Pioneering the Global Subsalt/Presalt Play: The World beyond Mahogany (USA) Field

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AAPG International Conference – Rio de Janeiro, Brazil – November 2009

Houston Geological Society General Meeting – March 2010

New Orleans Geological Society General Meeting – July 2010

Oklahoma Geological Foundation - Cronin Lecture – November 2009

ion

[CHARGED WITH INNOVATION]

From the Past into the Future

“Several times in the past we have thought we were running out of oil whereas actually we were only running out of ideas.”

Geology Professor Parke A. Dickey, 1958

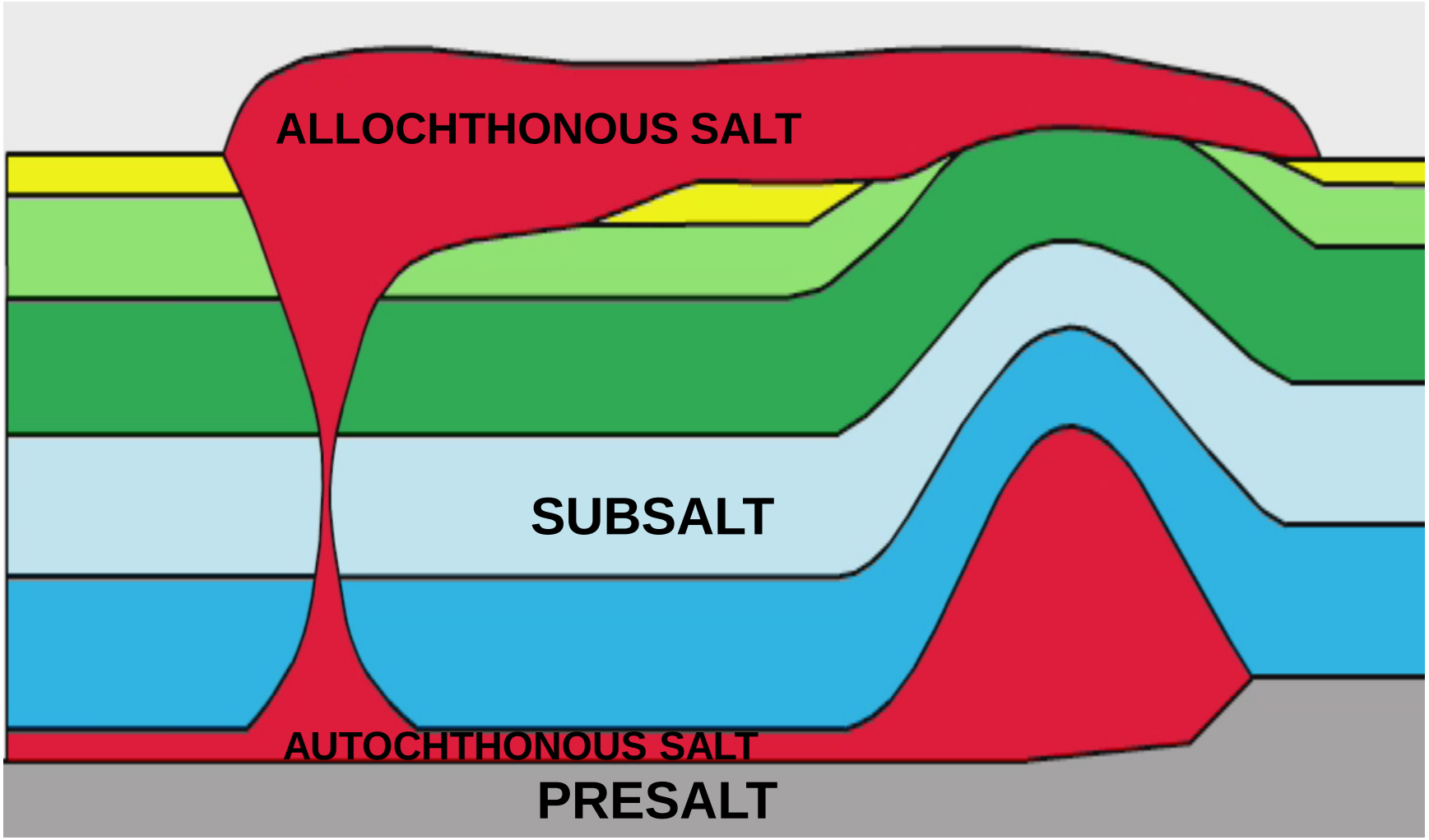
Pioneering is Discovery Thinking

Pioneering is Discovery Thinking

**“Discovery consists of seeing
what everybody has seen,
and thinking what nobody else has thought.”**

Albert Szent-Gyorgyi (1893-1986)
Nobel Prize in Medicine (1937) - Discoverer of Vitamin C

Subsalt vs. Presalt



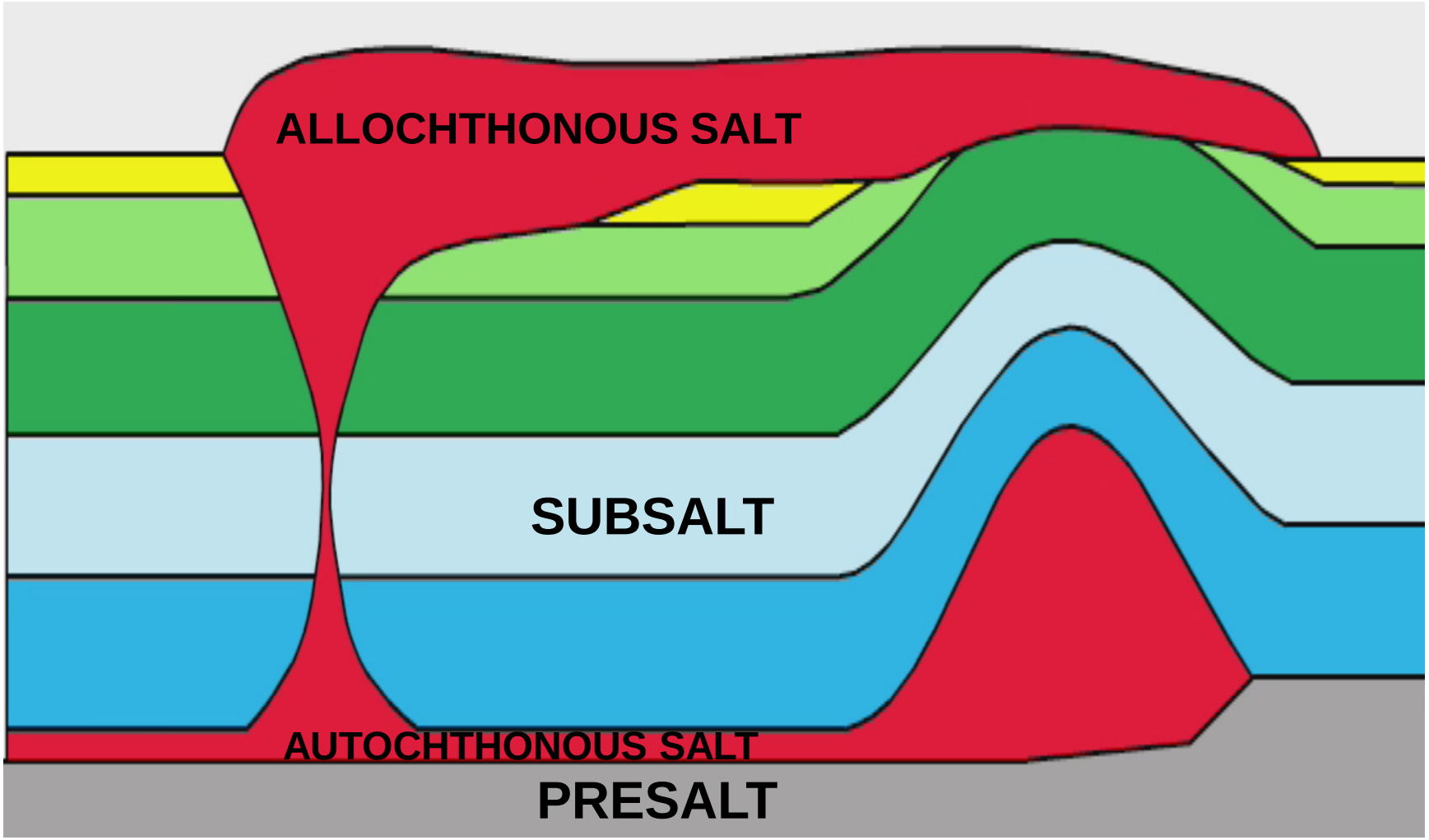
Graphic: Mike Hudec, Bureau of Economic Geology, The University of Texas at Austin;
Annotation: Clint Moore, ION Geophysical Corporation

Subsalt vs. Presalt Exploration

Subsalt – exploring beneath an allochthonous salt layer that overlies stratigraphically younger rock

Presalt – exploring beneath an autochthonous salt layer that overlies stratigraphically older rock

