Charles A. Sternbach

AAPG Past President 2017-18
University of Houston Energy Fellow
and Adjunct Professor

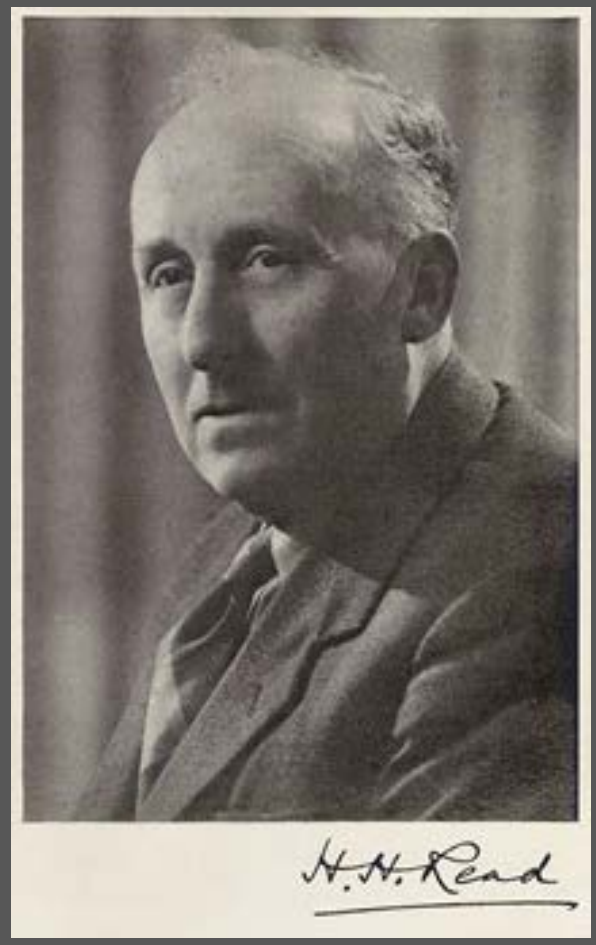
The Golden Age of Super Basins—An African Perspective

AAPG

Why Study Global Super Basins?

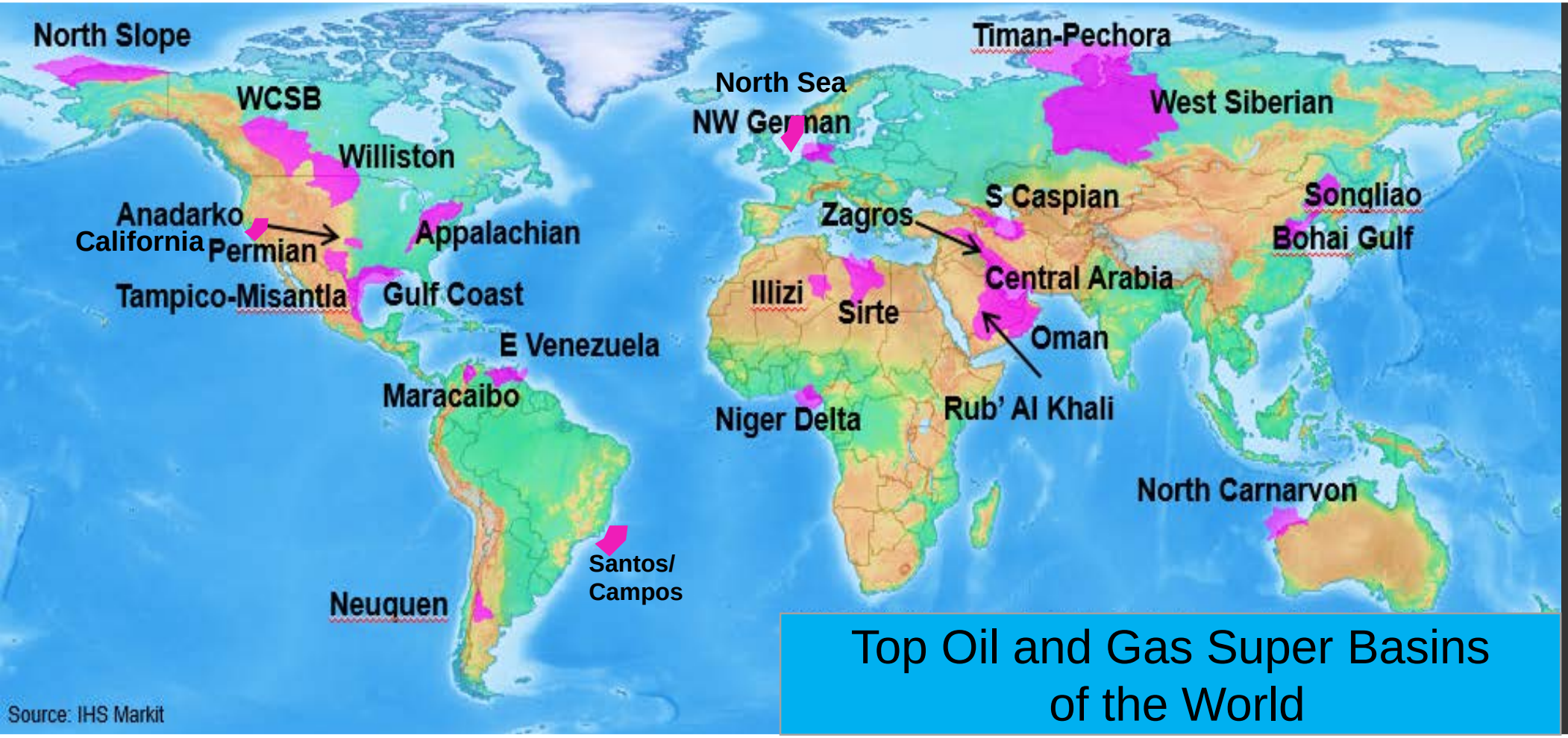
“I suggest that the best geologist is he/she who has seen the most rocks.”

— Herbert Harold Read (Imperial College)



Top Super Basins-Lessons for all basins

Estimated Technically Recoverable – 860 Bboe



Top Oil and Gas Super Basins of the World

Top 25 global "Super Basins"

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

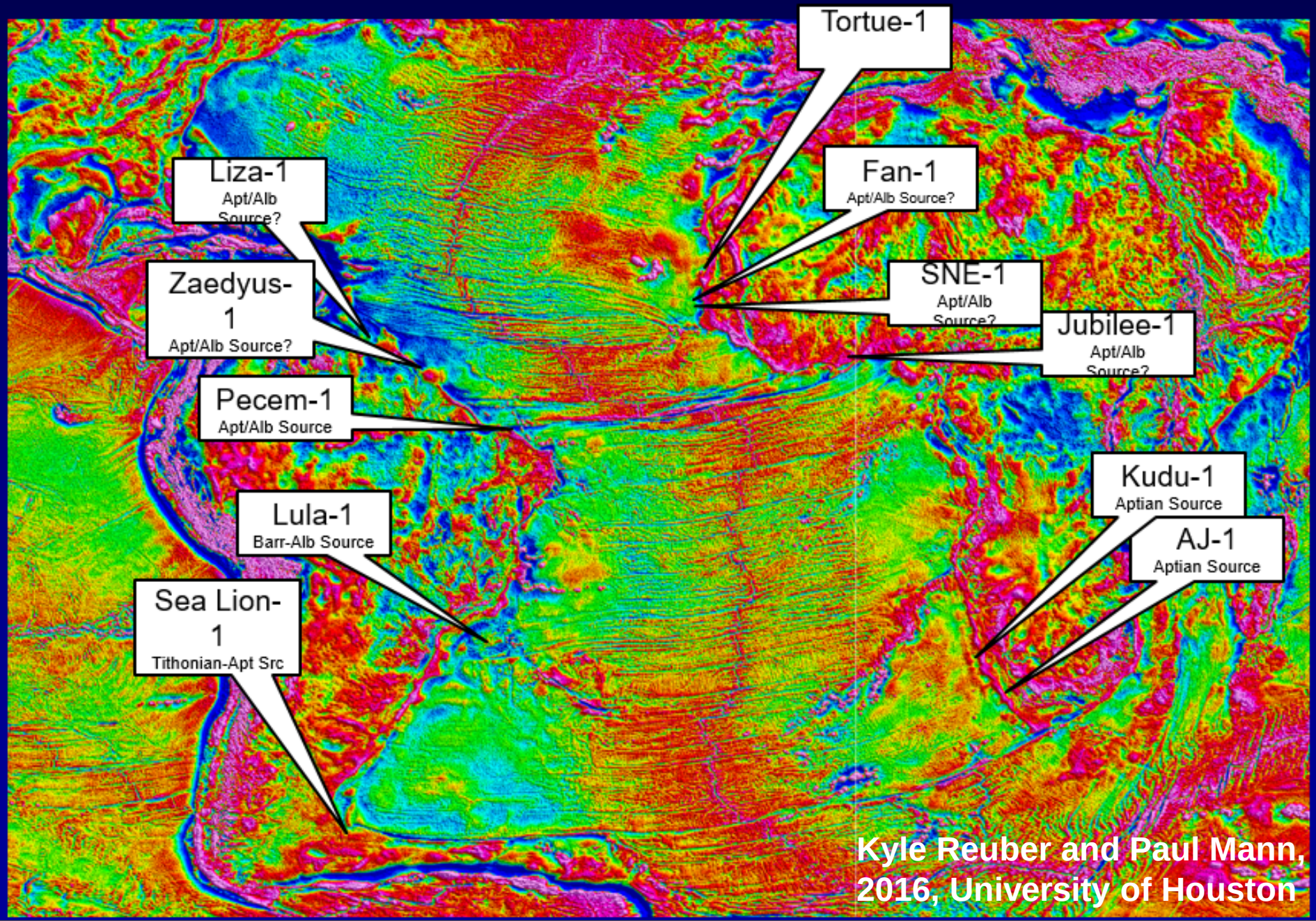
Multiple source rocks / petroleum systems

Infrastructure, services, ecosystems and supply chains

Special Thanks to Bob Fryklund, Pete Stark, Jerry Kepes and IHS

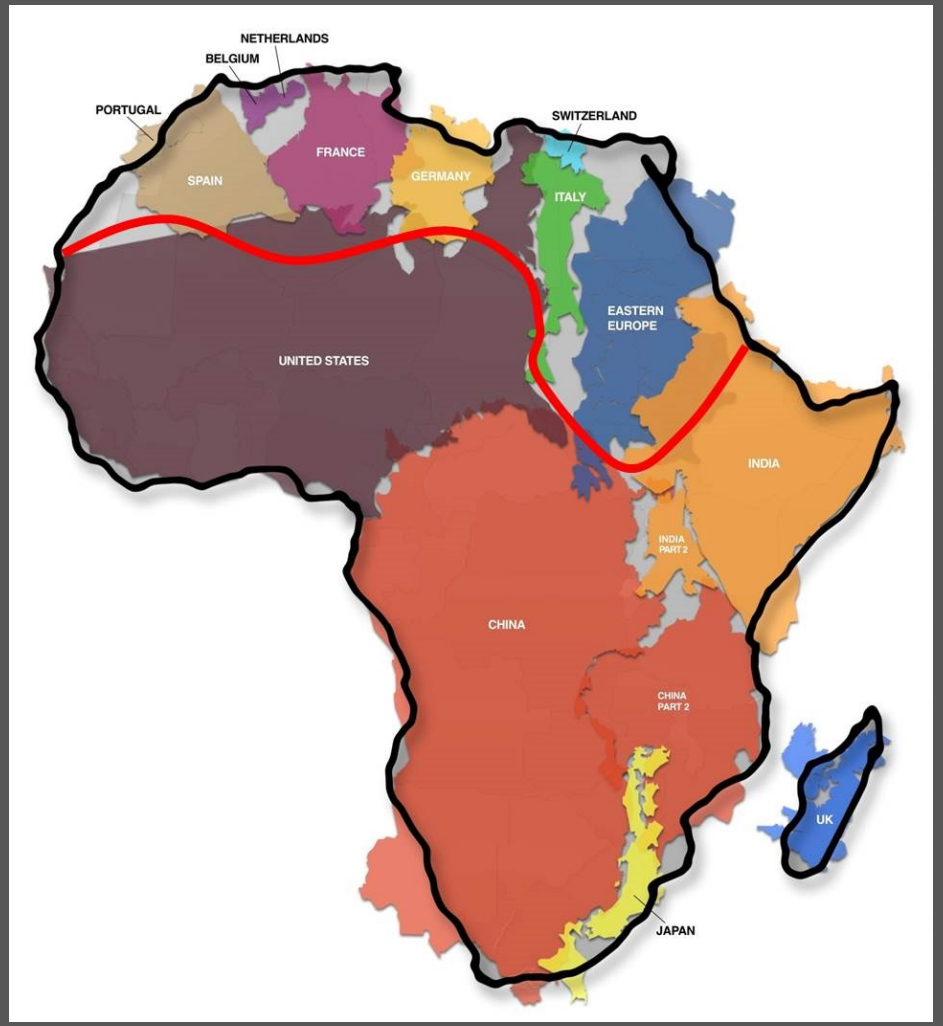
Source: IHSMarkit, *Super Basins – The basins that keep on giving, Sept. 2016.* Leta K. Smith, Pete Stark, Bob Fryklund

