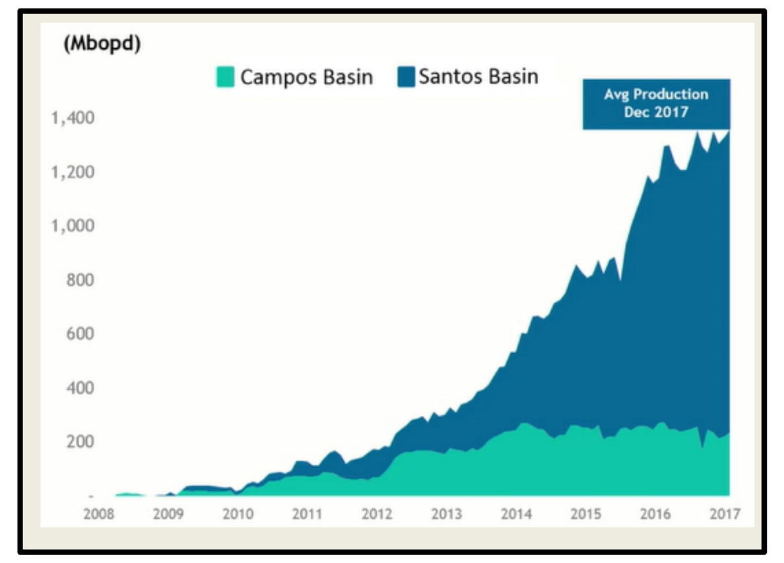
Why study super basins and giant fields?
"I suggest that the best geologist has seen the most rocks."
— Herbert Harold Read (Imperial College)

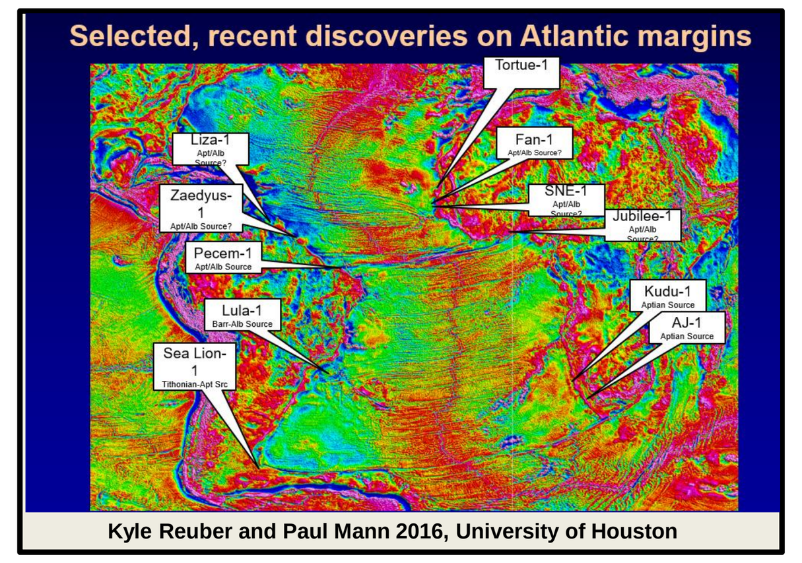
Production rejuvenation onshore "mature" Permian Basin, U.S.