Subsalt vs. Presalt



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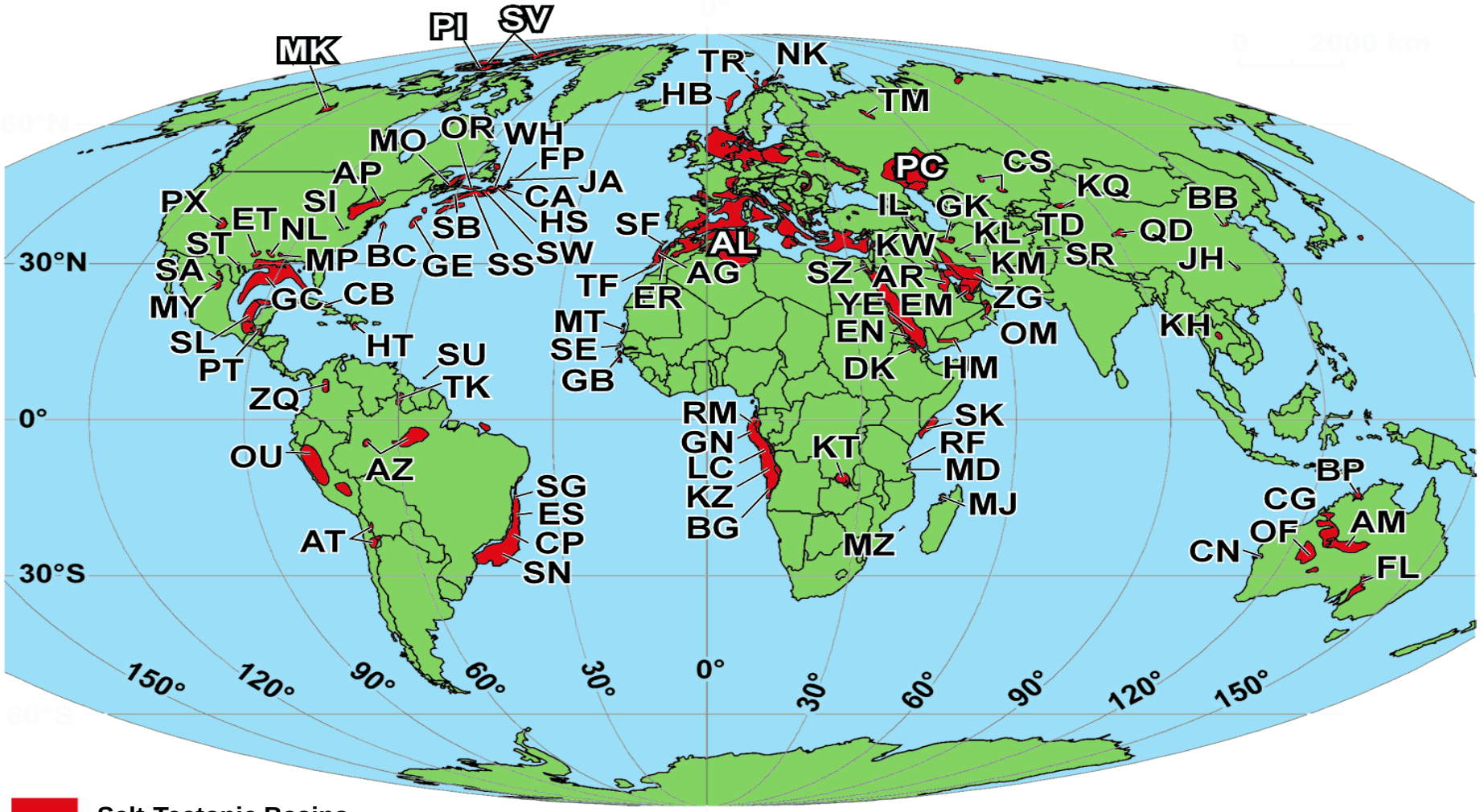
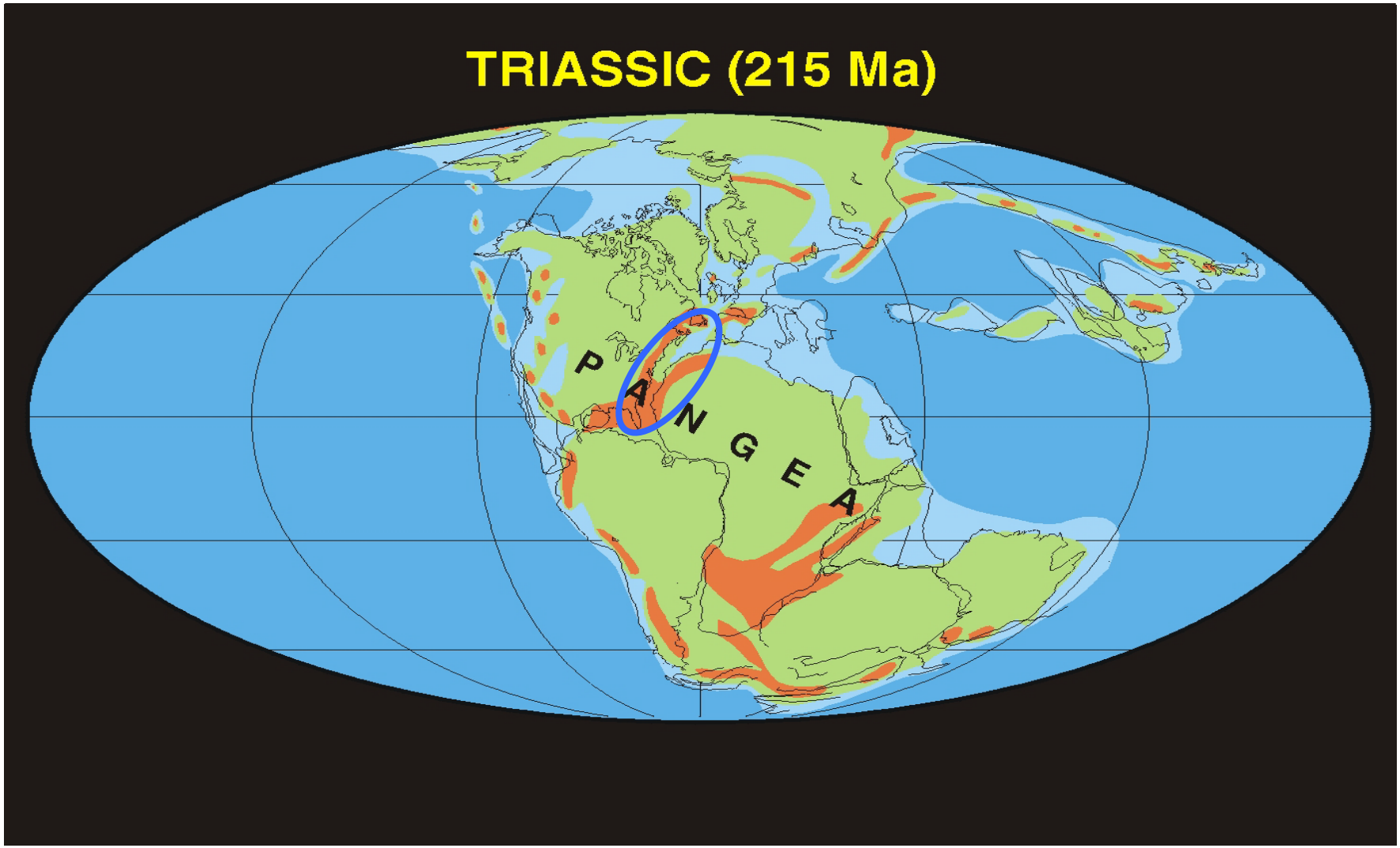
100+ Worldwide Salt Tectonic Basins