Selected, recent discoveries on Atlantic margins

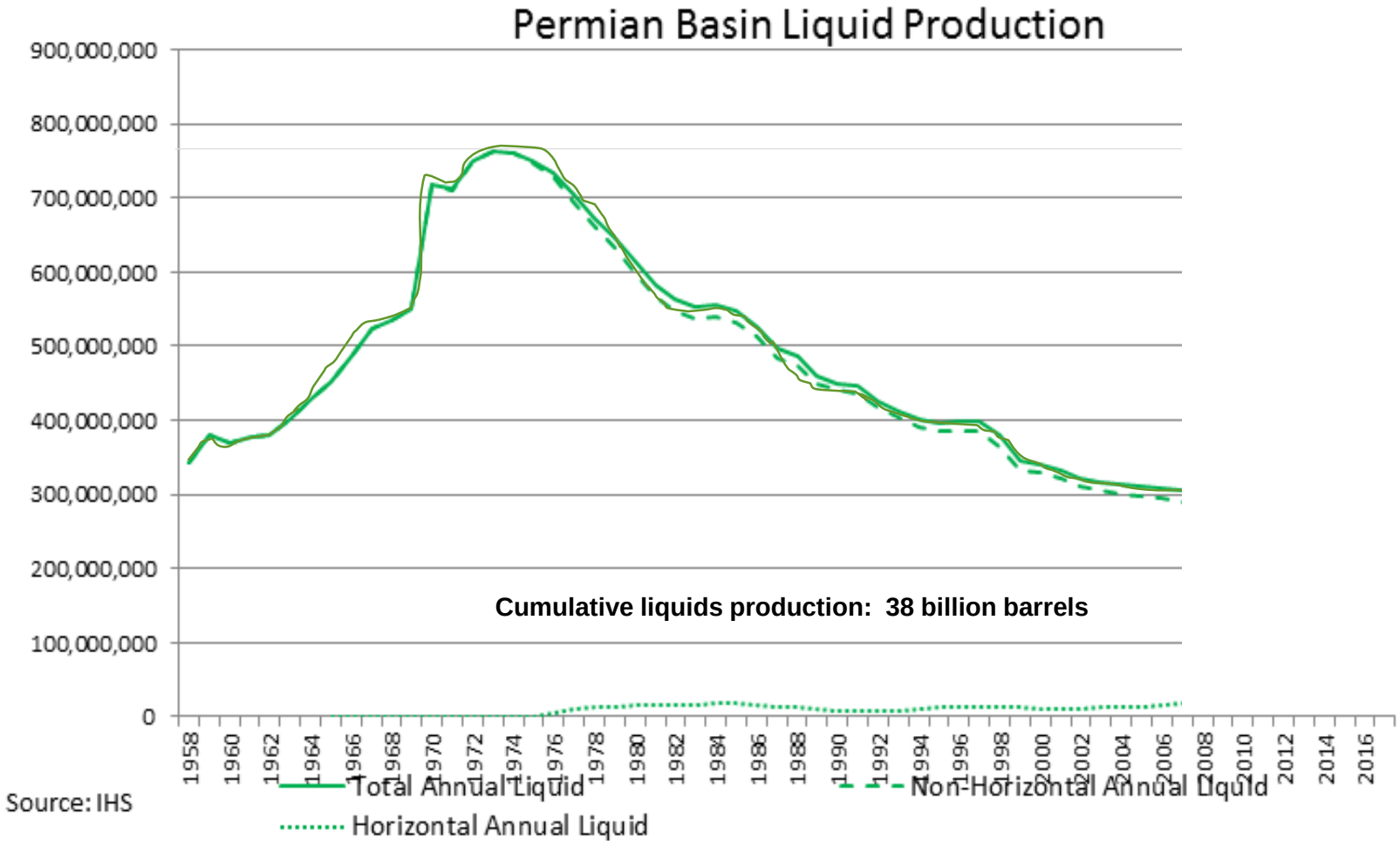


“Big Continent, Big Ideas and Big Opportunities”

Theme for this conference



Onshore Unconventional Analog Super Basin

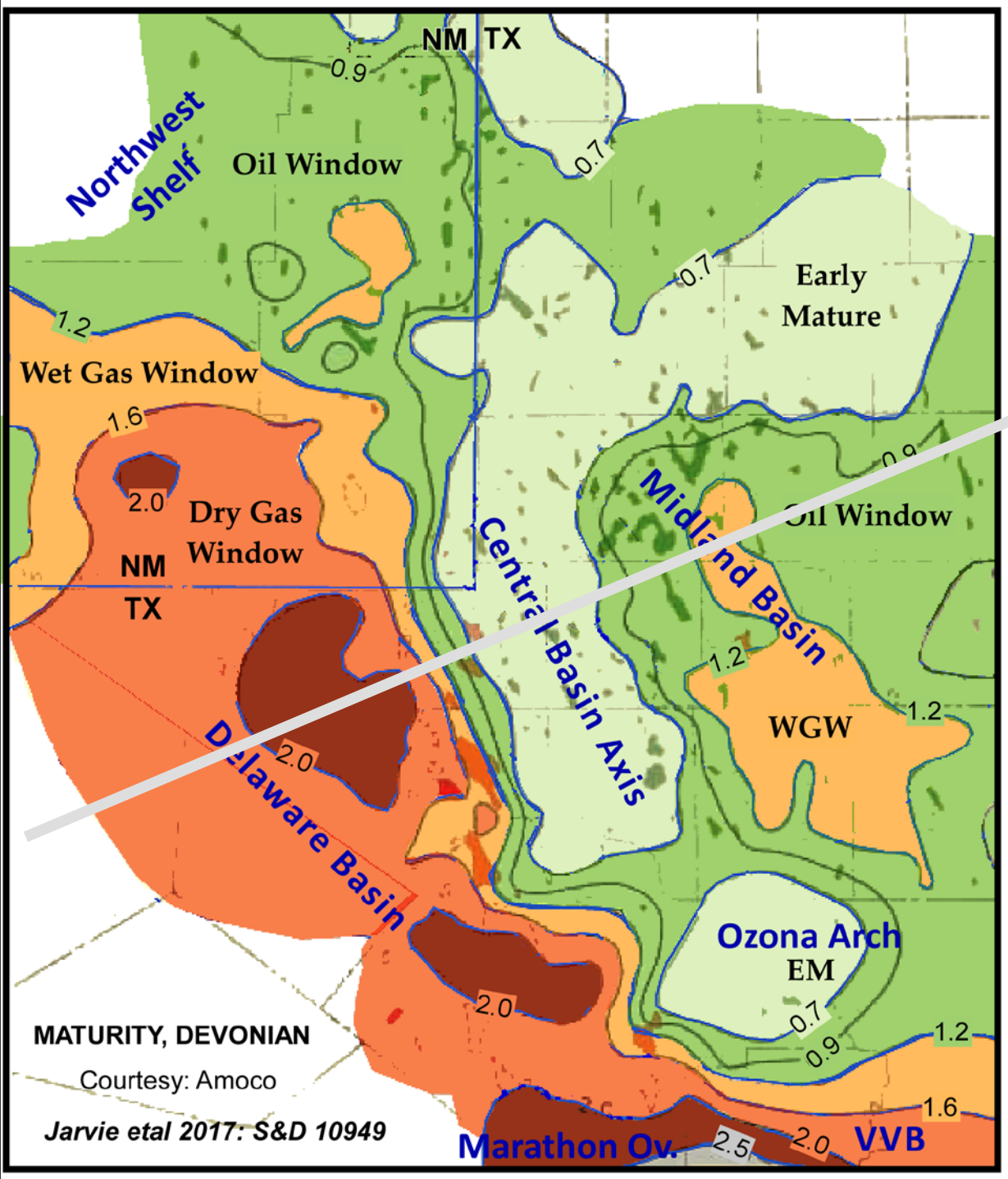


Source: IHS

Permian Basin Prototype

- How do new peaks happen?
- **Hydraulic fracturing horizontal wells** of unconventional shale
- **Enhanced seismic imaging** conventional targets previously unrecognizable
- **Hybrid Basins can have both!**

Taking Geoscience to Greater Heights



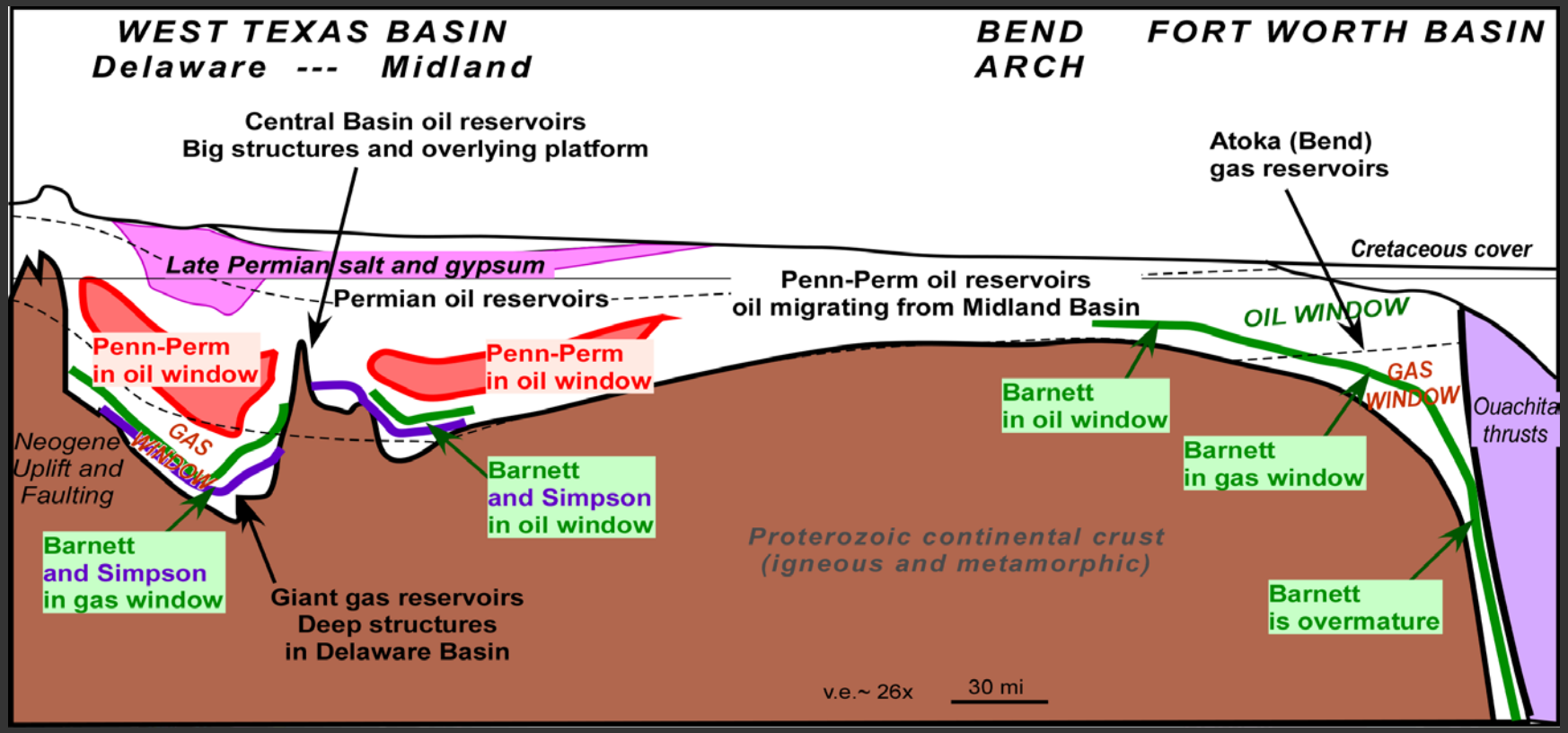
PERMIAN BASIN: DEVONIAN MATURITY AND PRODUCTION

Devonian is in the oil or wet gas window over most of the Permian Basin, with dry gas in the deeper Delaware Basin

This maturity over a broad area is due to the broad Permian Basin subsidence after ARM tectonics.

