Angola's Oil Industry - A Century of Progress in Exploration and Production*

Tako Koning[1]

Search and Discovery Article #70174 (2014)**
Posted November 30, 2014

*Adapted from oral presentation given at AAPG International Conference & Exhibition, Istanbul, Turkey, September 14-17, 2014

[1]Gaffney, Cline & Associates, Bellaire, TX, U.S. (tako.koning@gaffney-cline.com)

Abstract

In 2015 Angola will have experienced a century of oil exploration and production. A variety of wide-ranging, high potential plays have led to a dramatic surge in Angola's oil production. A decade ago, Angola was producing approximately 750,000 bopd (barrels of oil per day) and now production of almost 2.0 million bopd has been achieved. In the late 1700's Portuguese colonialists discovered oil seeps and asphalt deposits at Libongos, about 60 km north of Luanda and shipped some of the oil to Lisbon and Rio de Janeiro to be used as a caulking material to prevent water leakage into their ships. First-ever drilling for oil was in 1915 about 40 km northeast of Luanda. Dande-4 drilled in 1916 was tested at 6 bopd and was subsequently abandoned but it signified the first flow of oil in Angola. In 1956 the Benfica oil field, near Luanda, went on production representing the beginning of oil production in Angola. The first offshore oil field in Angola, Malongo, was discovered in 1968 in the Angola province of Cabinda by the American company, Gulf Oil. In 1996 Elf Petroleum discovered the Girassol oil field on Block 17 in 1,300 meters of water about 140 kilometers off the coast of Angola. Additional drilling by Elf proved Girassol to be a giant-size oil field, with the oil bearing reservoir located in clastics of Oligocene age which were deposited as turbidites. This led to many more such discoveries. As a result, about 75% of Angola's current production now comes from such reservoirs. In 2011, 11 deepwater to ultra-deepwater pre-salt blocks in the Kwanza and Benguela Basins were awarded by Sonangol to a number of operators. Since that time, very encouraging pre-salt oil discoveries have been drilled by Maersk and Cobalt. In July, 2013 the LNG plant at Soyo, in northern Angola commenced production at 5.2 million tonnes per year. On an energy-equivalent basis, this amounts to about 200,000 barrels of oil per day. The first shipment of LNG was to a Petrobras LNG deliquification plant in Rio de Janeiro and thereafter 4 shipments of LNG from Angola were delivered to customers in Asia.

Selected References

Kolla, V., P. Bourges, J.M. Urruty, and P. Safa, 2001, Evolution of Deep-Water Tertiary Sinuous Channels Offshore Angola (West Africa) and Implications for Reservoir Architecture: American Association of Petroleum Geologists, v. 85/8, p. 1373-1405.

Koning, T., 2013, Solving the Mystery of Angolan Oil: AAPG Explorer Magazine, v.34/4, p. 32-34.

Koning, T., 1997, Angola: Sedimentary Basins and Petroleum Geology: Sedimentary Events, Hydrocarbon Systems – CSPG-SEPM Joint Convention: Program with Abstracts, p. 156.

Koning, T., and O.G. De Deus, 1998, Petroleum Geology of the Lombo East and Essungo Oil Fields, Block 2, Offshore Congo Basin, Angola: ABGP/AAPG International Conference and Exhibition, Rio de Janeiro, Brazil, Abstract.

Oil and Gas journal, 2005, World's Remote Basins Afford Many Exploration Opportunities: Oil & Gas Journal, v. 103/20, p. 39-44.

Porter, M.L., A.R.G. Sprague, M.D. Sullivan, D.C. Jennette, R.T. Beaubouef, T.R. Garfield, C. Rossen, D.K. Sickafoose, G.N. Jensen, S.J. Friedmann, and D.C. Mohrig, 2006, Stratigraphic Organization and Predictability of Mixed Coarse- and fine-grained Lithofacies Successions in a Lower Miocene Deep-water Slope-channel System, Angola Block 15, *in* P.M. Harris and L.J. Weber (eds.) Giant hydrocarbon Reservoirs of the World: From Rocks to Reservoir Characterization and Modeling: AAPG Memoir 88, p. 281-305.

Gaffney, Cline & Associates

The Angola Oil Industry – A Century of Progress in Exploration and Production

Presentation to the American Association of Petroleum Geologists
International Conference & Exhibition
September 14 - 17, 2014
Istanbul, Turkey

Tako Koning, Senior Petroleum Geologist
Gaffney, Cline & Associates
Luanda - Angola

Disclaimer Statement

The material and opinions expressed in this presentation are those of the authors. While they reflect what is believed to be informed opinion, they are not represented as being the opinions of the SPE/WPC/AAPG/SPEE/SEG or the US Securities and Exchange Commission nor its staff. Readers are urged to obtain independent advice on any matter relating to the interpretation of reserves and resources definitions and guidance.

Sources of Information

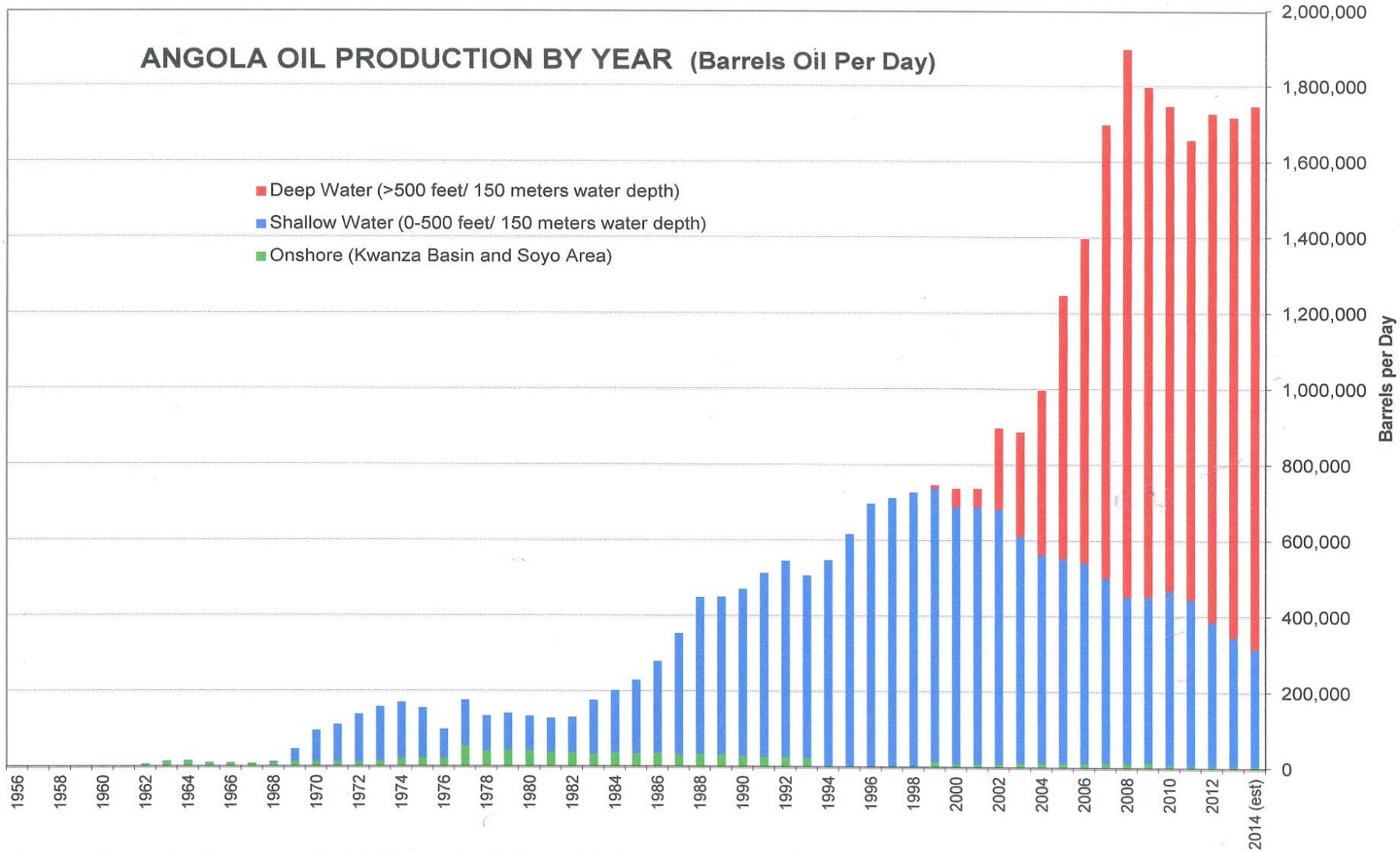
This presentation is based entirely on public domain published information, including:

- **Sonangol *Universo* magazines.**
- **Oil company magazines, e.g. BP *Calemas*, Chevron *CABGOC* magazines.**
- **SPE *Journal of Petroleum Technology*, AAPG *Explorer*, Upstream, World Oil, Offshore Engineer, BP Annual Oil & Gas Production Reviews, USA EIA reports.**
- **T. Koning presentations about Angola to AAPG, SPE, CSPG, GSL & PESGB.**

Presentation Outline

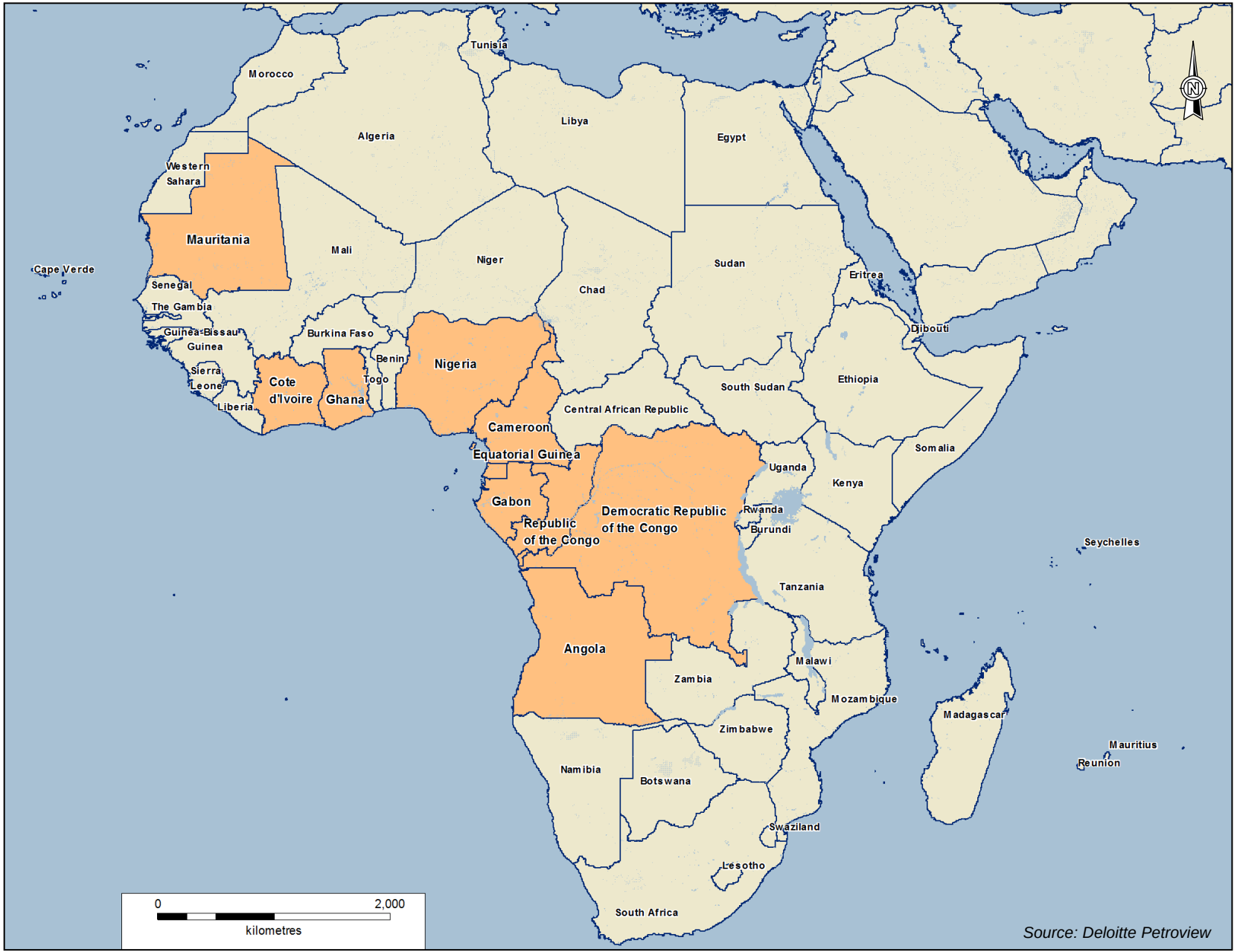
- Angola in West Africa & Global Context
- Geology
- Conventional Oil Fields
- LNG Project
- Pre-Salt Oil Play
- Angola’s Oil Future

Angola's Oil Production 1956 - 2014



Sources: Sonangol Universo magazines, Website - Angola Finance Ministry, 2013 BP World Energy Review

Oil Producing Countries on West Coast of Africa



Source: Deloitte Petroview

West Africa Oil Production – Current Production in BOPD (Barrels Oil Per Day)

Nigeria	2,200,000	BOPD
Angola	*1,650,000*	
Congo Brazzaville	340,000	
Equatorial Guinea	320,000	
Gabon	240,000	
Ghana	110,000	
Chad	100,000	
Cameroon	75,000	
Ivory Coast	30,000	
Congo DRC	25,000	
Mauritania	2,000	
Total	**5,092,000**	**BOPD**

From: Oil & Gas Journal, SPE Journal of Petroleum Technology ,Upstream

GLOBAL OIL PRODUCTION

Next 2 slides summarize

Global Oil Production –Top 20

Global Oil Production – Top 20

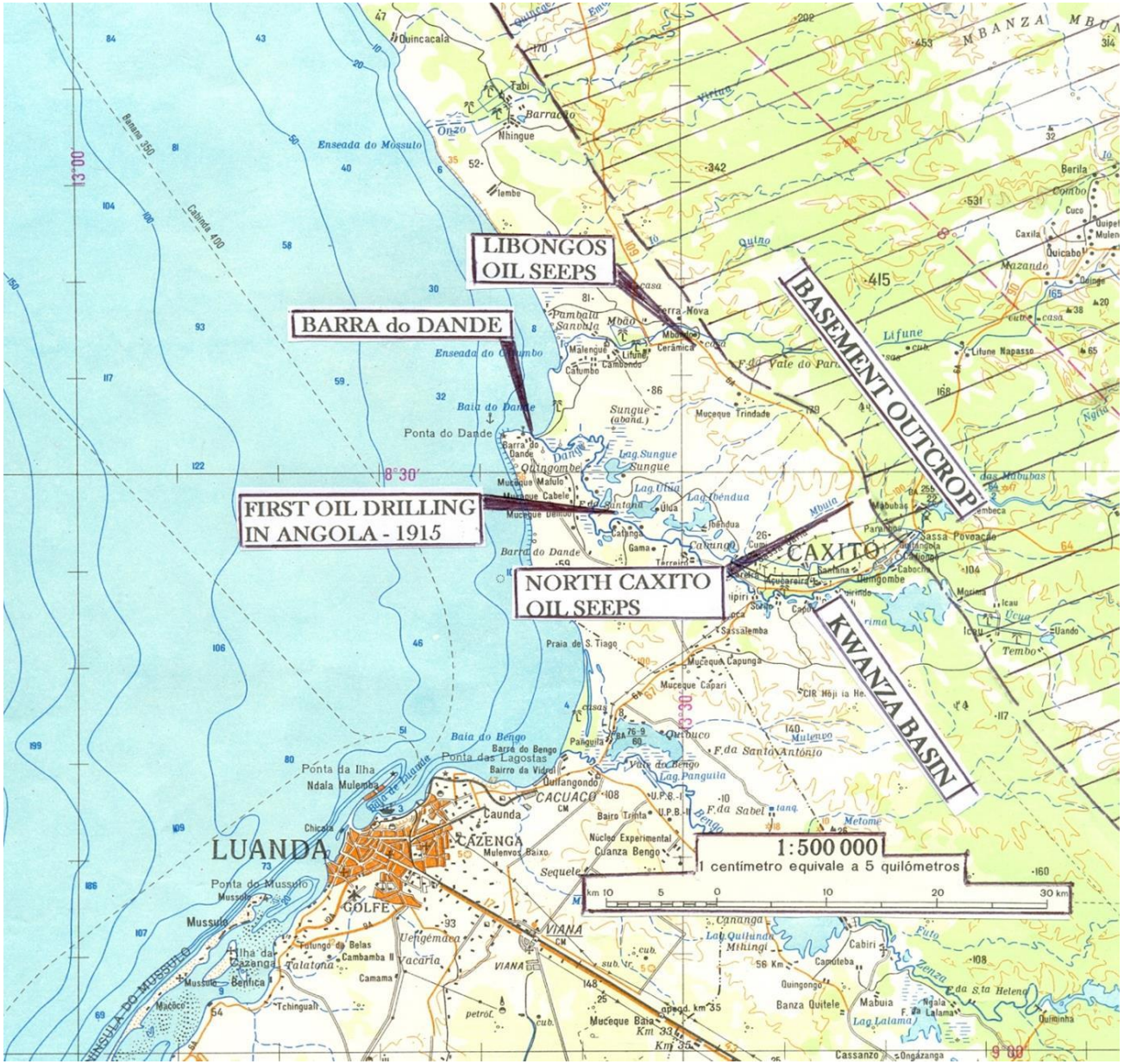
From: BP 2014 Energy Report, US EIA

1.) Russia	10,400,000 BOPD
2.) Saudi Arabia	9,500,000
3.) USA	8,400,000
4.) China	4,200,000
5.) Canada	3,400,000
6.) Iran	3,200,000
7.) Kuwait	2,600,000
8.) Mexico	2,500,000
9.) Iraq	2,400,000
10.) U.A.E.	2,400,000