Salt-Tectonic Basins

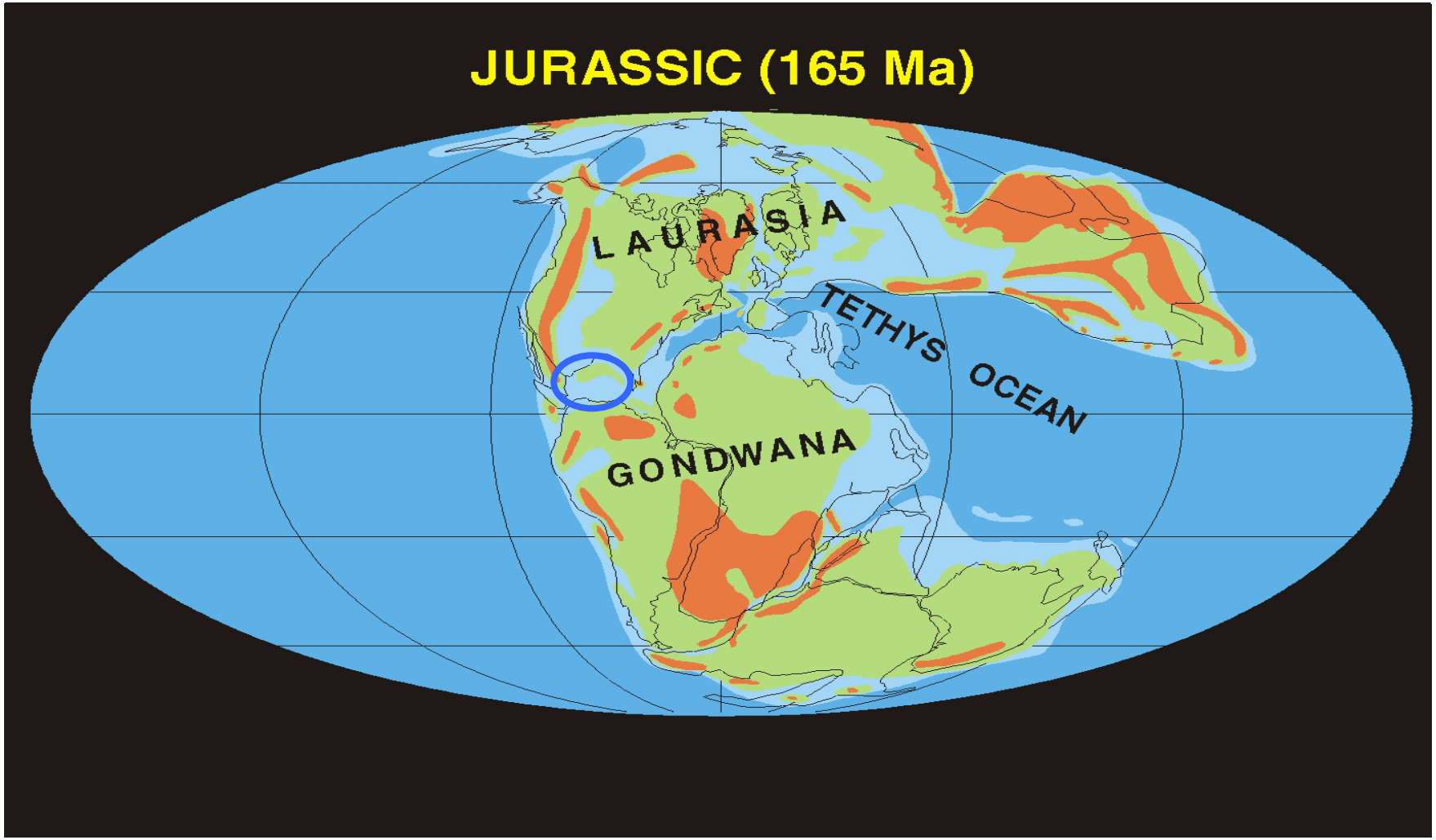
Source: Martin P. A. Jackson, 2007

North Atlantic Salt Basins - circa 210 - 200 mya



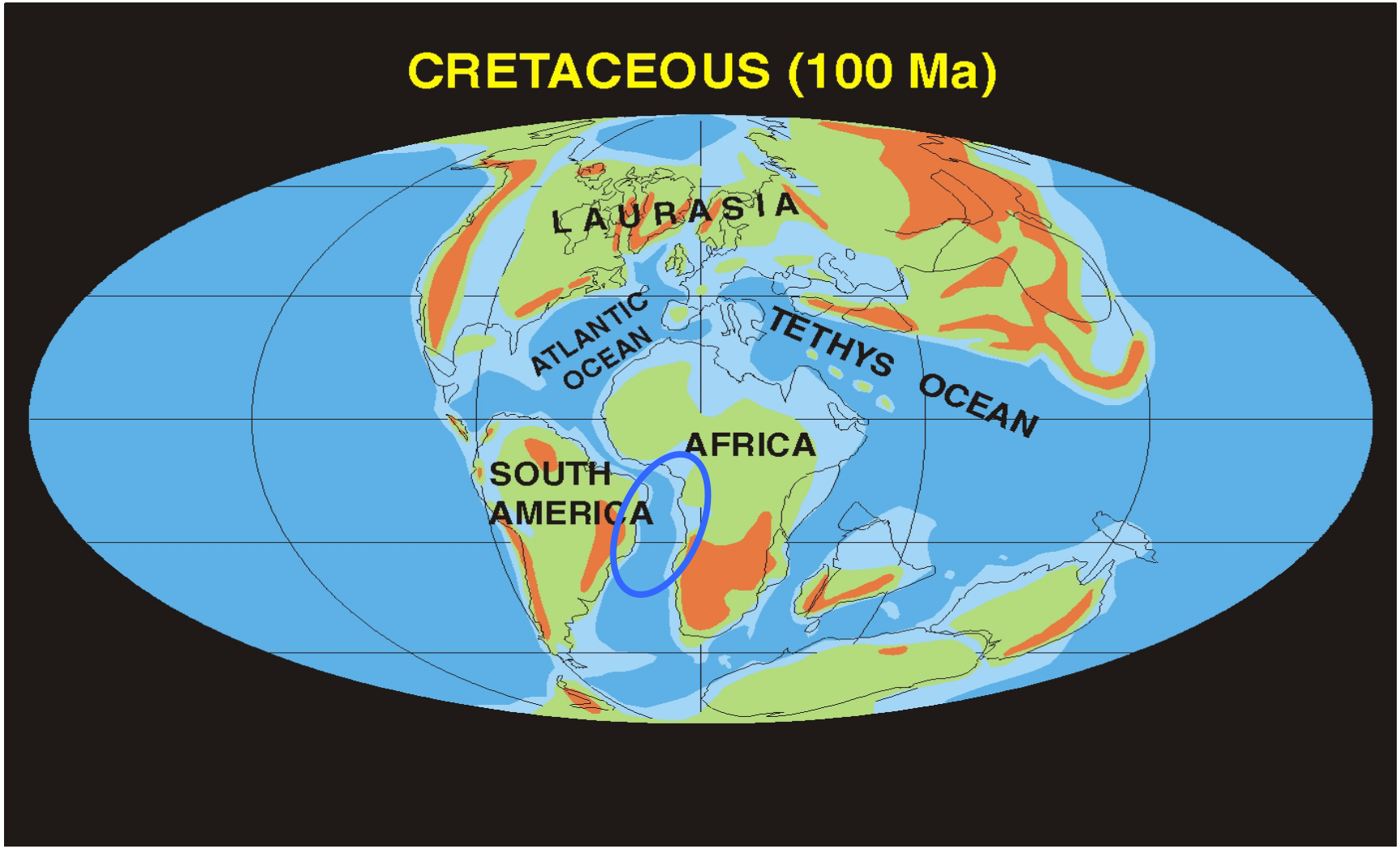
Source: Atlantic Geoscience Society & Geological Survey of Canada

Gulf of Mexico Salt Basins - circa 170 – 165 mya



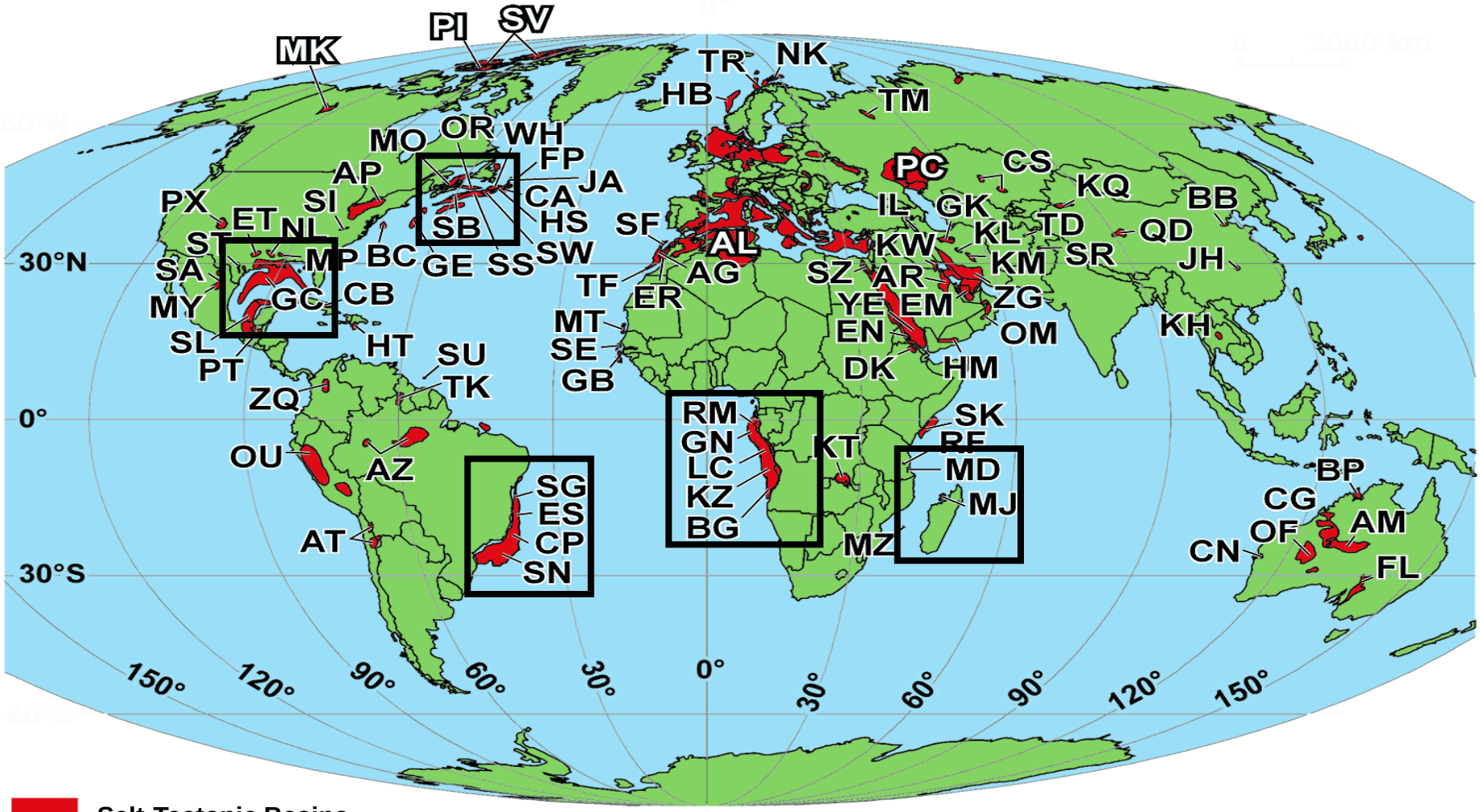
Source: Atlantic Geoscience Society & Geological Survey of Canada

