

Exploration Creativity in the Golden Age of Super Basins - AAPG Initiatives: An African Perspective*

Charles A. Sternbach¹

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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(er) 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 already possess social license and extensive infrastructure), will sustain us long into the future. The concept of super basins* – a new way of thinking – combines geoscience architecture, commerciality, infrastructure and aboveground 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. AAPG has instituted a series of conferences, forums, and publications to assist geoscientists. AAPG hosted the inaugural Global Super Basin Leadership Conference (GSBLC) Mar. 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. As of this writing (November 2018), AAPG’s branding of super basin programs has occurred in multiple venues. In March 2018, the AAPG Bulletin launched the Global Super Basin initiative. 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. With respect to African Basins, it is clear that energy resources are abundant and varied. Africa possesses a rich series of super basins in Niger Delta, Algeria, Libya and emerging places such as Mozambique and offshore Egypt in the Eastern Mediterranean. Natural gas and LNG appears to be a fuel for the future. There appear to be offshore extensions to some of the super basins (e.g. Sirte Basin, Libya) and the potential for onshore unconventional resources where need for water, sand, services and infrastructure remain important challenges to overcome.

*The concept and definition of Super Basins were initially developed by Bob Fryklund, Pete Stark, IHS market research paper, 2016.



Charles A. Sternbach

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University of Houston Faculty*

Exploration Creativity in the Golden Age
of Super Basins -- AAPG Initiatives
An African Perspective

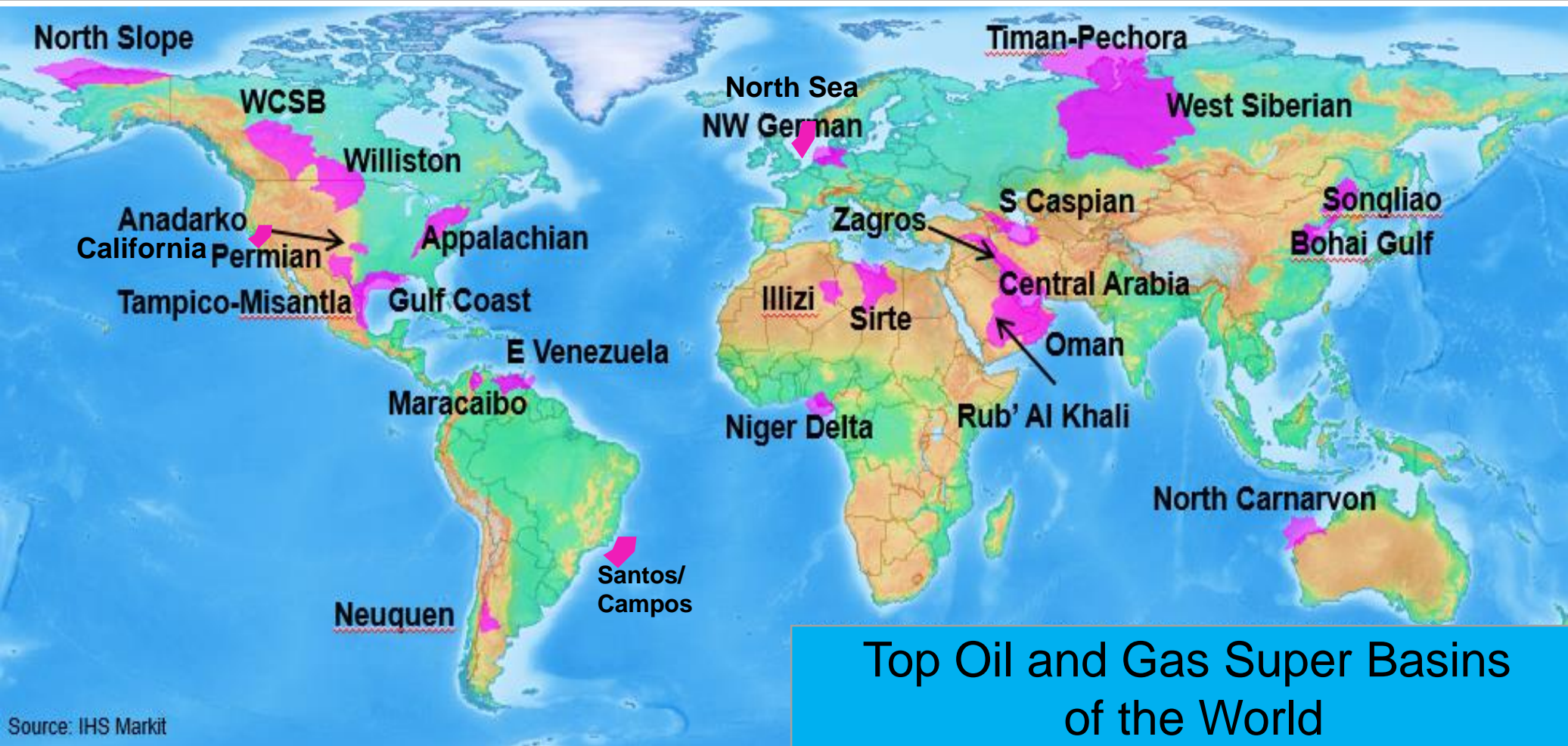


AAPG



Top Super Basins-Lessons for all basins

Estimated Technically Recoverable – 860 Bboe



Top 25 global
“Super Basins”

Cumulative production
and remaining oil and gas
both ≥ 5 billion boe

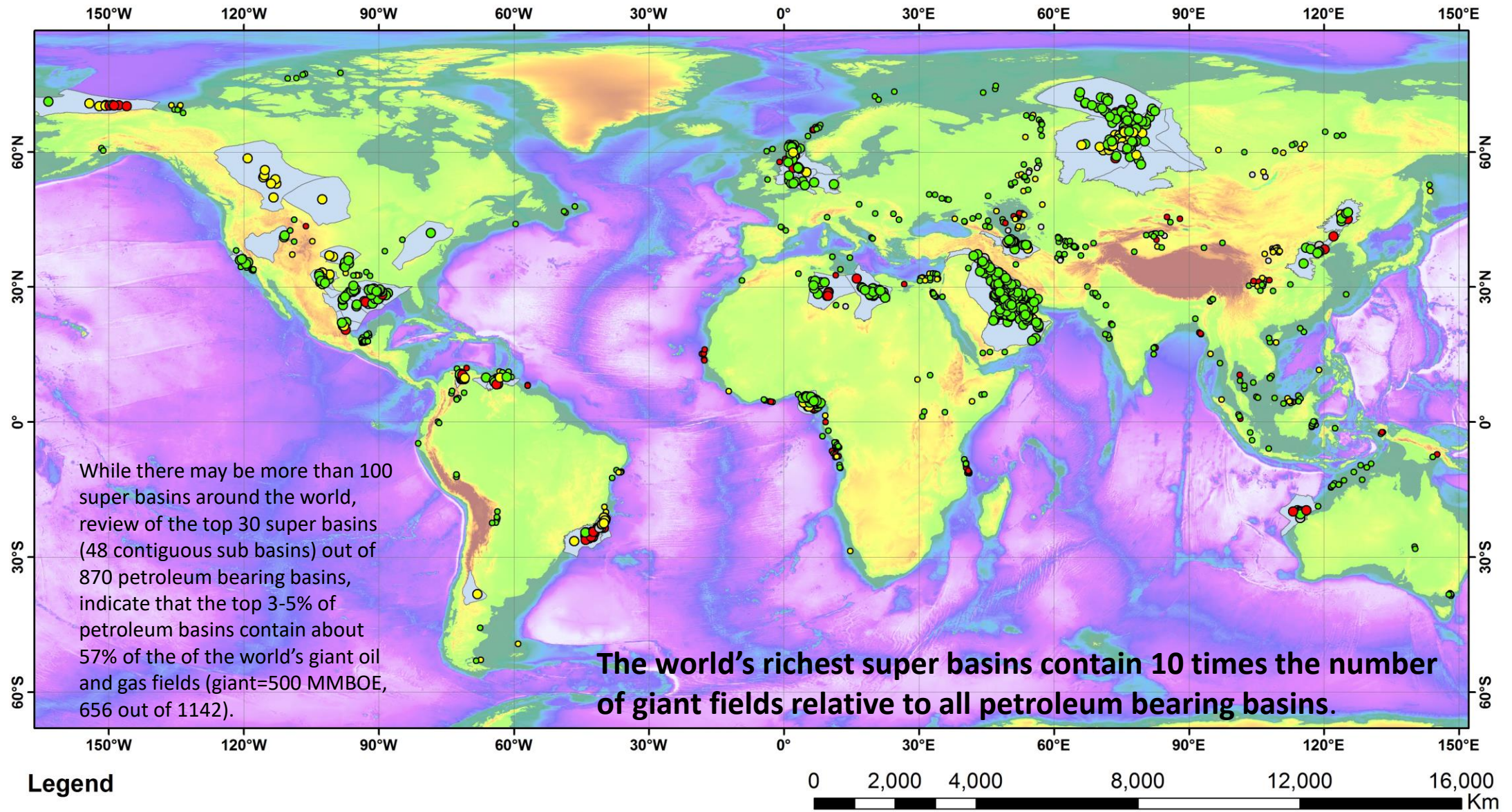
Multiple source rocks /
petroleum systems

Infrastructure, services,
ecosystems and supply
chains

Special Thanks to Bob
Fryklund, Pete Stark,
Jerry Kepes and
IHSMarkit, 2016

Top Oil and Gas Super Basins
of the World

World Giant Fields by Trap Types



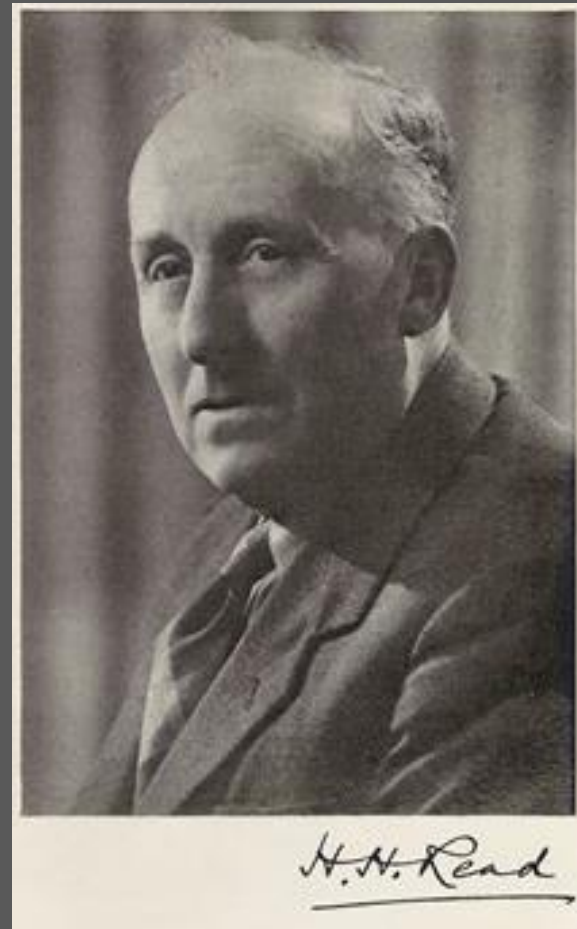
Author: Lei Sun and Charles Sternbach
Date: 10/22/2018

Coordinate System: GCS WGS 1984
Datum: WGS 1984
Units: Degree

Why study giant fields and super basins?