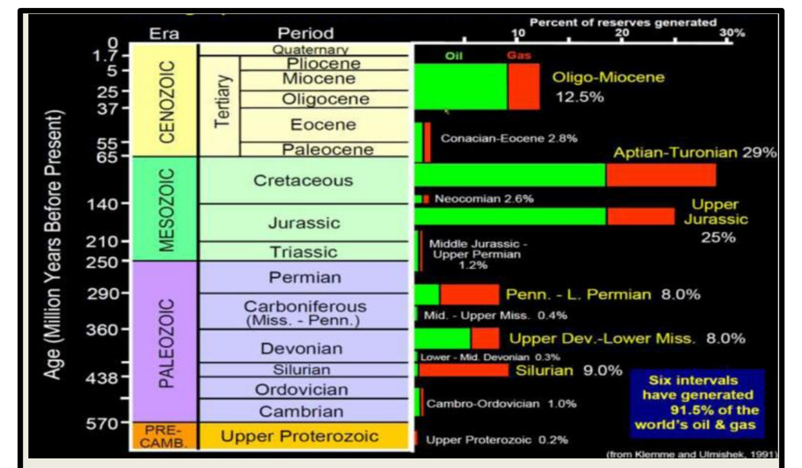


Production rejuvenation offshore "mature" Santos and Campos Basins, Brazil





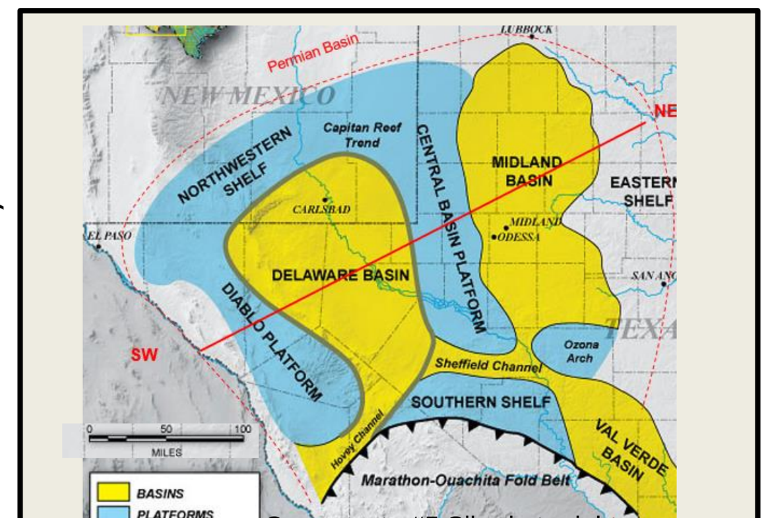
Key Source Rock Ages



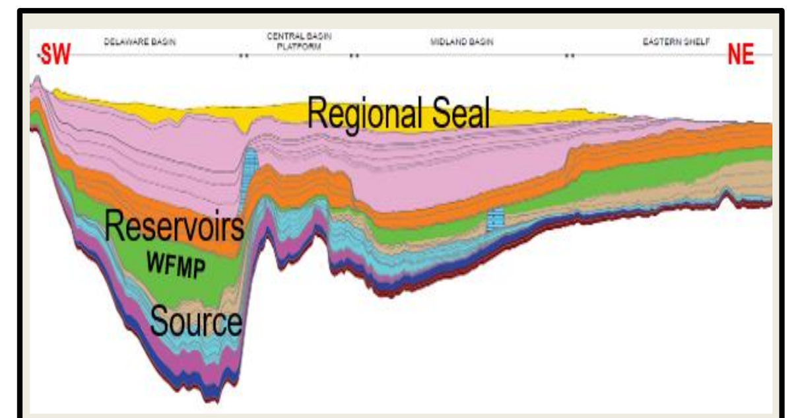
- Six intervals have generated 91.5% of worlds oil and gas
- Production from these intervals are increasing
- "Halo" plays of reservoirs around these source rocks

Maps | Cross Sections | Maps | Cross Sections | Maps and Cross Sections

1 Permian Basin, TX/NM



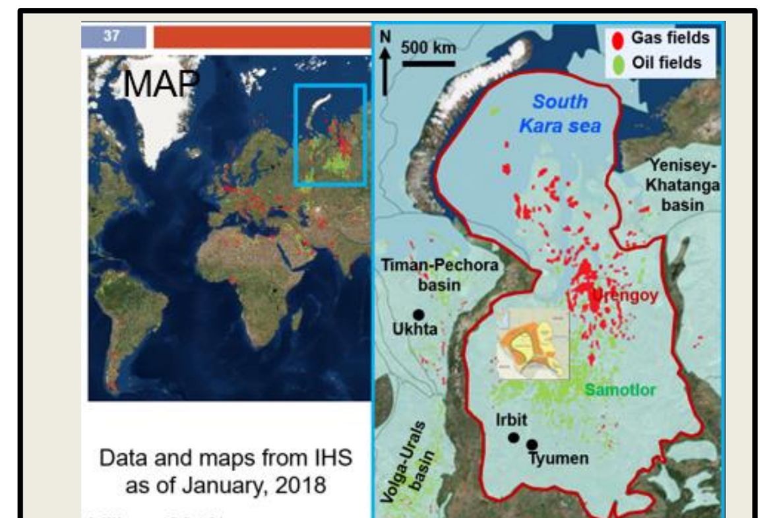
Compare to #5 Siberia to right



- Four source zones; three low in pile;
- Maturation due to Permian subsidence for most of basin;
- Late salt seal reduces leakage
- Modest structural movement