South Atlantic Salt Basins – circa 120 - 110 mya



Source: Atlantic Geoscience Society & Geological Survey of Canada

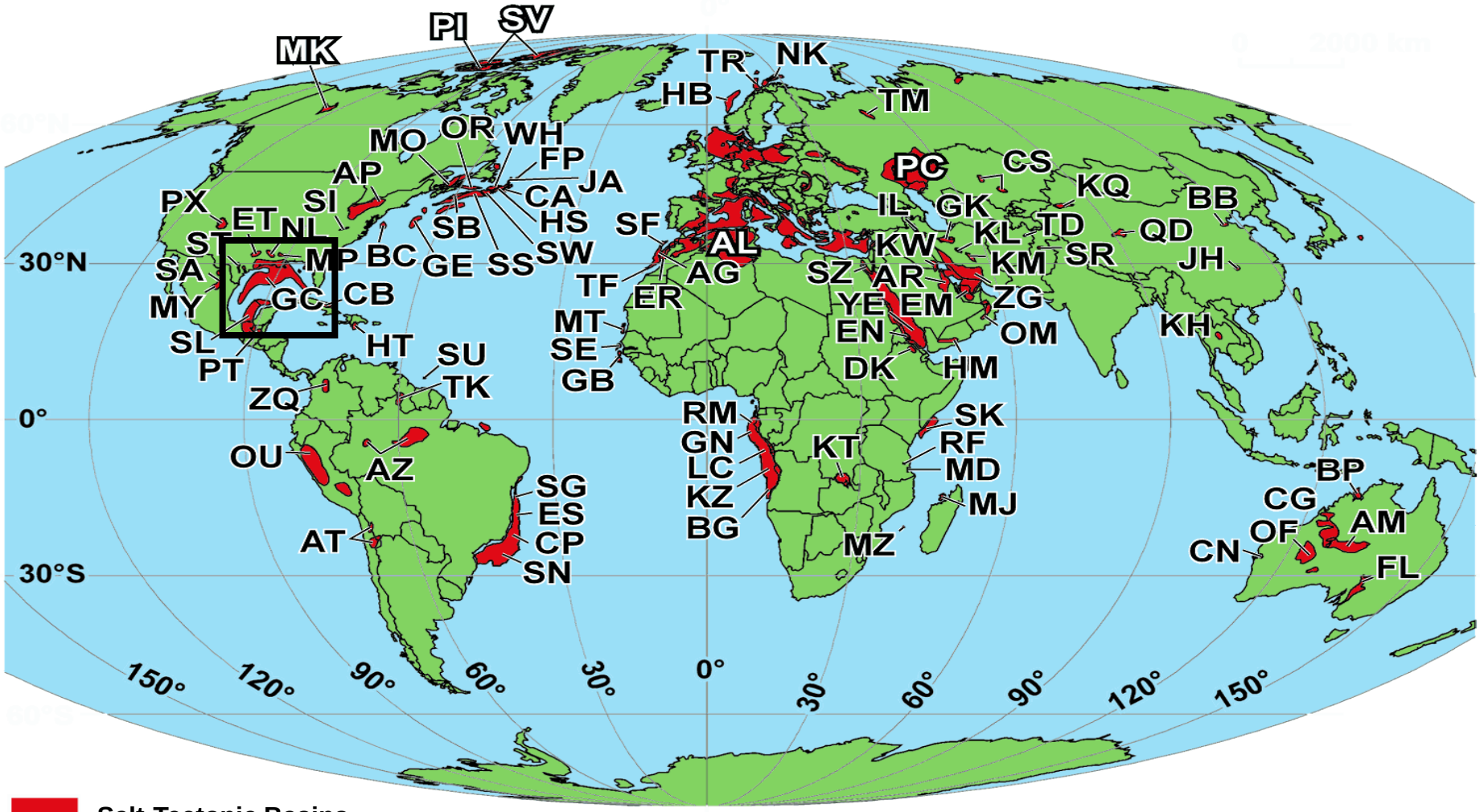
5 Major Salt Provinces - Subsalt-Presalt Potential