(Jarvie et al., 2017)

Permian Basin, W. Texas
Prototype Super Basin (Onshore, Unconventional)



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

Slide courtesy of Tom Ewing, 2017

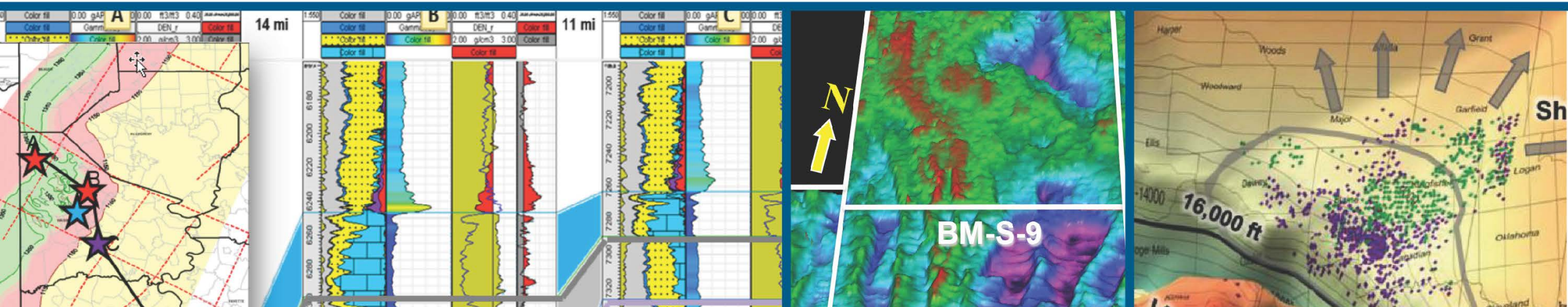
AAPG's

22-24 January 2019 • Sugar Land, Texas
Sugar Land Marriott Town Square

GLOBAL SUPER BASINS 2019

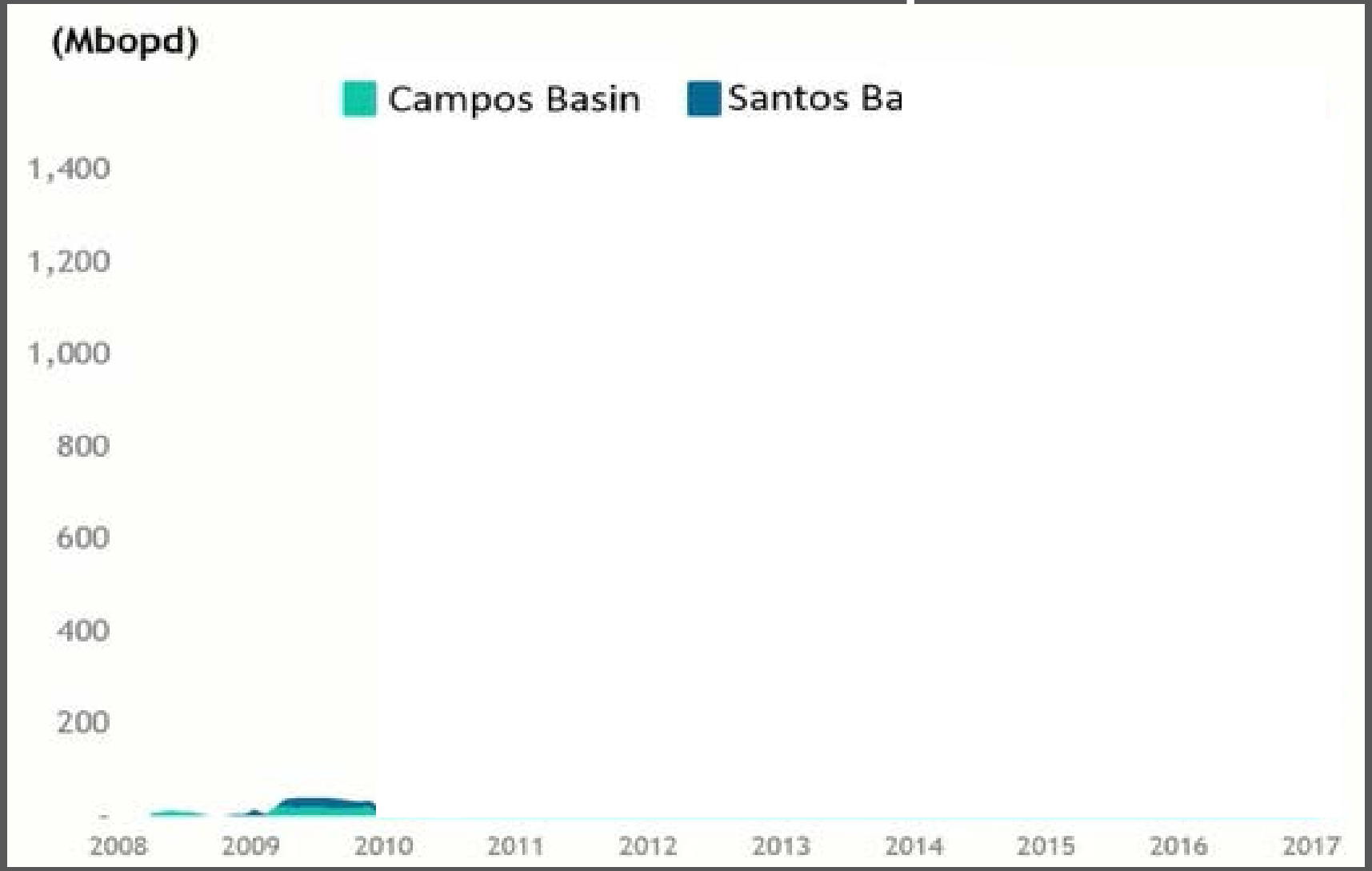
superbasins.aapg.org/2019

The Permian

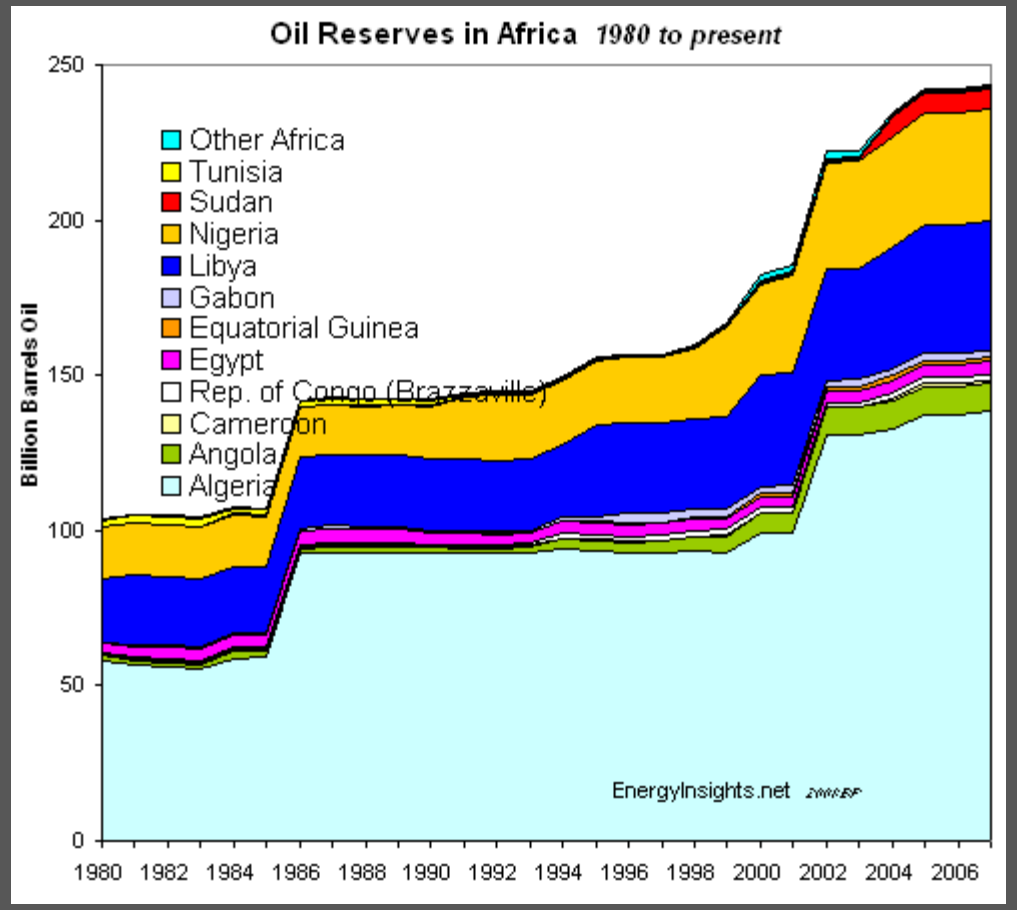


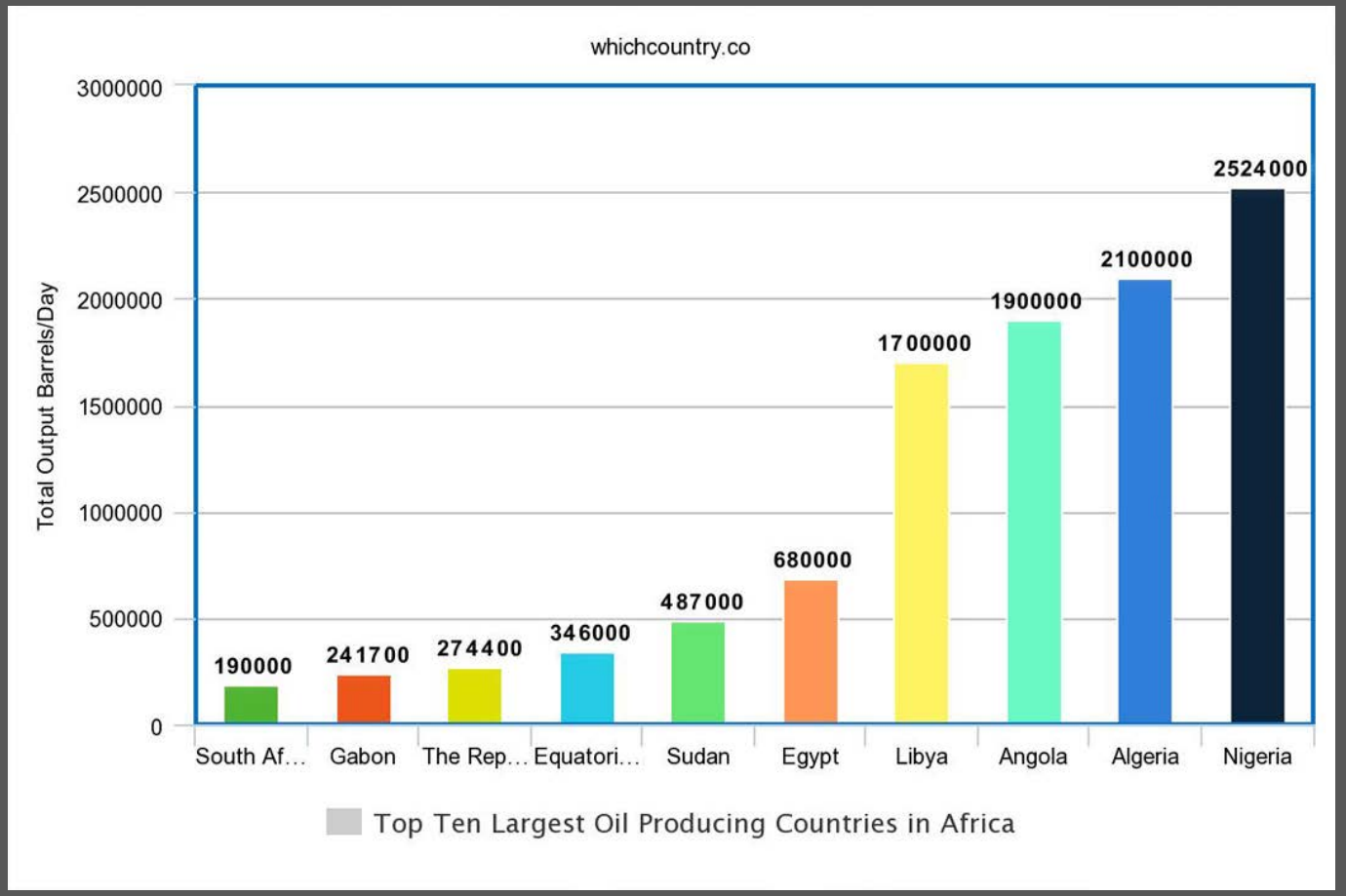
Offshore Conventional Analog Super Basin

Brazil Santos or Campos Pre Salt



Africa Production significant and increasing





Why study all super basins:

- Compare and contrast commonalities for actionable insights for quantum “leap frog” gains
- Think 3D: volumetric richness (one target plays like Appalachians or Williston vs many stacked targets like Permian, California, Anadarko; maps and cross sections helpful
- Think 4D (time): critical moments required for every basin
- Basin Mastery requires 10,000 hours or more of study
- Learn from Basin Masters early in career to build on Heritage
  - (Grad student Course, U of H, work in-house with industry experts)

Foundations

- Active world class petroleum systems, reservoirs, traps
- Structural Settings, Passive Margins and Rift and Continental basins hold 66% of worlds +/- 1,000 giant fields (Mann, 2003)
- Structural uplifts and pressure cells
- Unevenly uplifted (tilted) basins can produce residual oil zones
- Stratigraphic Traps: mature basins produce 20-40% from stratigraphic traps, Saudi Arabia in under represented with 95% structural traps
- In Situ, hybrid, migrated resource play
- Resource Play mineralogy
- Infrastructure and commonalities

Global Experts on the Largest Basins

Who are the future global experts?