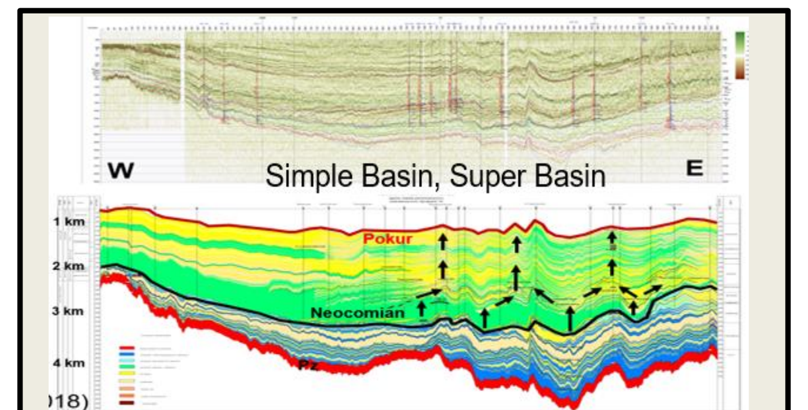
Ewing, 2018

5 W. Siberia Basin



Data and maps from IHS as of January, 2018

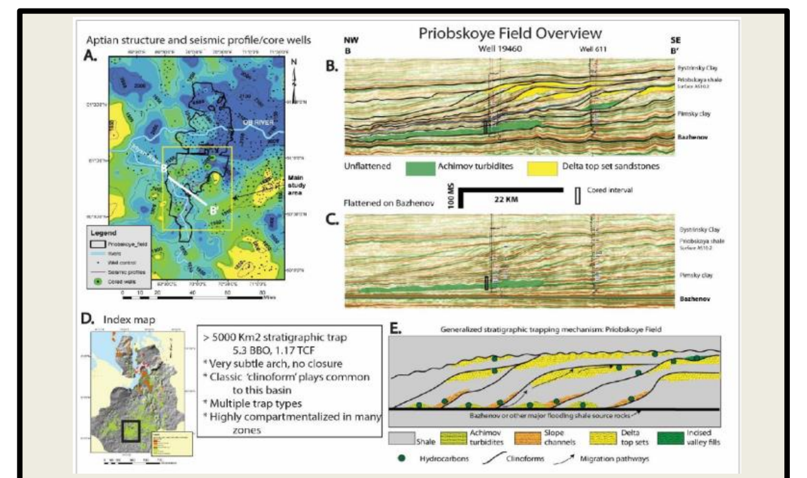
Milkov (2018)



- Mega Regional seal, Simple Anticlines
- Rich mature source rock, low in pile, ss reservoirs
- Waiting for alignment of above ground issues