Global Oil Production – Top 20

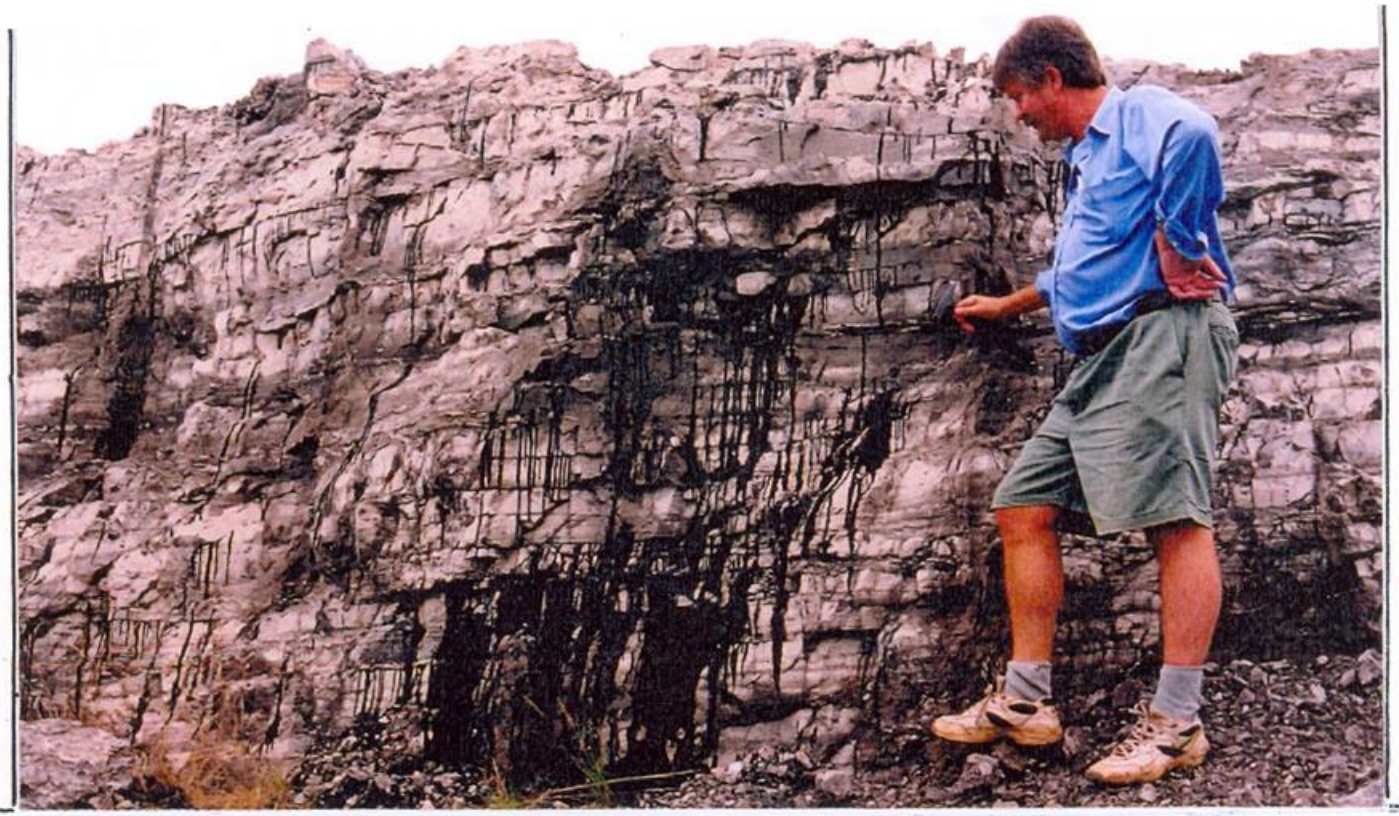
11.) Nigeria	2,200,000 BOPD
12.) Brazil	2,100,000
13.) Venezuela	2,100,000
14.) Angola	*1,650,000*
15.) Norway	1,600,000
16.) Kazakhstan	1,600,000
17.) Algeria	1,200,000
18.) Qatar	1,200,000
19.) Colombia	1,000,000
20.) U.K.	1,000,000

Angola's Oil History – the Past



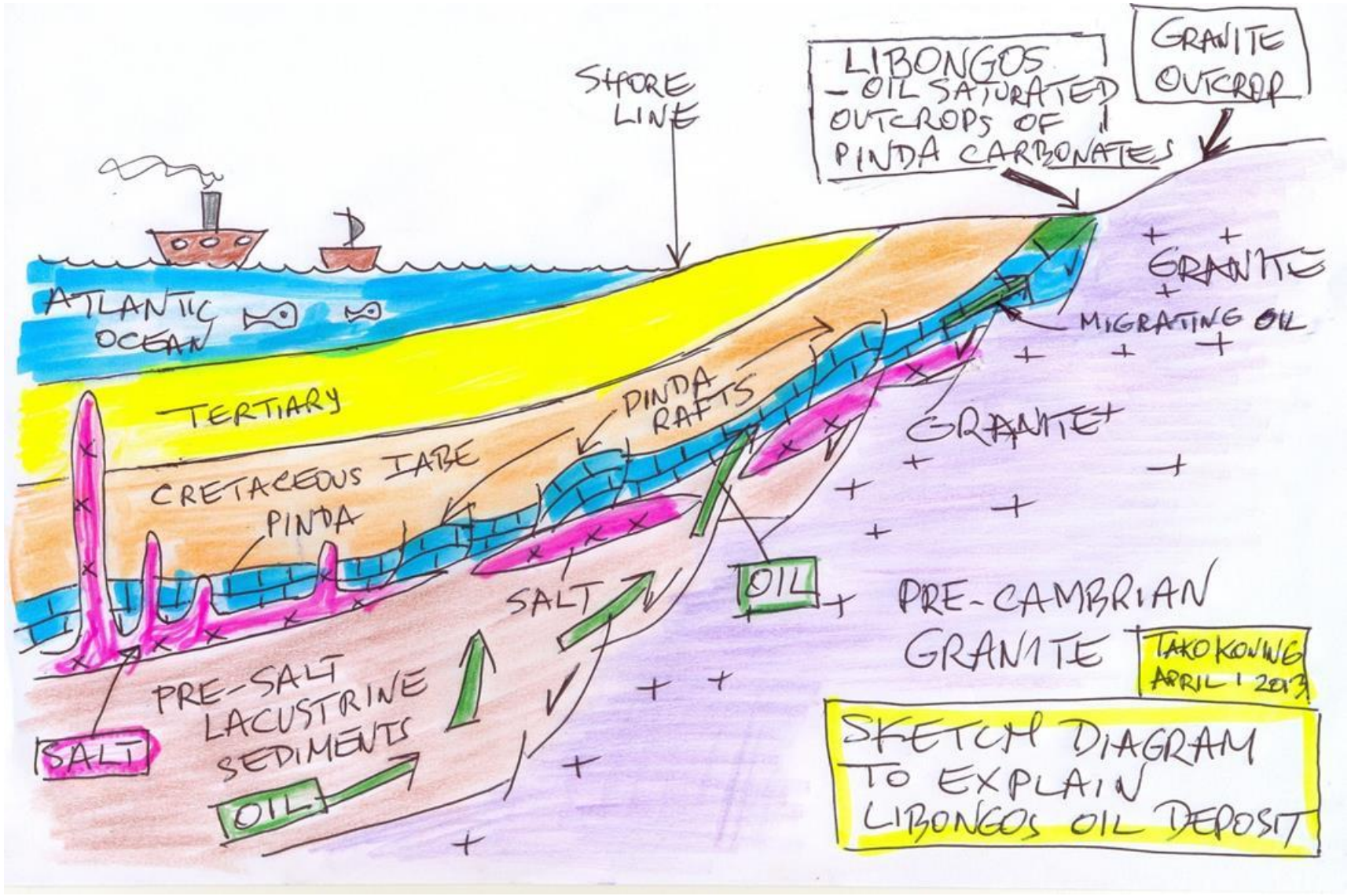
Source: T. Koning, AAPG Explorer magazine, April 2013

Angola's Oil History – the Past
The Libongos Oil Seeps – *Pre-Salt Oil*

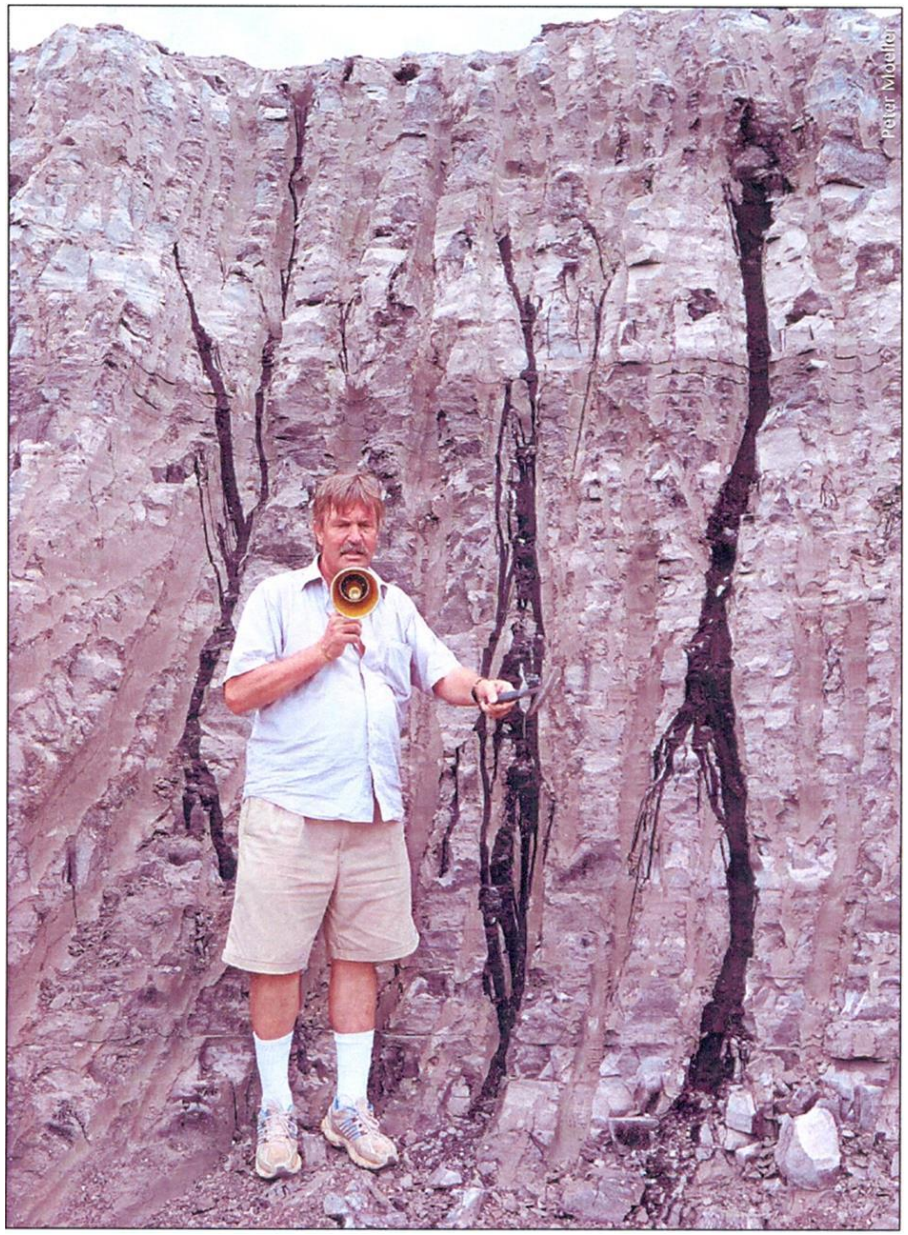


Libongos oil seeps. Here oil has migrated into Pinda-equivalent porous carbonates. This oil has been analyzed by Norsk Hydro and Chevron to be pre-salt oil. The oil-filled Pinda has been eroded exposing it at the surface and creating these oil seeps. Recent (2011 & 2012) pre-salt discoveries in the deepwater Kwanza Basin by Maersk Oil (Azul-1) and Cobalt International Exploration (Cameia-1) has focused attention on these oil seeps since they provide an important data point on the pre-salt of the Kwanza Basin.

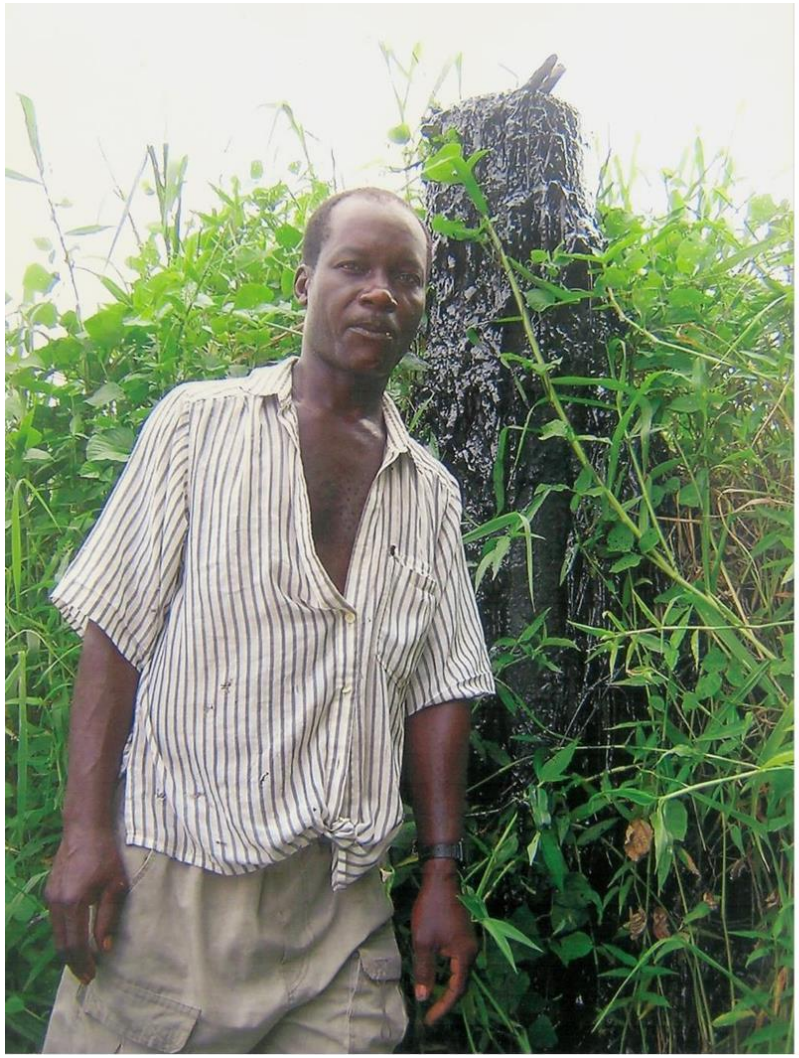
Angola's Oil History – the Past
The Libongos Oil Seeps – *Pre-Salt Oil*



Angola's Oil History – the Past
The Libongos Oil Seeps – *Pre-Salt Oil*



Angola's Oil History – Dande-4 Drilled in 1916, Tested 6 BOPD – *Pre-salt Oil*

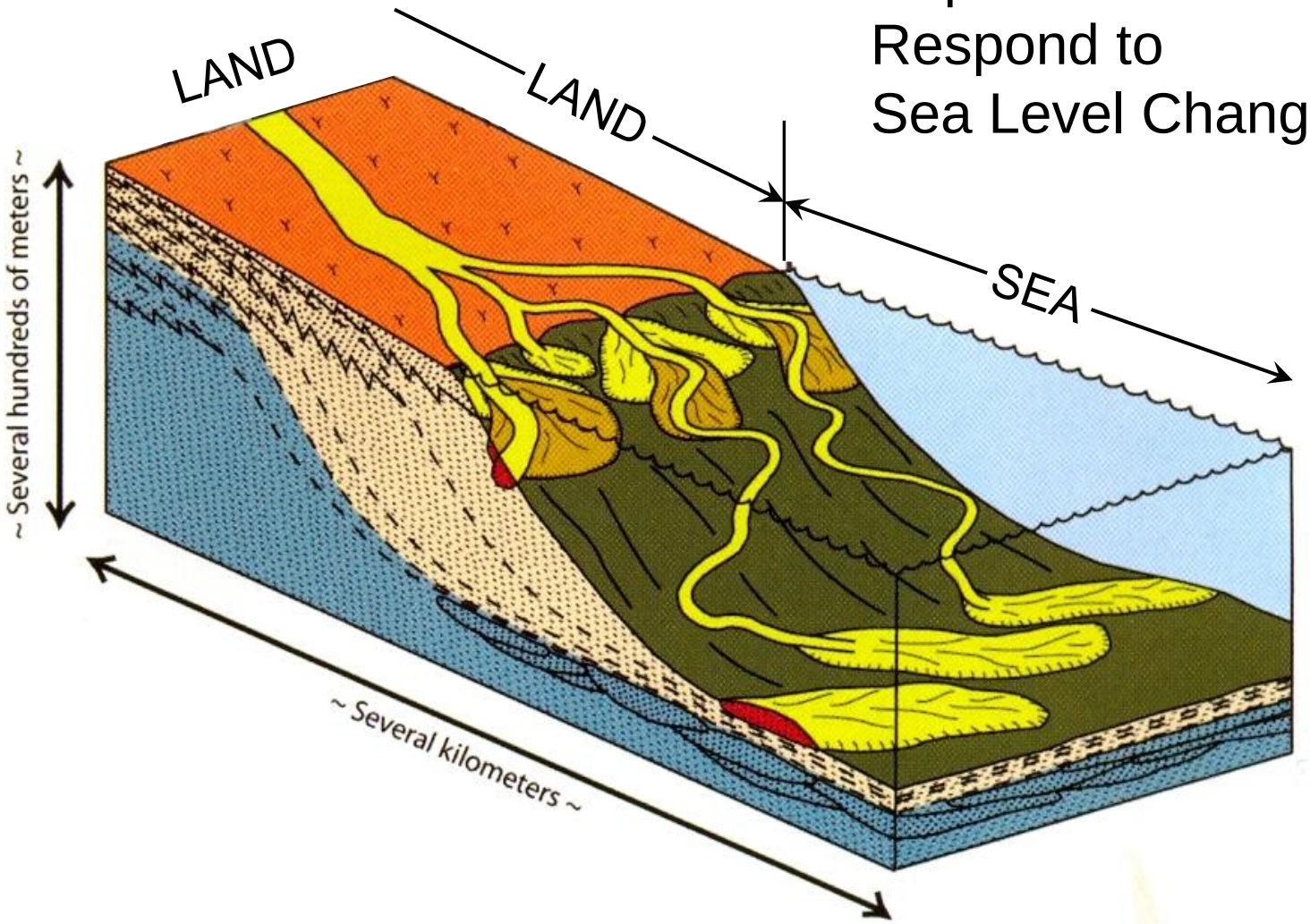


GEOLOGY – WHERE IT ALL STARTS

We begin with an introduction to the basic types of oil and gas fields

Geology

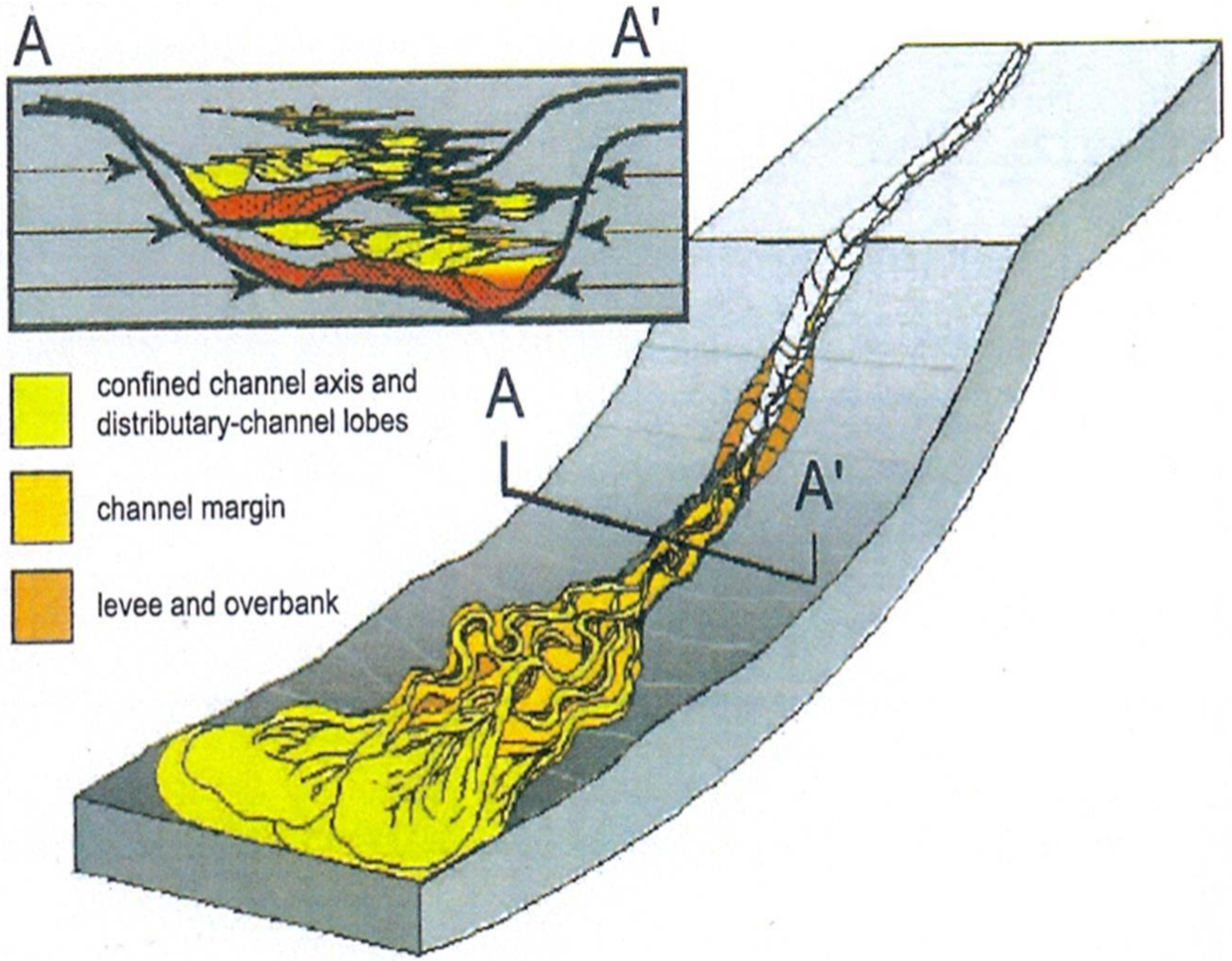
Depositional Processes
Respond to
Sea Level Changes