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

- West Africa
- East Africa
- South Africa

AAPG Super Basins Forum: Nov 4-7 Cape Town

"Africa and Middle East, Big Basins, Big Successes and More to find"

Co-Chairs:

Charles A. Sternbach, AAPG Past President (2017–18) & Nosa Omorodion, Director, Nigerian Independents, Schlumberger

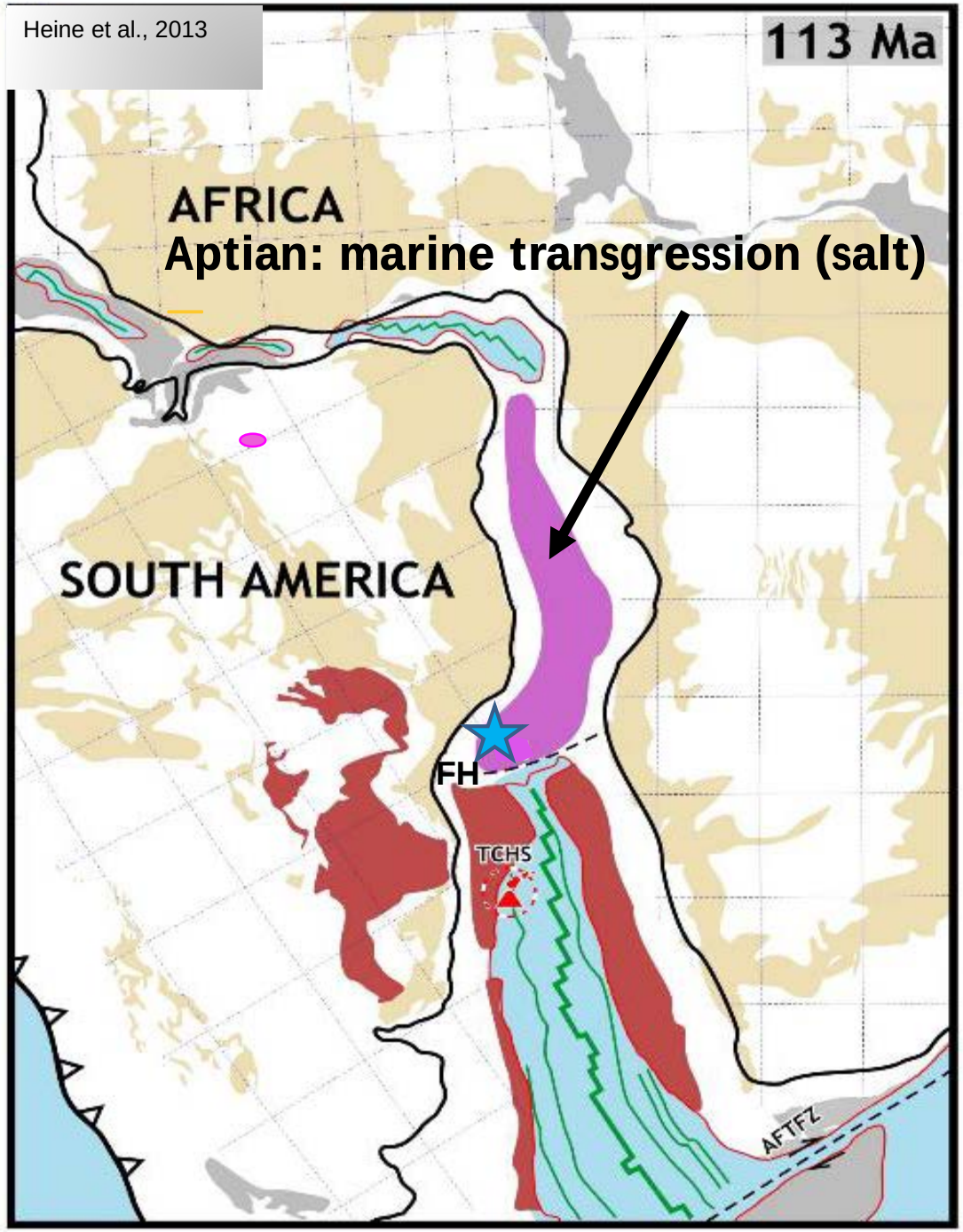
Invited Speakers:

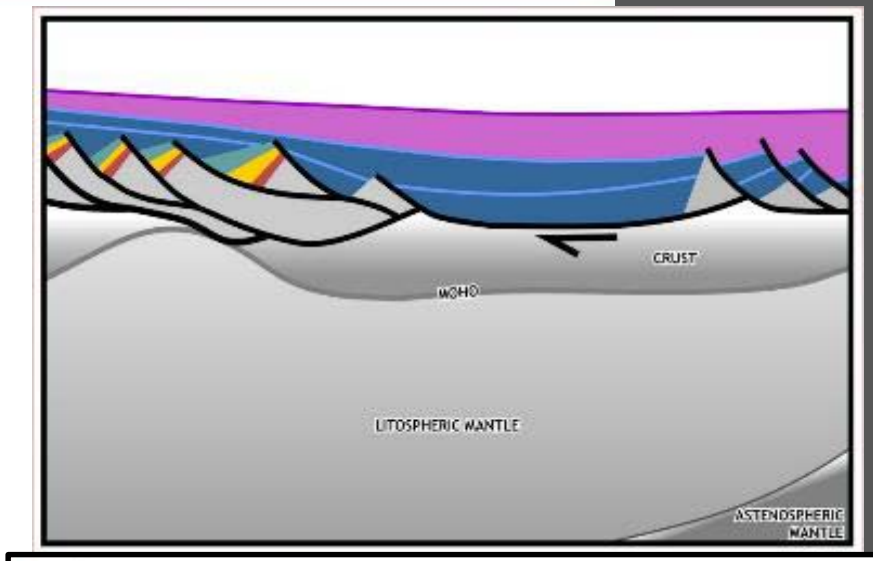
- **Exploration Creativity in the Golden Age of Super Basins and What AAPG is Doing About Them**: Charles A. Sternbach, AAPG Past President (2017–18)
- **Giant Basins of Africa: The More We Explore the More We Find**: Adebayo Akinpelu, Managing Consultant, Fixital
- **North Africa – A Rejuvenated Super Basin**: Andrea Cozzi, Vice President, Exploration North/East Africa and Middle East, ENI
- **East Africa and Mozambique, Waking a Sleeping Super Basin**: Brian Russel Frost, Distinguished Geophysical Advisor, International New Ventures, Anadarko Petroleum Corporation
- **Basins and Petroleum Systems of the Middle East**: Sa'id Al Hajri, Manager, Geological Operations Department, Saudi Aramco

African Perspective

West Africa

Heine et al., 2013





Legenda:

- Aptian Salt Basin (Marine Restricted)
- Microbial Carbonate Platforms (Lacustrine)
- Sin-Rift Successions
- Parana Large Igneous Province (LIP)
- Source Rocks / Coquina Carbonate Platforms (Lacustrine)
- Stretched Crust

★ **Santos Basin**

Legenda:

FH - Florianopolis High

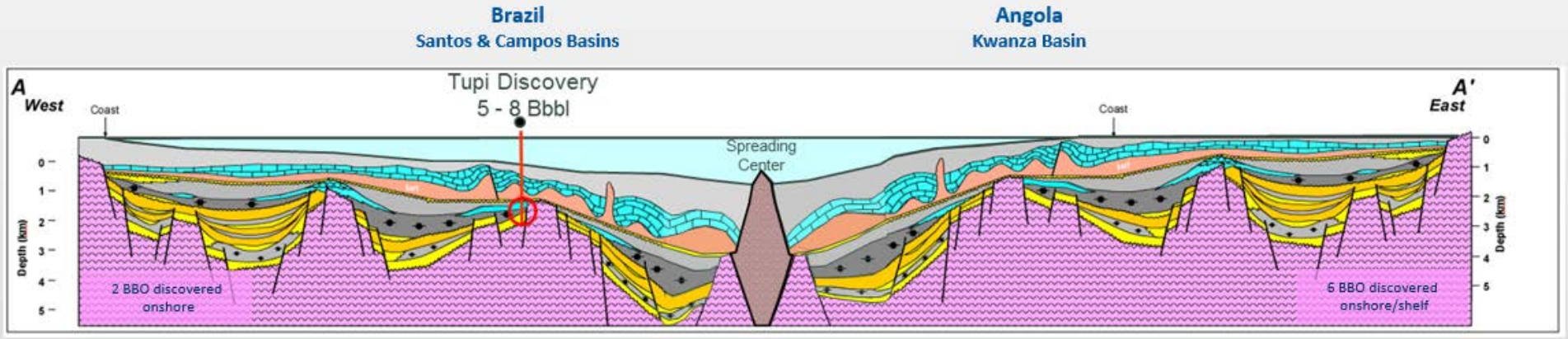
TCHS - Tristão da Cunha Hot Spot

AFTFZ - Agulhas-Falkland Transform Fault Zone

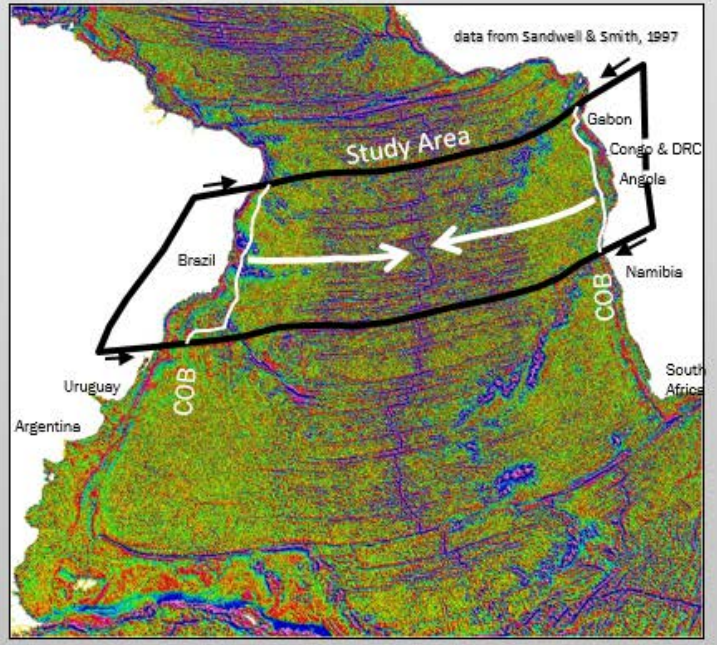
- Aptian Salt Basin (Marine Restricted)
- Microbial Carbonate Platforms (Lacustrine)
- Source Rocks / Coquina Carbonate Platforms (Lacustrine)
- Parana Large Igneous Province (LIP)
- Stretched Crust
- Pre-Paleozoic Rocks