Milkov, 2018

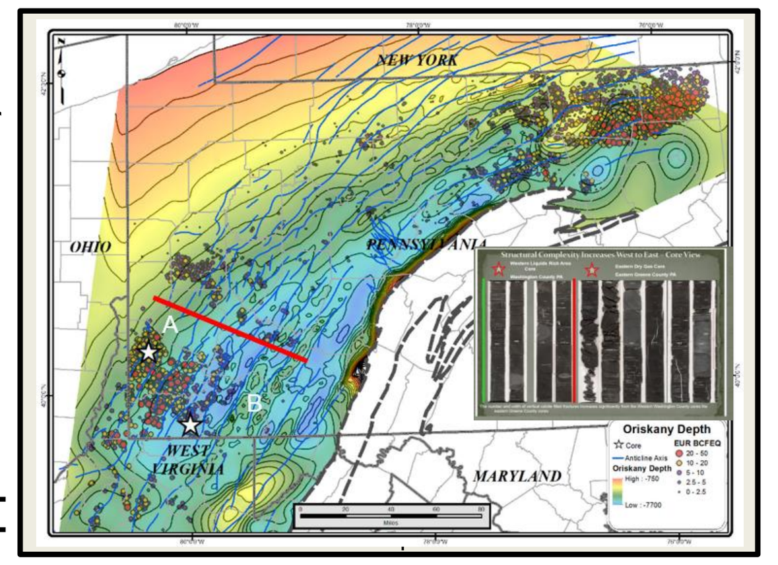
9 W. Siberia Basin

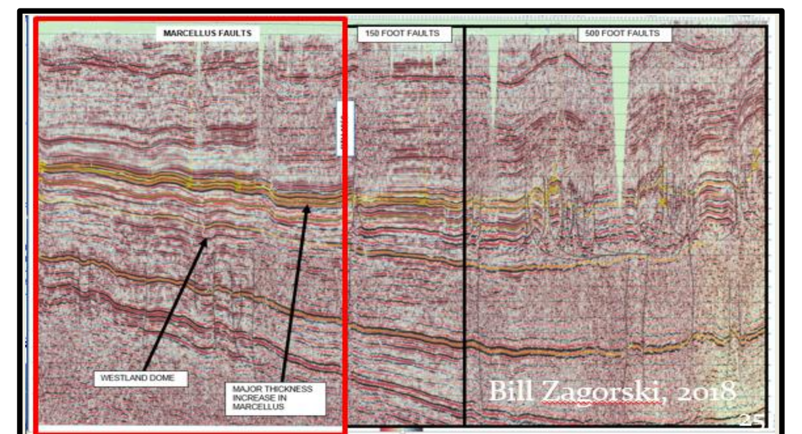


- Topsets produce in W. Siberia, also Kansas; Smackover and N. Slope Alaska

Dolson, He, and Horn, 2018

2 Appalachian Basin, PA

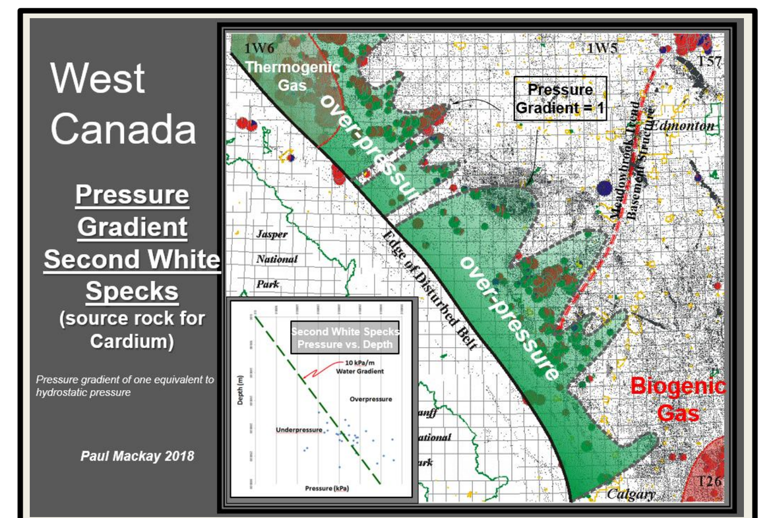




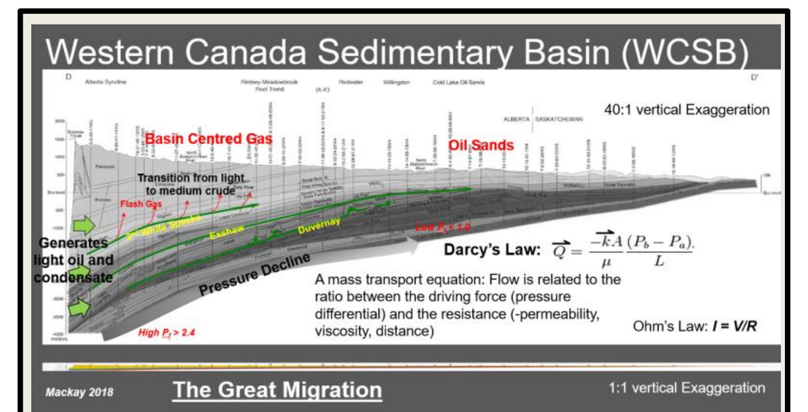
- Best Marcellus production in non deformed areas (west)
- One of the worlds biggest natural gas fields
- Best production from most brittle shale