Source: GeoExPro 2013

Geology – Lower Congo Basin, Esso Block 15, Slope Channel System in Oligocene-Miocene Malembo formation

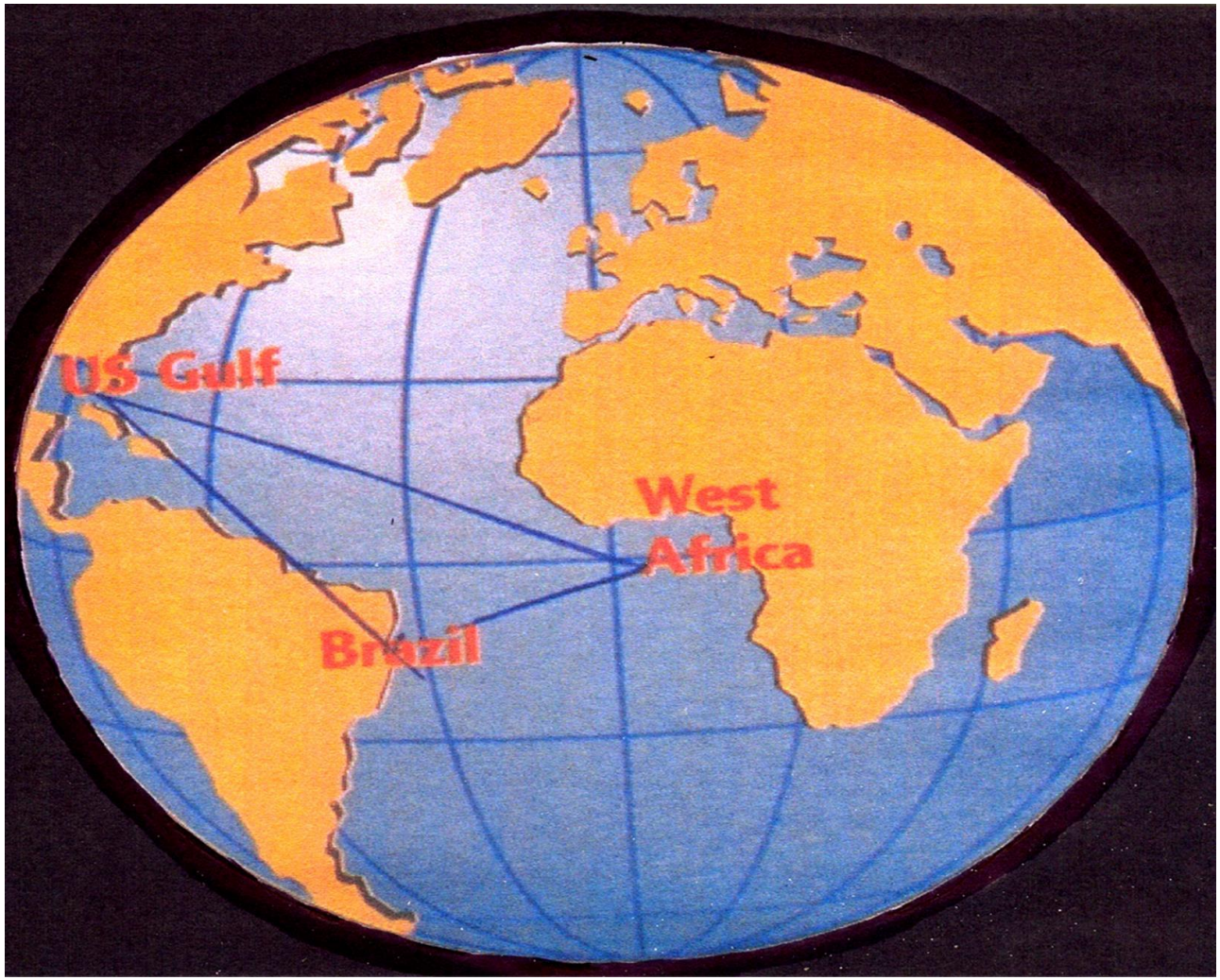
From: Porter et al, Exxon, 2006, AAPG Memoir 88



Major Oil & Gas Fields Continue to be Discovered in Angola in Past *Five* Years

- ENI has drilled 8 oil discovery wells on Block 15/06 (9 wells, 8 discoveries)
- MAERSK has drilled 3 oil discovery on Block 16
- TOTAL has drilled 3 oil discoveries on Block 17/06 (3 wells, 3 discoveries)
- PETROBRAS has drilled 1 oil discovery on Block 18/06
- PLUSPETROL has drilled 1 oil discovery on Cabinda South Block

The Golden Triangle for Deepwater Oil & Gas Exploration: The Gulf of Mexico – Brazil & West Africa



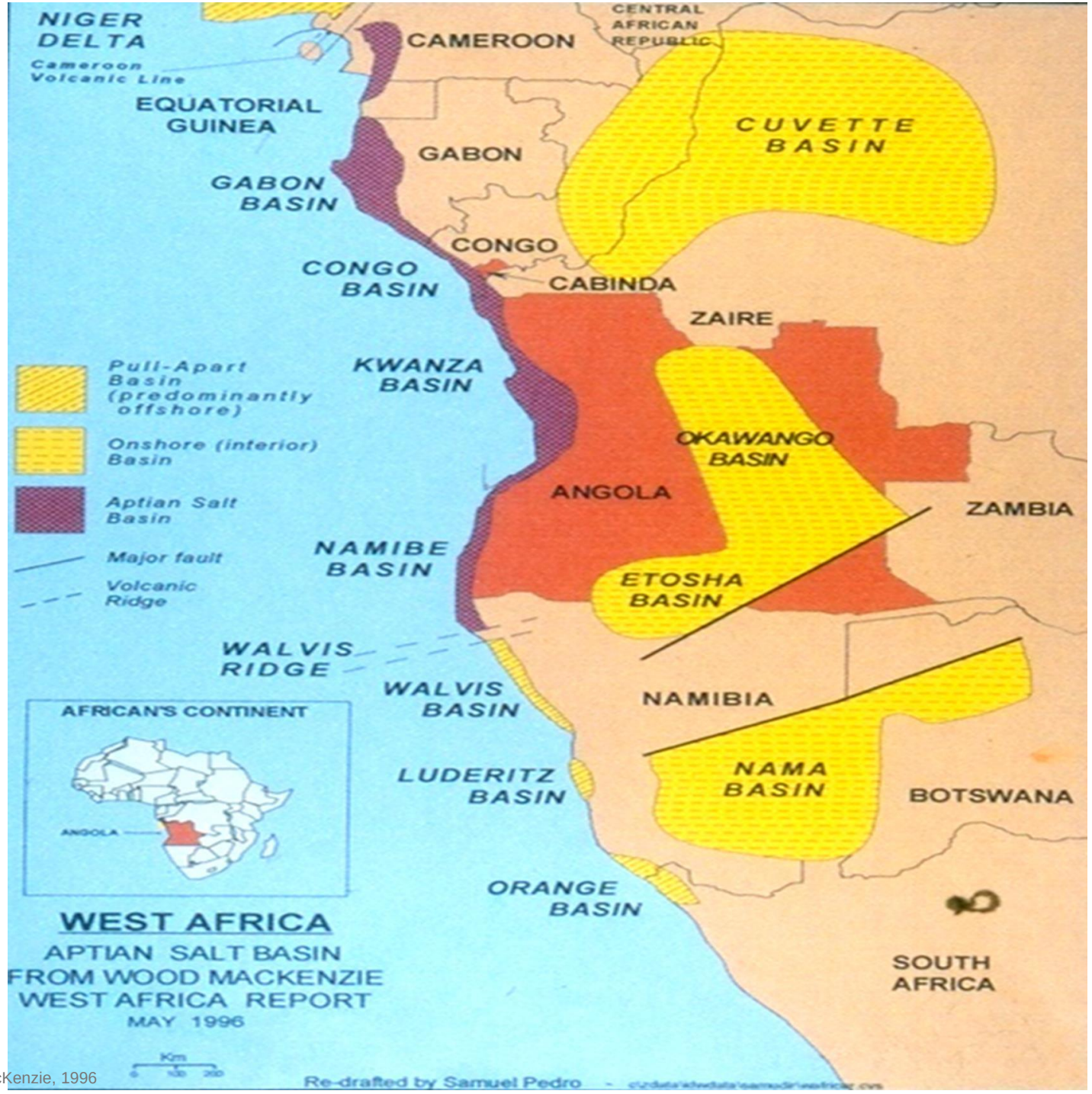
Source: T. Koning, SPWLA Angola Forum, 2010

QUOTATION

"Hardly anywhere in the world measures up to the recent exploration significance of Angola"

Source: Oil + Gas Journal, May 23, 2005

This quotation still applies to today, according to this presenter.

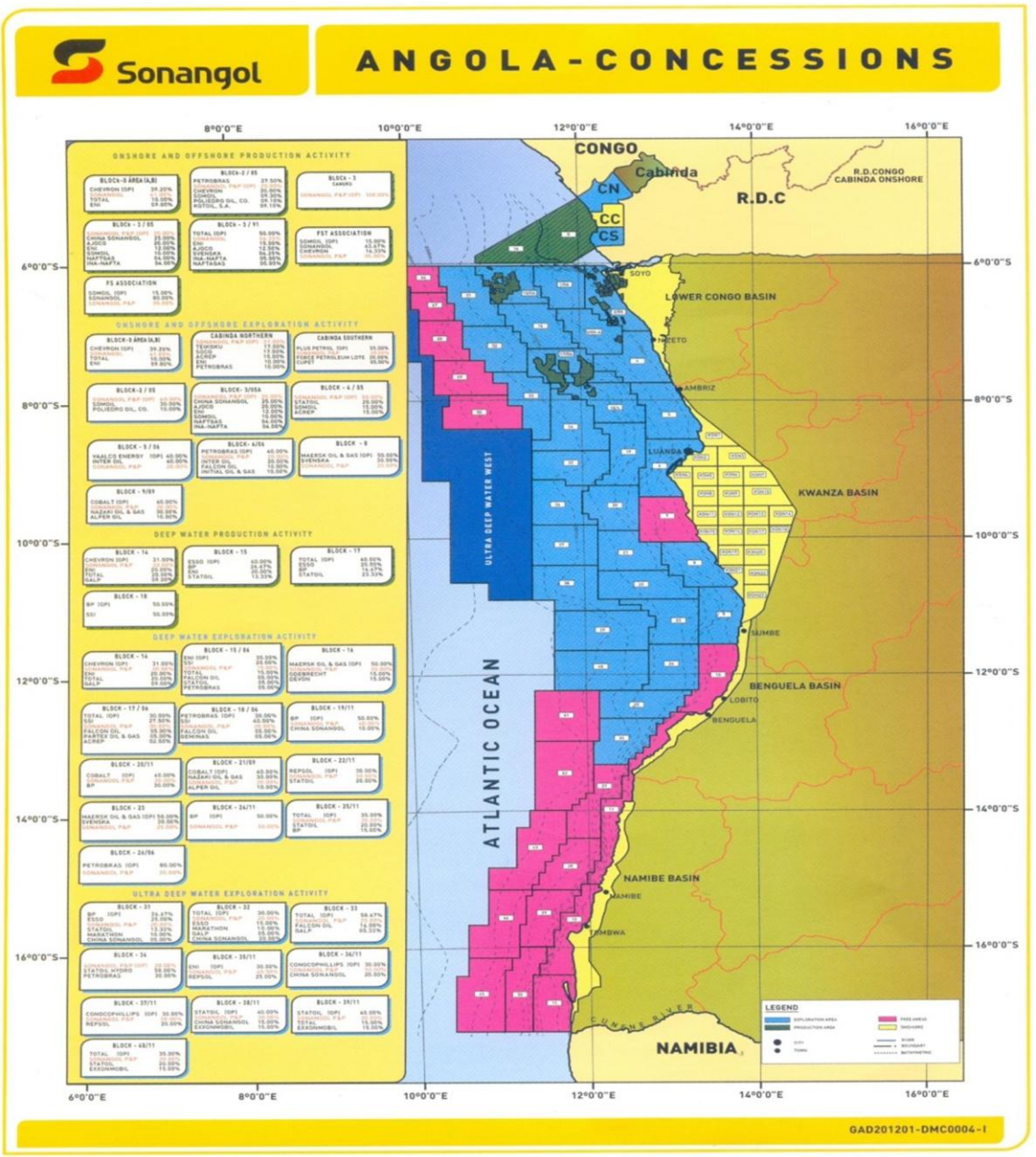


Source: Wood MacKenzie, 1996

Lower Congo Sedimentary Basin - Key Points

- Basin covers 115,000 sq km from shoreline to water depths of 3500 meters
- Since the discovery of Girassol in 1996, exploration has focused on the deepwater turbidite sands associated with the ancestral Congo River
- Excellent seismic imaging has led to the high rates of exploration success (85%)

Angola Oil Concessions



Source: Sonangol website, 2014

Oil Companies Present in Angola: Operators of Blocks

Chevron	American
Esso	American
Vaalco	American
Cobalt	American
ConocoPhilips	American
Total	French
BP	British
ENI	Italian
Repsol	Spanish
Petrobras	Brazilian
Pluspetrol	Argentinean
Statoil	Norwegian
Maersk	Danish
Sonangol P&P	Angolan (state oil company)

Oil Companies Present in Angola: Non-operators

- Naftagas
- Partex
- Odebrecht
- Teikokou
- Sinopec
- ACR
- Force
- Partex

Prodoil
SOCO
Svenska
Falcon
China
Somoil
Interoil
Etc etc

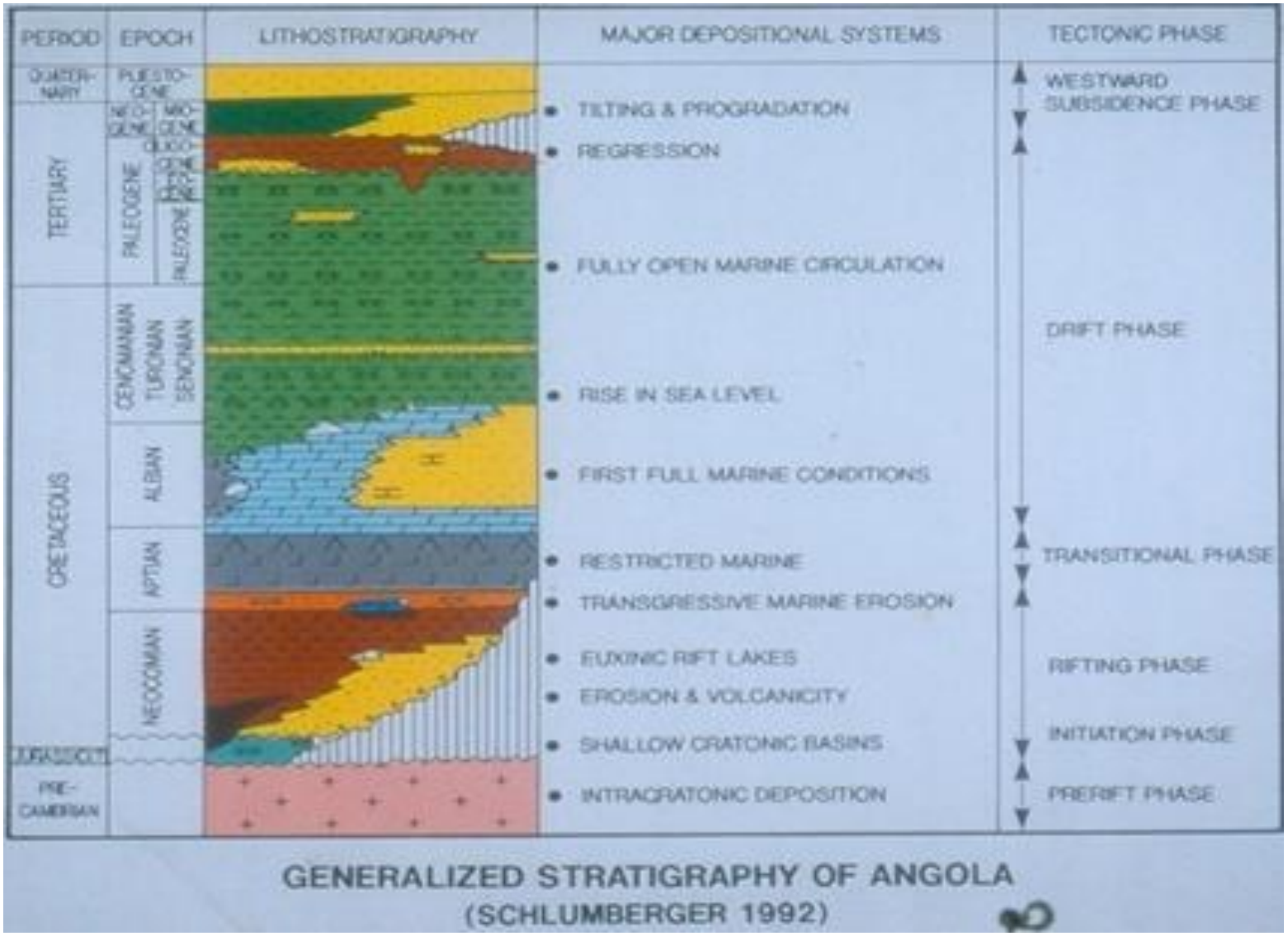
Initial Oil
Marathon
Ajoco
Petrogal
Sonangol
Grupo Gema
Galp Enegia