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

— Herbert Harold Read (Imperial College)



Global Experts on the Largest Basins

Who are the future global experts?



AAPG Super Basin Initiative:

- 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
- Value Innovation: learning from global technical mastery and supply chain commercial mastery

Things that Matter: Insights from many basins

- Active world class petroleum systems, reservoirs, traps (can be powerful predictor of “yet to find”)
- Structural Settings matter: Passive Margins, Rift and Continental basins hold two thirds of worlds giant fields (Mann, 2003)
- Structural uplifts, pressure cells, tilted basins (residual oil zones)
- In Situ, hybrid, migrated resource play
- In resource plays clay mineralogy (smectite/illite), silts, carbonates, silica impact “landing zones” for hydraulic fracturing in horizontal wells
- Infrastructure, ecosystem, community (giant fields bring resources that also benefit smaller fields)
- Early movers tend to be independents

“Big Continent, Big Ideas and Big Opportunities”



MARKET ISSUES

Africa has been called the 'leap-frog continent'.



Africa is Big, Africa needs energy, Africa has favorable energy basins (passive margin and rift)

African Perspective

A brief tour around a very big continent

Atlantic Margins in the west (1,2,3) and Affinities for South America offshore plays

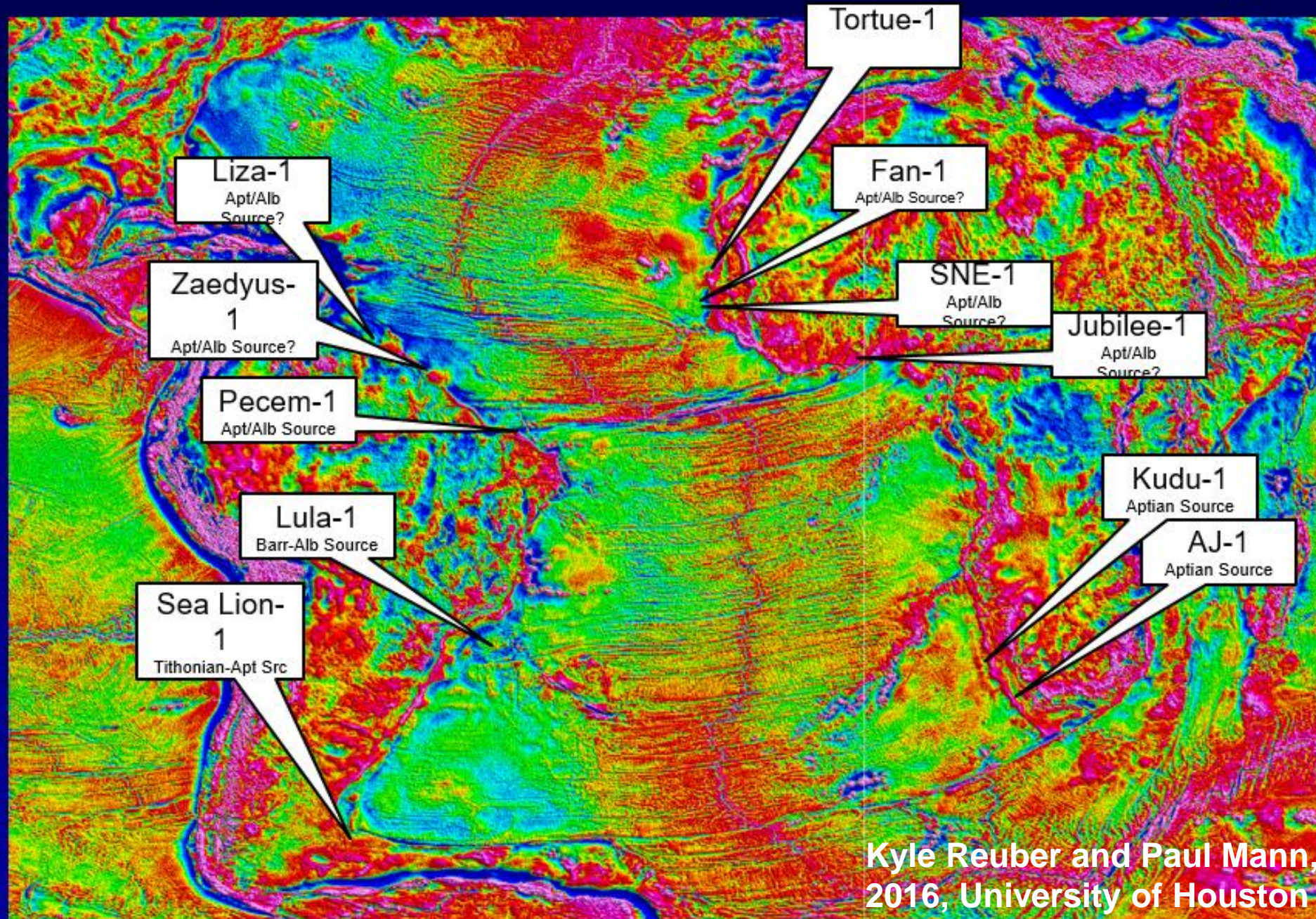
Northern basins (4) and Middle East affinities, possibilities for unconventional resources?

East Africa (5) rift basins and a growing cluster of giant fields and major gas reserves, LNG

South Africa (6), and intracratonic basins (7), possibilities for unconventional resources?



Selected, recent discoveries on Atlantic margins

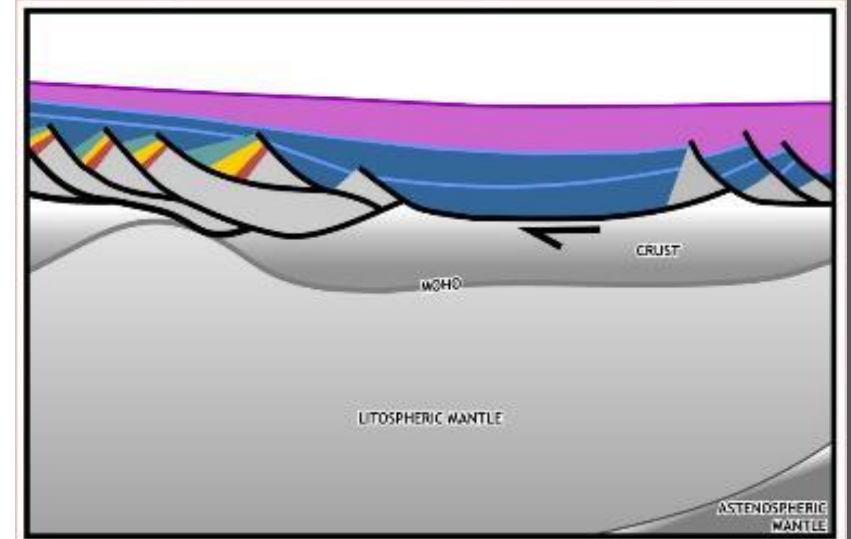
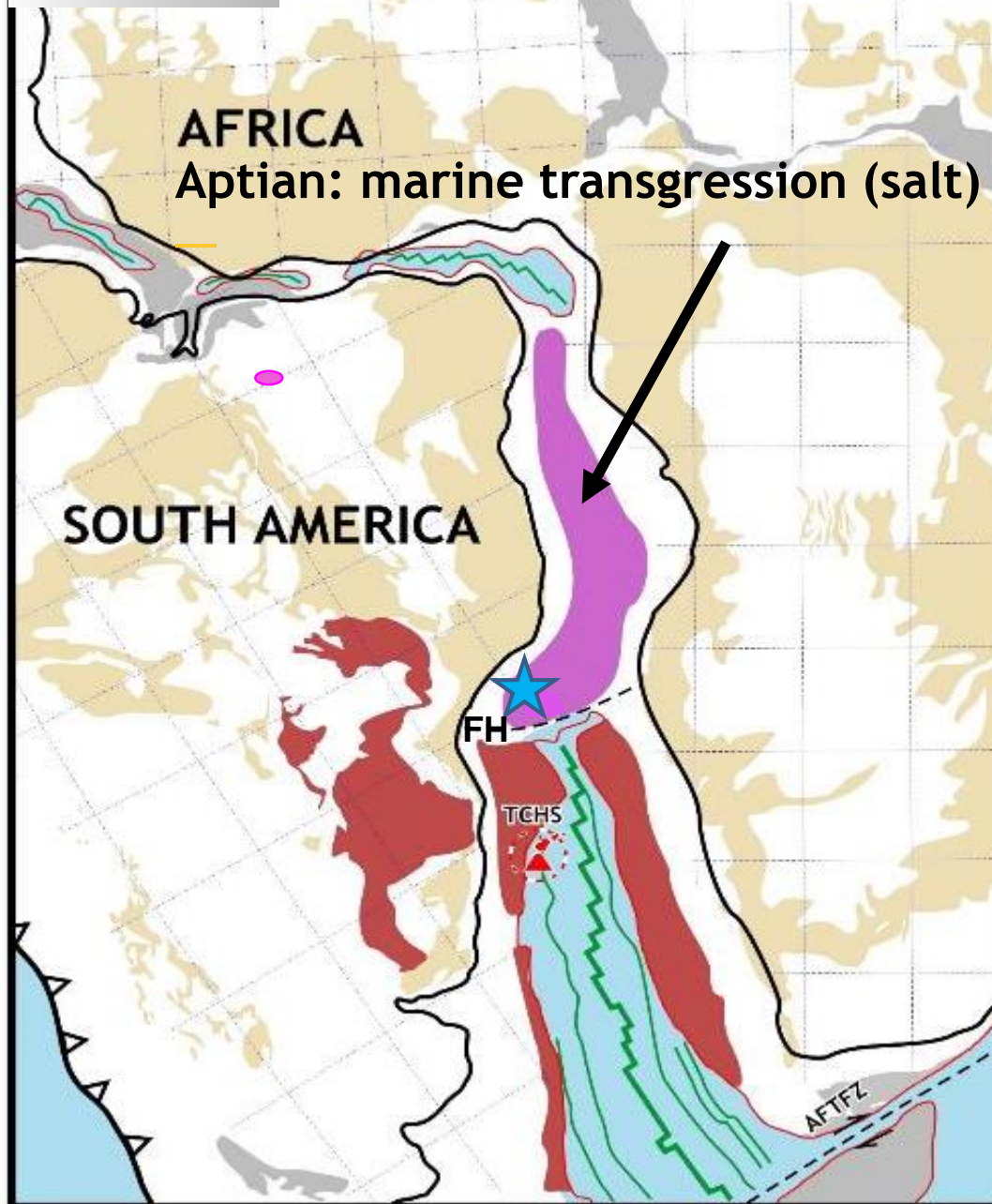