Zagorski, 2018

6 W. Canada Basin



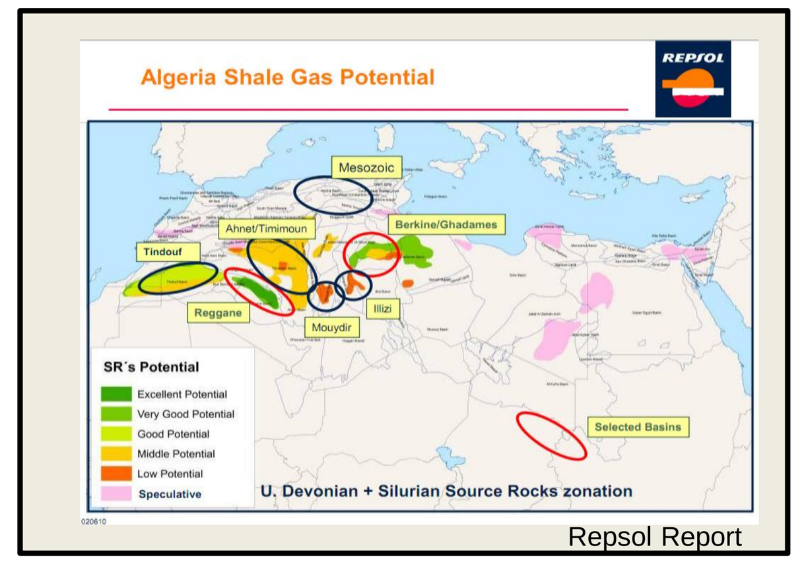
P. Mackay, 2018



- Best Devonian production in non deformed areas (east)
- Over pressured reservoirs charged, leakage to oil sands
- Hydrocarbons migrate from mountain belt to outcrop, west to east