Angola

Mirror Image Potential Being Tested Across the Atlantic



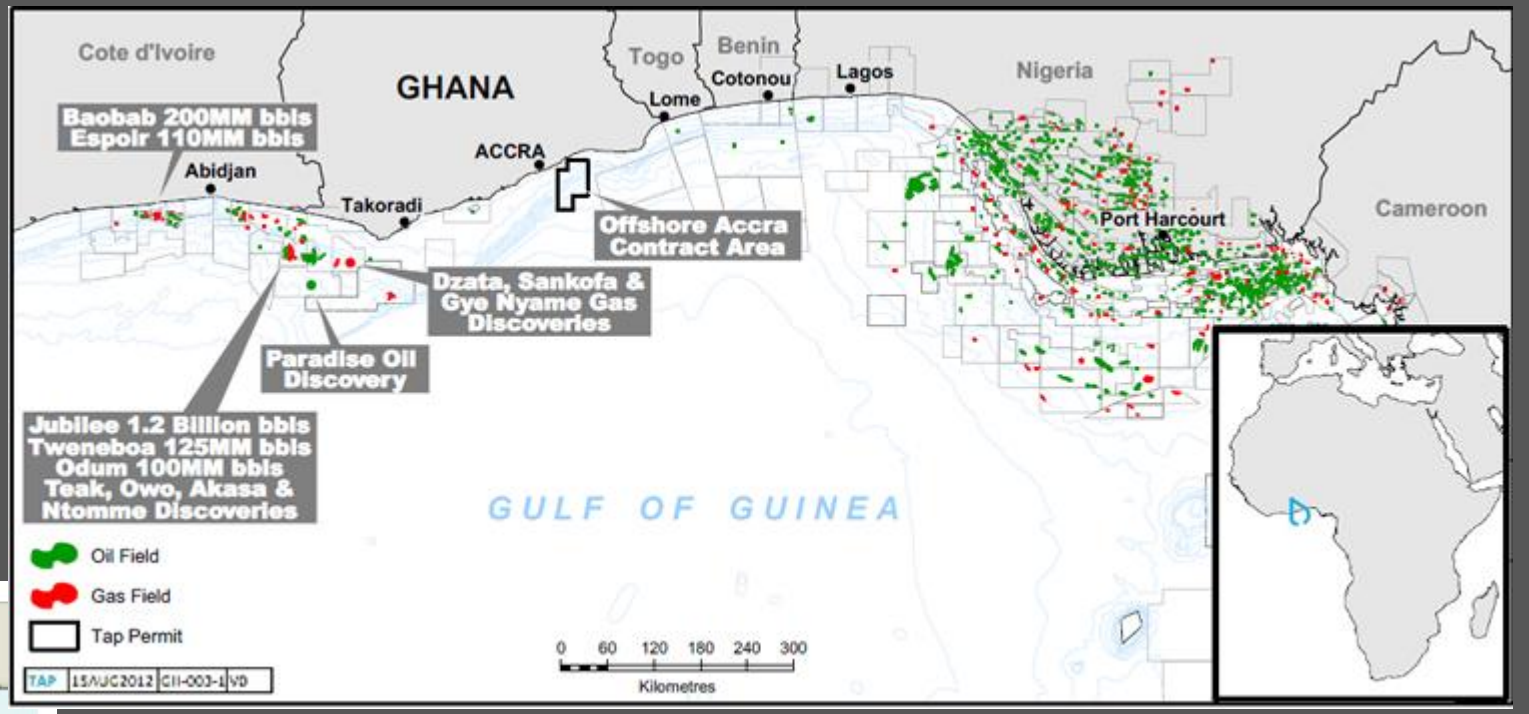
2007 vintage



- The Pre-salt play was proven onshore and within shallow water areas of the West African margin
- Post-Salt oil fields in shallow waters of the Campos and Congo basins known to be sourced from Pre-salt source rocks
- Cobalt estimated the West Africa Pre-salt play contained 20+ BBOE of total Pre-salt potential with significant volumes yet to find
- Cobalt began evaluating the viability of extending the Pre-salt play into underexplored deepwater basins along the margin
- **In July of 2006 there were indications that Petrobras and BG's initial Tupi well had positively identified oil within Pre-salt reservoirs**

Shinol, 2015 Cobalt

Cote d'Ivorie, Ghana



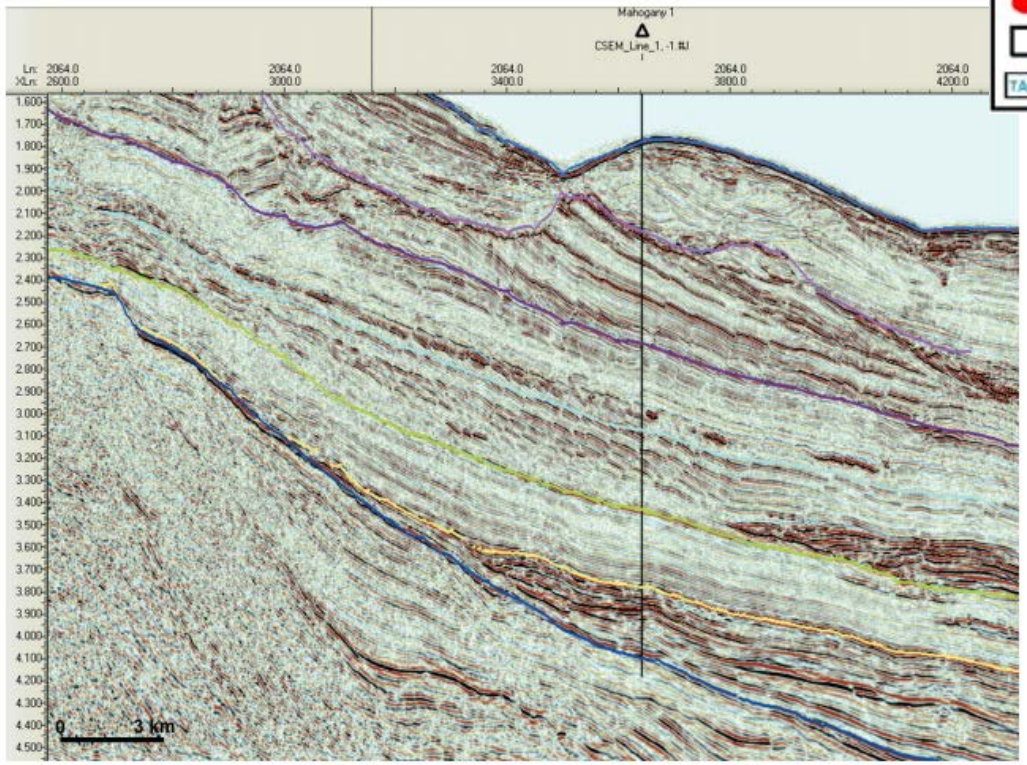


Figure 18. North–south line showing Mahogany 1 location and pinch out of Mahogany fan to the north. (Modified from Jewell, 2011.)

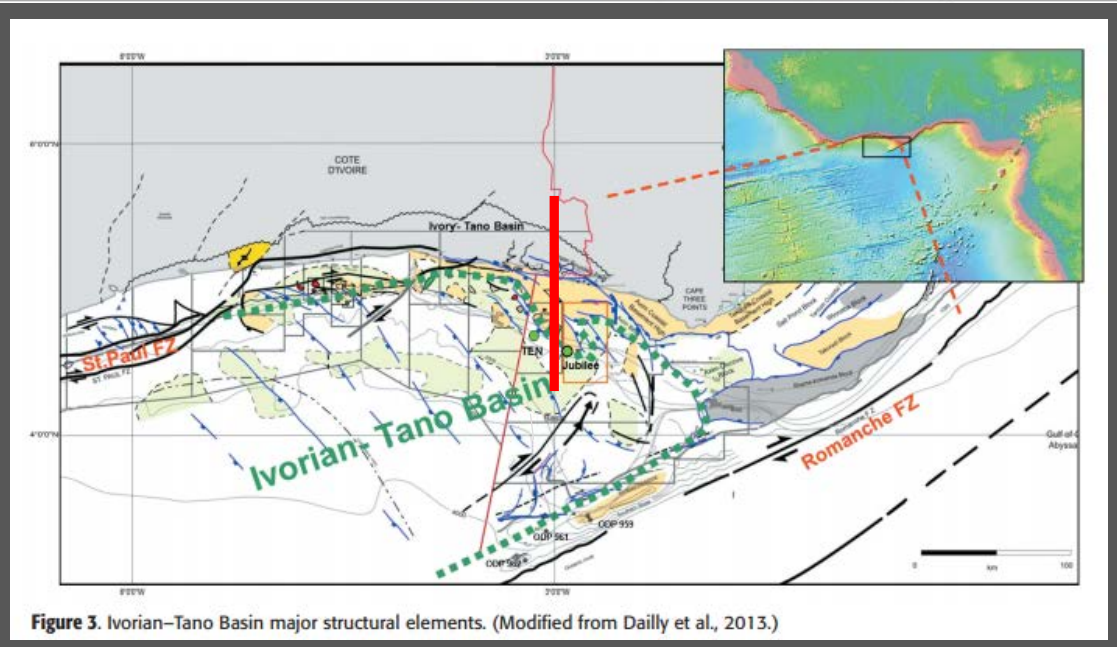
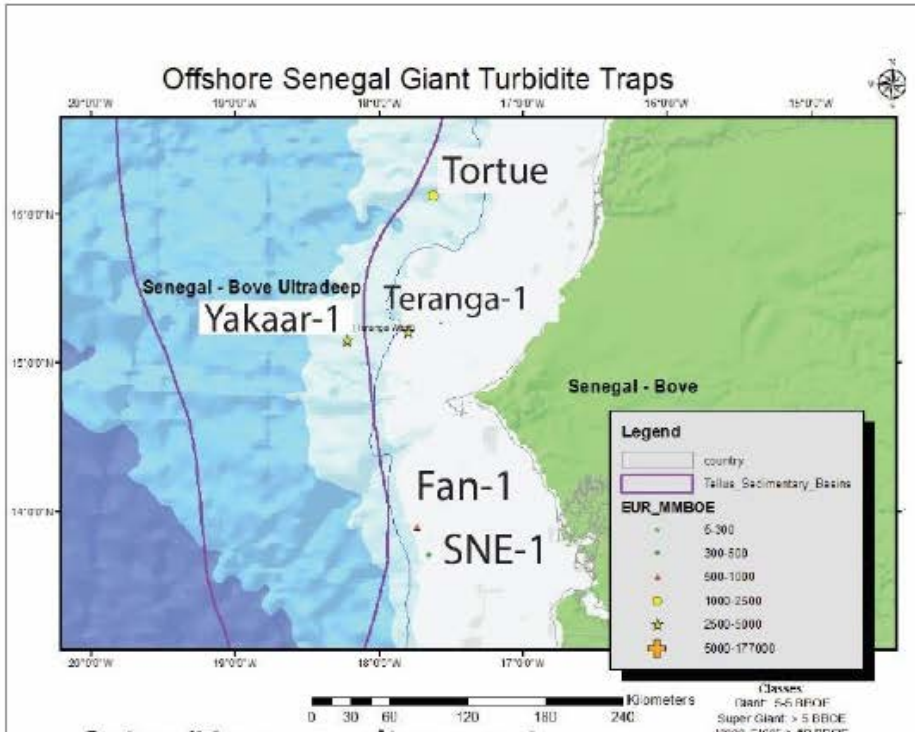


Figure 3. Ivorian–Tano Basin major structural elements. (Modified from Dailly et al., 2013.)