Kyle Reuber and Paul Mann,
2016, University of Houston

West Africa

Heine et al., 2013

113 Ma



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

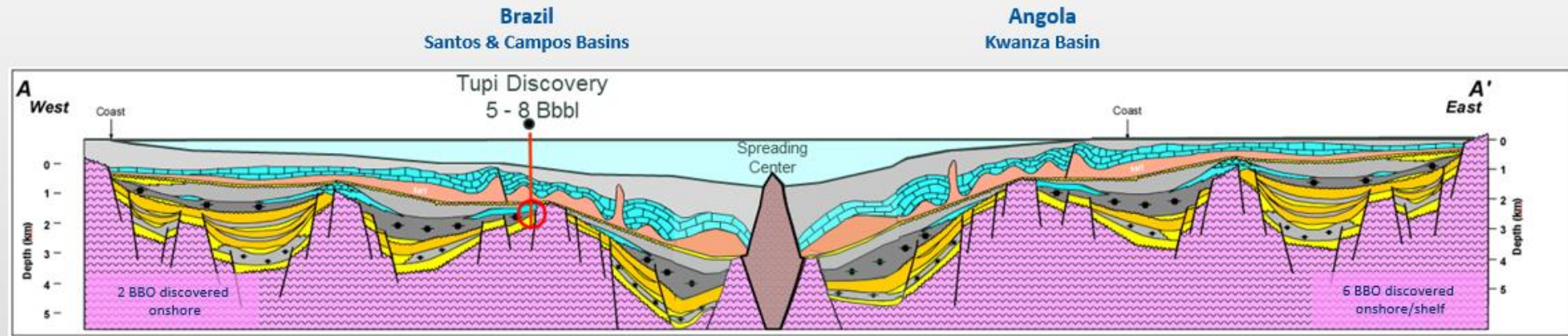
★ Santos Basin

Legenda:

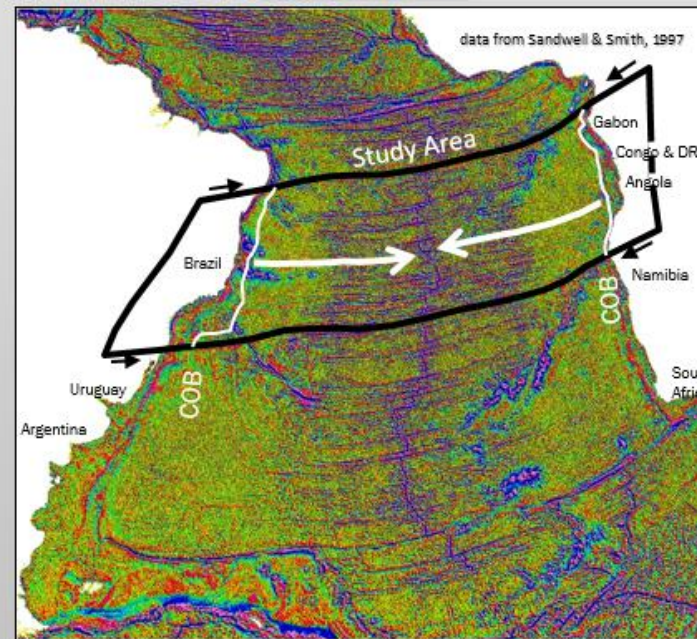
- FH - Florianópolis High
- TCHS - Tristão da Cunha Hot Spot
- AFTFZ - Agulhas-Falkland Transform Fault Zone
- Aptian Salt Basin (Marine Restricted)
- Microbial Carbonate Platforms (Lacustrine)
- Source Rocks / Coquina Carbonate Platforms (Lacustrine)
- Parana Large Igneous Province (LIP)
- Stretched 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



Offshore Nigeria

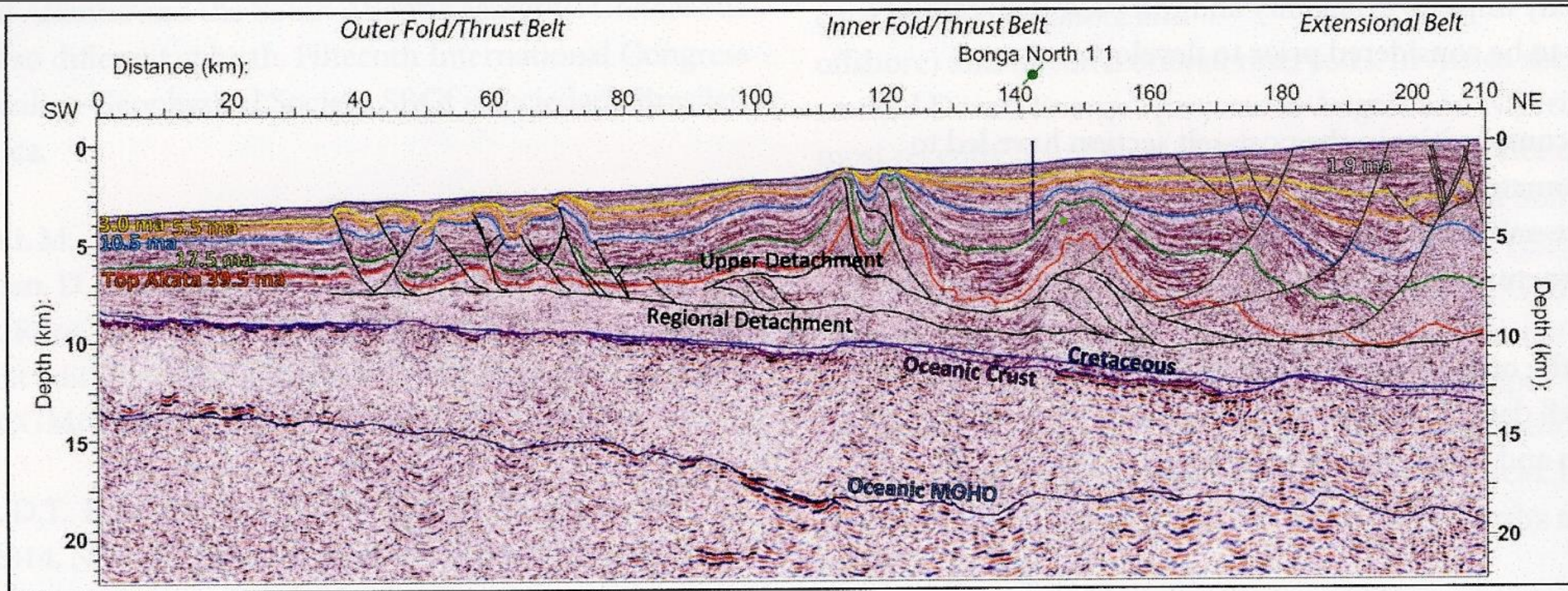


Figure 1: Regional PSDM seismic line across the main provinces of the offshore Niger Delta. The extensional domain, Inner fold and thrust belt and the Outer fold and thrust belt are all shown. Courtesy ION Geophysical

Cote d'Ivoire, Ghana

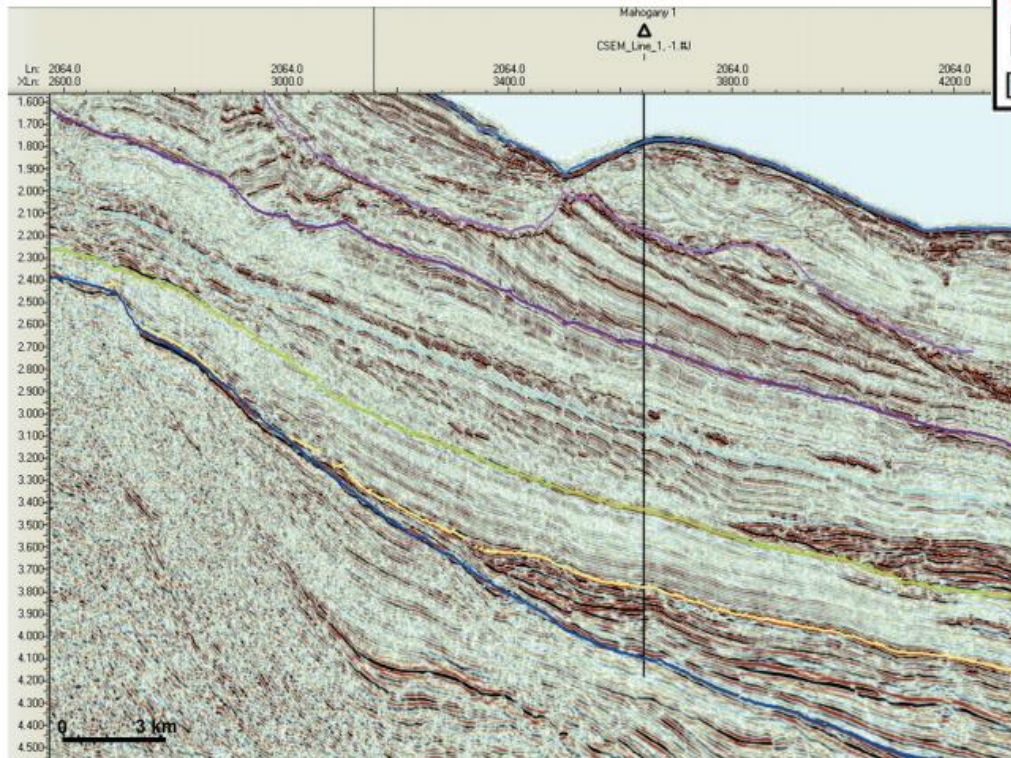


Figure 18. North-south line showing Mahogany 1 location and pinch out of Mahogany fan to the north. (Modified from Jewell, 2011.)