Salt-Tectonic Basins

Source: Martin P. A. Jackson, 2007

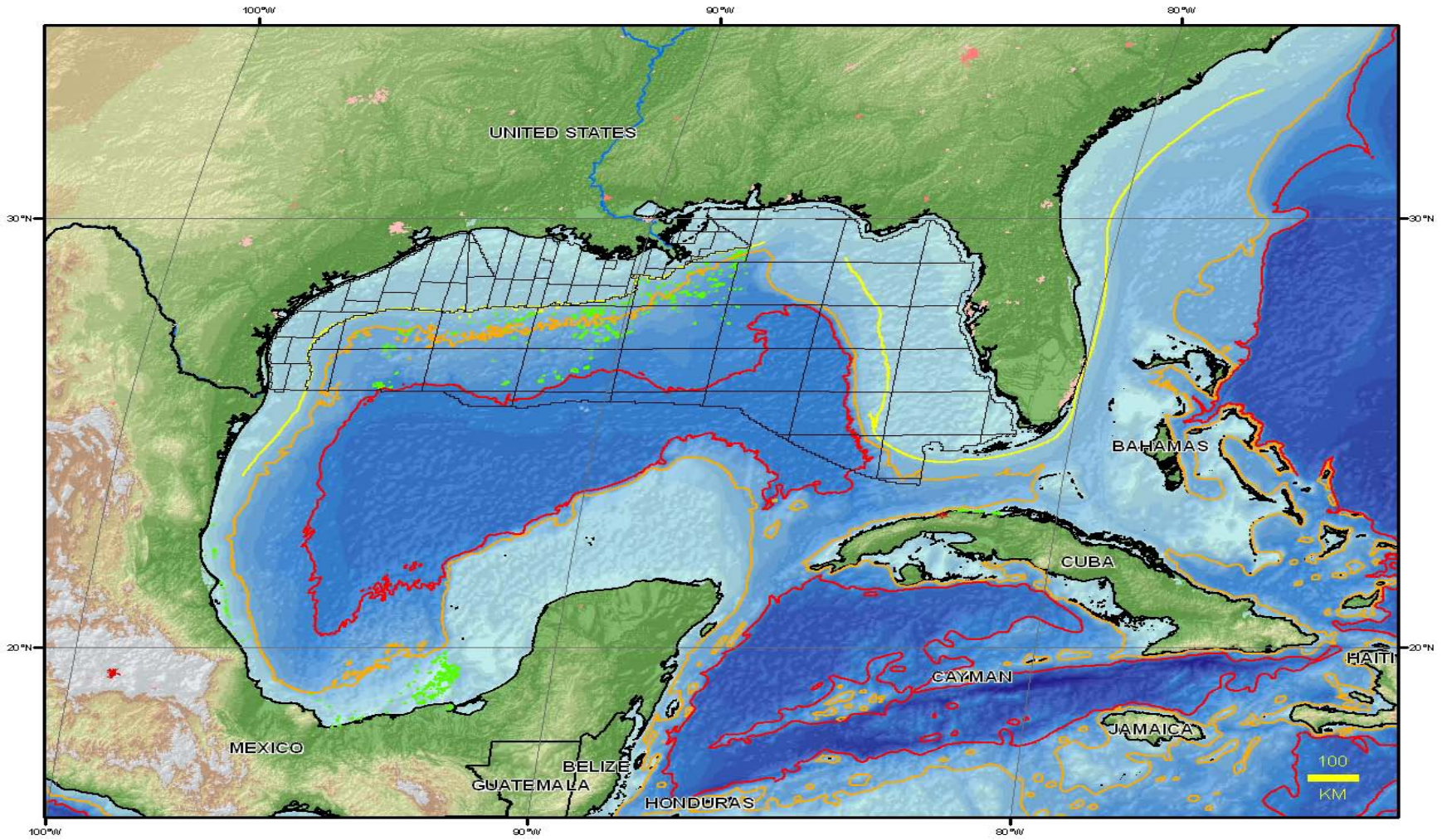
Gulf of Mexico Offshore Salt Basins



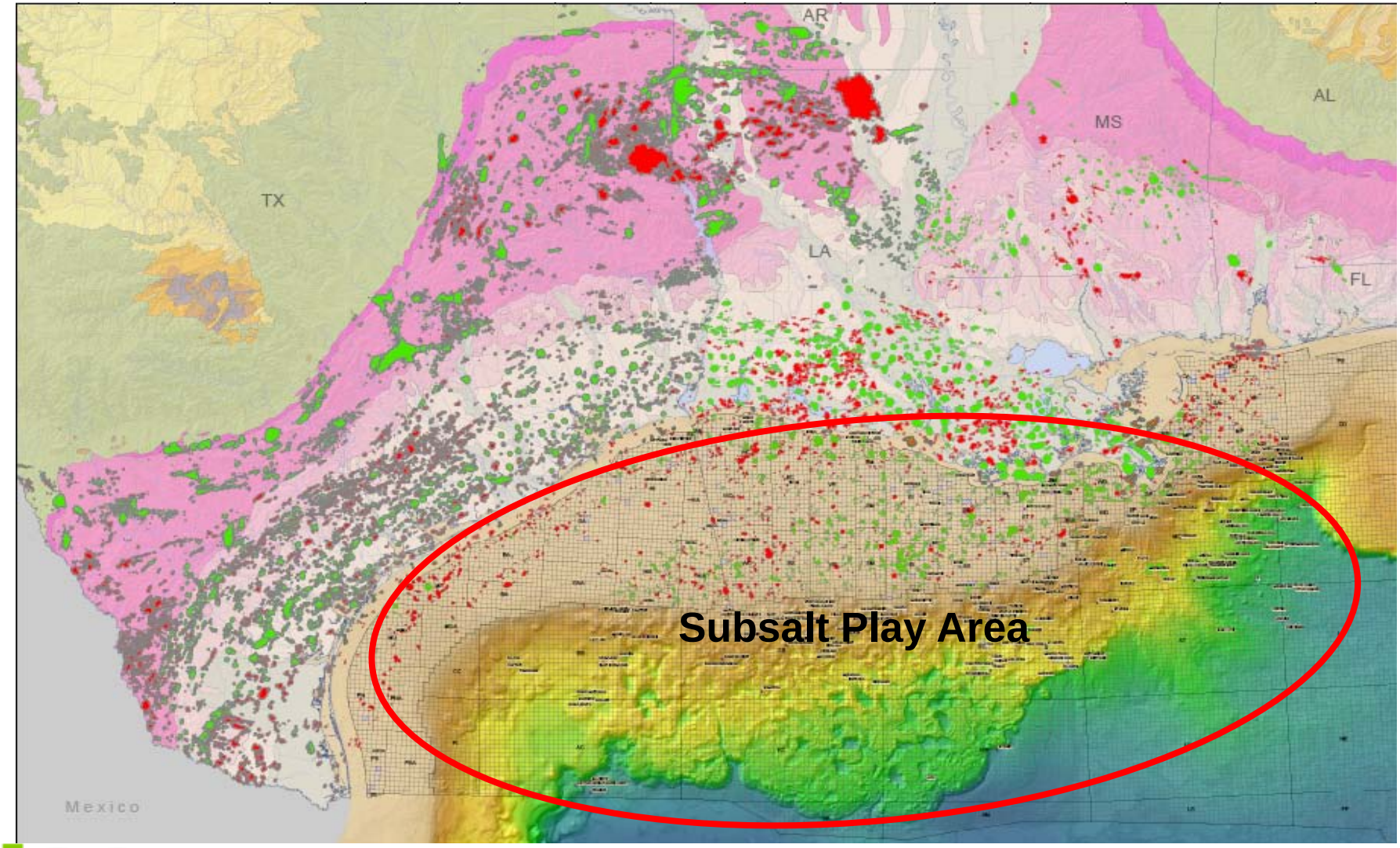
Salt-Tectonic Basins

Source: Martin P. A. Jackson, 2007

Gulf of Mexico Basin