Current Angola Oil Production – By Operator in Bopd - Data from Minfin Website

TOTAL	600,000 BOPD
ESSO	350,000
CHEVRON	340,000
BP	300,000
SONANGOL P&P	55,000
SOMOIL	5,000

Note: Aprox 3/4's of the oil production is from deep water fields, 1/4 of the oil production is from shallow water fields & onshore

Stratigraphic Column



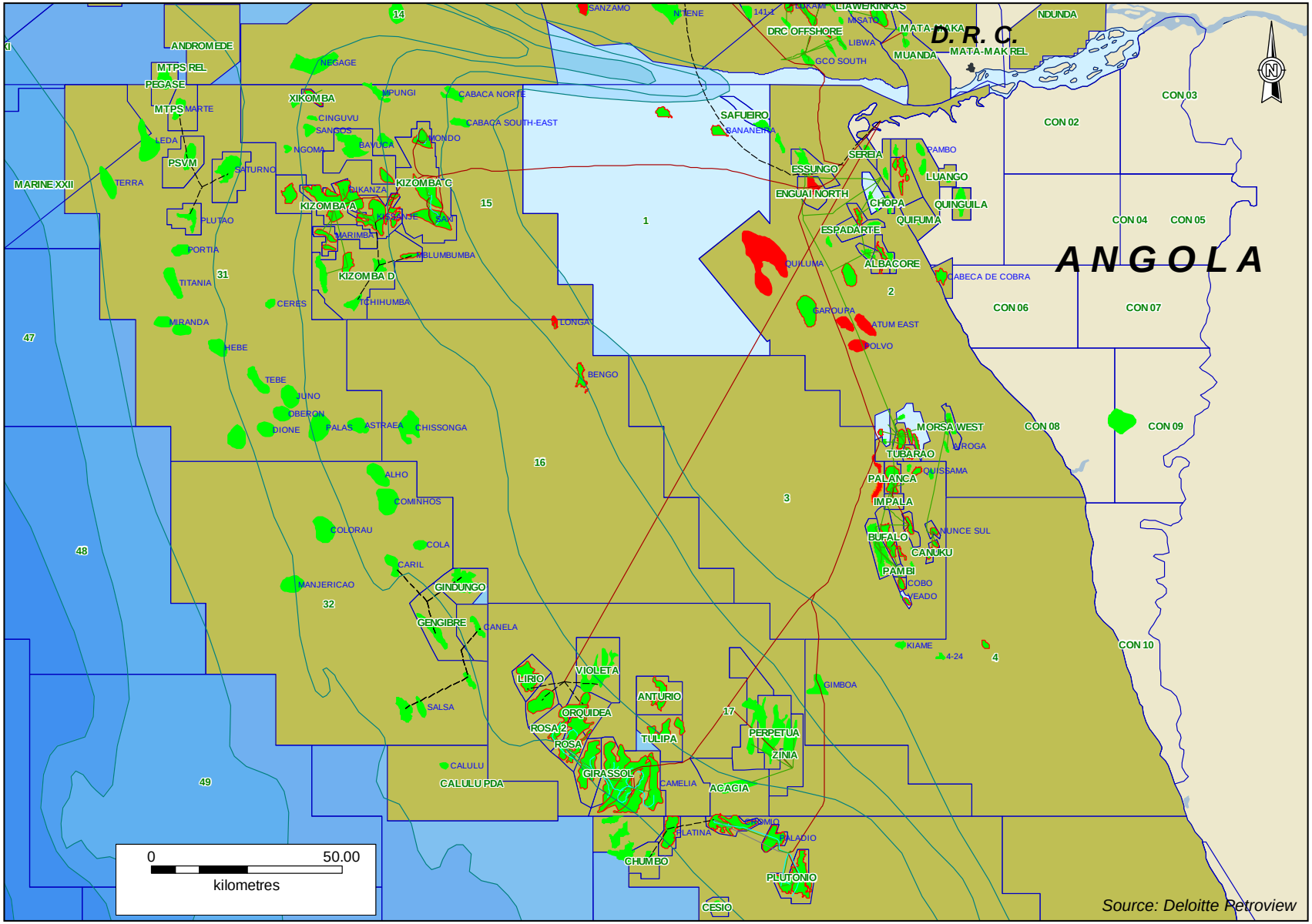
GENERALIZED STRATIGRAPHY OF ANGOLA
(SCHLUMBERGER 1992)

Source: Schlumberger, 1992 - WEC (Well Evaluation Conference)

Post-Salt Oil Fields

- LOMBO EAST as an example of a post-salt Pinda carbonate oil field

Offshore Angola



The Lombo East Oil Field

- Lombo East is a Typical Pinda Carbonate (Dolomite & Limestone) Oilfield
- OOIP 310 MMSTB
- Recovery Factor 47%
- Cummulative Production 140 MMBLS
- Peak Production 33,000 BOPD from 9 wells (3,500 BOPD/ Well)

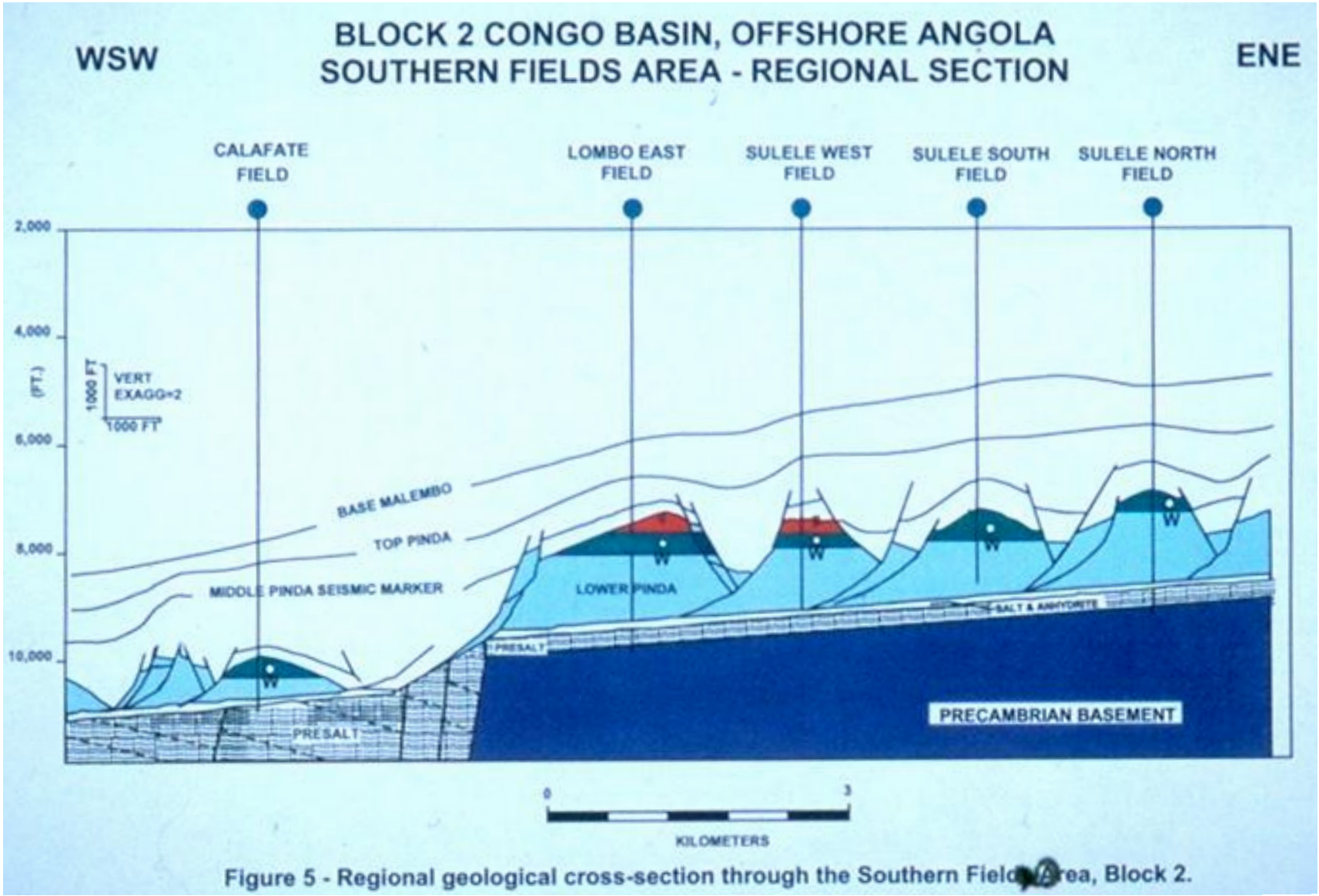
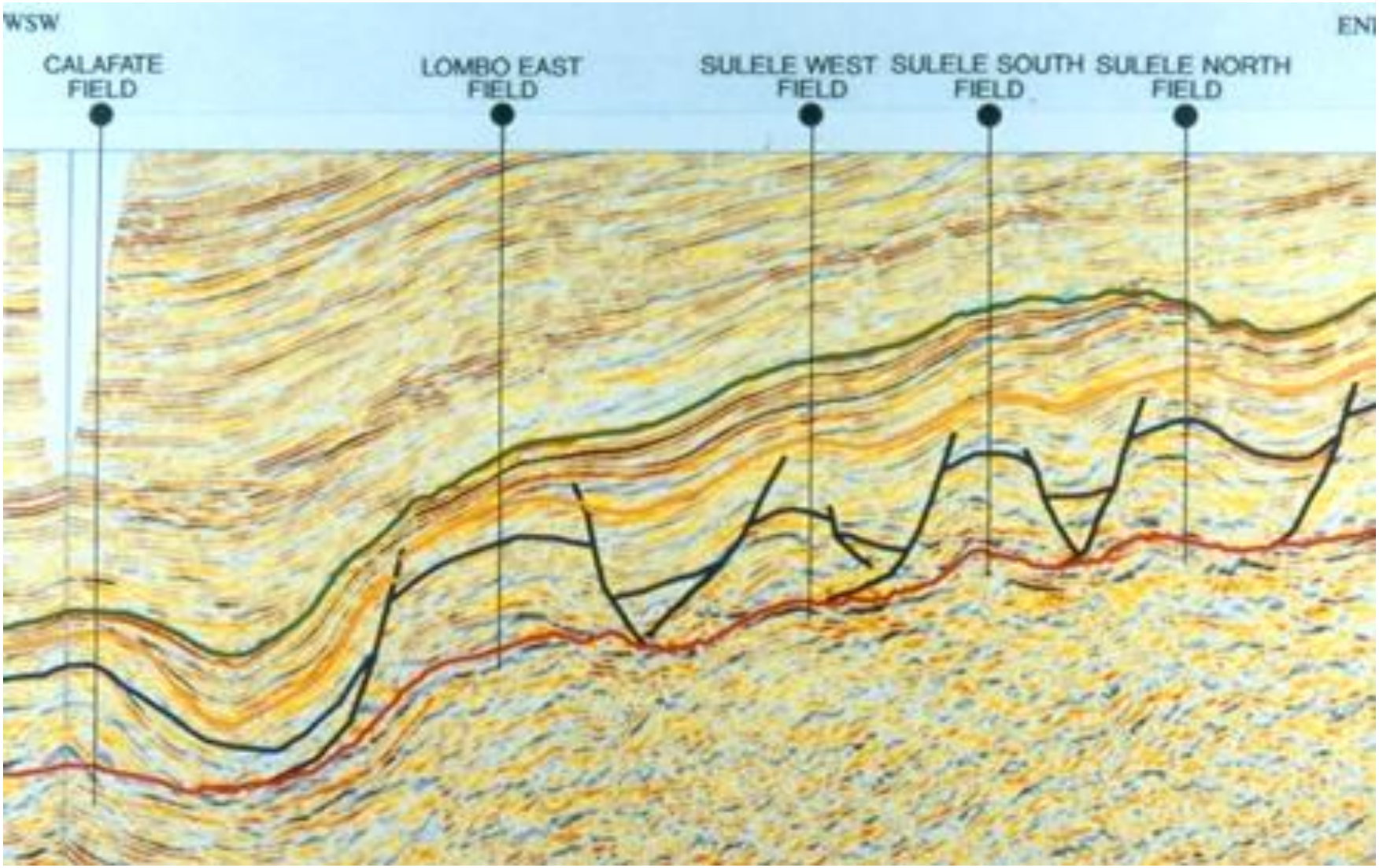
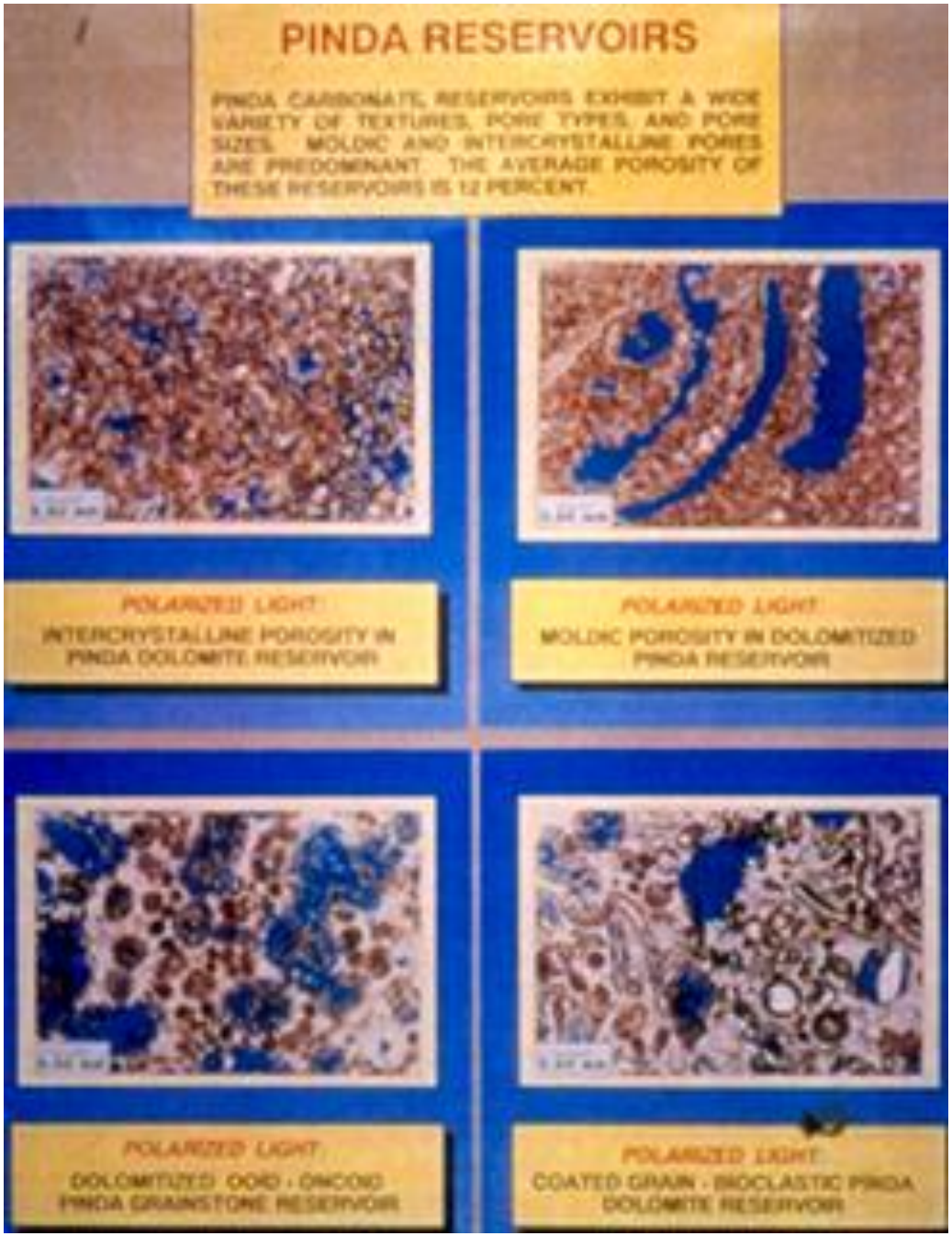


Figure 5 - Regional geological cross-section through the Southern Fields Area, Block 2.