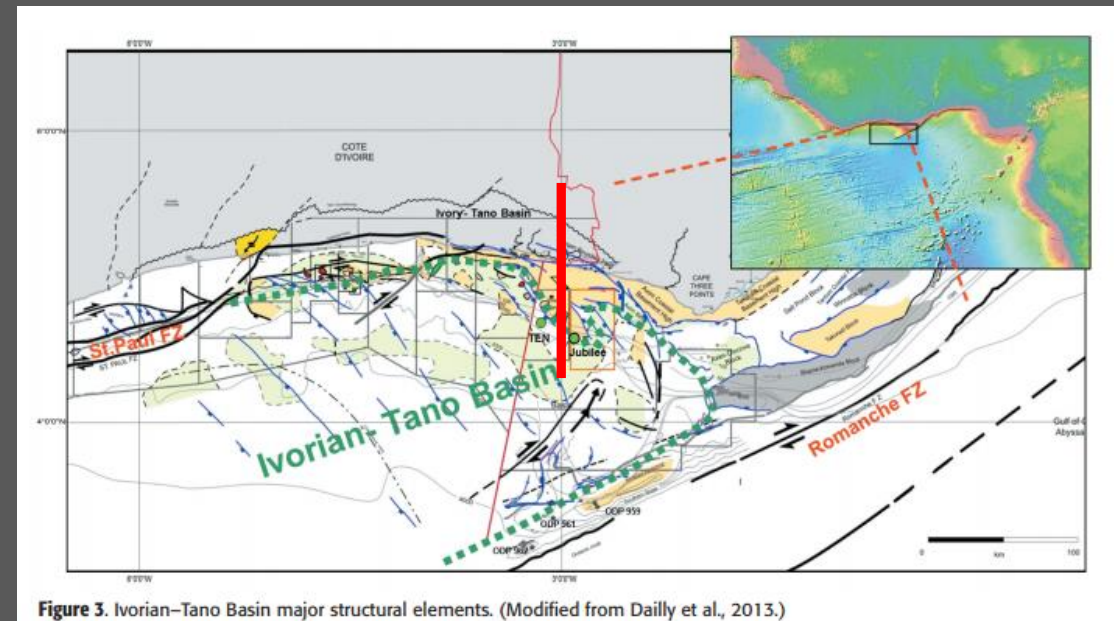
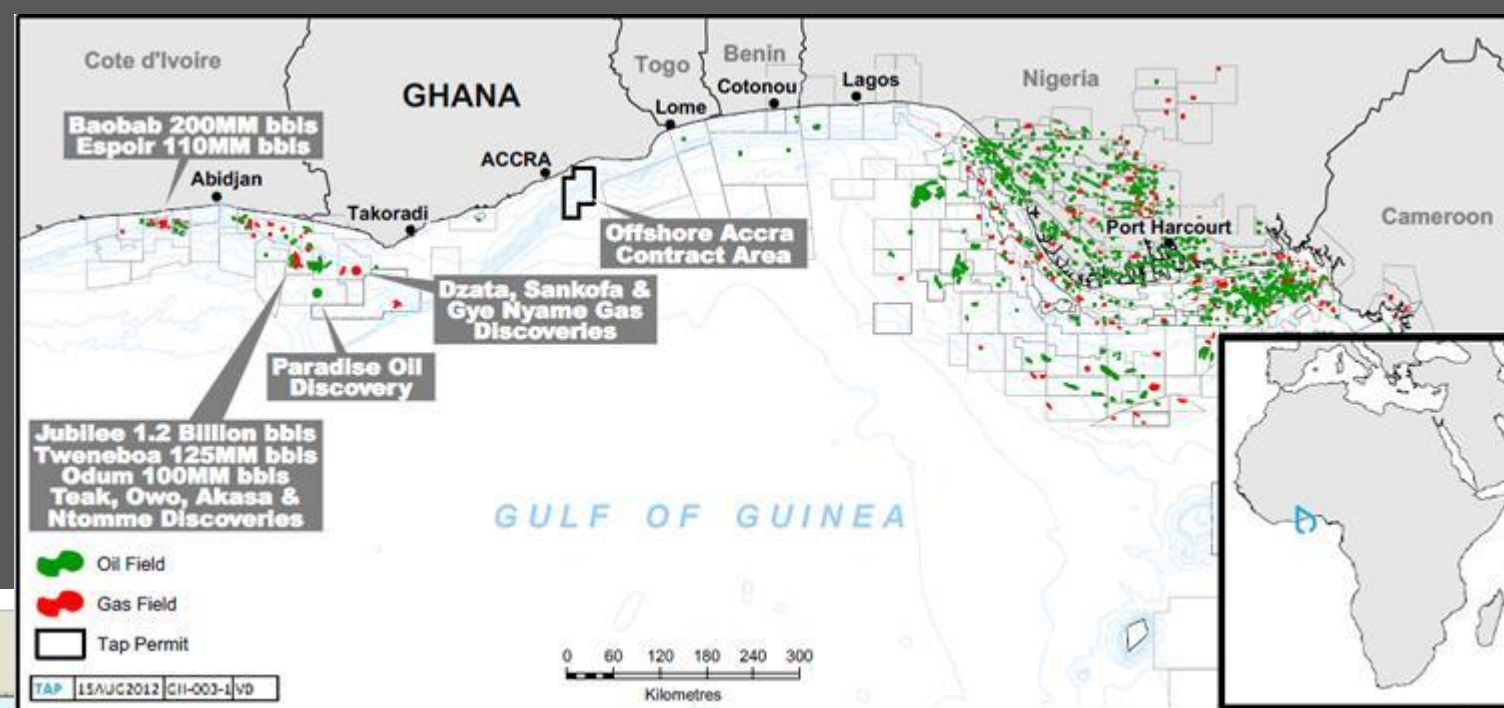
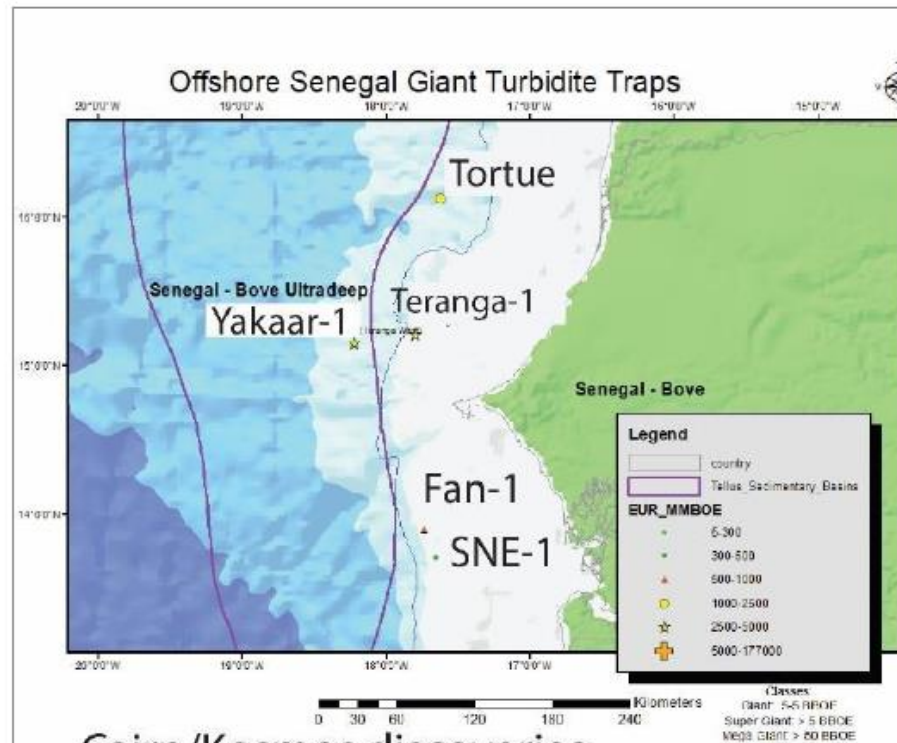


Figure 3. Ivorian-Tano Basin major structural elements. (Modified from Dailly et al., 2013.)