Dailly, et al, 2017 Chapter 14 in Giant Fields, Merrill and Sternbach

Senegal



Cairn/Kosmos discoveries

Fan-1: 2014 (Cairn)
- 950 MMBO P50; P10 2.5 BBO
- Fan-South-1 successful 31º API oil

SNE-1: 2014 (Cairn)
- Paleotopographic: 385 MMBO
- SNE-1 extensions successful

Yakaar (Teranga West): 2016: 15 TCF (Kosmos)

Tortue: 2015: 15 TCF (Kosmos)

Teranga: 2016: 15 TCF, 300 MMBO

Mature kitchen/source rock strat traps

Play schematic

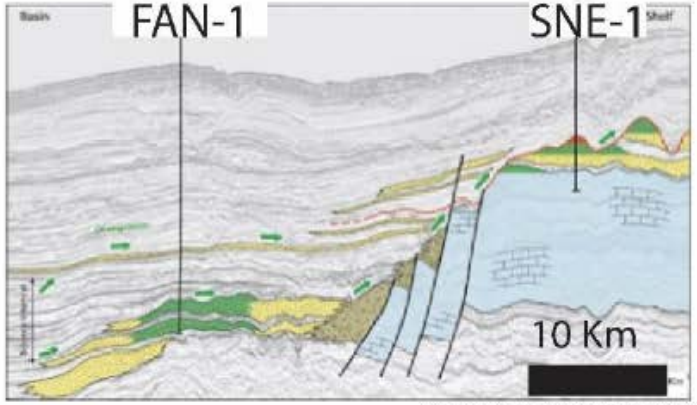


Figure from Reynolds, 2016

FAN and SNE Discoveries

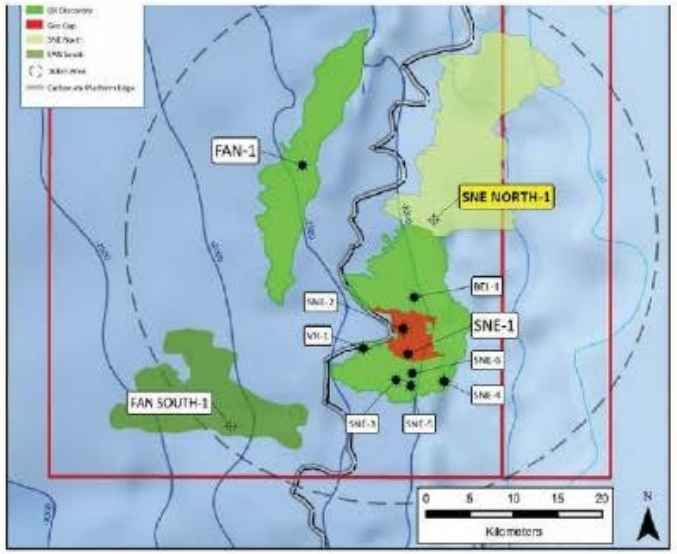
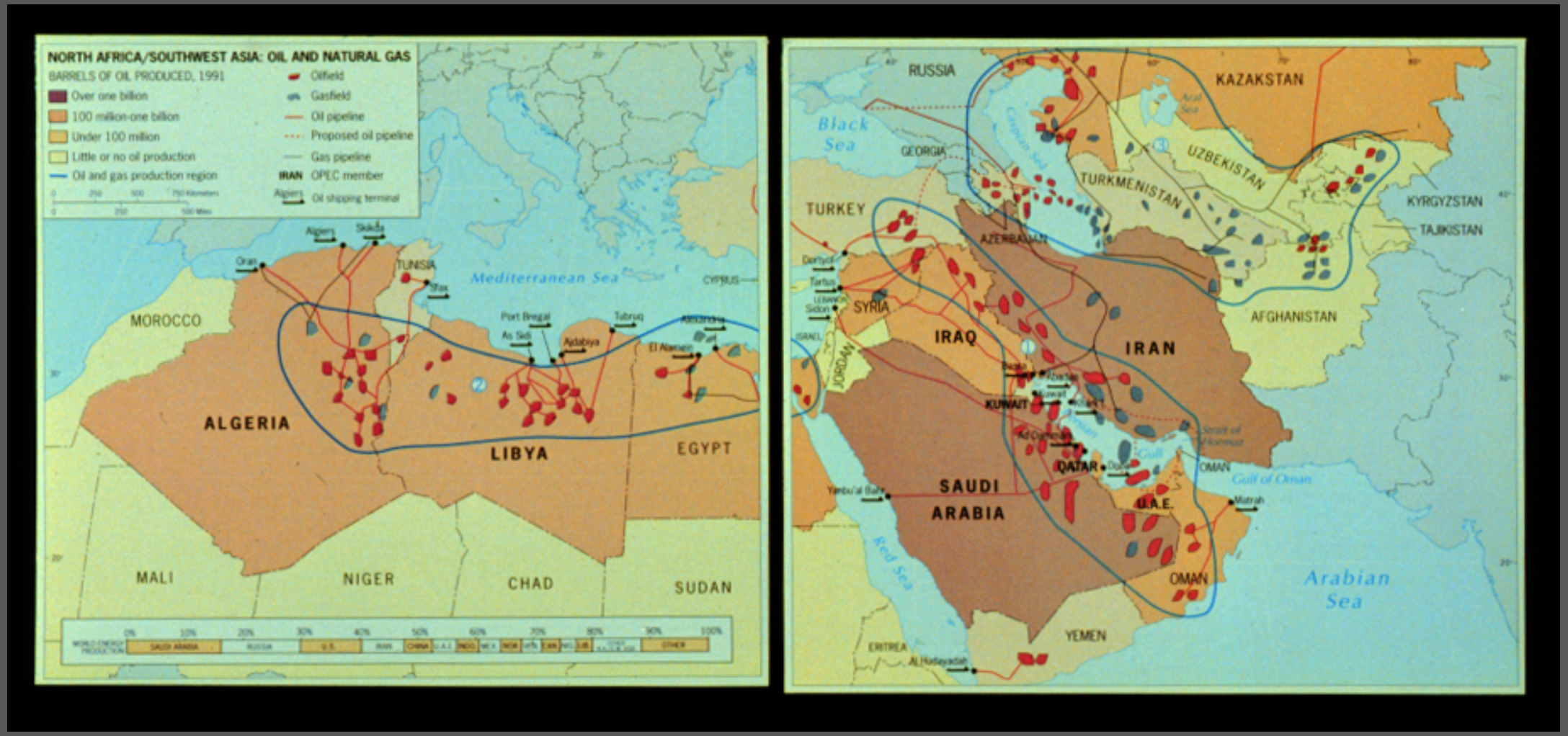


Figure from Cairn August 7, 2017 press release

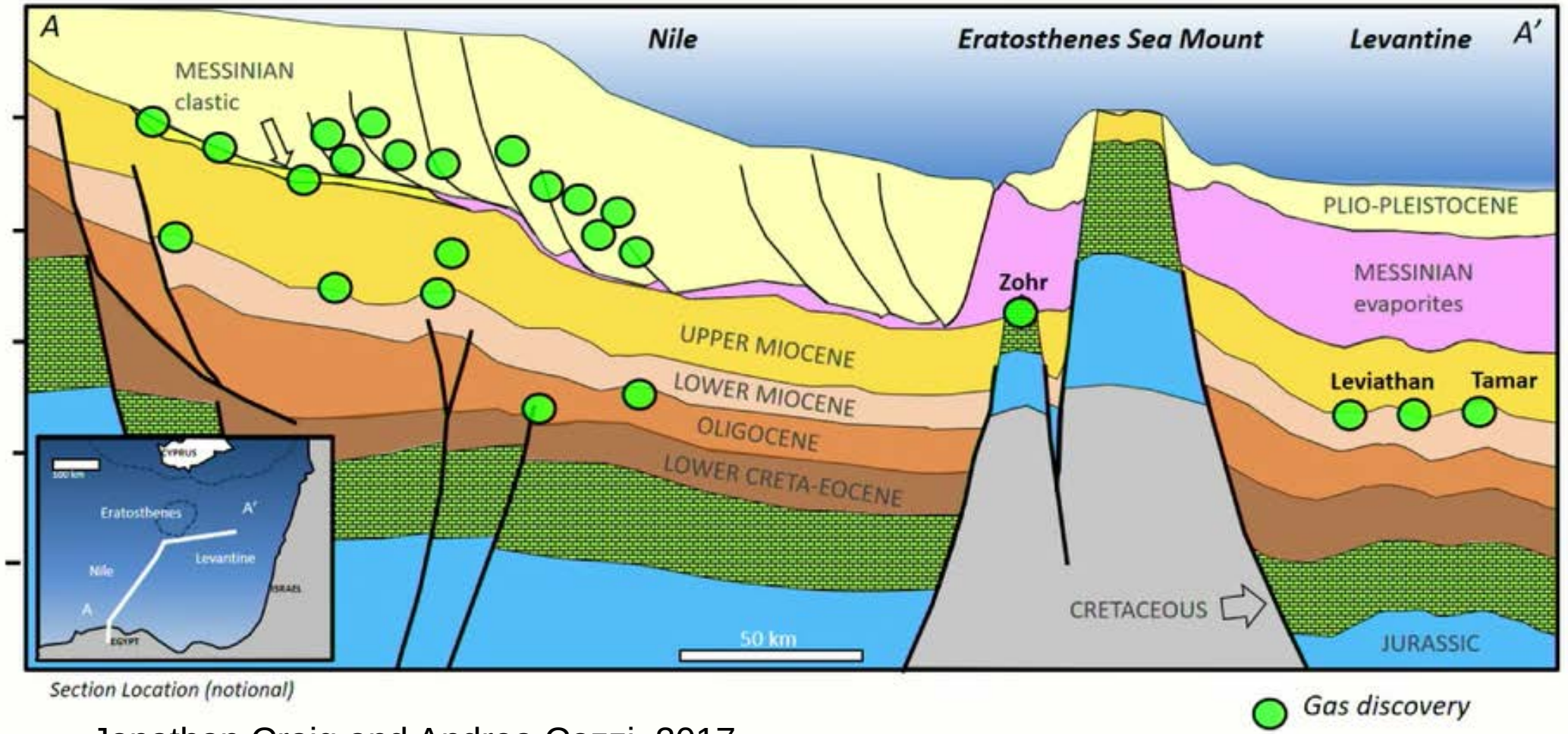
Figure 21. Cairn and Kosmos discoveries of fan, channel and other traps, offshore Senegal.

Dolson, He, and Horn, June 2018

North Africa and Middle East



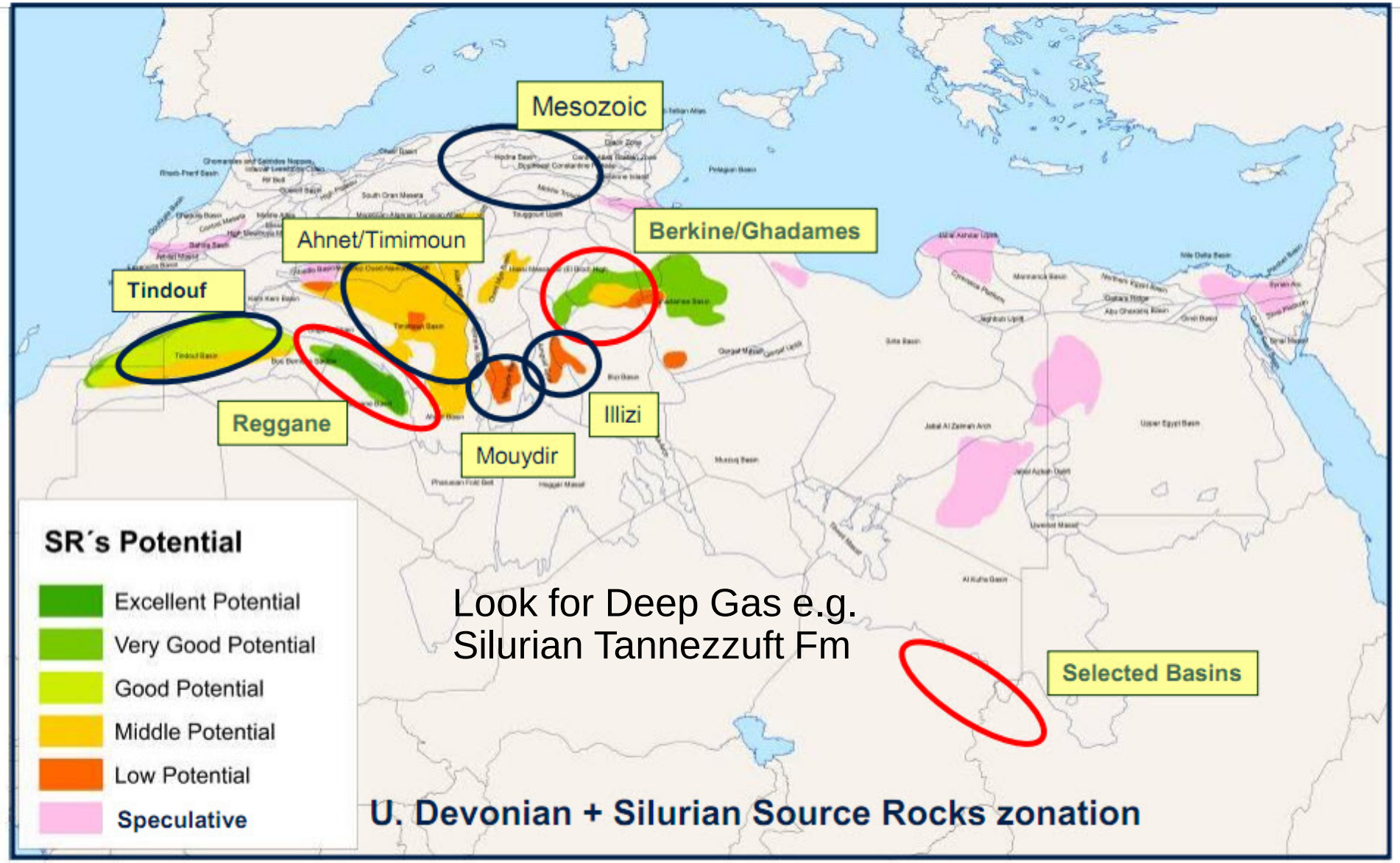
Mediterranean-scale Geological Section through the offshore Nile Delta