Source: T. Koning (Texaco) & O. De Deus (Sonangol), AAPG 1997, 1998, 2000



Source: T. Koning (Texaco) & O. De Deus (Sonangol), AAPG Hedberg Research Conference 1997, 1998, 2000



Source: T. Koning (Texaco) & O. De Deus (Sonangol), AAPG 1997, 1998, 2000

Source: T. Koning (Texaco) & O. De Deus (Sonangol), AAPG 1997, 1998, 2000

Source: T. Koning (Texaco) & O. De Deus (Sonangol), AAPG 1997, 1998, 2000

Review of Angola's Deep Water Oil Fields

- Chevron Block 14
- Esso Block 15
- Total Block 17
- BP Block 18

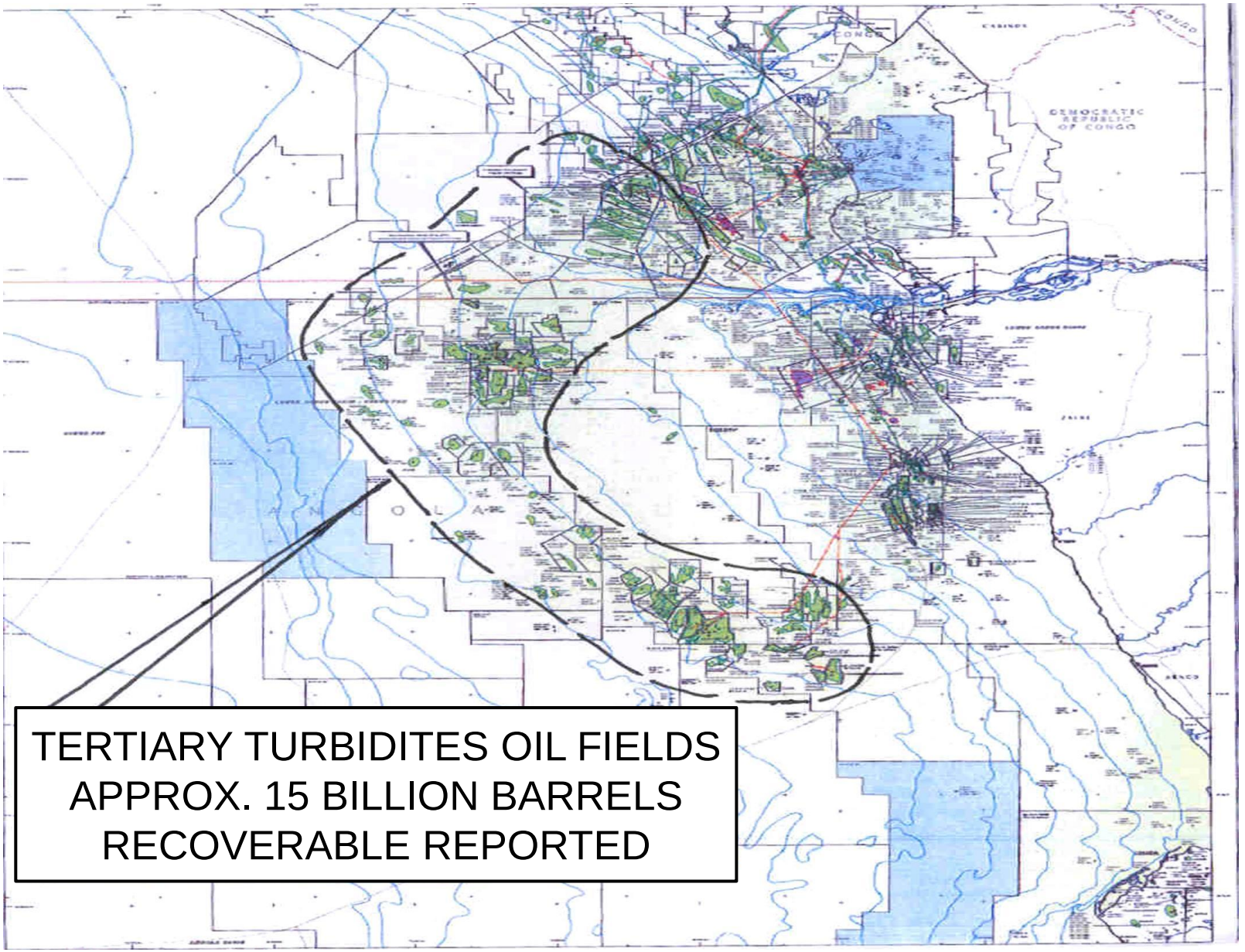
Deepwater Discovery

Source: TransOcean website, 2009

Deepwater Turbidite Deposits

- Turbidites are sands and gravels which flowed in subsea rivers from land seawards & downwards to the sea floor
- 3/4’s of Angola’s oil production is now from the deepwater and comes from turbidite sand and gravel deposits

Tertiary Oil-bearing “Fan”



Source: T. Koning, SPWLA Angola Formation Evaluation Forum, 2014

CHEVRON Deepwater Block 14

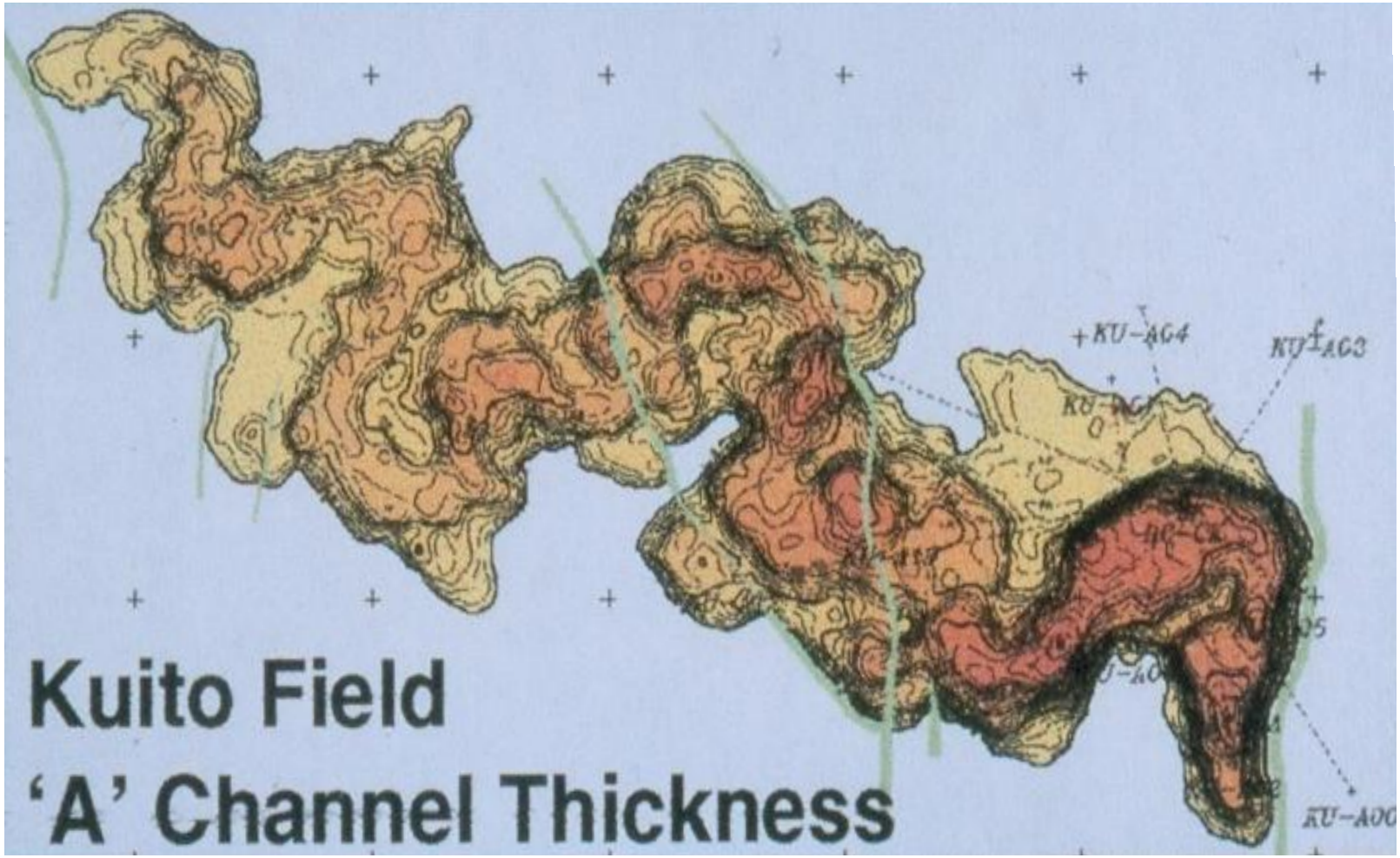
- CHEVRON is operator with partners Sonangol, Total, Agip, Petrogal

- Kuito Field – First Tertiary deepwater field on production, discovered in 1997 and fast-tracked onto production in 1999

Offshore Angola

Source: Chevron Angola corporate magazine, 2012

Seismic View of the Kuito Field



Source: Chevron

Source: Chevron & Sonangol, AAPG Memoir, Giant Oil Fields, 2002

CHEVRON Deepwater Block 14 Kuito Oil Field

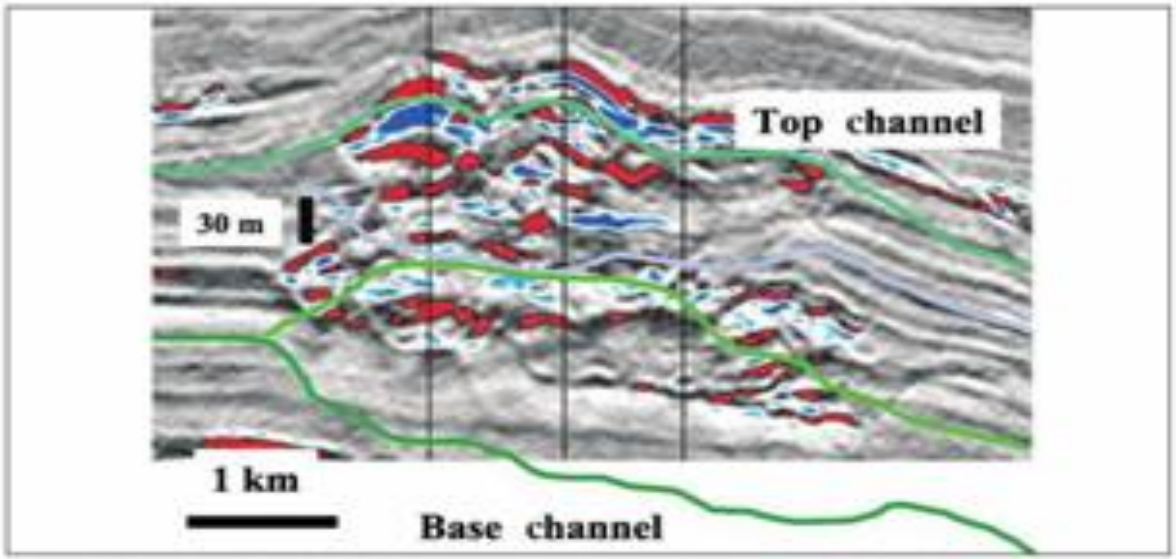


Figure 6. Seismic line through Kuito field. Line is oriented across depositional axis of channel. Note differential compaction and stacking of amplitude packages that indicate sandy turbidite channel systems.

Da Costa, J. L., T. W. Schirmer, and R. R. Laws, 2001, Lower Congo Basin, deep-water exploration province, offshore West Africa, in M. W. Downey, J. C. Threet, and W. A. Morgan, eds., Petroleum provinces of the twenty-first century: AAPG Memoir 74, p. 517–530.

Source: Chevron & Sonangol, AAPG Memoir, Giant Oil Fields, 2002

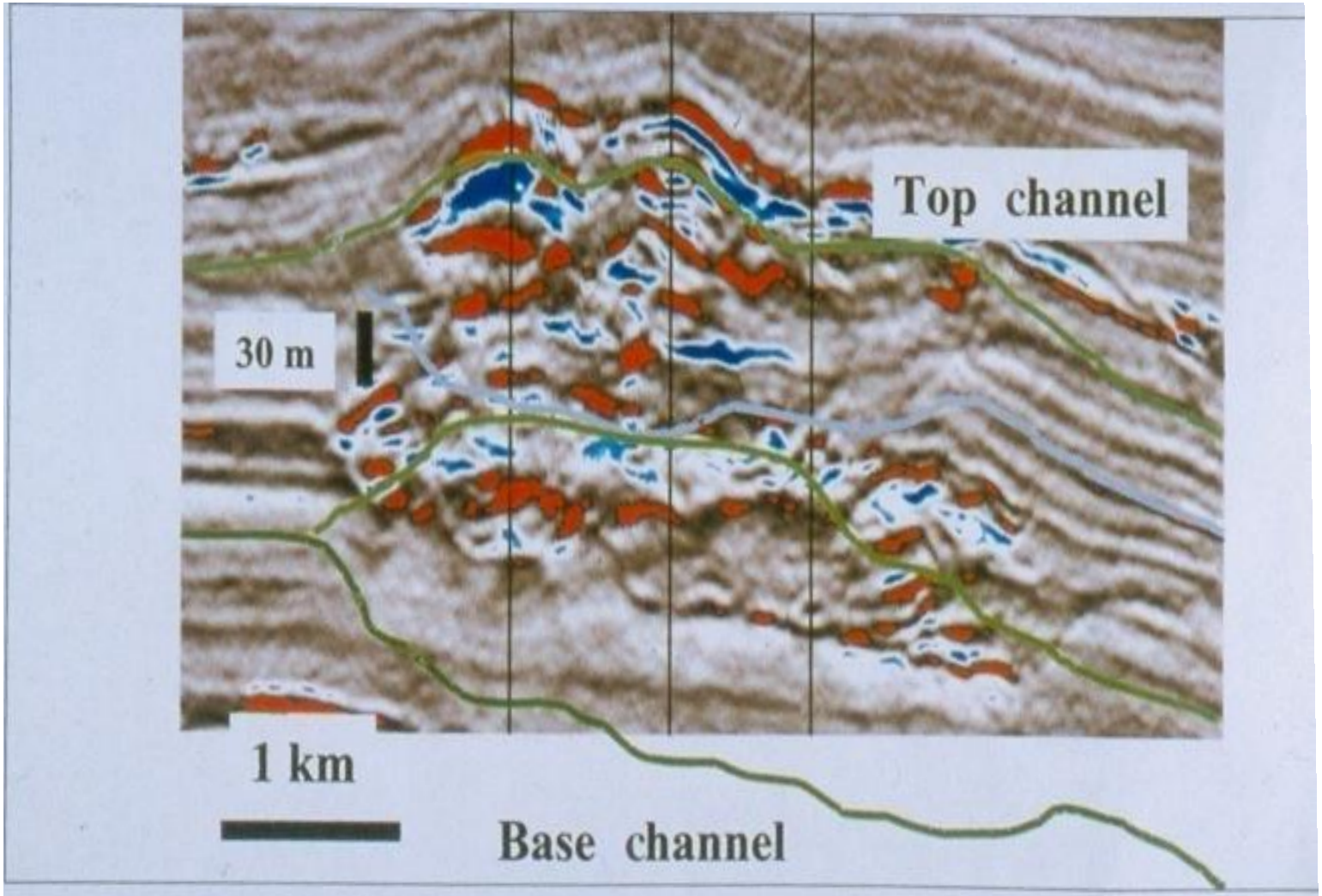
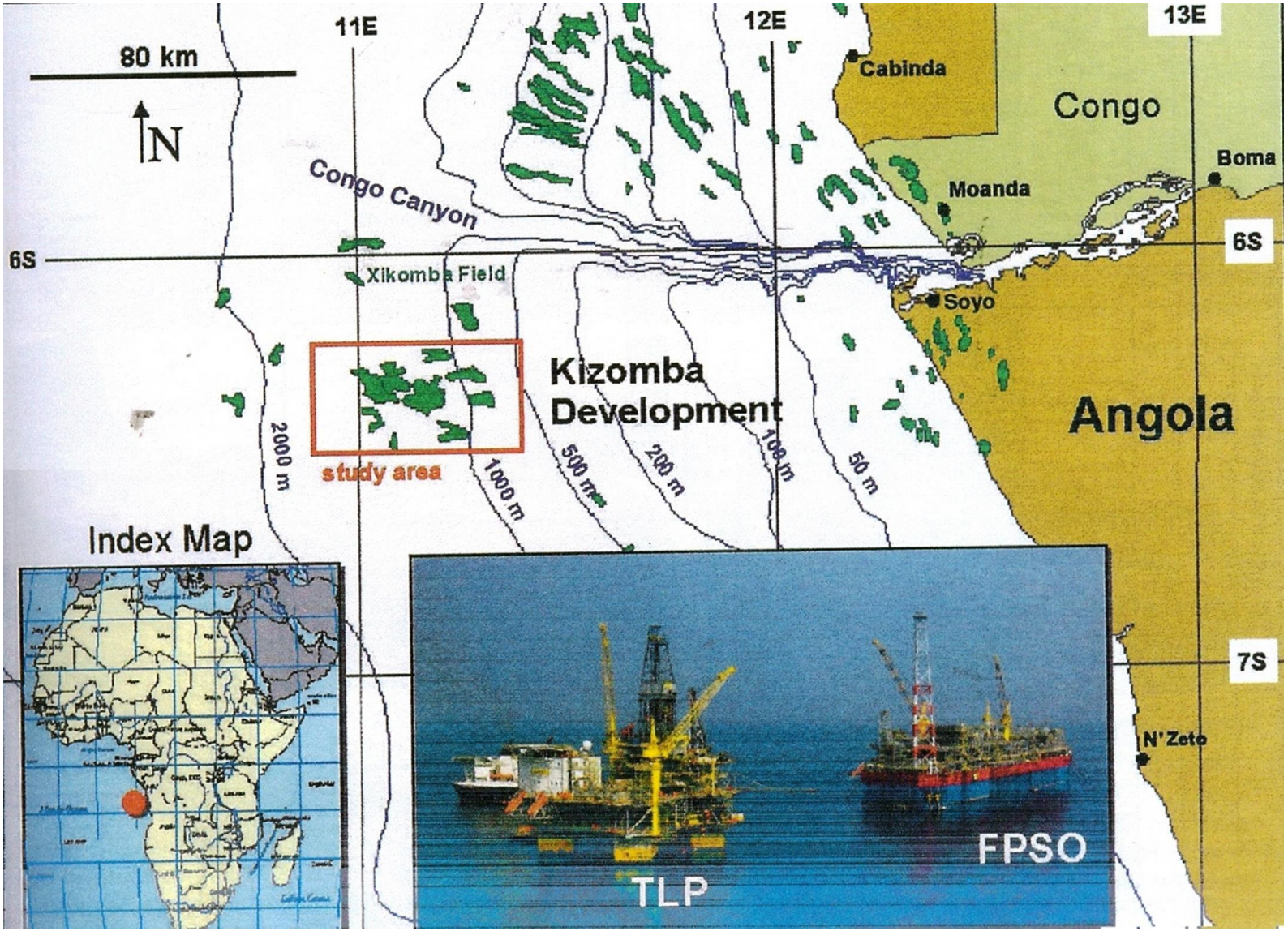


Figure 6. Seismic line through Kuito field. Line is oriented across depositional axis of channel. Note differential compaction and stacking of amplitude packages that indicate sandy turbidite channel systems.