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 31° 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

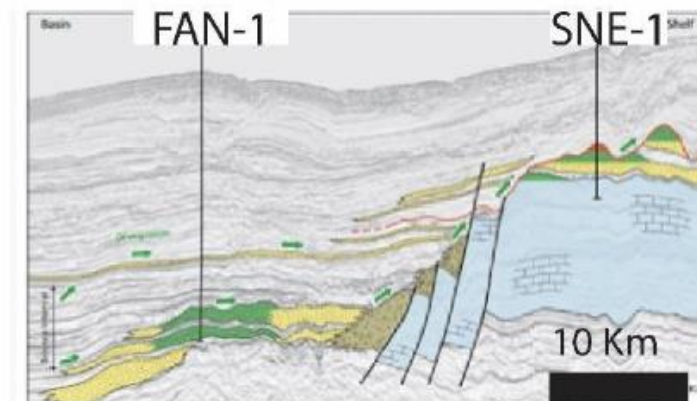


Figure from Reynolds, 2016

FAN and SNE Discoveries

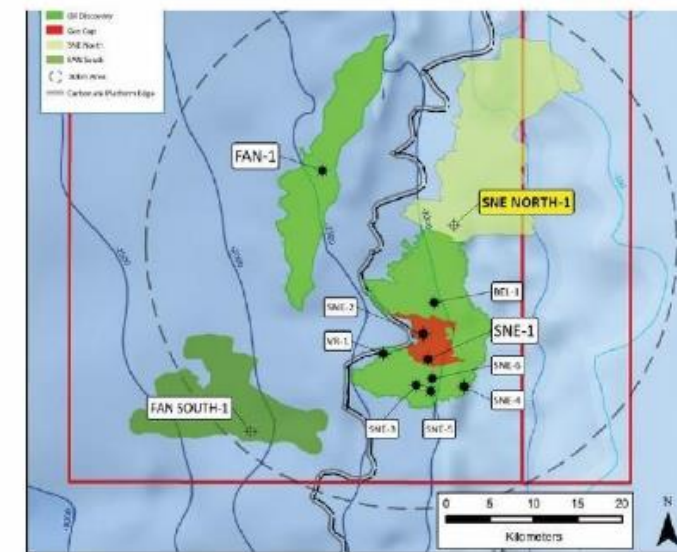
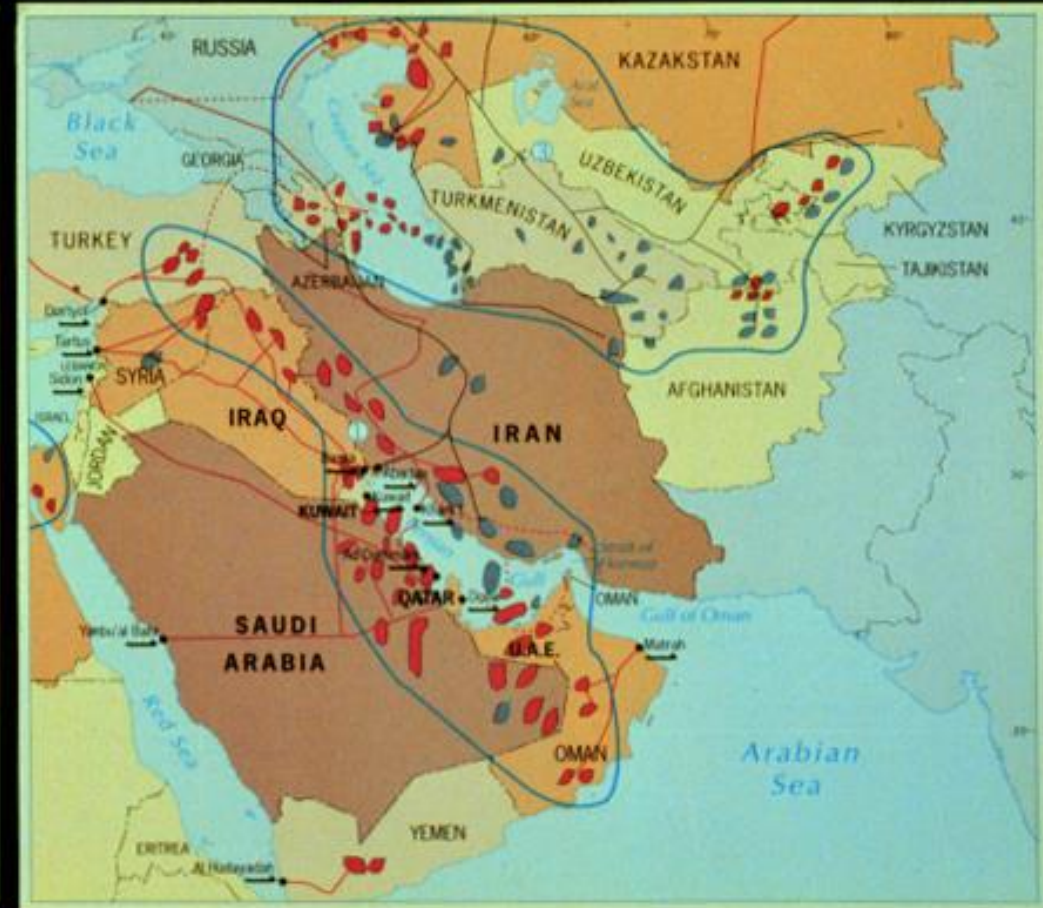
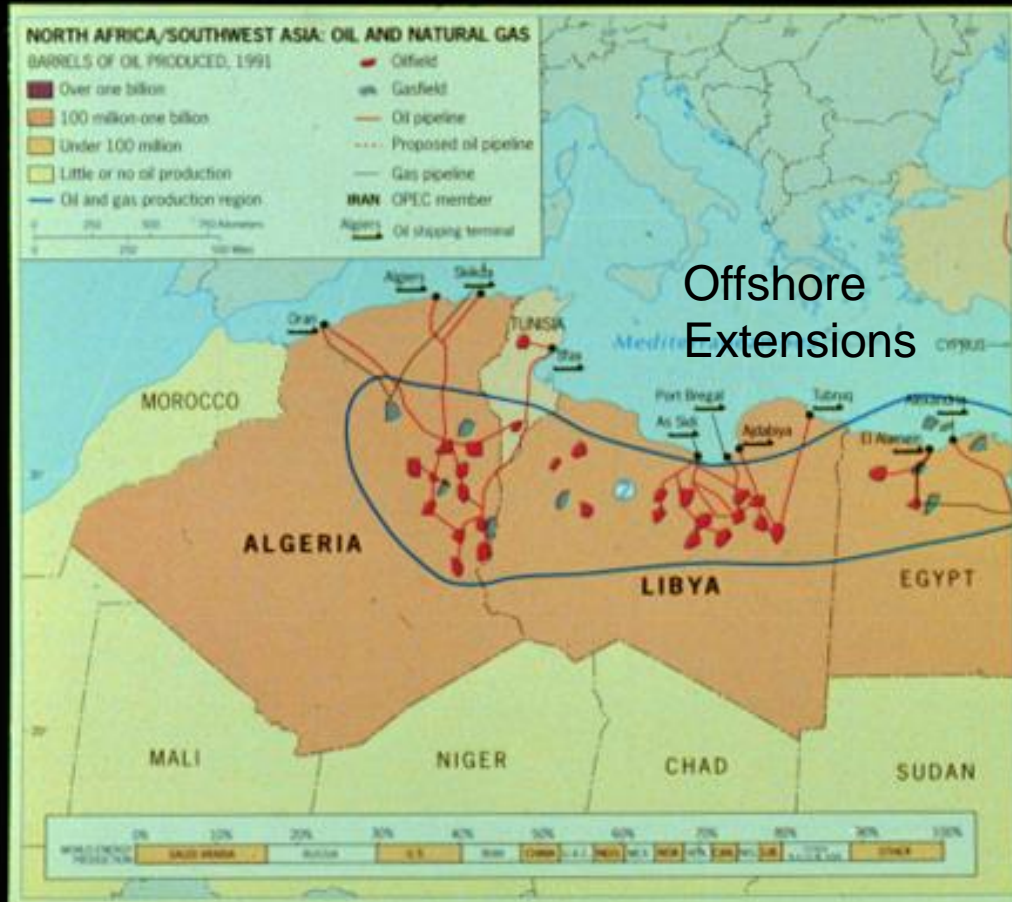