Jonathan Craig and Andrea Cozzi, 2017
Discovery Thinking Forum AAPG ICE London

North Africa

Algeria Shale Gas Potential



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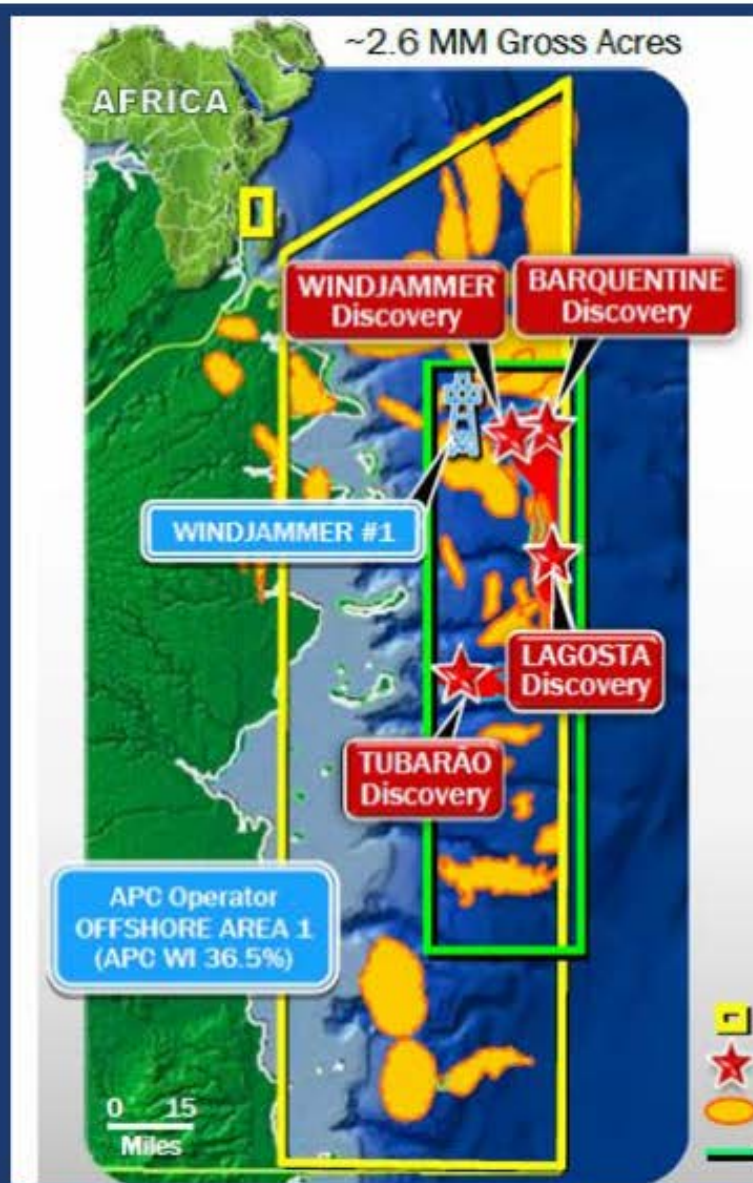
East Africa

Offshore Mozambique Wildcat Success Story

Anadarko
Moçambique Área 1, Lda

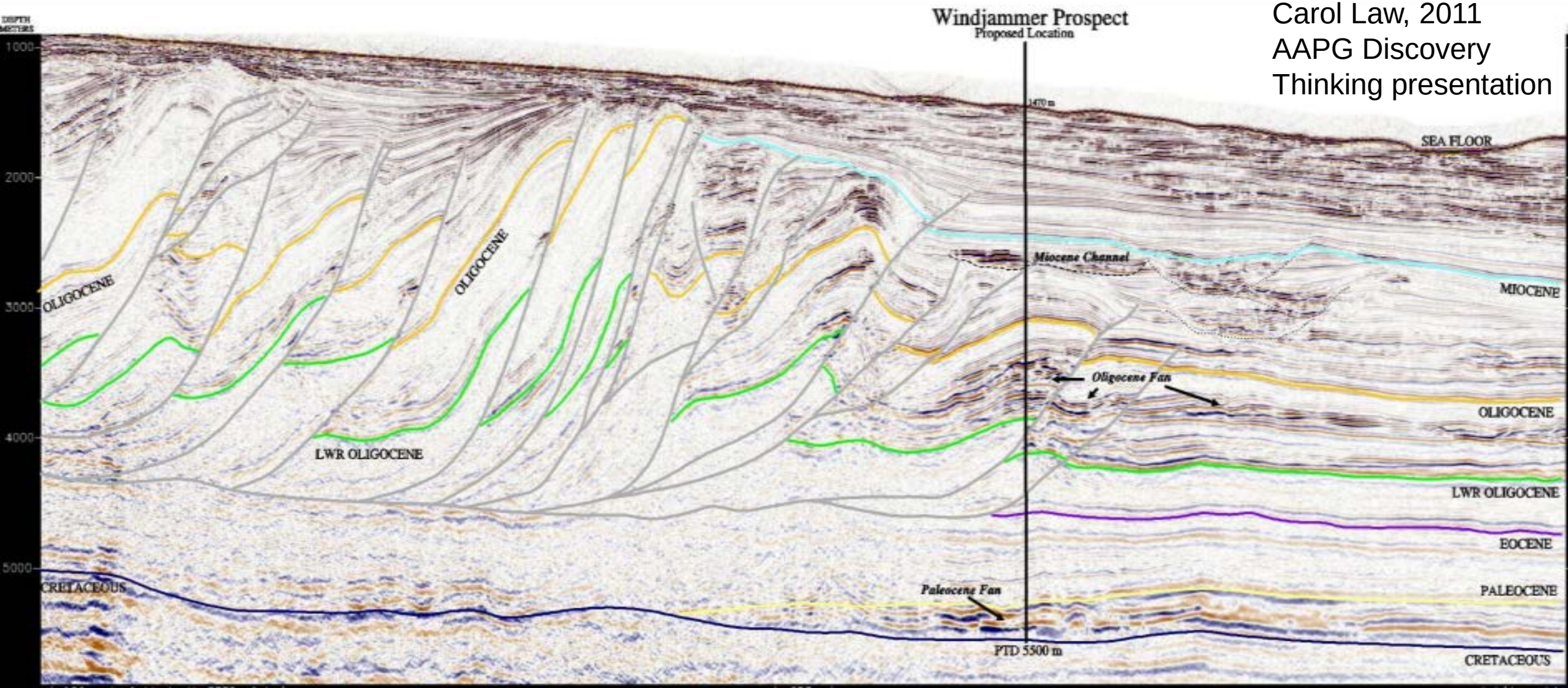


- **4 Major Discoveries**
  - Lagosta - 550 Net Feet of Pay
  - Barquentine - 416 Net Feet of Pay
  - Windjammer - 555 Net Feet of Pay
  - Tubarão - 110 Net Feet of Pay
- **2011 Planned Activity**
  - Dedicated Rig
  - Add Second Rig in Q4
  - Appraise Discoveries
  - Continue Exploration Program
- **Robust Exploration Inventory**

Carol Law, 2011
AAPG Discovery
Thinking presentation

Windjammer Palma FB Thrust Play

Anadarko
Moçambique Área 1, Lda



Carol Law, 2011
AAPG Discovery Thinking presentation

South Africa

USGS Sub-Saharan P50 assessments

In inland Karoo

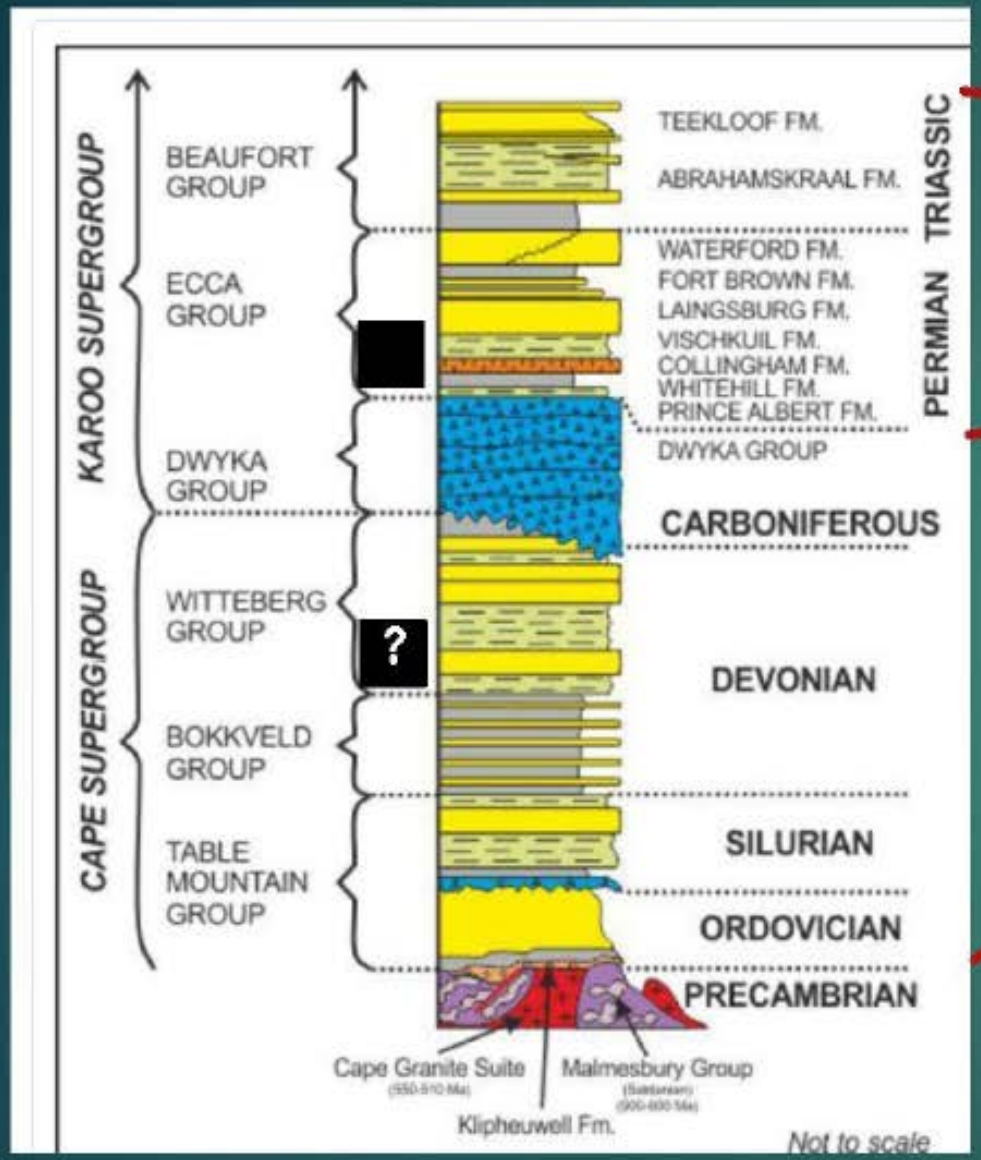
- 23.5 TCF shale gas in Karoo Basin (Whitehill-Collingham and Prince Albert sources) **Permian Age source rocks, Permian Basin 2.0??**
- 8 TCF CBM outside strict Karoo (foreland) Basin (Botswana-Zambia-etc.)