Source: Chevron & Sonangol, AAPG Memoir, Giant Oil Fields, 2002

ESSO Deepwater Block 15 Kizomba Field



Source: Esso, AAPG Memoir 88, 2006

ESSO Deepwater Block 15, Kizomba Oil Field

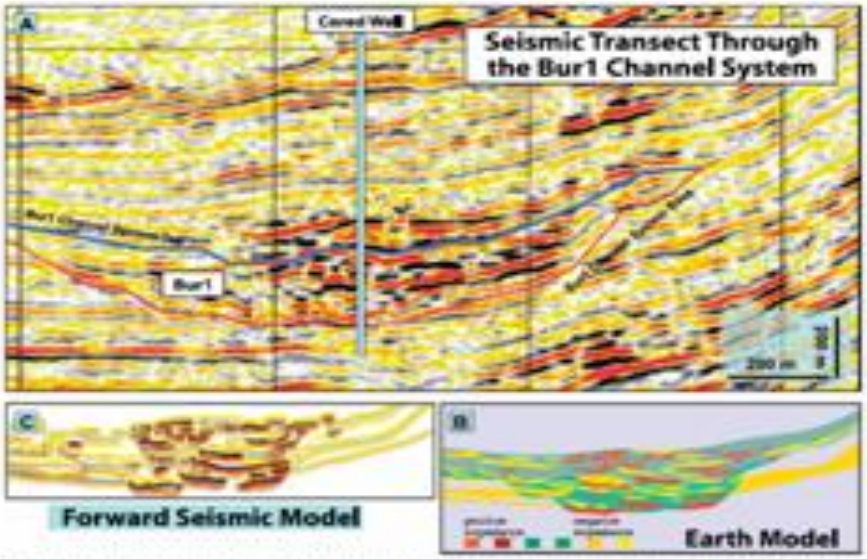
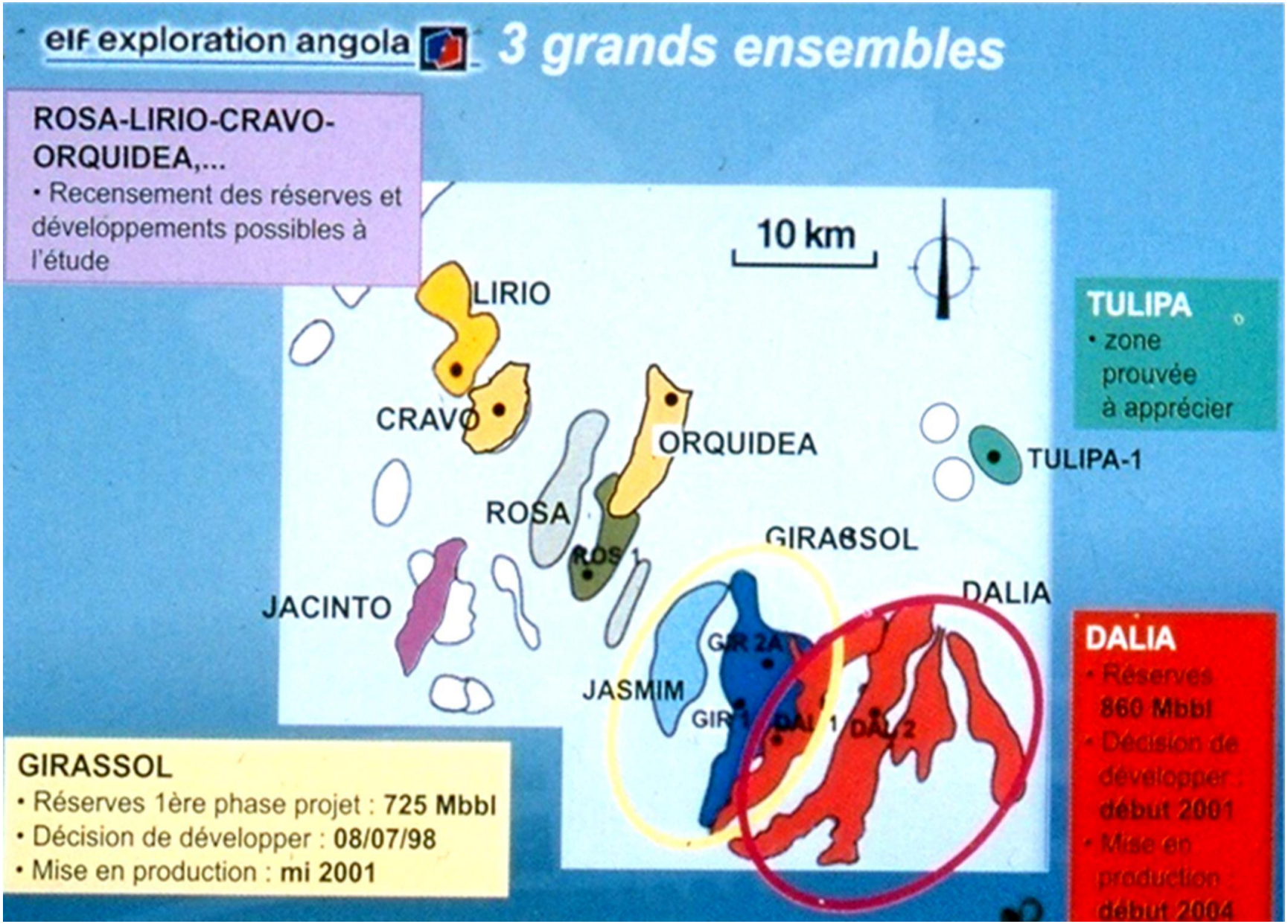


FIGURE 4. Seismic cross section through the Bur1 slope-channel system. (A) The seismic expression of the Bur1 is varied because of multiple rock types and a stratigraphy built up through multiple episodes of erosion and deposition. The axial parts of the system are seismically characterized as multicyclic, high-amplitude, semicontinuous seismic facies. Off-axis and channel-margin successions show moderate- to low-amplitude response, and these strata onlap the erosional boundary of the system. An Earth model of mixed impedance channel fills and nonchannelized depositional elements (B) is convolved with a seismic wavelet to produce a modeled seismic response (C) that is similar to the actual seismic traverse.

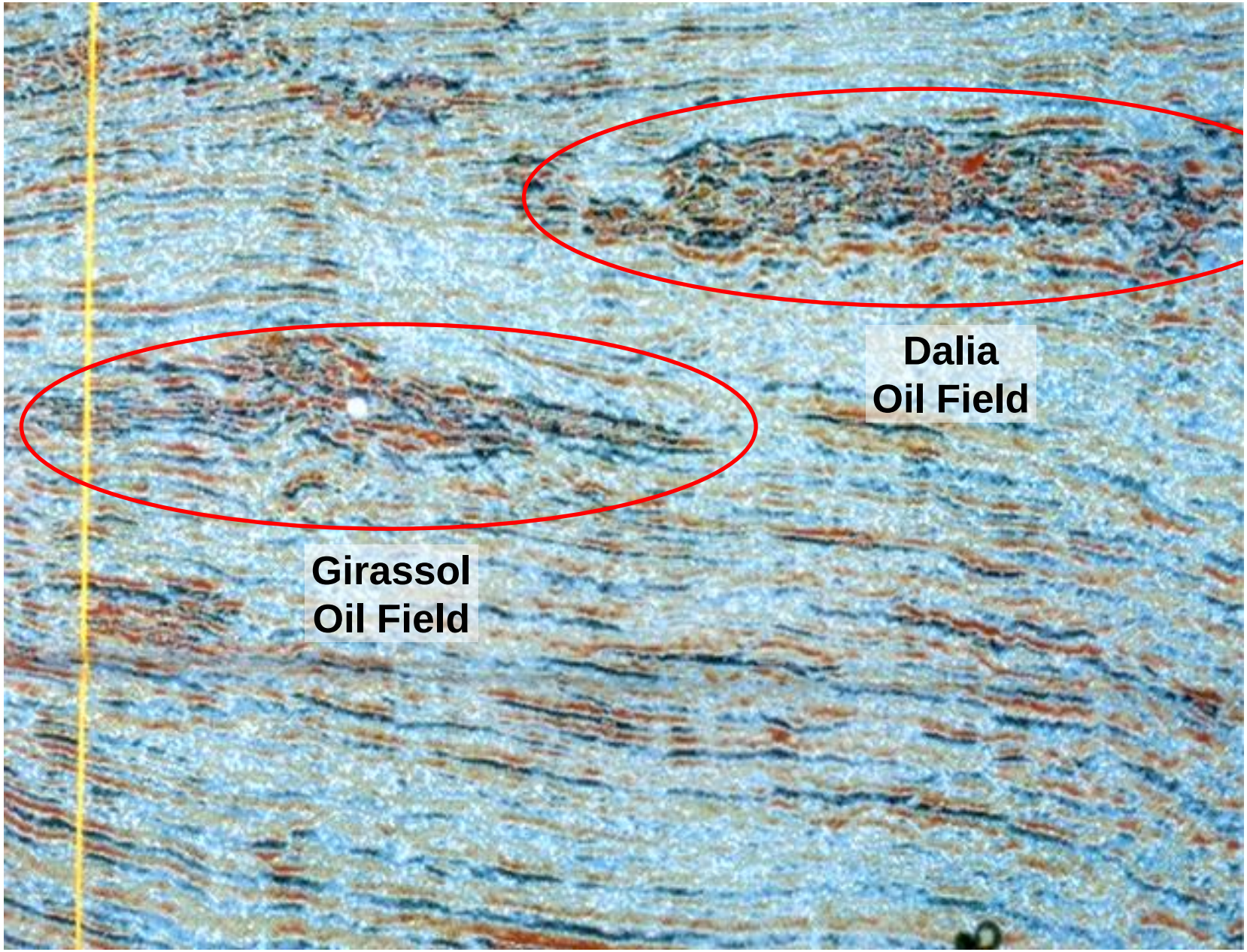
Source: Esso, AAPG Memoir 88, 2006

ESSO Deepwater Block 15 Kizomba “A” FPSO

Source: Esso corporate magazine, 2007



Source: Elf Petroleum corporate magazine, 1999



Source: TotalFinaElf, AAPG Bulletin, 2001

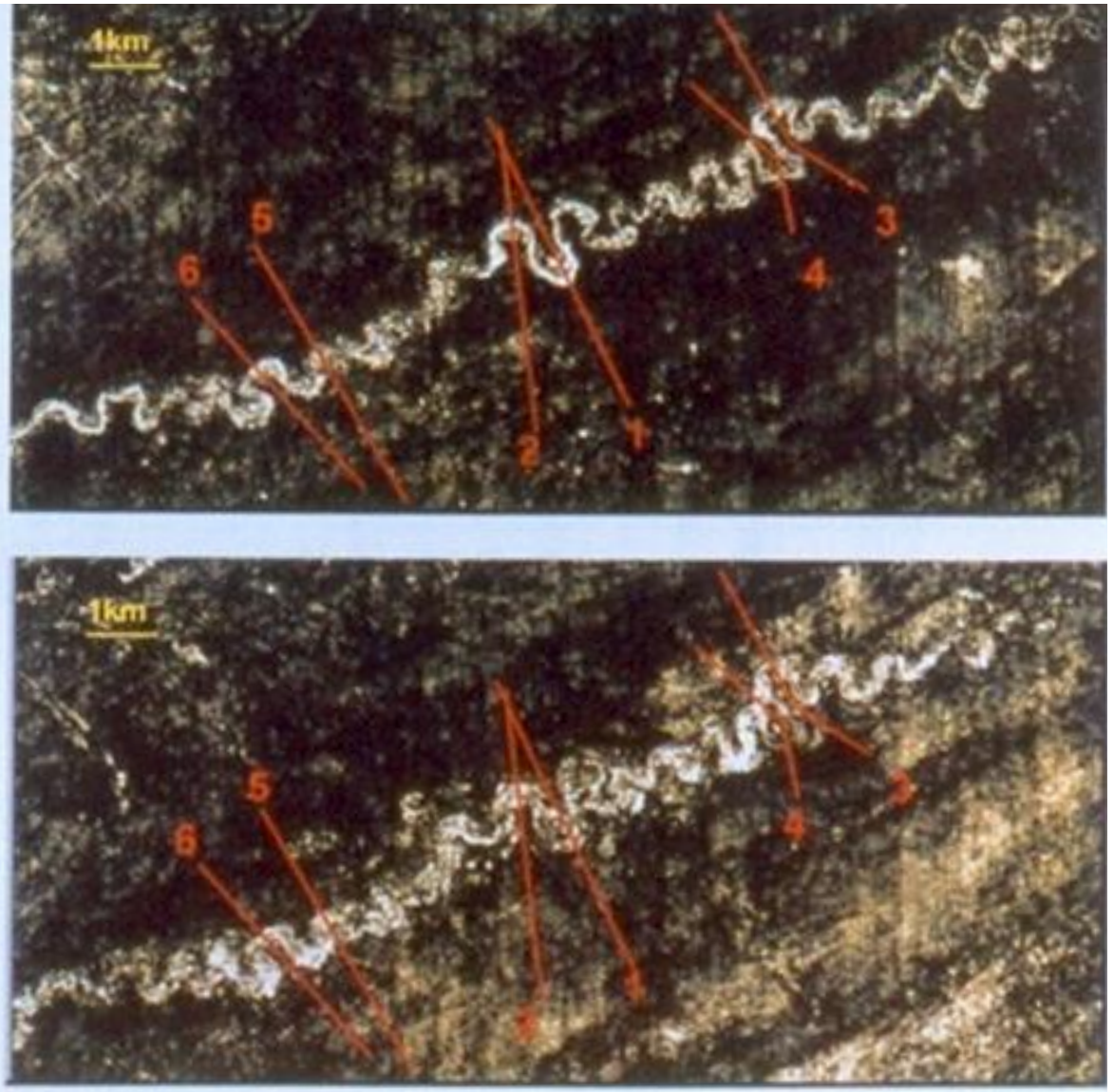


Figure 5. Average-amplitude displays in three intervals showing a simple, but highly sinuous channel form with at least one possible neck-cutoff loop. (A) Deepest interval just below the H horizon, that is, 0 to +20 ms. (B) The first interval just above horizon H, that is, 0 to −20 ms. (C) The second interval above horizon H, that is, −20 to −40 ms. The width of the high-amplitude facies increases from the lower to upper intervals. Lines 1, 2, 3, 4, 5, and 6 are seismic sections shown in Figures 8–15.

Source: TotalFinaElf, AAPG Bulletin, 2001

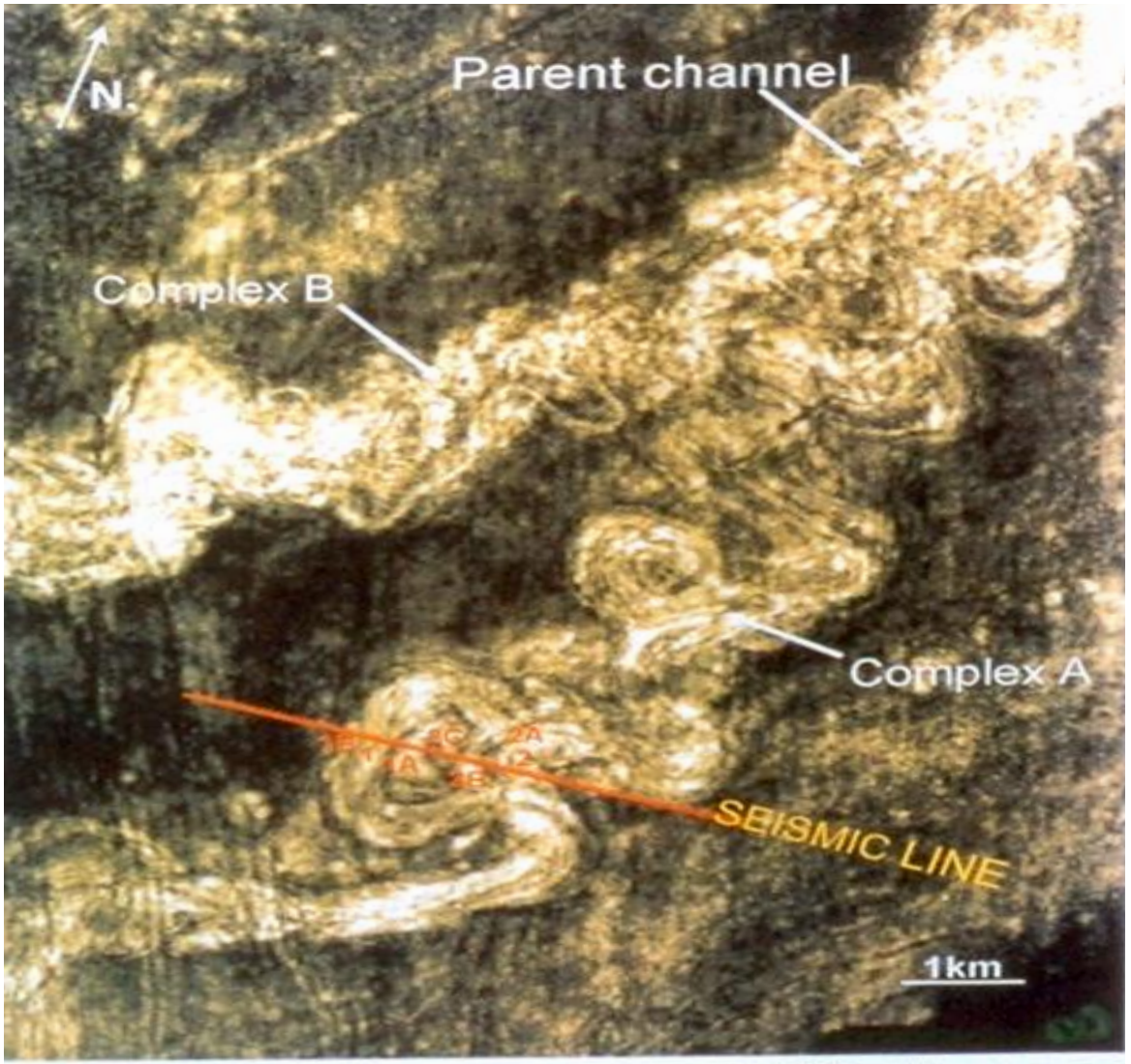


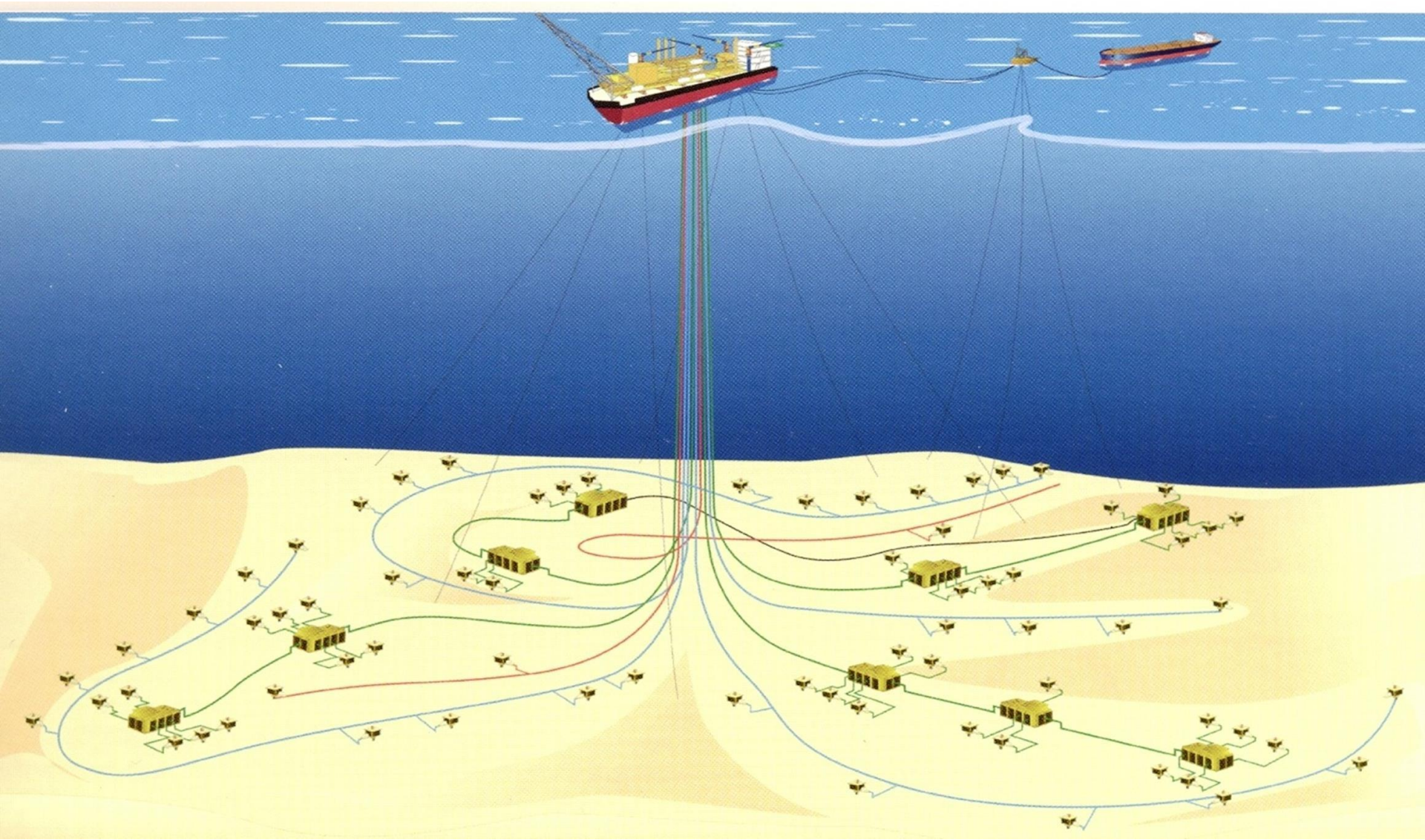
Figure 17. Amplitude display of a composite interval (combining all four intervals shown in Figure 3) of complex sinuous-channel systems. Two sinuous channel complexes—complex A and complex B—both originating from a single parent channel, are shown. The parent channel first took the course of complex A and then avulsed to complex B. Features that resemble cutoffs are present in complex A. The sinuous loop that shows the seismic line (Figure 3) location is the focus of our article and is our complex sinuous channel example 1 in the text. The sinuous loop consists of crescent-shaped high-amplitude seismic facies 2, 2A, 2B, 2C, and 1 (1A, 1B), interpreted to be migratory channel courses (see Figure 18A).