Figure from Cairn August 7, 2017 press release

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

Dolson, He, and Horn, June 2018

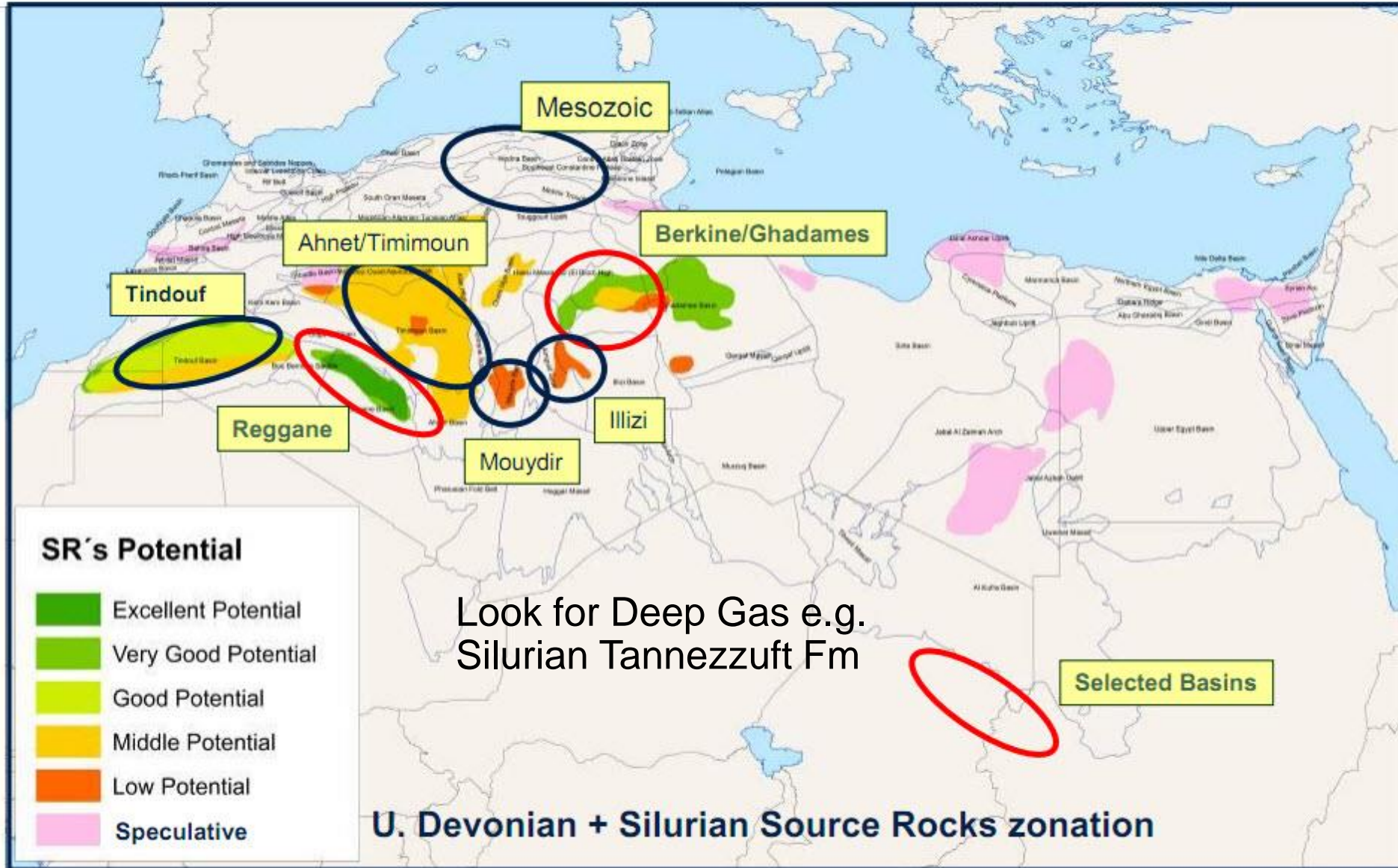
North Africa and Middle East



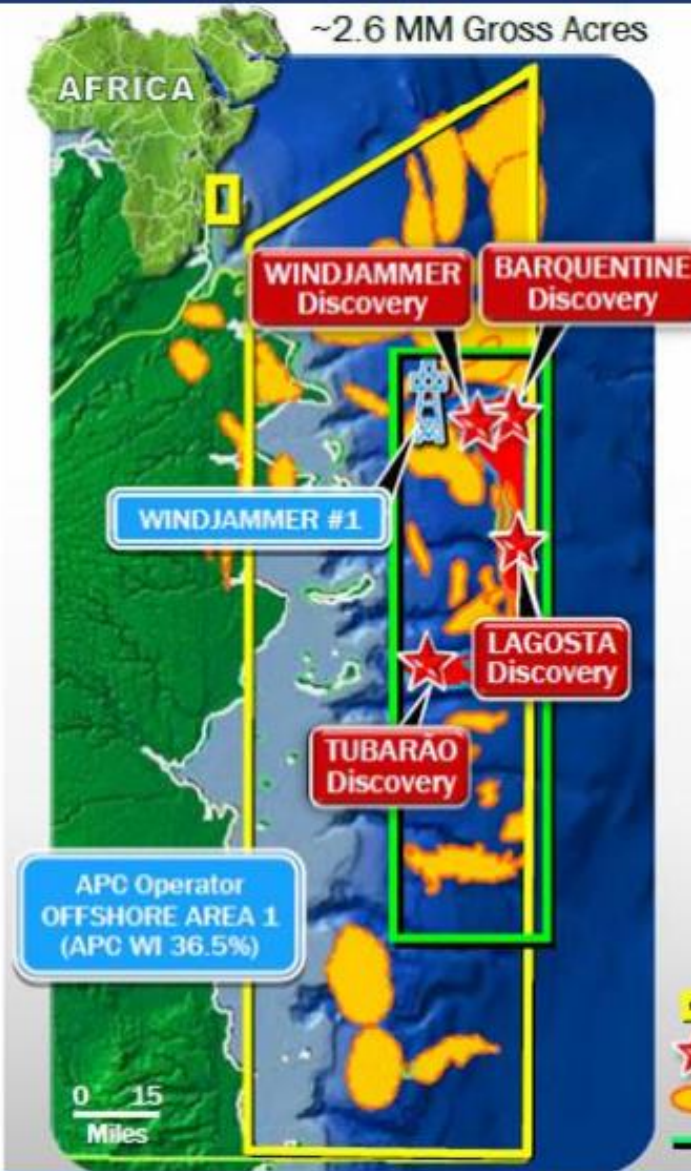
Algeria Shale Gas Potential



North
Africa



Offshore Mozambique Wildcat Success Story



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

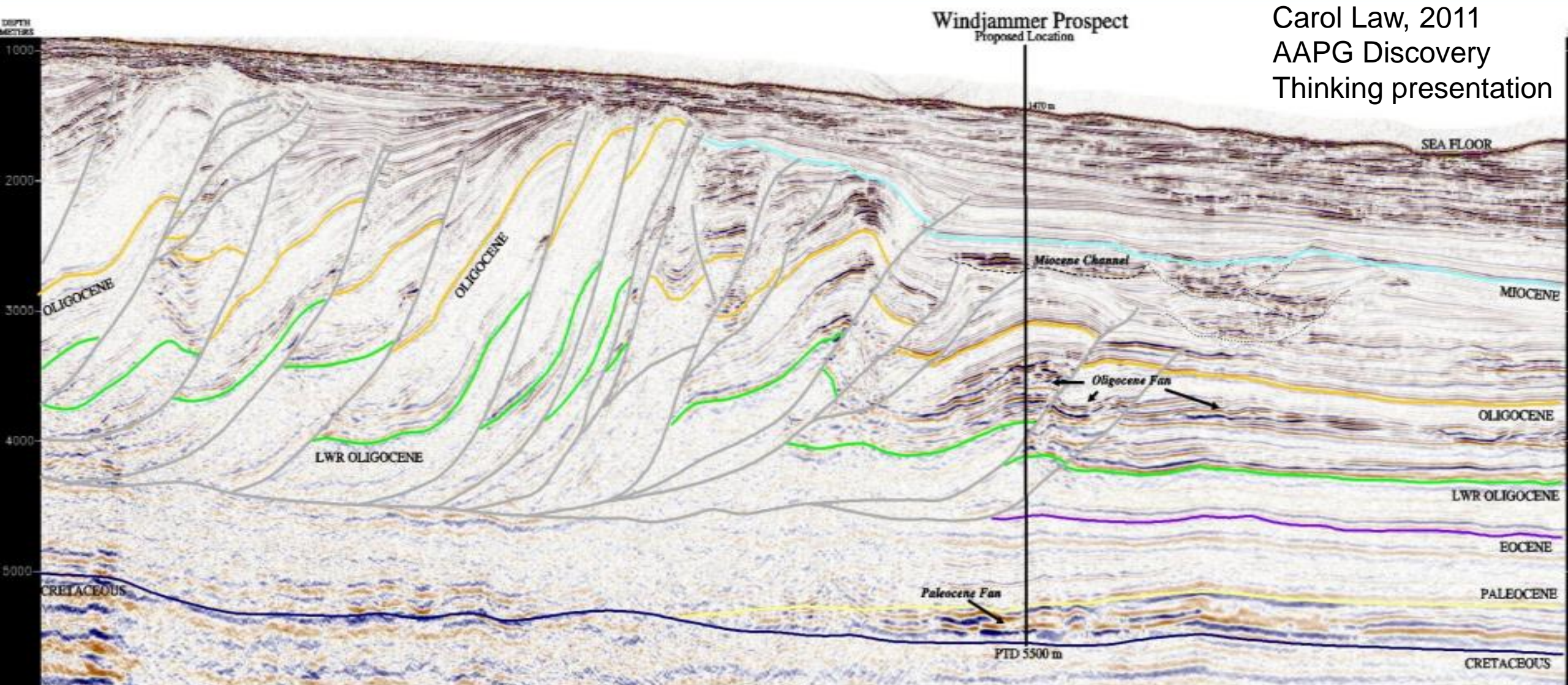
Robust Exploration Inventory

- ANADARKO WI BLOCK
- ★ GAS DISCOVERY
- PROSPECTS AND LEADS
- EXISTING 3D SEISMIC

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.)

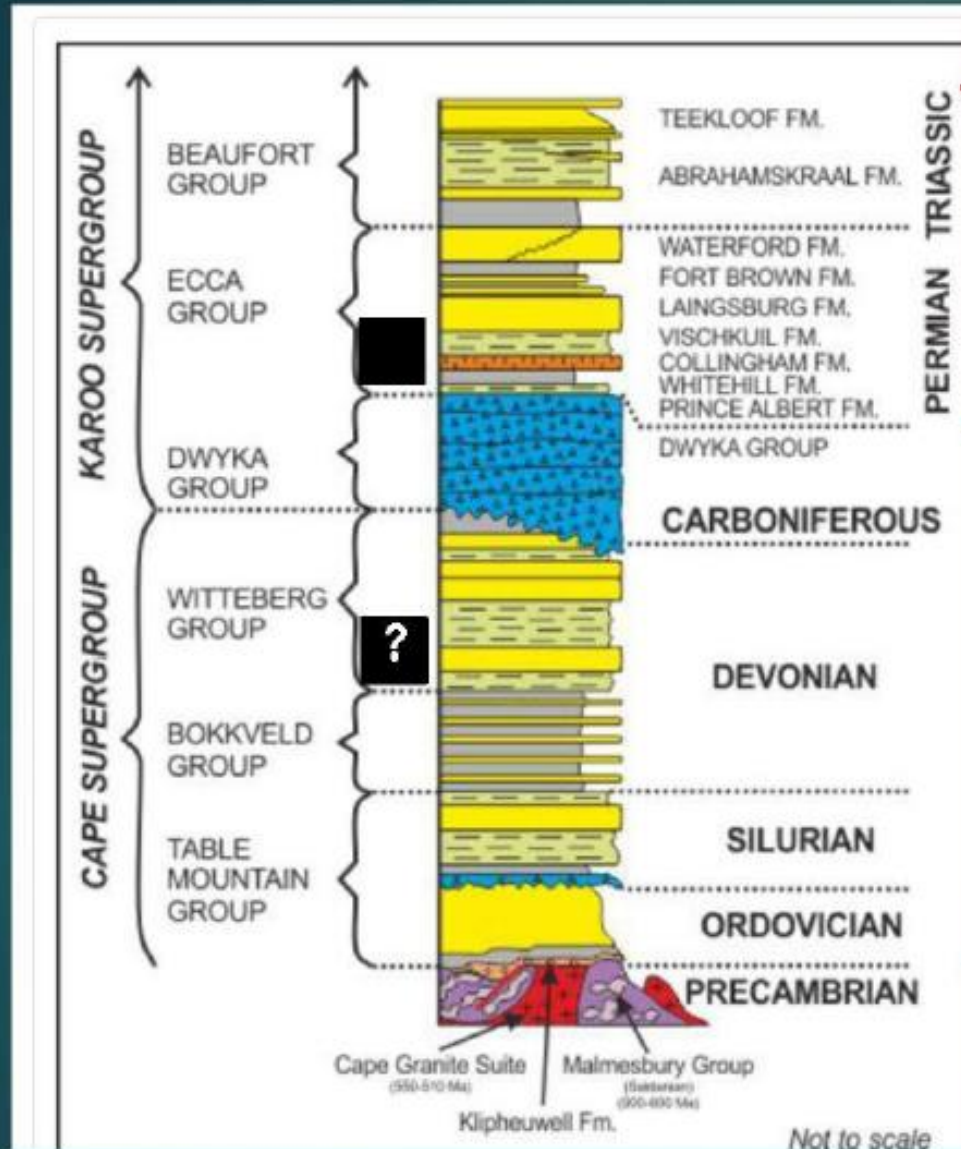
In coastal basins and CARS/CASZ (MZ+CZ reservoirs)