In coastal basins and CARS/CASZ (MZ+CZ reservoirs)

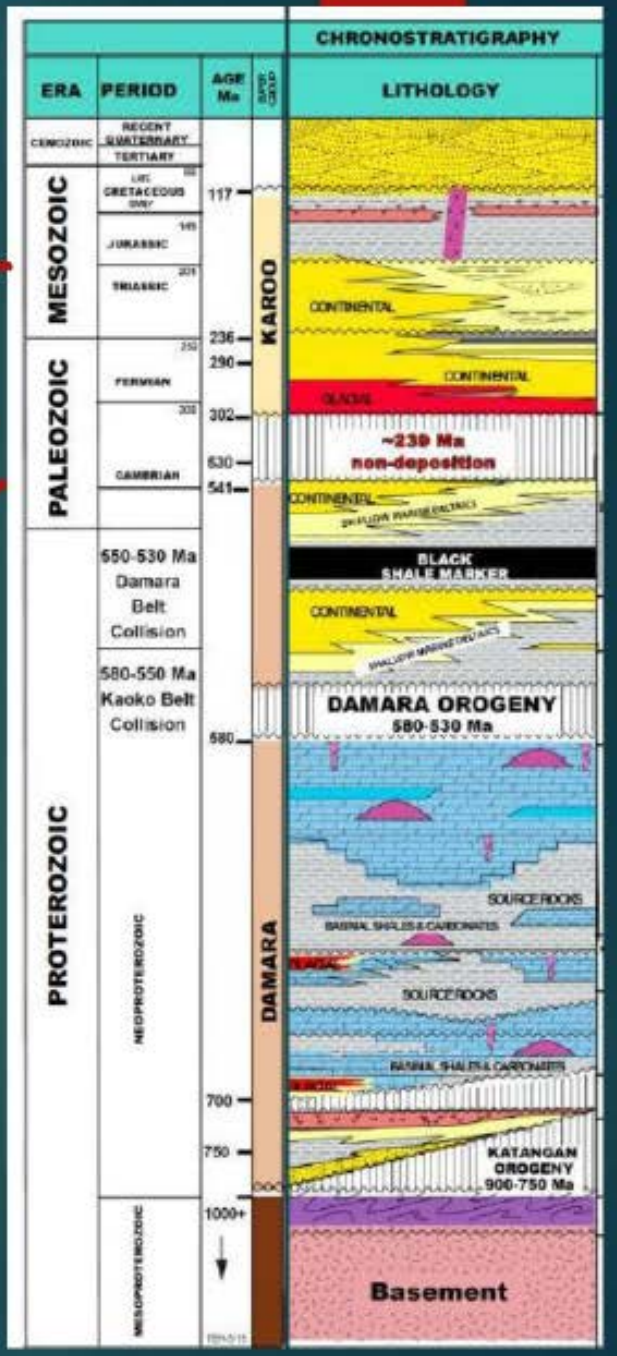
- 104 BBO conventional oil
- 645 TCF conventional reservoirs)

Jim Granath et al, 2017

South Africa



Namibia



"Mid-Paleozoic"

550-530 Ma Damara Belt Collision

580-550 Ma Kaoko Belt Collision

How representative of central Africa ?

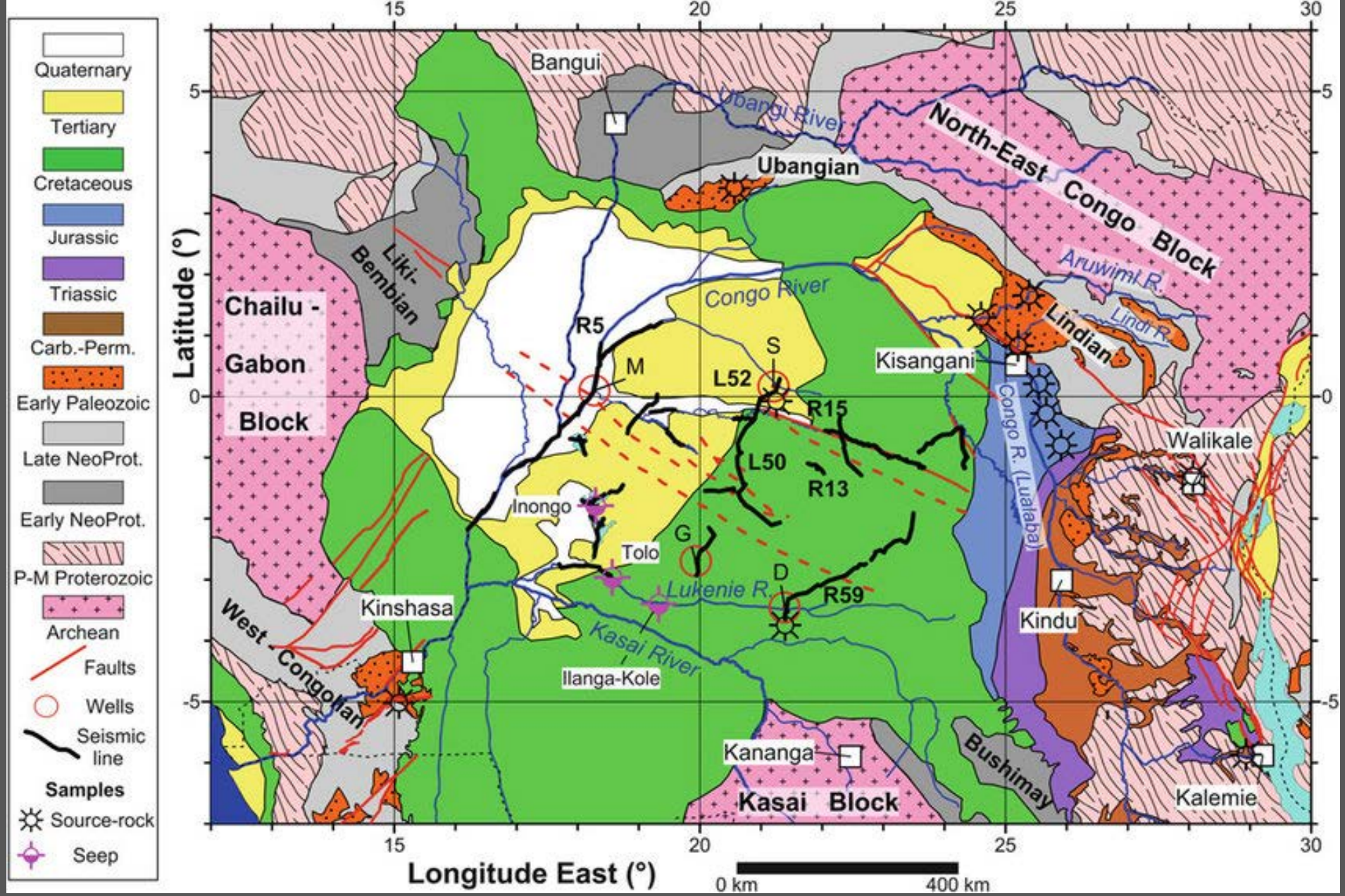
Hoak et al., S&D 2014

http://www.sees.manchester.ac.uk/our-research/research-areas/pes/basin-studies-and-petroleum-geoscience/research-themes/clasticsedimentologyandsequencestratigraphy/currentresearch/slope4/karoogeology/

Jim Granath et al, 2017

Central Africa

Intra cratonic Sag Basin(s)
e.g. 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

Resources for Explorers: AAPG Bulletin Articles

SUPER BASIN INITIATIVE

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

Manuscript received January 8, 2018
DOI:10.1306/pn010818

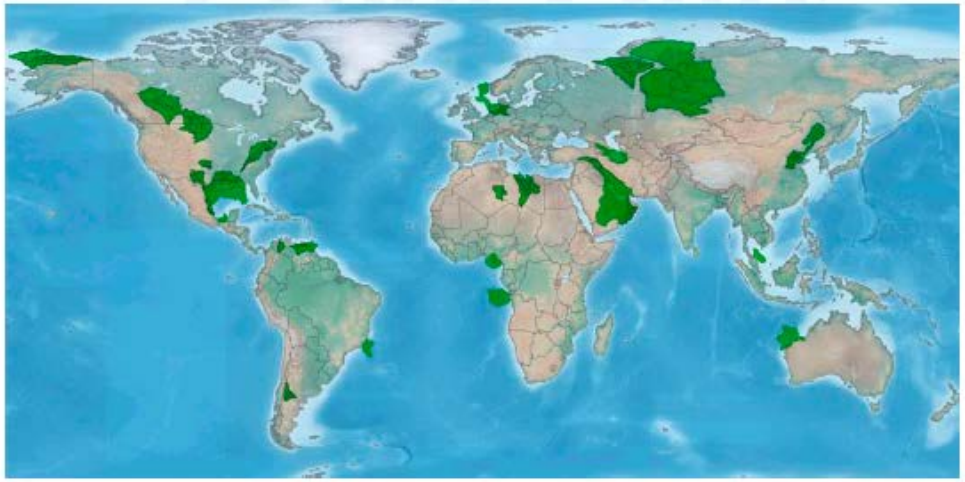


Figure 1. Map of top 25 super basins (courtesy IHS Markit).

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?

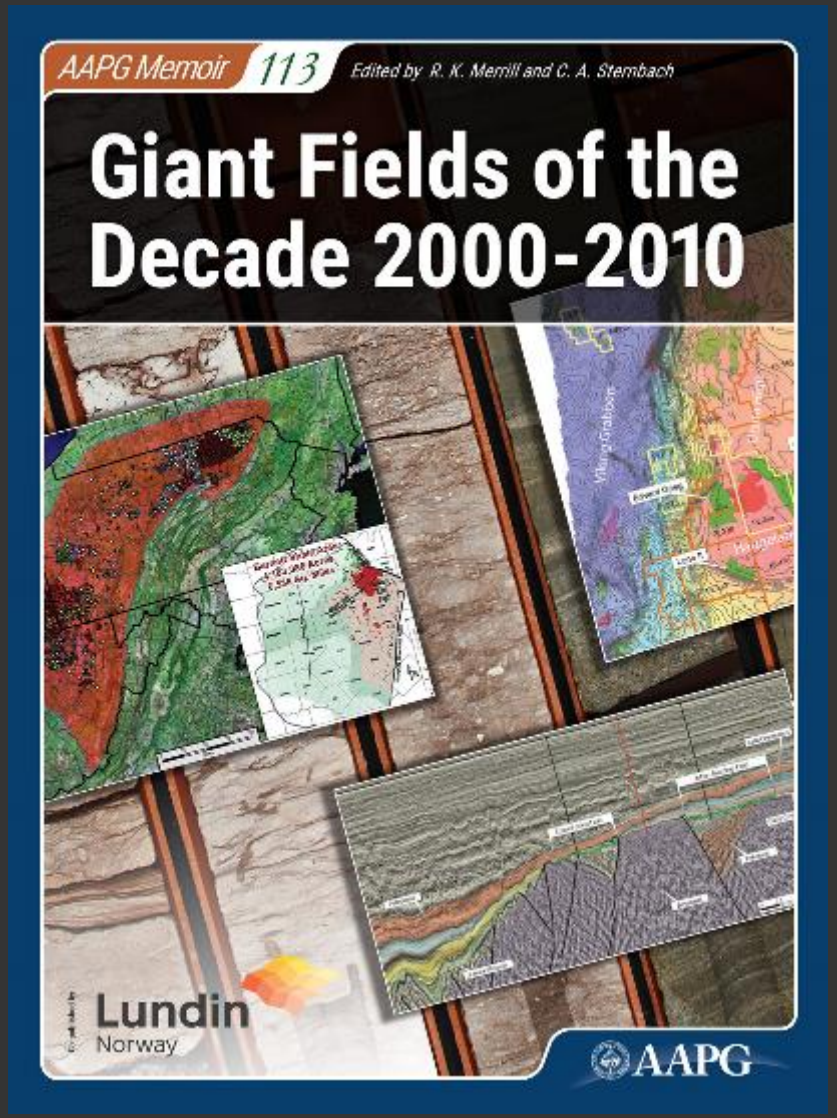
In addition to their geologic energy endowment, super basins have large scale and infrastructure to incubate new technology. Technology nurtured and proven in super basins has great relevance and application to basins of all sizes. Thus, super basin papers will have widespread value to energy producers 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 AAPG Bulletin

Papers On Africa Basins Needed

New AAPG Book on Giant Fields; Another Coming!



Plans For Super Basin Programs

- **March 27-29, 2018 Inaugural AAPG Global Super Basin Leadership Conference**
- May 21 2018 Super Basin Forum at AAPG (ACE) Salt Lake City, Utah
- June 13 2018 EAGE: Europe, North Sea and North Africa super basins
- August 22, 2018 Conjugate Margins Conference, Halifax CA
- **Sept. 11 2018 HGS Africa Conf., Super Basins African Perspective (TODAY)**
- Oct. 3, 2018 INGEPET, Lima Peru, Super Basins Latin America Basins
- November 4-7, AAPG (ICE) Africa and Middle East Basins, Cape Town South Africa
- **January 2019, AAPG, Permian Prototype Super Basin, Houston, TX**
- March 3-5 2019 Hedberg on Petroleum Systems, Houston TX
- May 25, 2019, AAPG (ACE) Global super basins session, San Antonio TX
- June 3-6, 2019 EAGE, London GB, Embrace Change - Creativity for the Future
- November 2019 AAPG (ICE), Buenos Aires, Argentina, Latin American Super Basins

Future for Industry and AAPG

- Super Basins are important
- The top 25 basins alone may add 800+ Billion Bbls
- Studying the worlds greatest basins helps all basins
- Skills and techniques apply globally,
  - Hydraulic fracturing horizontal wells in unconventional mainly onshore basins
  - Enhanced seismic imaging in conventional offshore basins
- Energy, Environment, Economy, Security, Sustainability
- Thanks to Geoscientists for playing a key role