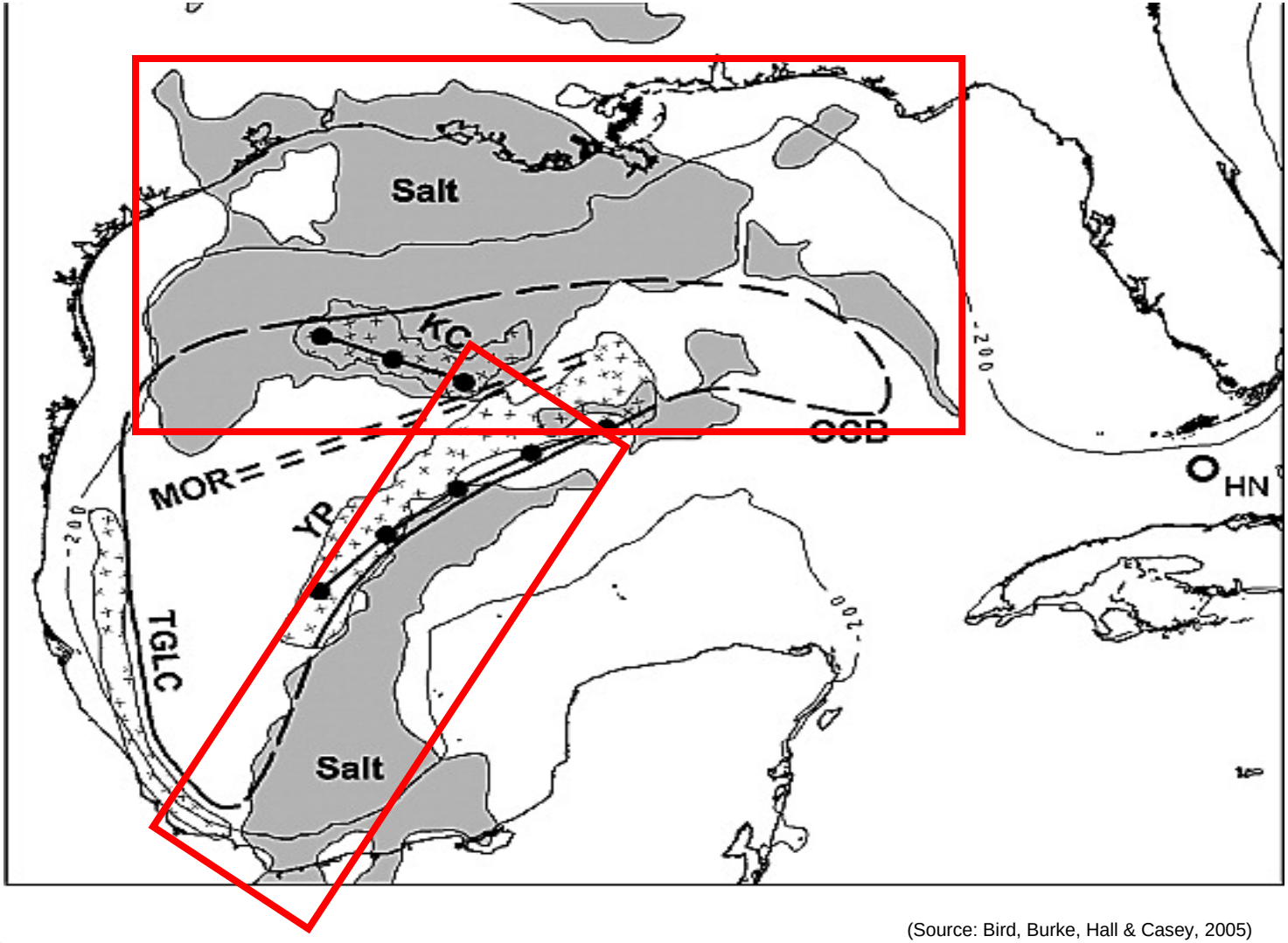


U.S. Gulf of Mexico Oil & Gas Fields



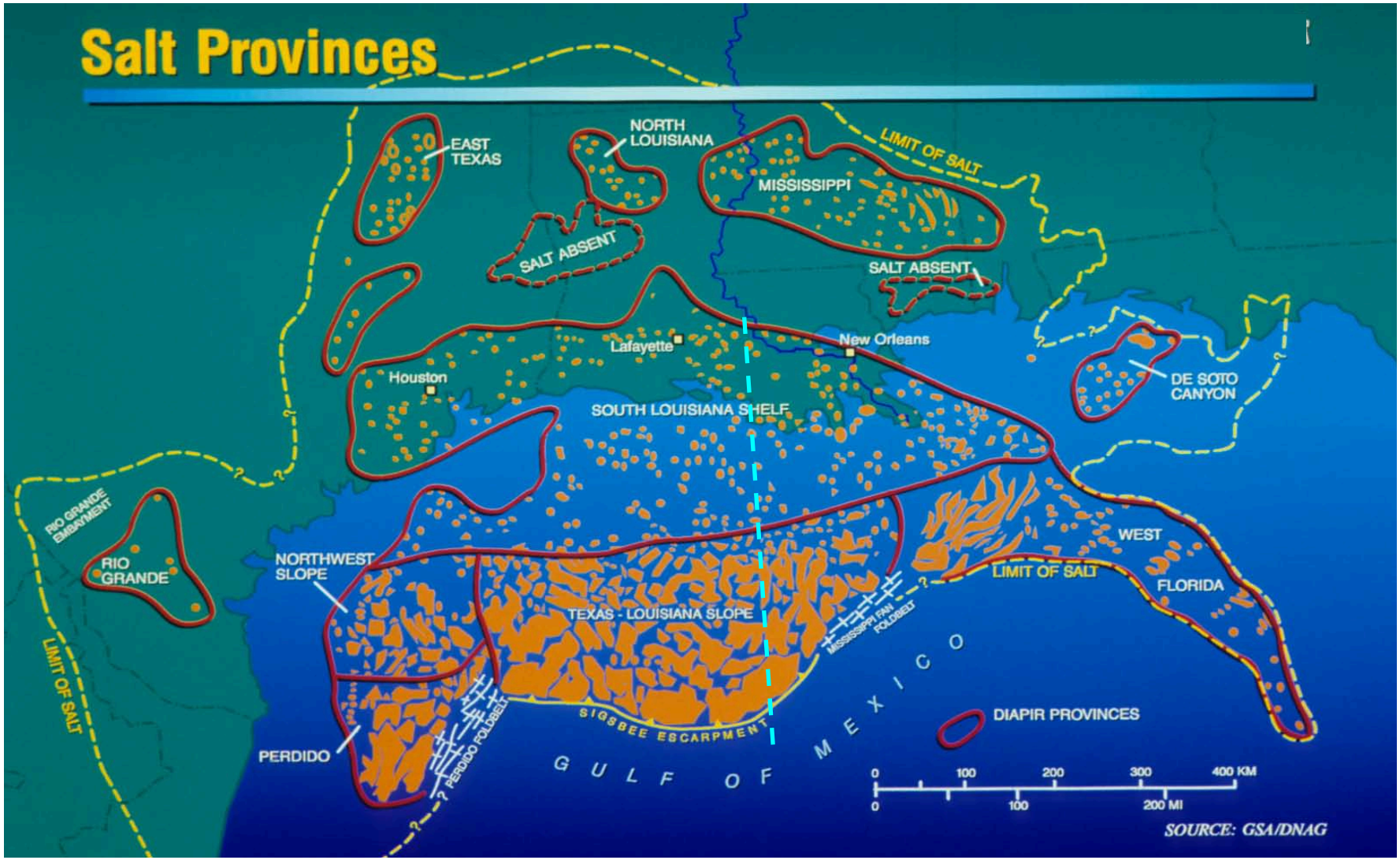
Source: Earth Science Associates

Salt Provinces in the Gulf of Mexico Basin



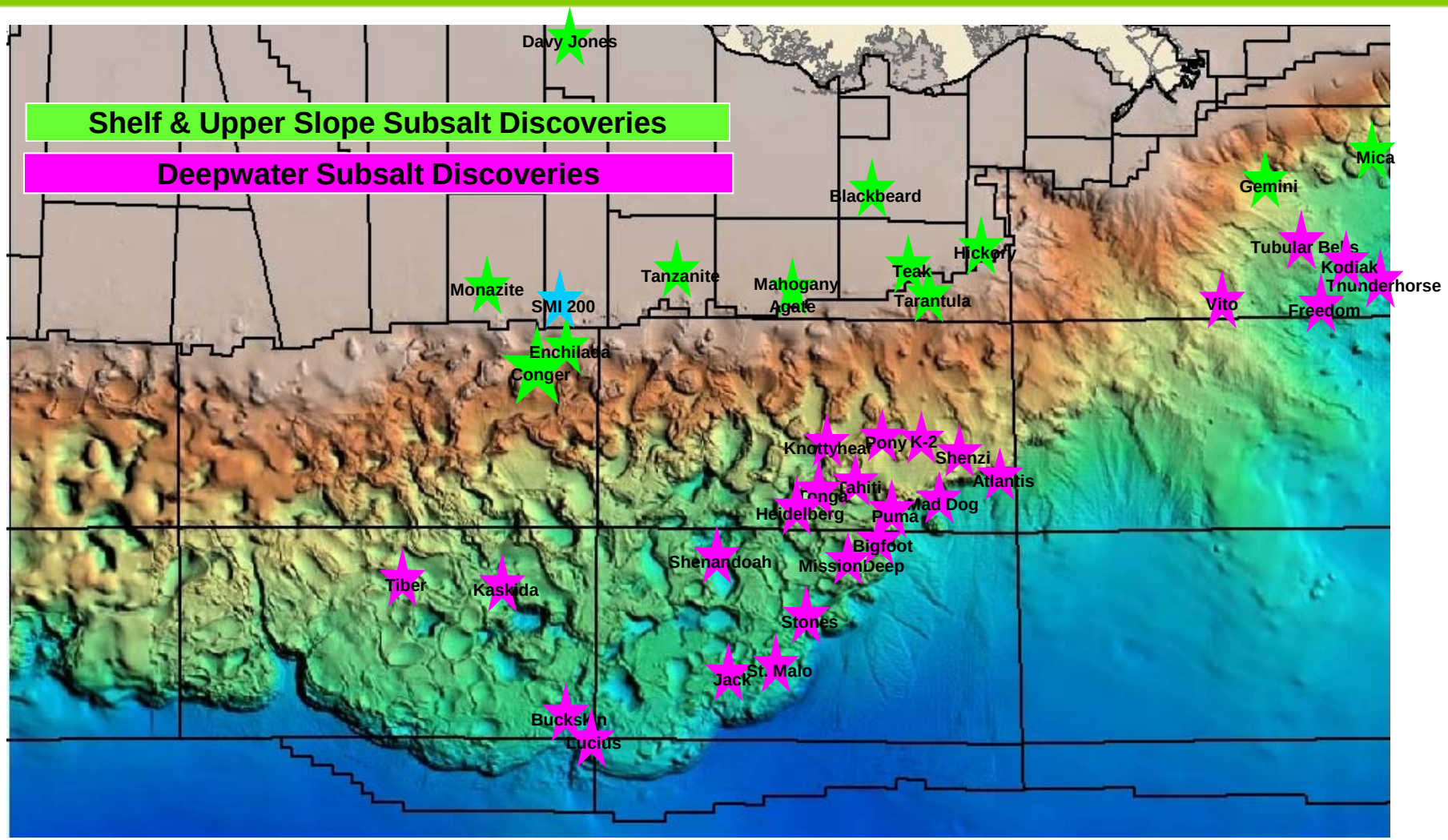
(Source: Bird, Burke, Hall & Casey, 2005)