- ▶ 104 BBO conventional oil
- ▶ 645 TCF conventional reservoirs)

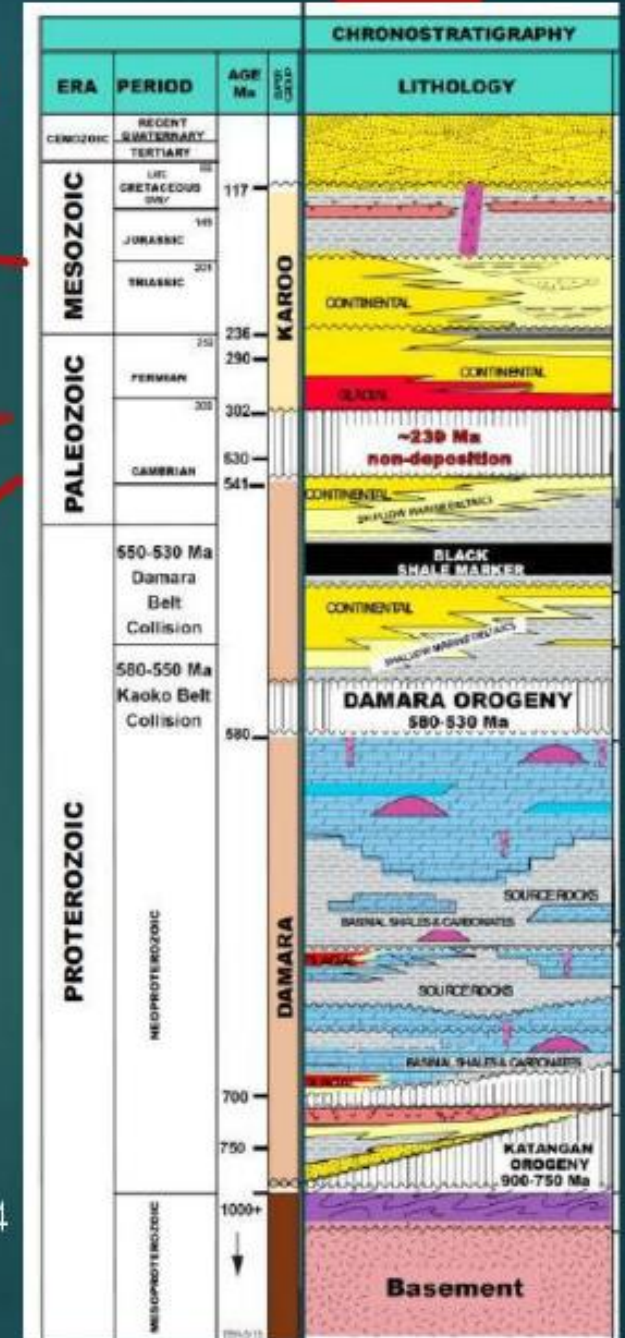
Jim Granath et al, 2017



South Africa



Namibia



“Mid-Paleozoic”

How representative of central Africa ?

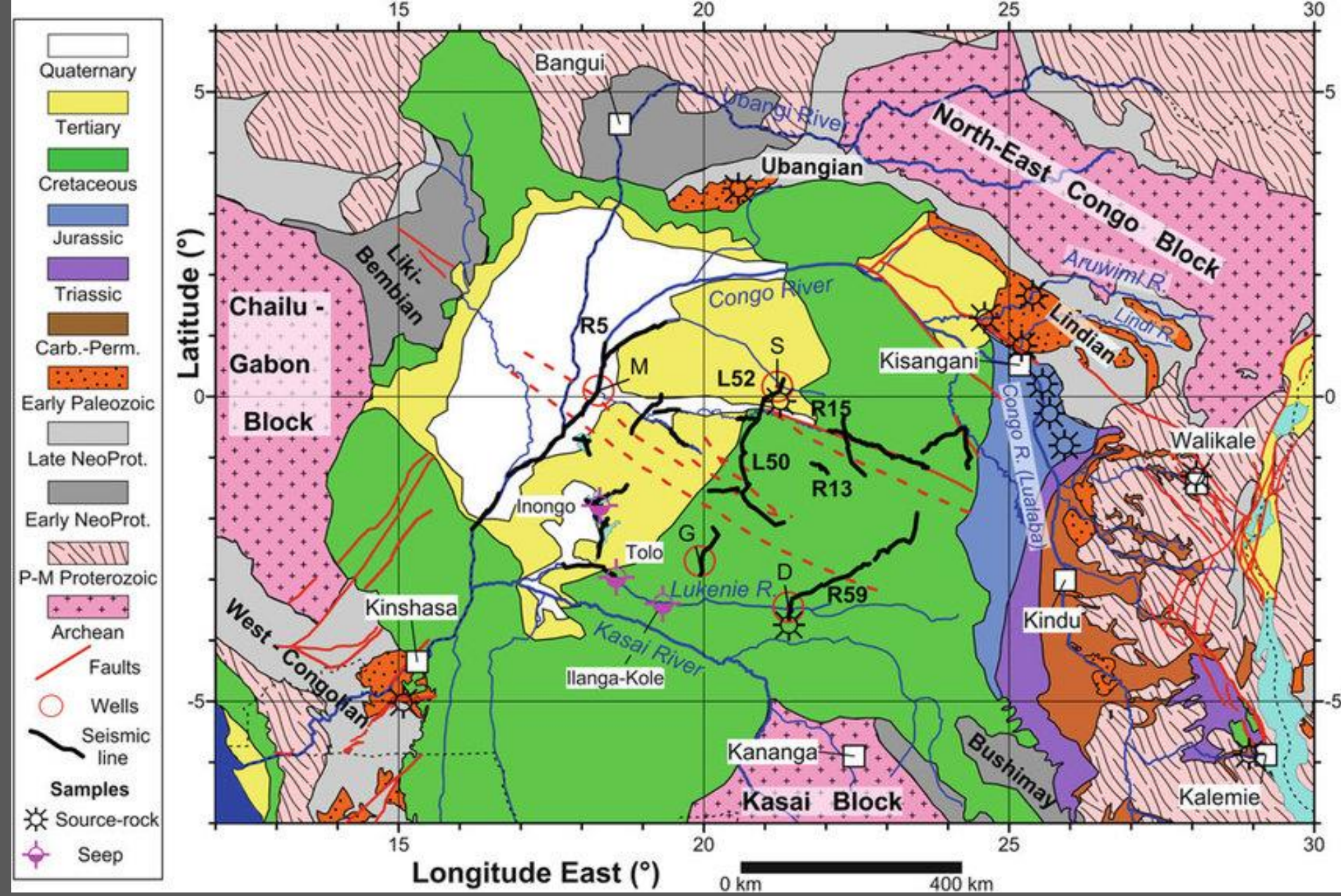
Hoak et al., S&D 2014

<http://www.sees.manchester.ac.uk/our-research/research-areas/pes/basin-studies-and-petroleum-geoscience/research-themes/clastic-sedimentology-and-sequence-stratigraphy/current-research/slope4/karoo-geology/>

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.

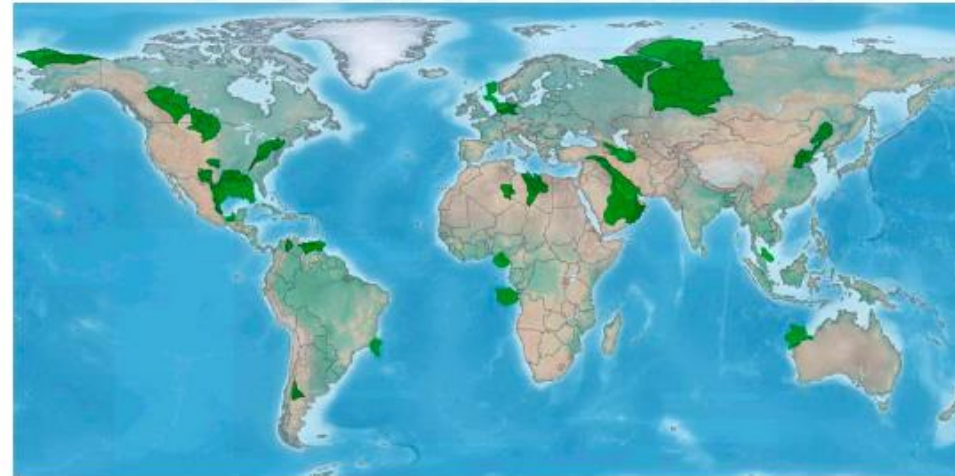


Figure 1. Map of top 25 super basins (courtesy IHS Markit).

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?