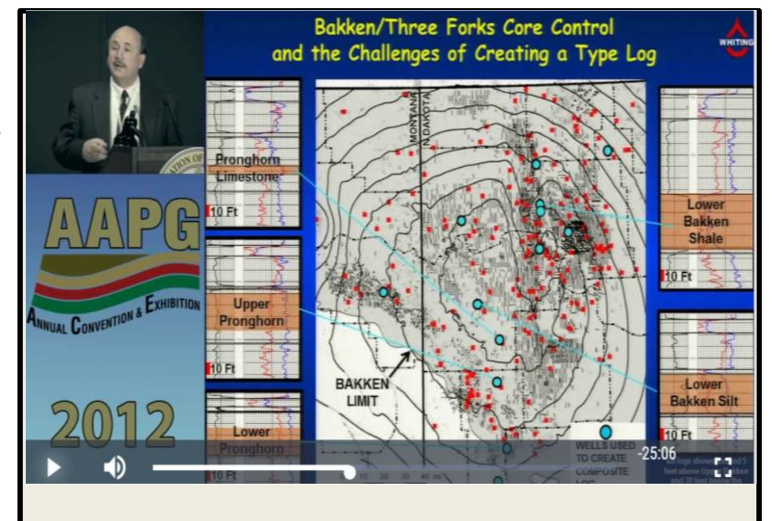
P. Mackay, 2018

10 Sirte and Illizi Basins

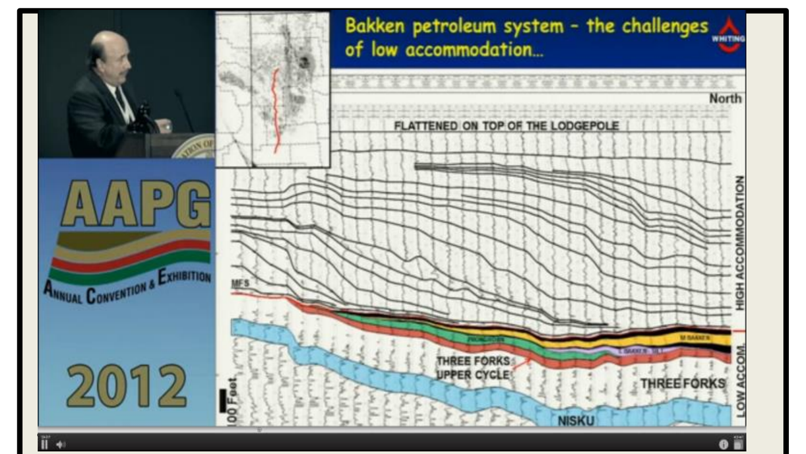


Repsol Report

3 Williston Basin, ND

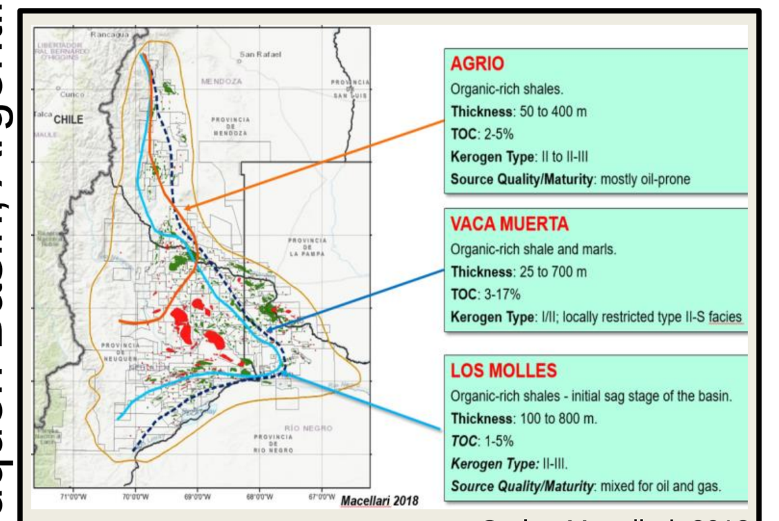


Orion Skinner, 2012, AAPG Outstanding Explorer

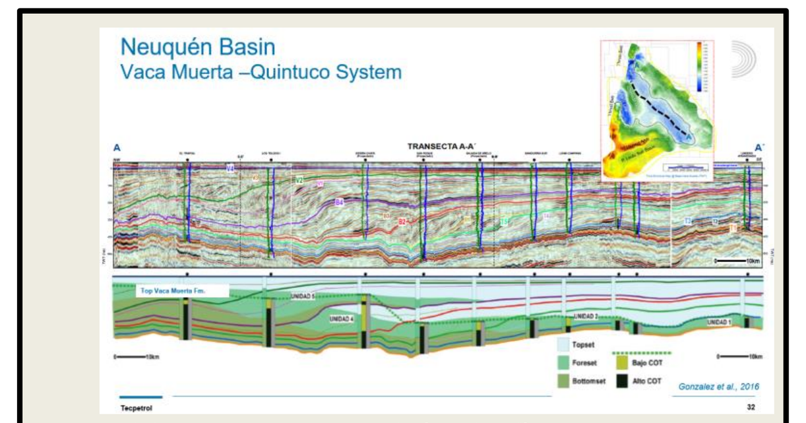


- Toe set clinoforms, preferred landing zones
- Cores and 1 foot contour maps define sub basins
- Target zones brittle benches in and amongst Bakken SR