Salt Provinces in Northern Gulf of Mexico

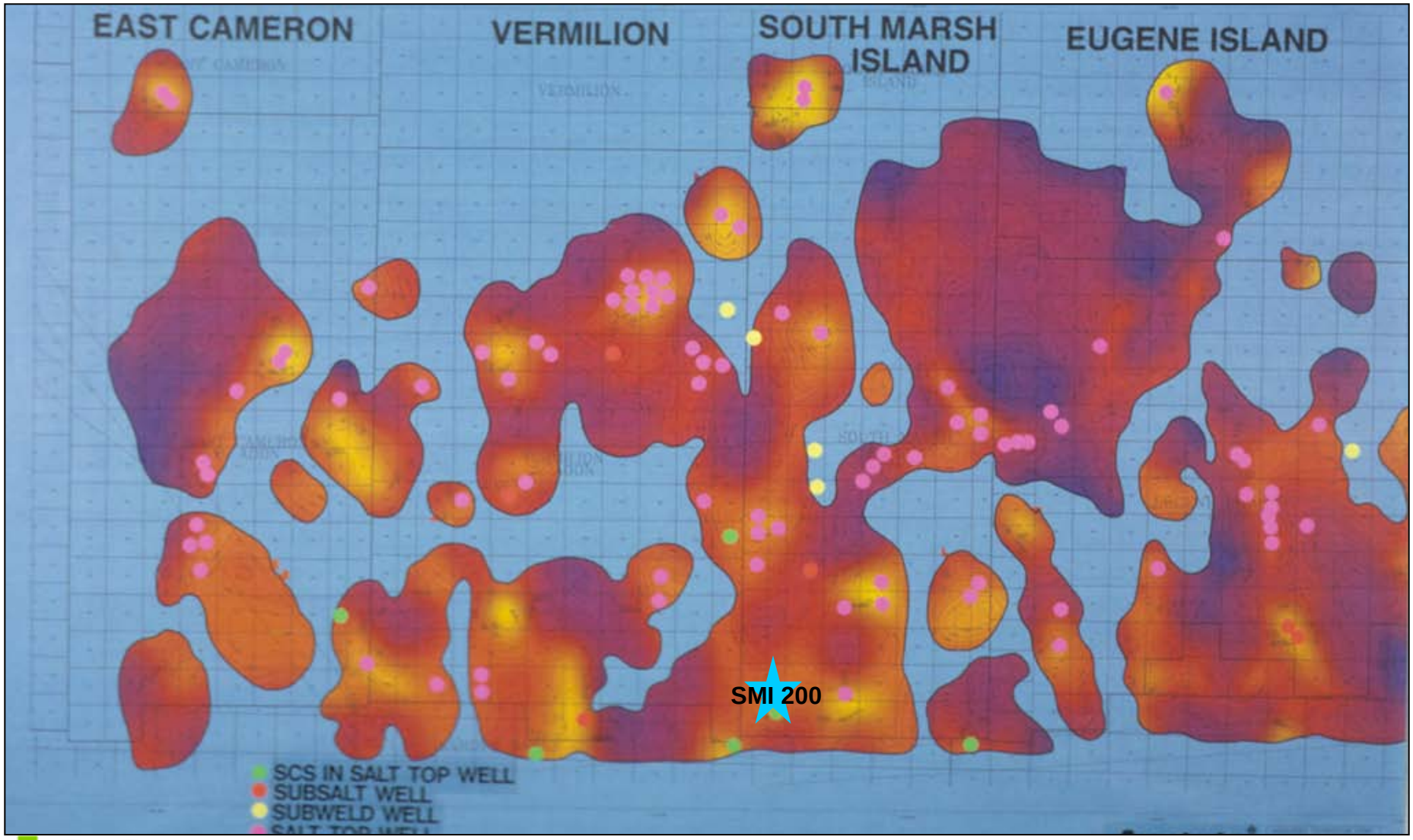


Source: AAPG Search & Discovery – Moore & Brooks 1995

U.S. Gulf of Mexico Subsalt Discoveries

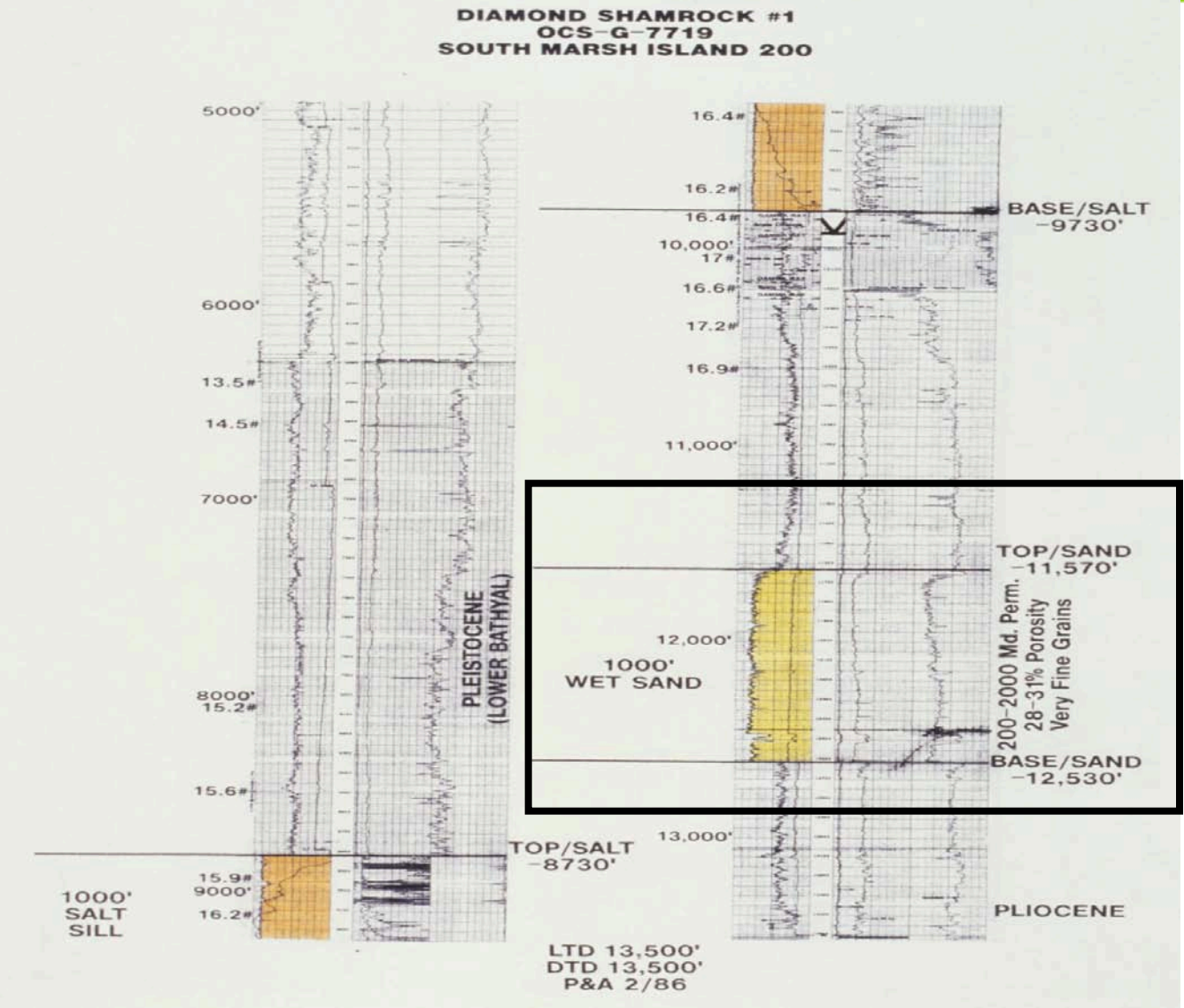


A Chapter in Discovery Thinking



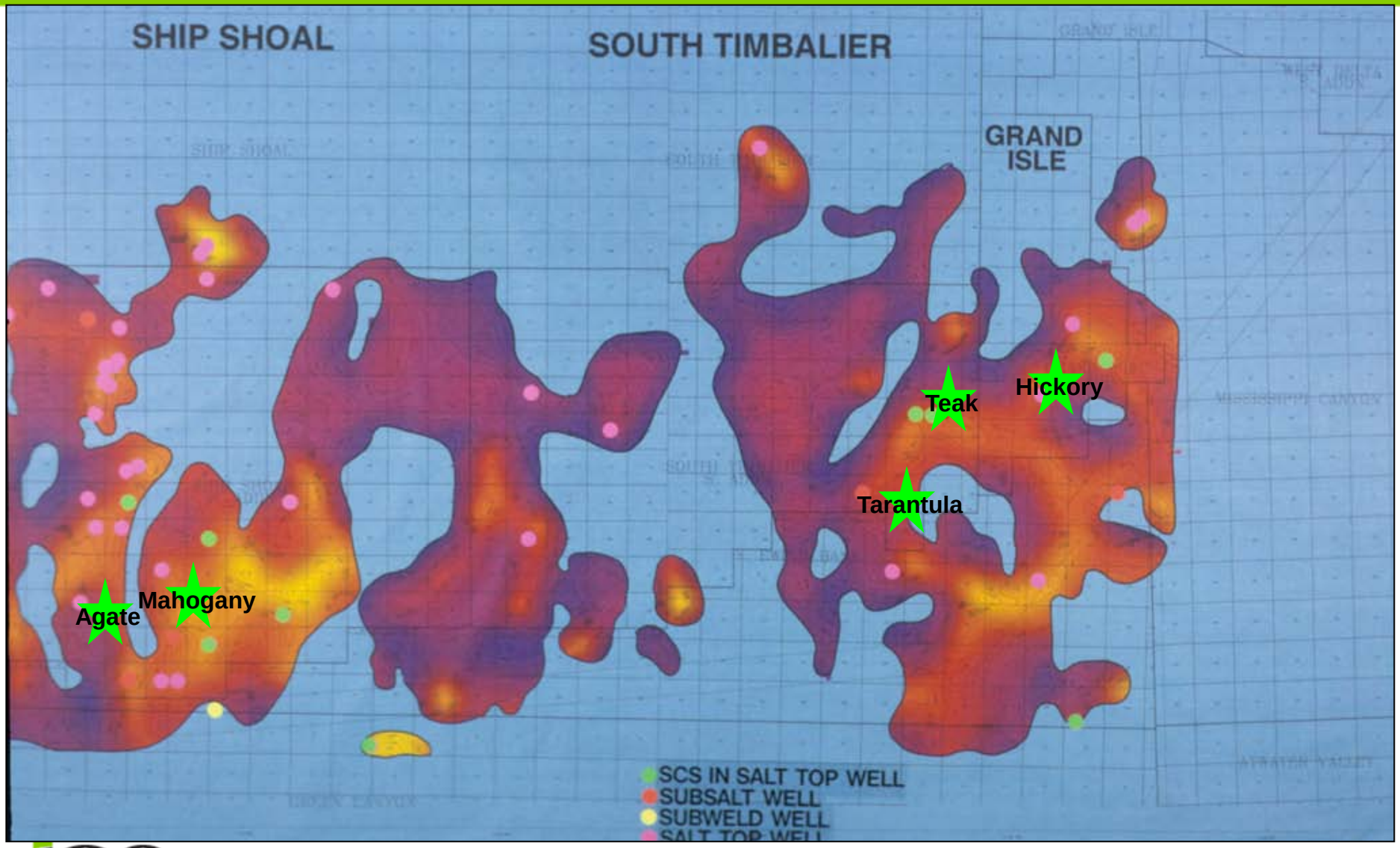
Source: AAPG Search & Discovery – Moore & Brooks 1995

Hint: Thick Wet Sand Below Salt Sheet - 1985



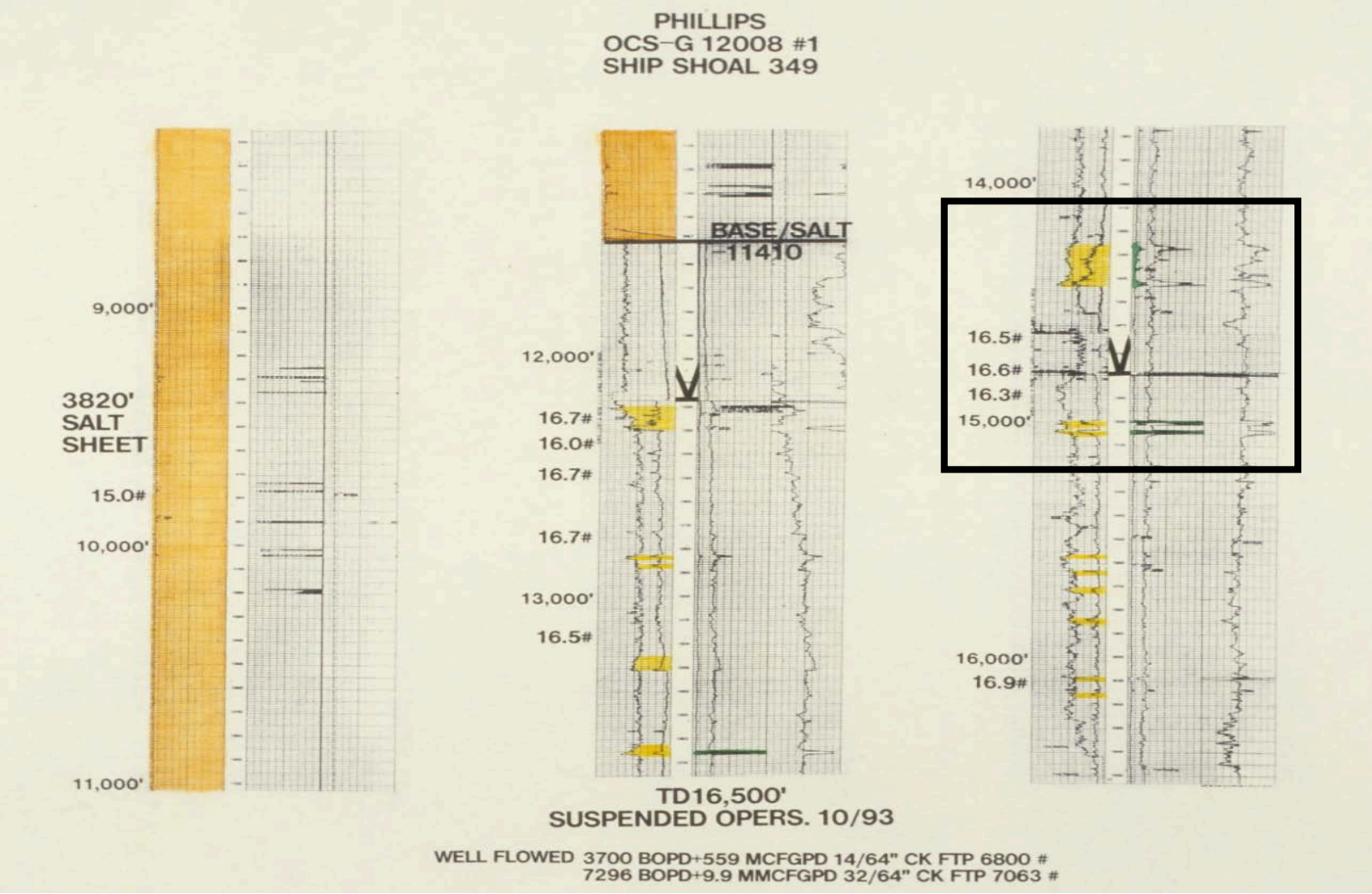
Source: AAPG Search & Discovery – Moore & Brooks 1995

1993 – 1998 – Shelf Discoveries



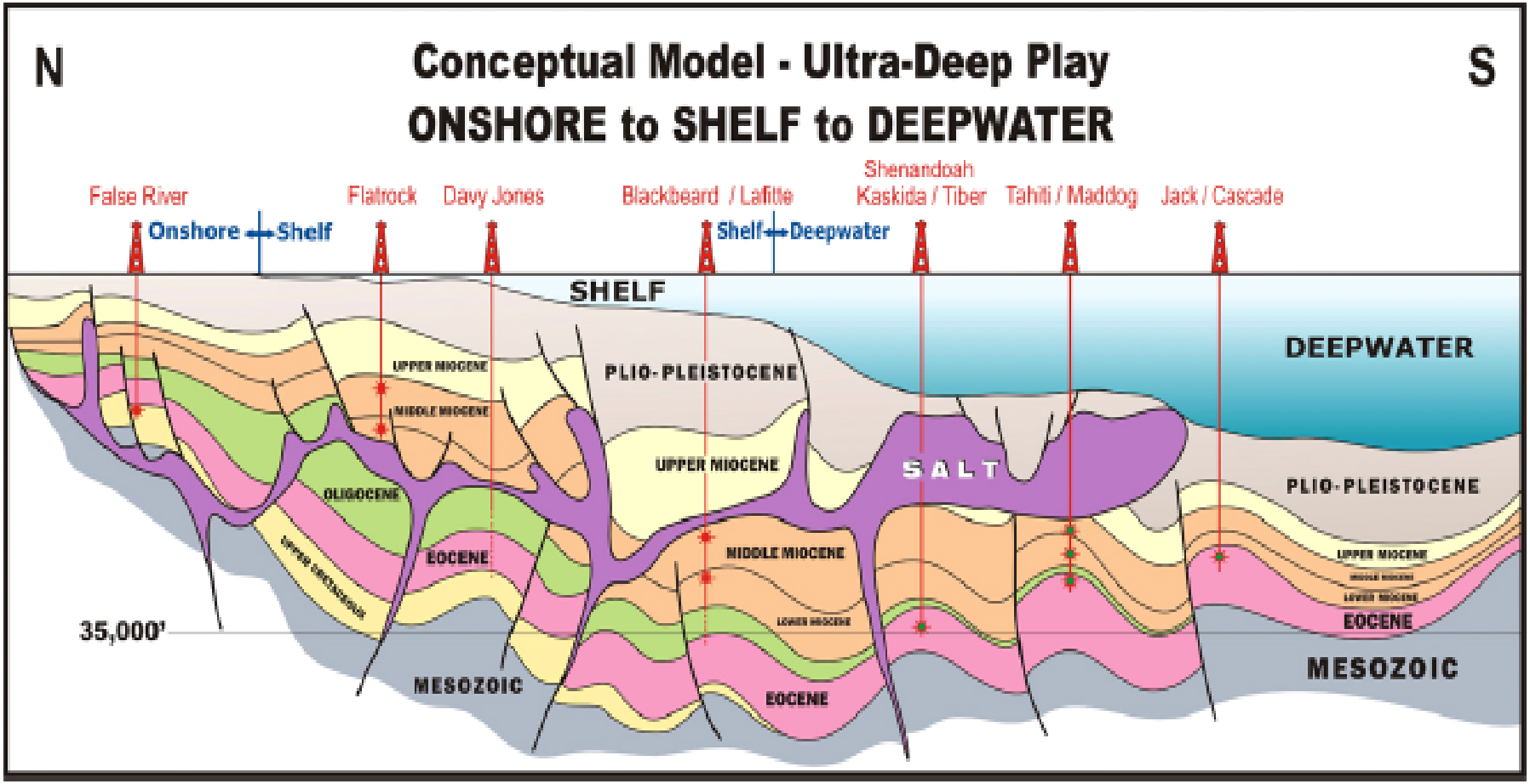
Source: AAPG Search & Discovery – Moore & Brooks 1995