Source: TotalFinaElf, AAPG Bulletin, 2001

Girassol Moves West

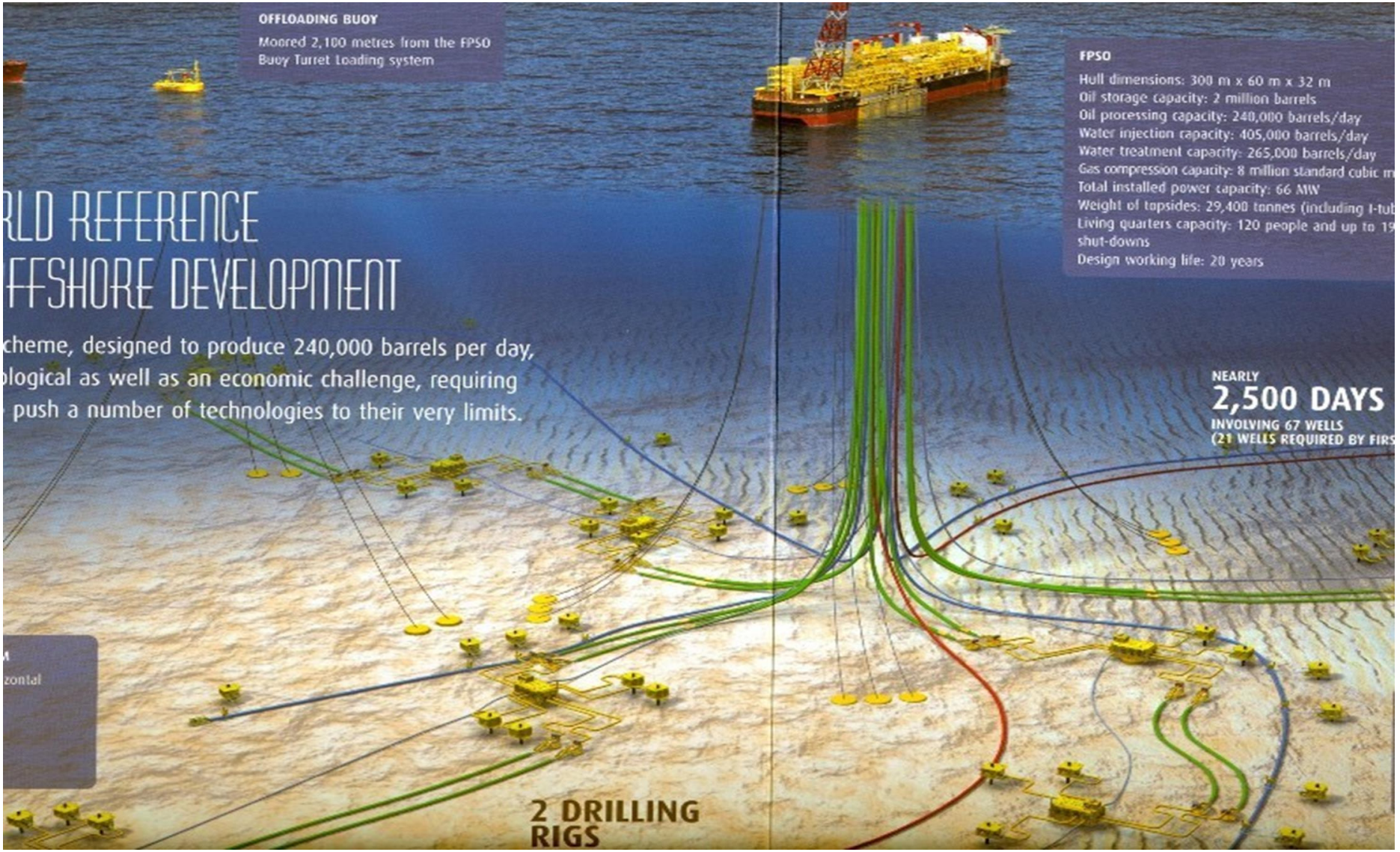
Source: Total corporate magazine, 2011

TOTAL Deepwater Block 17, Girassol Oil Field



Source: Total corporate magazine, 2011

TOTAL Deepwater Block 17, Dalia Oil Field

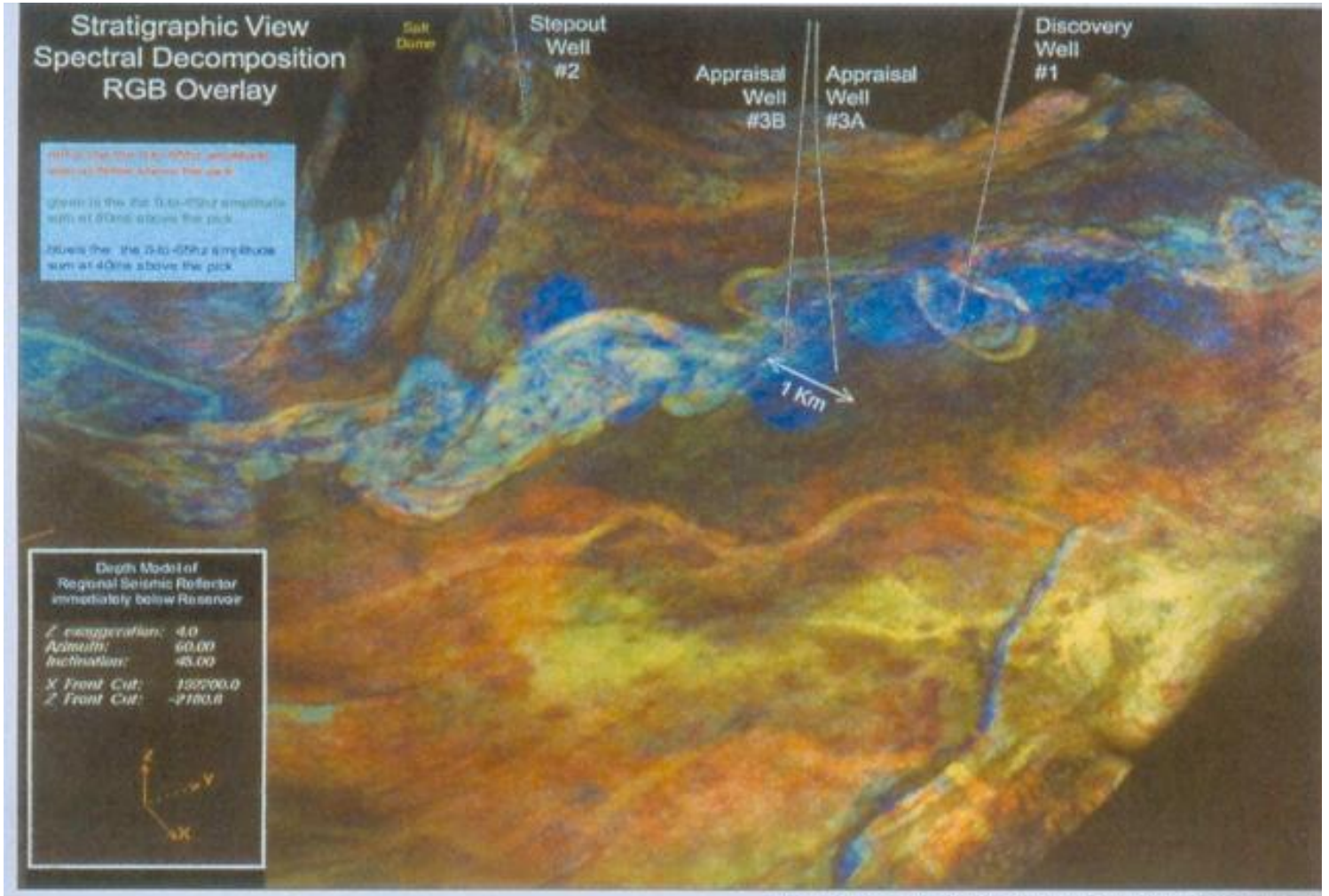


Source: Total corporate magazine, 2011

BP Block 18 Deepwater Block:

- Block operator is BP (50%); partner is Sonangol Sinopec (50%)
- Area of block is 4,900 sq km
- On production in 2008, has produced up to 220,000 BOPD

Information source: GeoLuanda Conference, 2000 & SEG & other publications



Images, data courtesy of Greg Partyka, BP Upstream Technology Group

A 3-D perspective view of a subsurface structure map, undeveloped offshore West Africa reservoir, draped with a 2-D spectral decomposition image. The reservoir is a sandy turbidite filling an erosional valley at a depth of about 3,100 meters. The draped image also conveys a 3-D perspective by showing three different slices through the reservoir section with different color bars (red, green and blue). Understanding the vertical stacking patterns of flow units is important for determining optimum drainage.

Source: BP, SEG First Break, 2009

BP Blk 18, Greater Plutonio

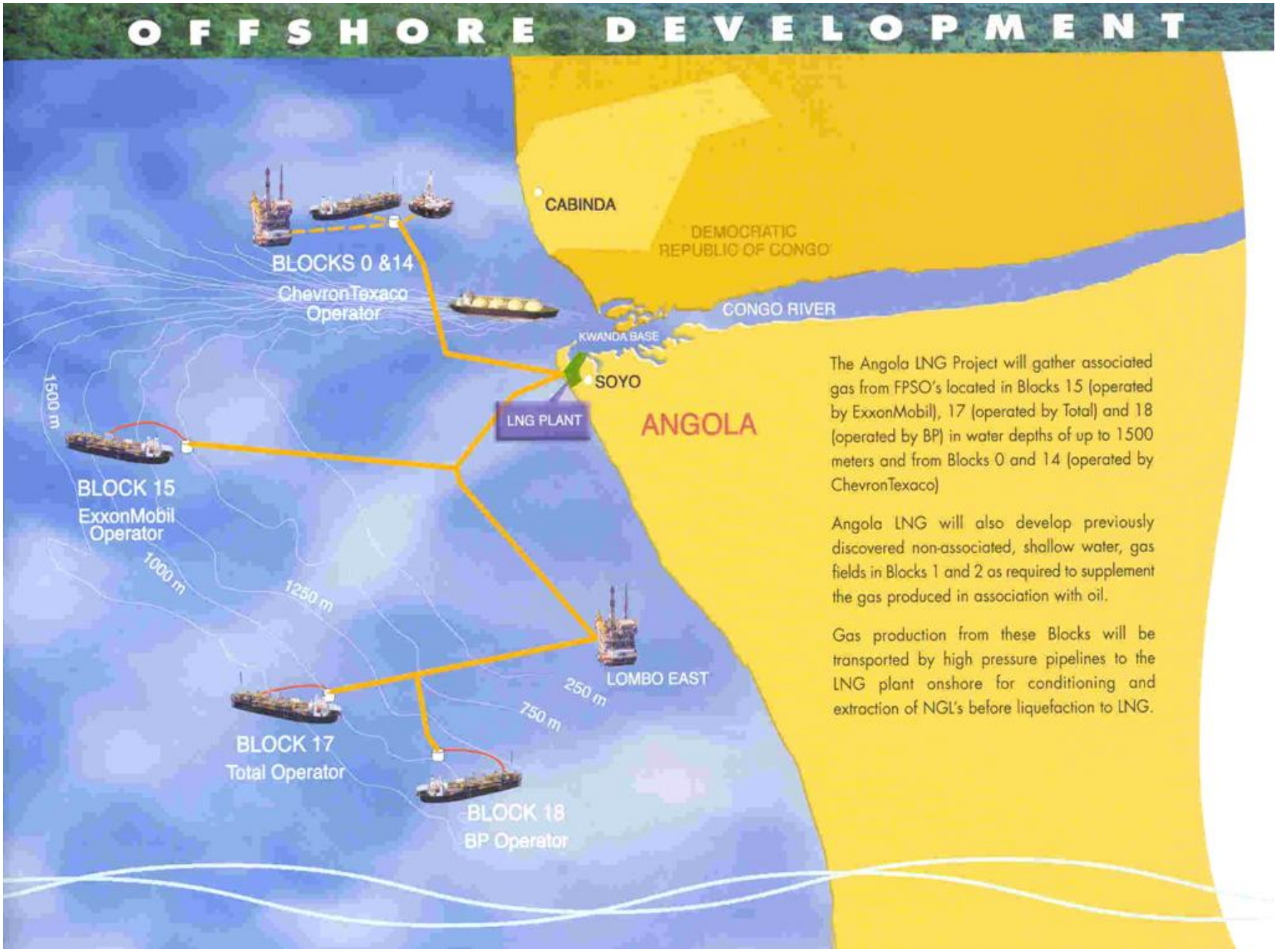
Source: BP corporate magazine, 2013

BP Block 31 PSVM

Source: BP corporate magazine, 2013

Angola LNG Project

- $10.0 billion project constructed at Soyo, northern Angola
- Purpose is to monetize gas currently being flared
- Partners are Sonangol, Chevron, BP, Total and ENI
- Started production in July, 2013, goal is 5.2 million tons per year LNG mainly for USA markets, also 125 MMSCFG/D for industrial development in Soyo



Source: Angola LNG corporate magazine, 2013

Angola LNG Project

Source: Angola LNG corporate magazine, 2013

Angola LNG Project

Source: Angola LNG corporate magazine, 2013

Angola LNG Project

- SIGNIFICANT ECONOMIC IMPACT!
- 5.2 MMTonnes/year LNG is energy equivalent to 200,000 barrels of oil per day
- Angola currently producing 1,650,000 barrels of oil per day but with LNG it will be total of 1,850,000 barrels of oil equivalent per day (BOEPD)

Angola LNG Project

- A “win-win” mega-project
- Commercializes natural gas which previously was flared off
- Creates significant job opportunities for Angolans
- Creates secondary industries in the Soyo area such as possible fertilizer plants, petrochemicals

PRE-SALT!!!

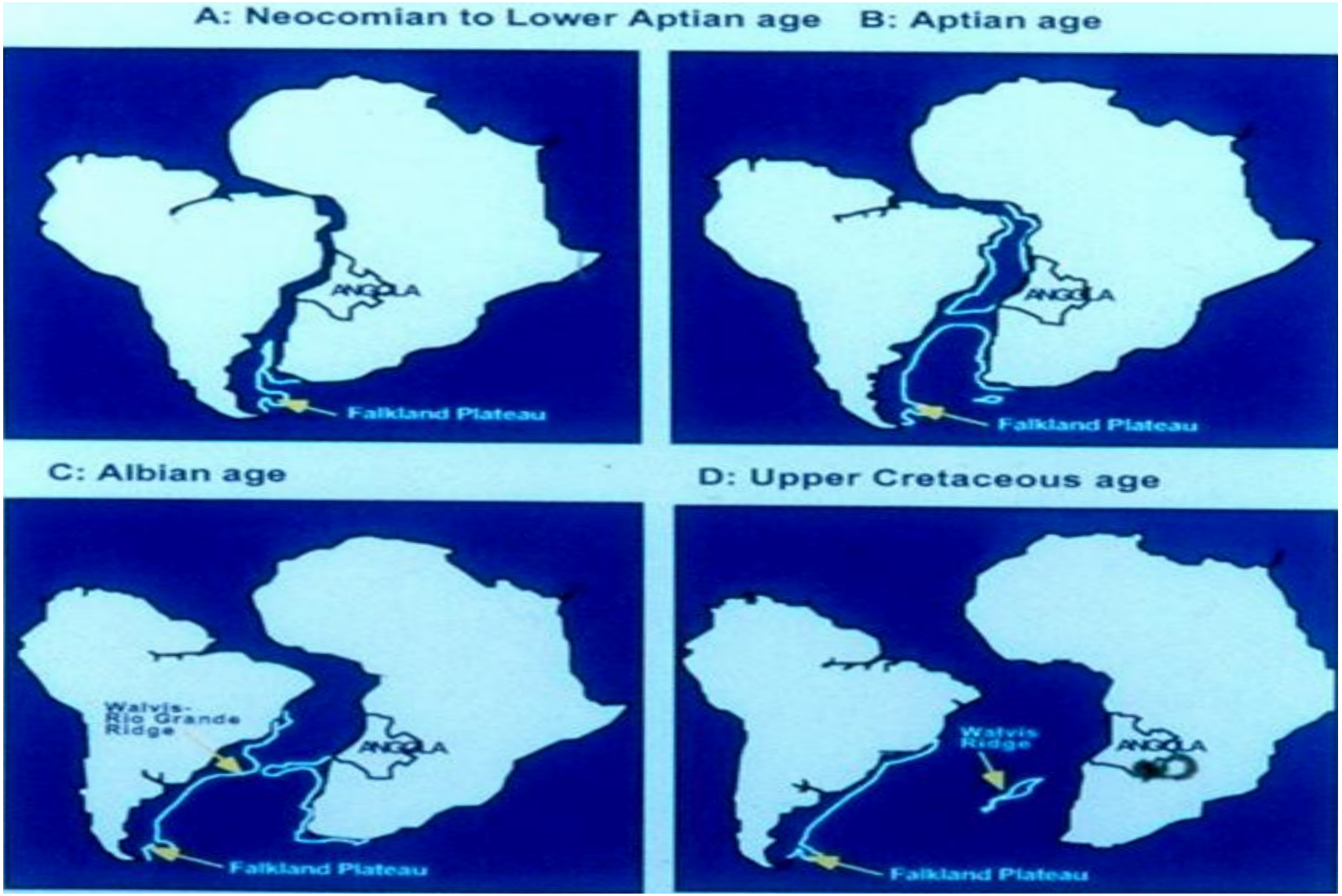
- BRAZIL

- ANGOLA

Impact of Brazil's Recent Pre-Salt Mega- Oil Discoveries on Angola's Oil & Gas Potential