7 Neuquen Basin, Argentina

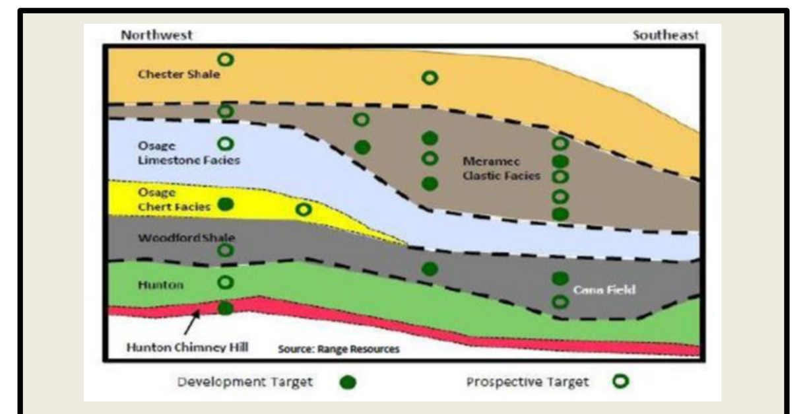


Carlos Macellari, 2018



- Rich mature source rock, low in pile
- Seismogenic clinoform infill reservoirs
- Andean basin east of major structural deformation
- Favorable infrastructure and supportive regulations

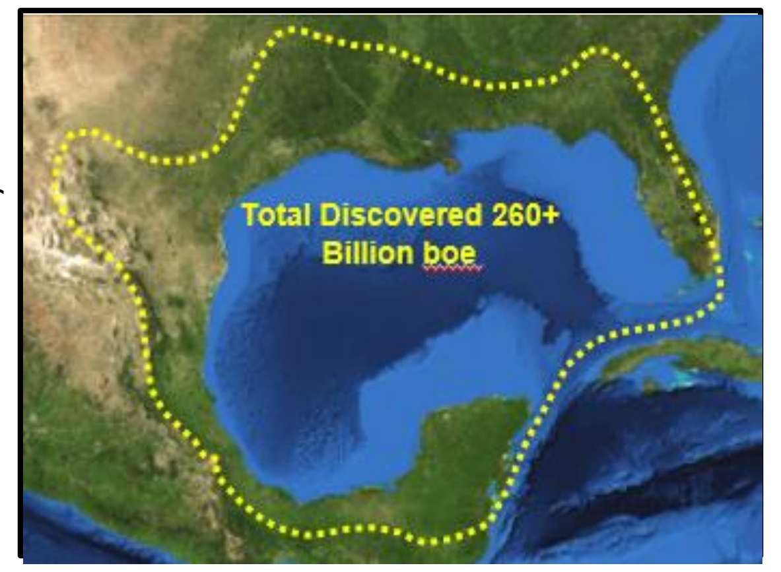
11 Anadarko Basin, OK

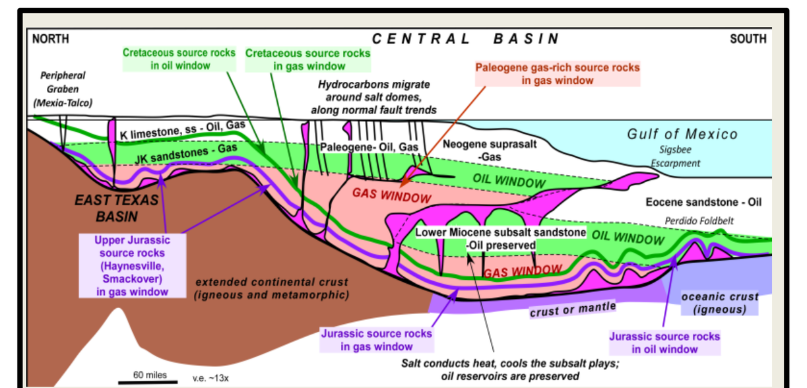


- Rich mature source rock, low in pile (Woodford)
- All reservoirs developed in the SCOOP/STACK/MERGE
- Basal chert in the Osage, siliceous good for fracturing