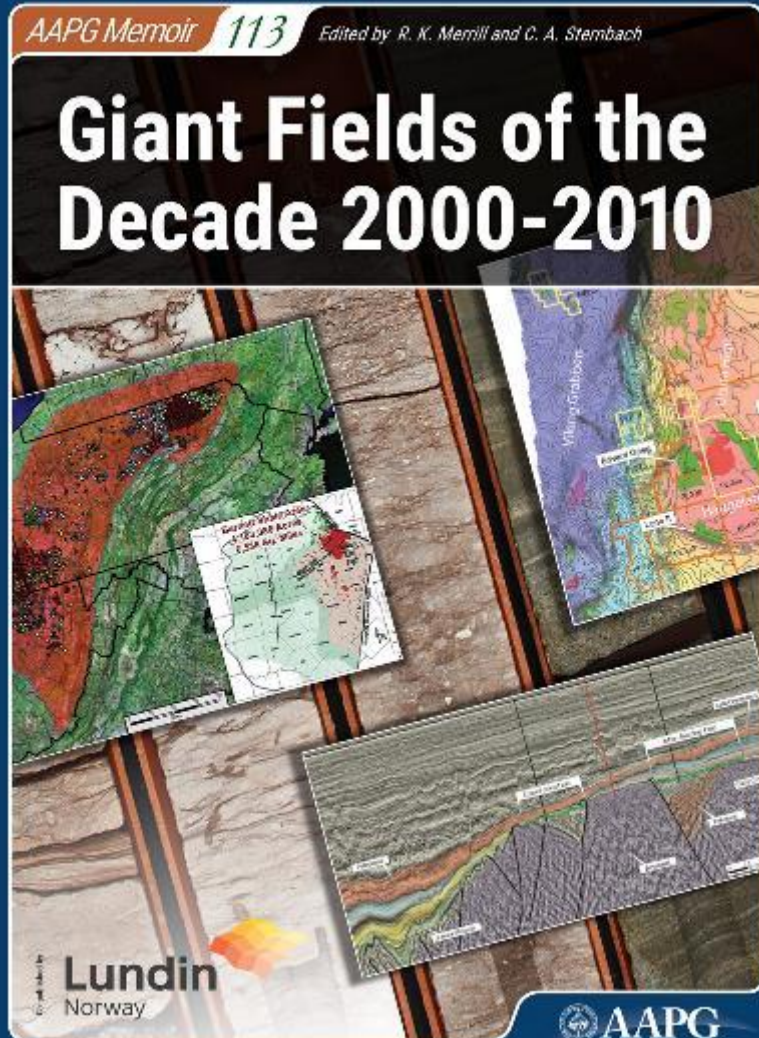
In addition to their geologic energy endowment, super basins have large scale and infrastructure to incubate new technology. Technology nurtured and proven in super basins has great relevance and application to basins of all sizes. Thus, super basin papers will have widespread value to energy producers 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 (2017) AAPG Book on Giant Fields; Another Coming to Feature Giant Fields 2010-2020!

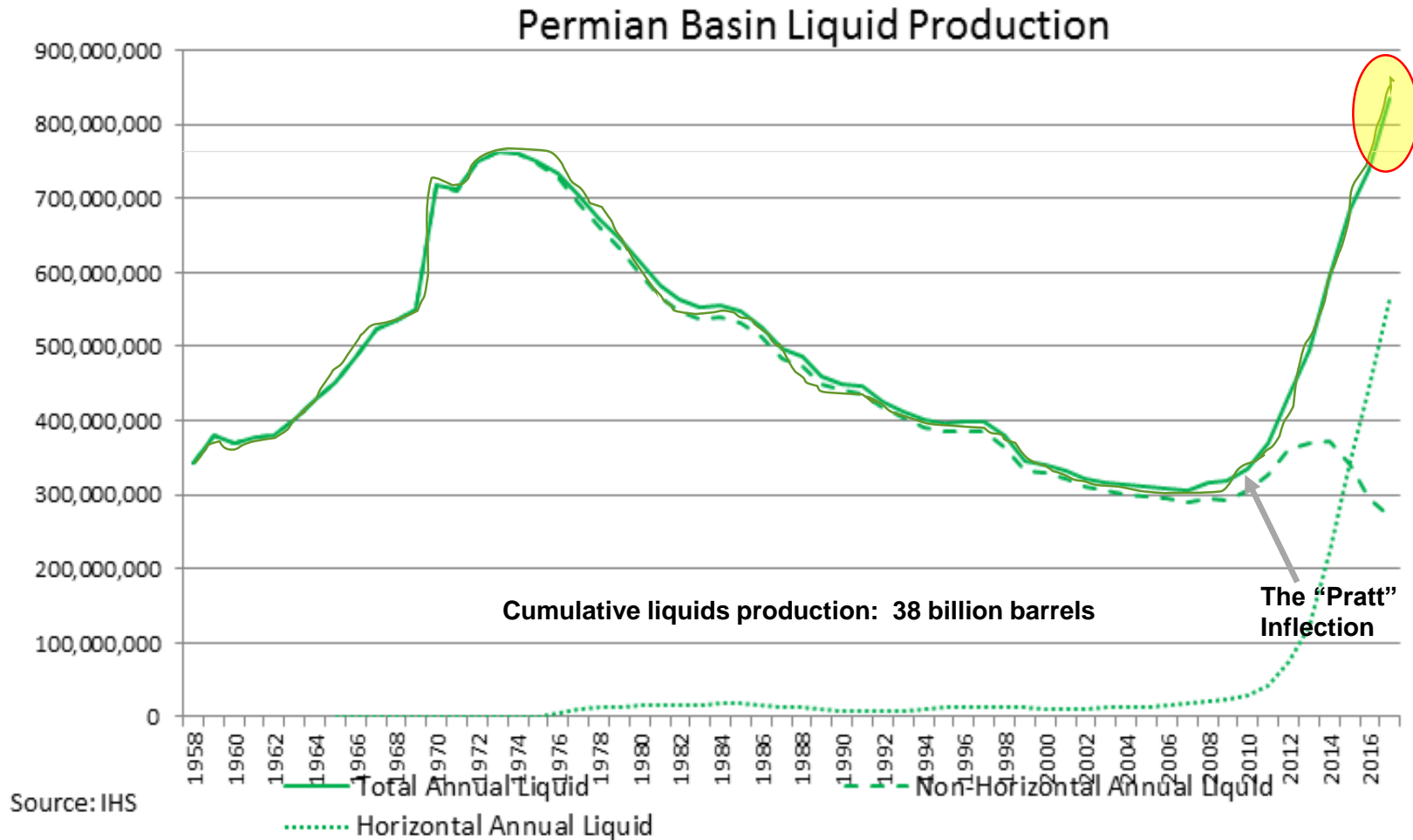


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Libra: A Newborn Giant in the Brazilian Presalt Province <i>Marco Antonio Carlotto, Rodrigo Correia Baptista da Silva, Arlindo Akio Yamato, Wagner Luz Trindade, Jobel Lourenço Pinheiro Moreira, Ricardo Augusto Rosa Fernandes, Orlando José Soares Ribeiro, Wenceslau Peres Gouveia Jr., Julien Philippe Carminati, Deng Qicai, Zhao Junfeng, and Augusto Carlos da Silva-Telles Jr.</i>	
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Breaking Barriers and Paradigms in Presalt Exploration: The Pão de Açúcar Discovery (Offshore Brazil) <i>Pedro Henrique Vieira de Luca, Hugo Matias, José Carballo, Diana Sineva, Gustavo Antunes Pimentel, Jordi Tritlla, Mateu Esteban, Rubén Loma, José Luis Algíbez Alonso, Ricardo Perona Jiménez, Matthieu Pontet, Pedro Bonillo Martinez, and Victor Vega</i>	
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The Discovery Process behind the Giant Johan Sverdrup Field <i>Hans Chr Rønnevik, Arild Jørstad, and Jan Erik Lie</i>	
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The Tamar Giant Gas Field: Opening the Subsalt Miocene Gas Play in the Levant Basin <i>Daniel L. Needham, Henry S. Pettingill, Christopher J. Christensen, Jonathan ffrench, and Zvi (Kul) Karcz</i>	
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The Jubilee Field, Ghana: Opening the Late Cretaceous Play in the West African Transform Margin <i>Paul Dailly, Tracey Henderson, Kathy Kanschä, Phil Lowry, and Stephen Sills</i>	
Chapter 15	273
The Windjammer Discovery: Play Opener for Offshore Mozambique and East Africa <i>Tom Fletcher</i>	

Plans For Super Basin Programs

- **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 (600)
- June 13 2018 EAGE: Europe, North Sea and North Africa super basins (350)
- August 22, 2018 Conjugate Margins Conference, Halifax CA (250)
- Sept. 11 2018 HGS Africa Conf., Super Basins African Perspective (300)
- 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 (800)
- **Nov. 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
- August 2019 AAPG (ICE), Buenos Aires, Argentina, Latin American Super Basins

Onshore Unconventional Analog Super Basin



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

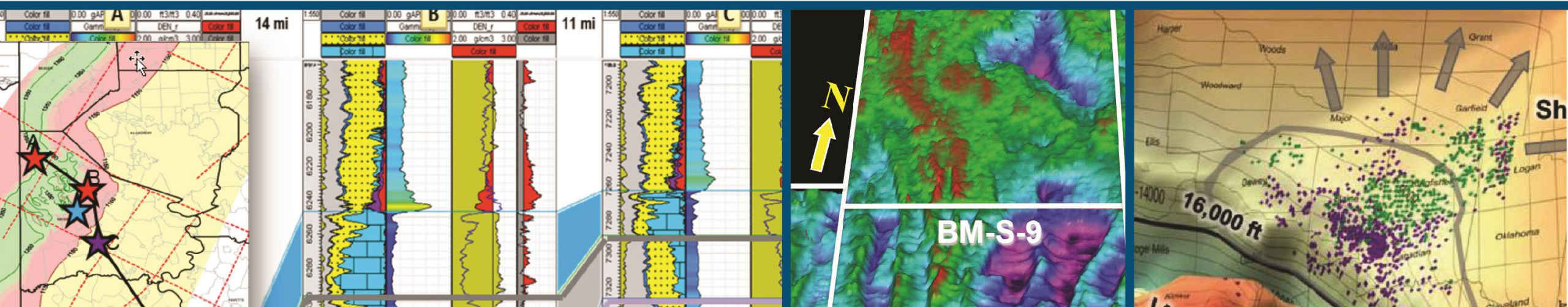
AAPG's

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

GLOBAL SUPERBASINS²⁰¹⁹

superbasins.aapg.org/2019

The Permian



AAPG Super Basins Forum: Nov 7 Cape Town

“Africa and Middle East, Big Basins, Big Successes and More to find”

Speakers

- **Exploration Creativity in the Golden Age of Super Basins and What AAPG is Doing About Them:** Charles A. Sternbach, AAPG 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:** Lorenzo Meciani, Exploration Strategies Manager, Eni
- **East Africa and Mozambique, Waking a Sleeping Super Basin:** Malcolm Francis, Exploration Lead, Sub Saharan Africa, WesternGeco, Schlumberger
- **Basins and Petroleum Systems of the Middle East:** Sa'id Al Hajri, Manager, Geological Operations Department, Saudi Aramco

Session Moderators

- **Charles A. Sternbach**, AAPG President (2017-18)
- **Nosa Omorodion**, Director, NOCs / Nigerian Independents, Schlumberger



“Shaping the Future in a Changing Energy Landscape.”