- Major world class pre-salt (sub-salt) oil and gas discoveries have been made since 2007 in the deepwater of Brazil
- Petrobras believe the pre-salt fields could be producing 2.0 MM BOPD by 2020 thereby doubling Brazil's oil production to about 4 MM BOPD
- Brazil and Angola were contiguous (joined up) in Cretaceous time
- This play has been minimally evaluated in the deepwater of Angola

Reconstruction of the South Atlantic Ocean Evolution



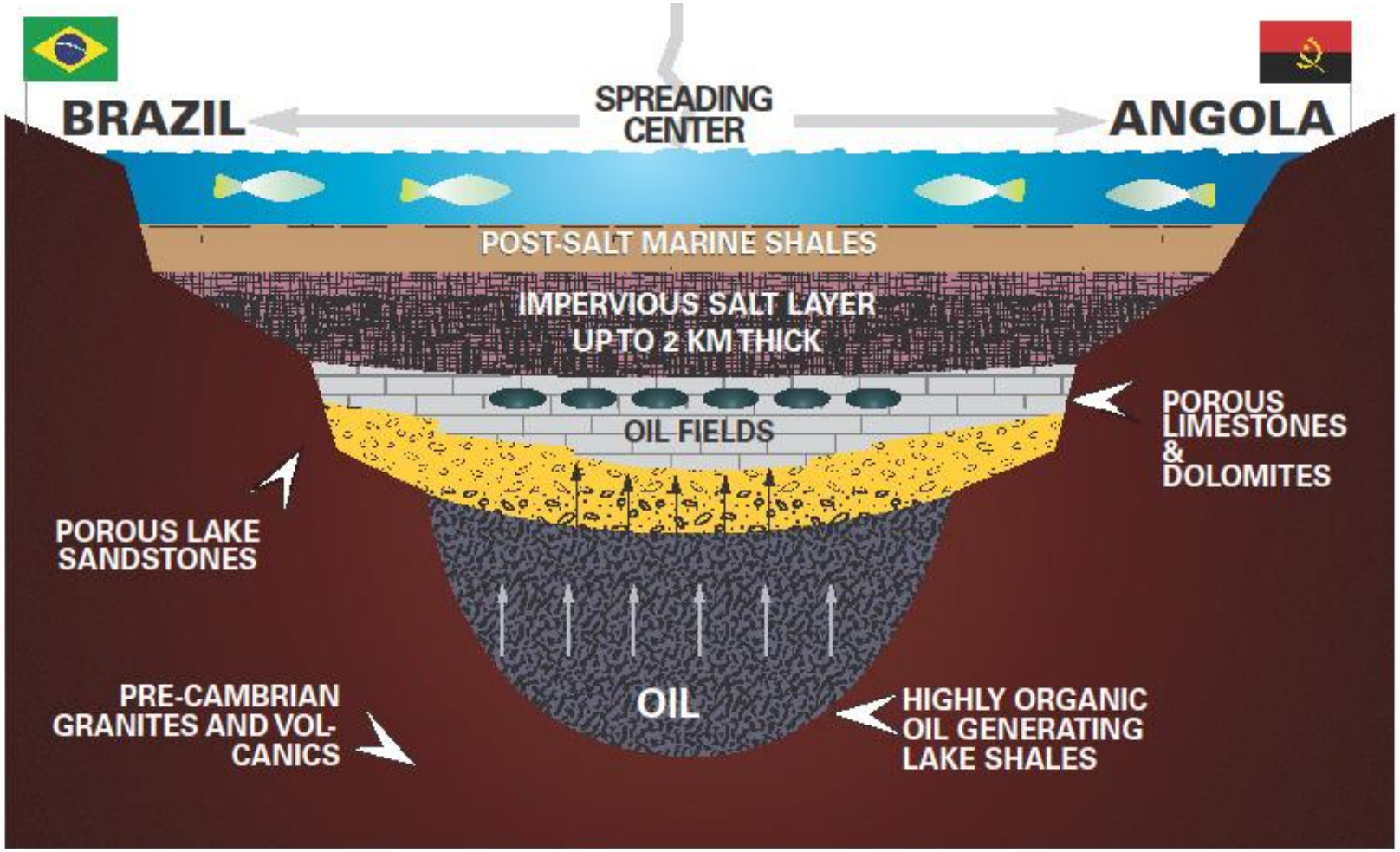
From: M.S. Albio, 1986 Ministry of Petroleum SADC paper

Source: T. Koning, SPWLA Formation Evaluation Forum, 2013 & 2014

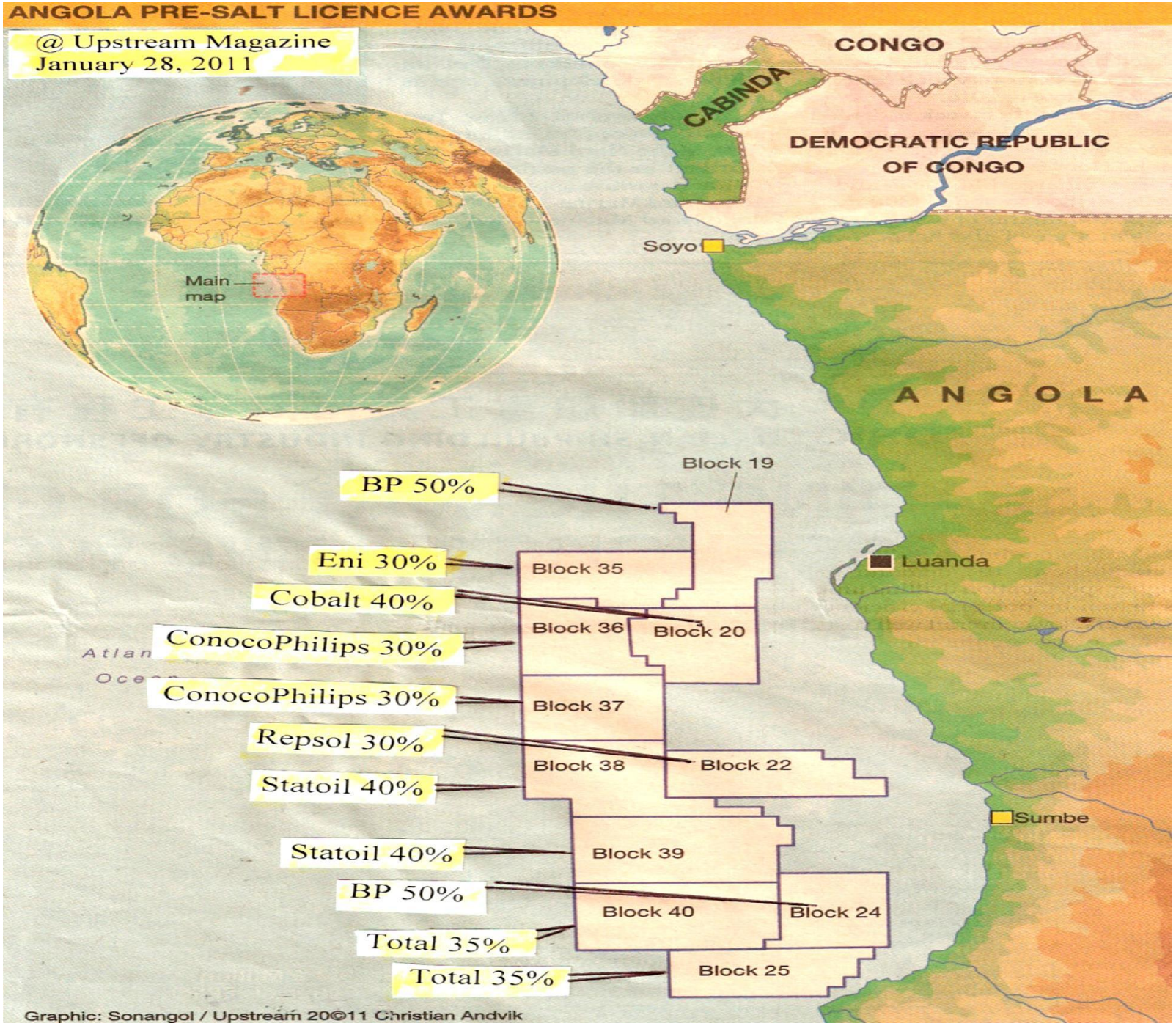
Pre-Drift Reconstruction of S. America-Africa (124 MYBP)

Source: T. Koning, SPWLA Formation Evaluation Forum, 2013 & 2014

Geology – Brazil vis-à-vis Angola



Source: T. Koning, SPWLA Formation Evaluation Forum, 2013 & 2014

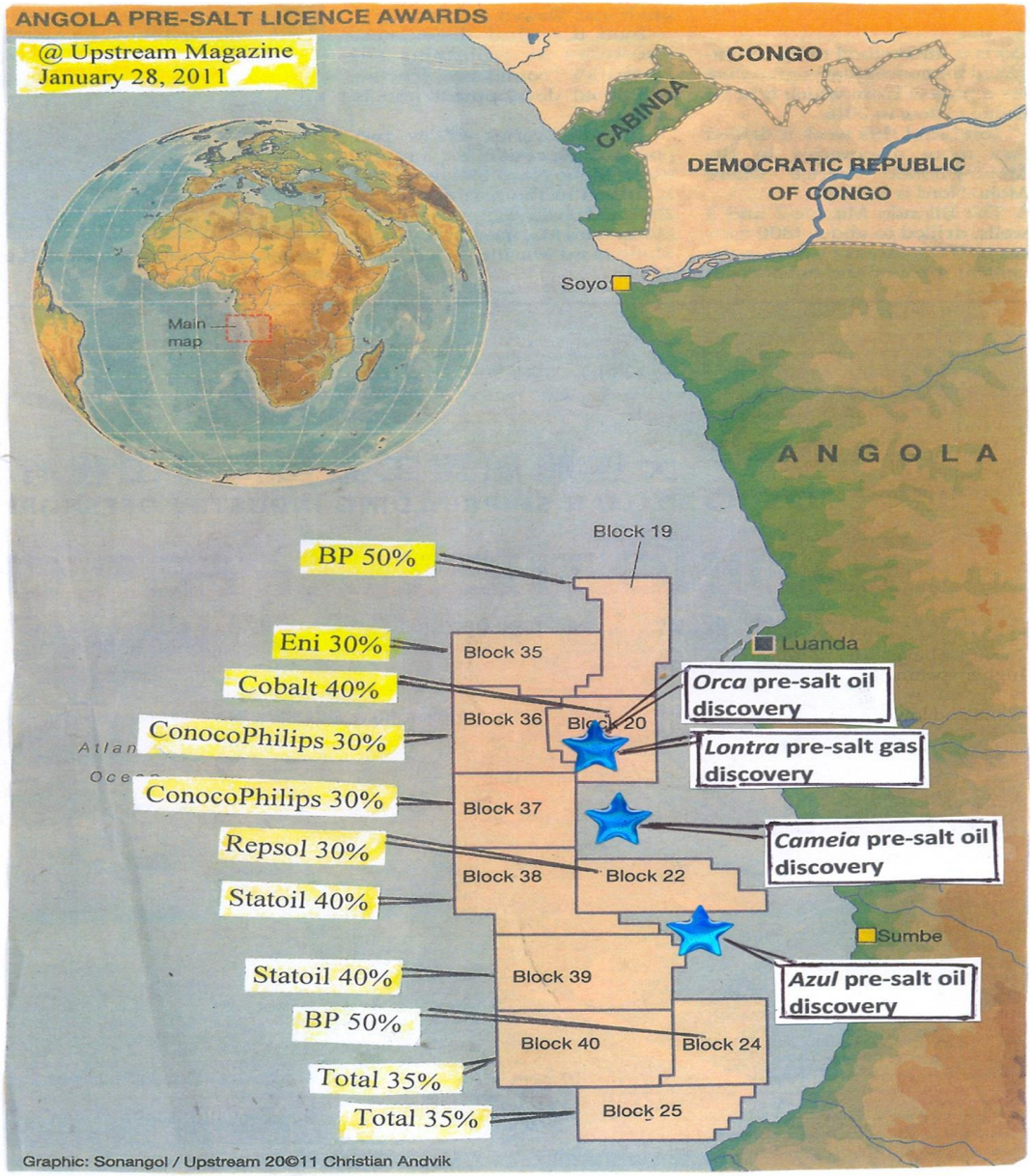


Source: T. Koning, SPWLA Formation Evaluation Forum, 2013 & 2014

Angola 2011 Bid Round – Award of Pre-salt Blocks

- All blocks are located in the deepwater Kwanza Basin
- Bid round was described as “a historic event in Angola’s oil industry”
- Operators include BP, ENI, ConocoPhillips, Cobalt, Repsol, Total, Statoil
- Blocks were officially awarded in December, 2011
- Chevron, Exxon, Petrobras, Shell & Galp Energia were absent

Kwanza Basin – Deepwater Drilling Results – Wells which Flowed Oil & Gas from the Pre-Salt



Publically Announced Info on Pre-salt Drilling – Maersk – Azul-1

- January 14, 2012 MAERSK OIL announced that their first well on deepwater Block 23, AZUL-1 was “mini-tested” indicting a flow capacity of greater than 3,000 BOPD; Maersk viewed the results as “encouraging”
- Azul-1 was the first ever deep water well targeting pre-salt reservoirs in the Kwanza Basin
- Drilled in 920 meters water to a depth of 5,330 meters

Publically Announced Info on Pre-salt Drilling – Cobalt – Cameia-1

- February 9, 2012 COBALT announced that CAMEIA-1 drilled on Block 21 in 1,680 meters (5,500 feet) of water tested at 5,010 barrels of oil per day from pre-salt carbonates
- 360 meters (1,180 feet) of gross pay of which 75% is net pay
- No gas/oil or oil/water contacts encountered
- Well has potential to produce at excess of 20,000 barrels of oil per day

Publically Announced Info on Pre-salt Drilling – Cobalt – Lontra-1

- December 1, 2013 COBALT announced that LONTRA-1 was drilled on Block 20 to a depth of 4,195 meters
- 75 meters of net pay “in a very high quality reservoir section”
- Lontra-1 tested at 2,500 barrels per day of condensate and 39 MMcfgpd; flow rates were restricted by the surface test facilities on the rig
- Press reports: 2.2 – 3.8 TCF gas or 900 MMBOE

Publically Announced Info on Pre-salt Drilling – Cobalt – Orca-1

- May 9, 2014 COBALT announced that ORCA-1 was drilled on Block 20 to a depth of 3,872 meters
- 76 meters of net pay “in excellent reservoir quality section”
- Orca-1 tested at 3,700 barrels pol per day of and 16.3 MMcfgpd; flow rates were restricted by the surface test facilities on the rig
- Cobalt reports a resource range of 400 to 700 million barrels of oil

The “Angola Advantage” – Oil & Gas Industry

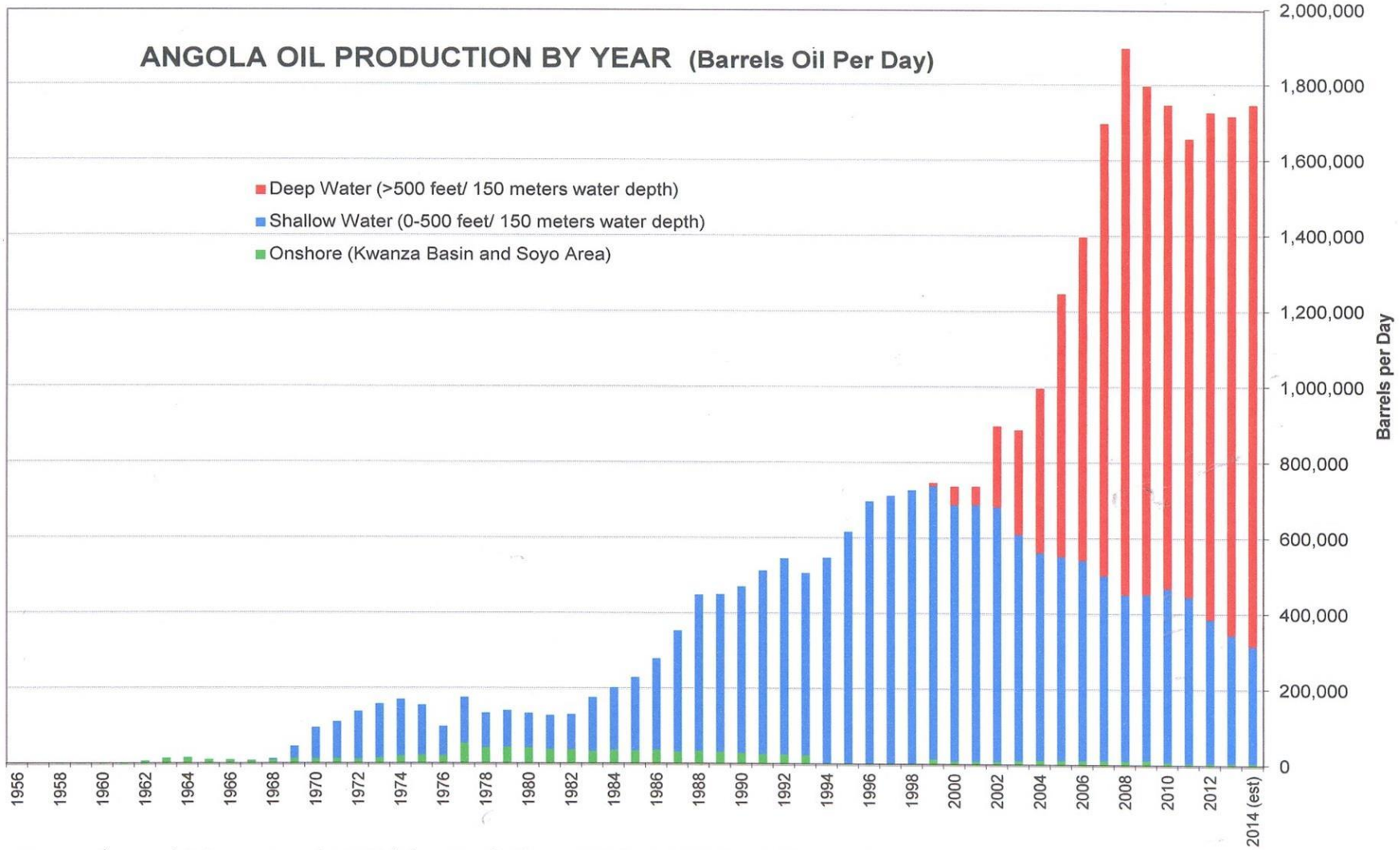
- World class geology
- Benign operating environment (no ice bergs, hurricanes, high seas)
- Subsurface drilling is not difficult, e.g. no major over-pressuring problems, etc
- Contractual stability due to political stability (government has been led by MPLA since independence in 1975)

CONCLUSIONS

- Significant undiscovered oil and gas resources remain to be found in Angola in the deepwater and also in the minimally explored pre-salt oil play; if the pre-salt play is successful, Angola's oil production could double

- Many opportunities are available for companies willing to invest and be active for the *long term*

Angola's Oil Production 1956 - 2014



Sources: Sonangol Universo magazines, Website - Angola Finance Ministry, 2013 BP World Energy Review

Obrigado!

Thank You!

www.gaffney-cline.com