R.K. Stoneburner, 2018

4 Gulf o Mexico, US

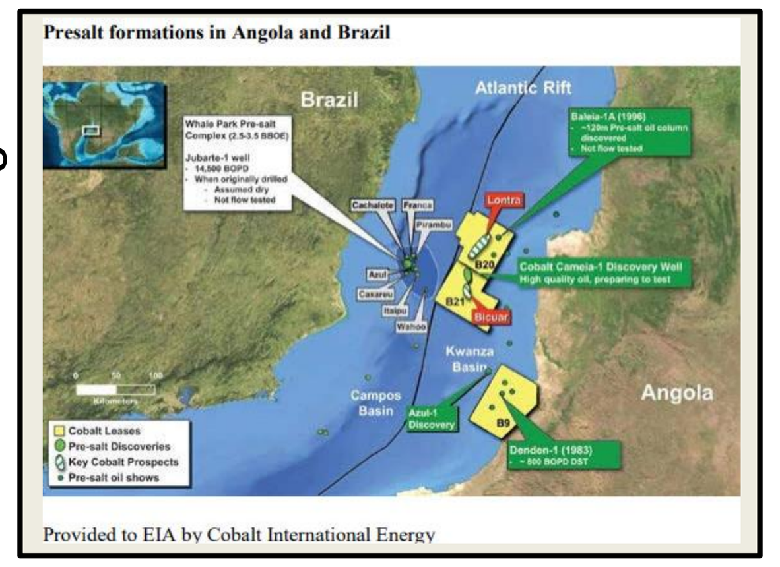


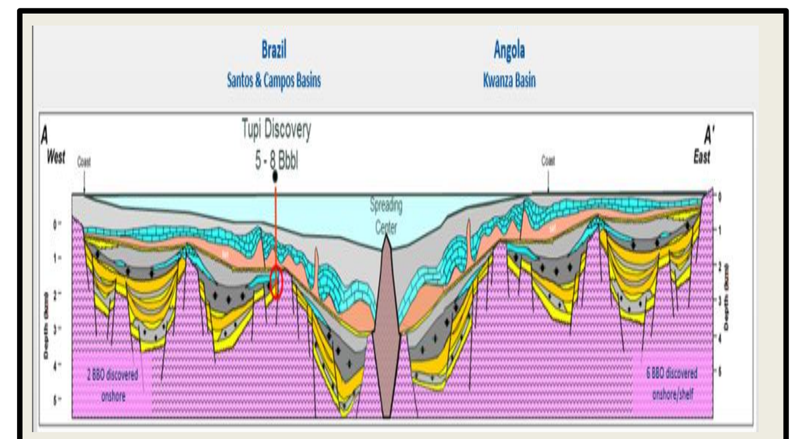


- Three main sources, two low in section (Jr and Mid Cret)
- Generation continuing at present
- Repetition of oil window by salt nappe(s)
- Strong vertical migration, no superseal; leaky basin

Yeilding 2018 and Ewing, 2018

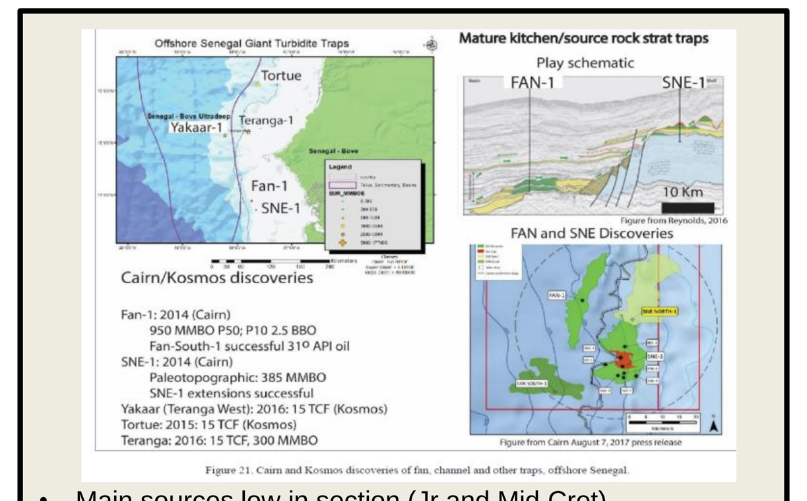
8 Brazil and Angola





- Main sources low in section (Jr and Mid Cret)
- Pre-salt carbonate microbialite reservoirs
- Thick and widespread salt seal, obscures deep pays

12 West Africa Margins



- Main sources low in section (Jr and Mid Cret)
- Search for the subtle trap

Dolson, He, and Horn, 2018