Mahogany – 1st GOM Producing Field - 1996



Source: AAPG Search & Discovery – Moore & Brooks 1995

Deep Shelf Subsalt vs. Deepwater Subsalt



Source: McMoran IR

What is Reverse Time Migration Imaging?

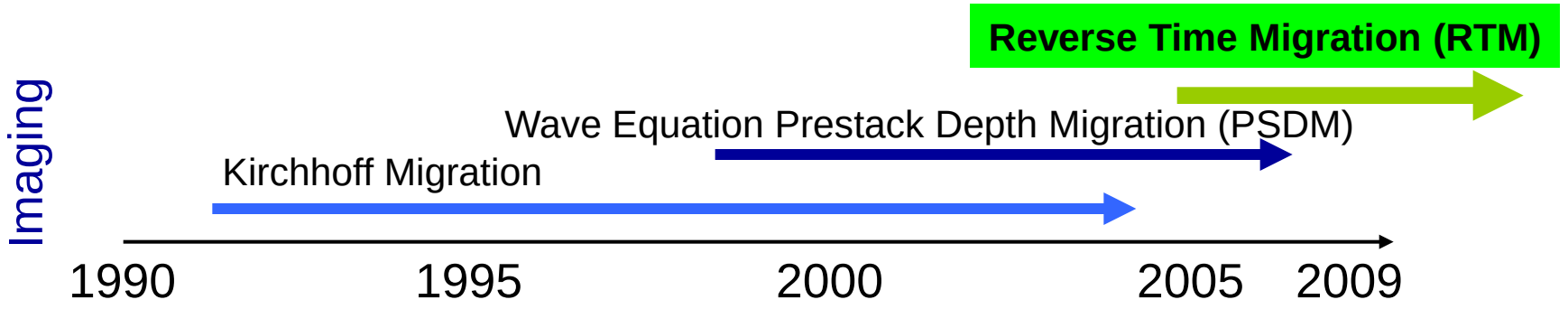
Reverse Time Migration Depth Imaging

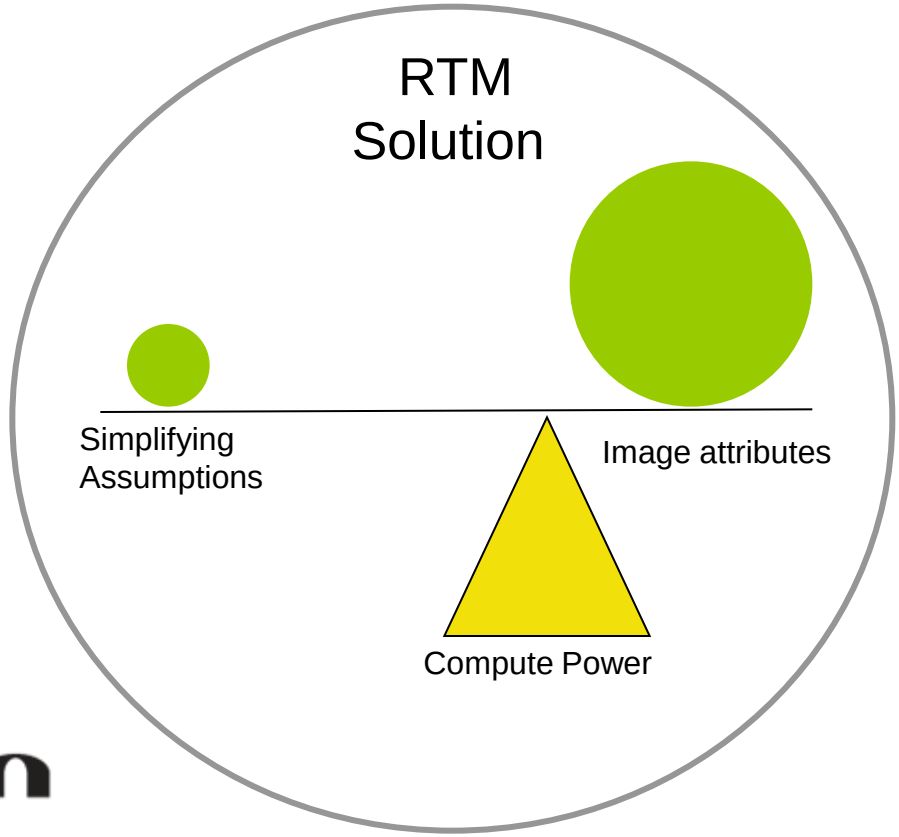
Enhances depth imaging of seismic data by processing the seismic wave equation forward in time for the source AND backwards in time for the receiver.

Rapidly computes actual numerical solutions to the complete wave equation.

Our RTM algorithm breakthrough significantly reduces processing time, and includes high frequencies.

ION-GX Technology Progression to RTM





RTM Advantages

Best Images salt & flanks

Low subsalt noise

Optimal for WAZ data

ION faster than anyone

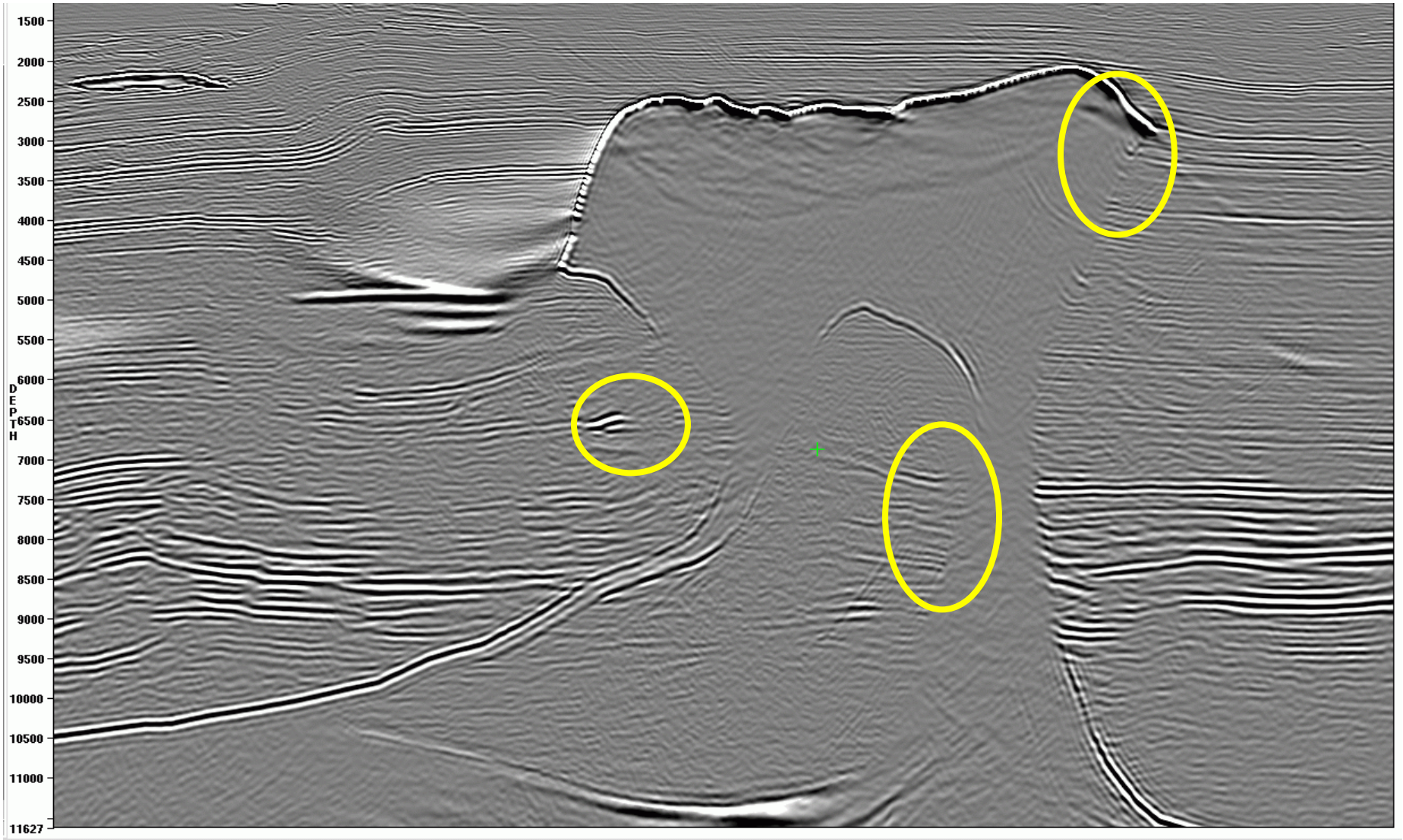
Key for Modeling

Includes high frequencies

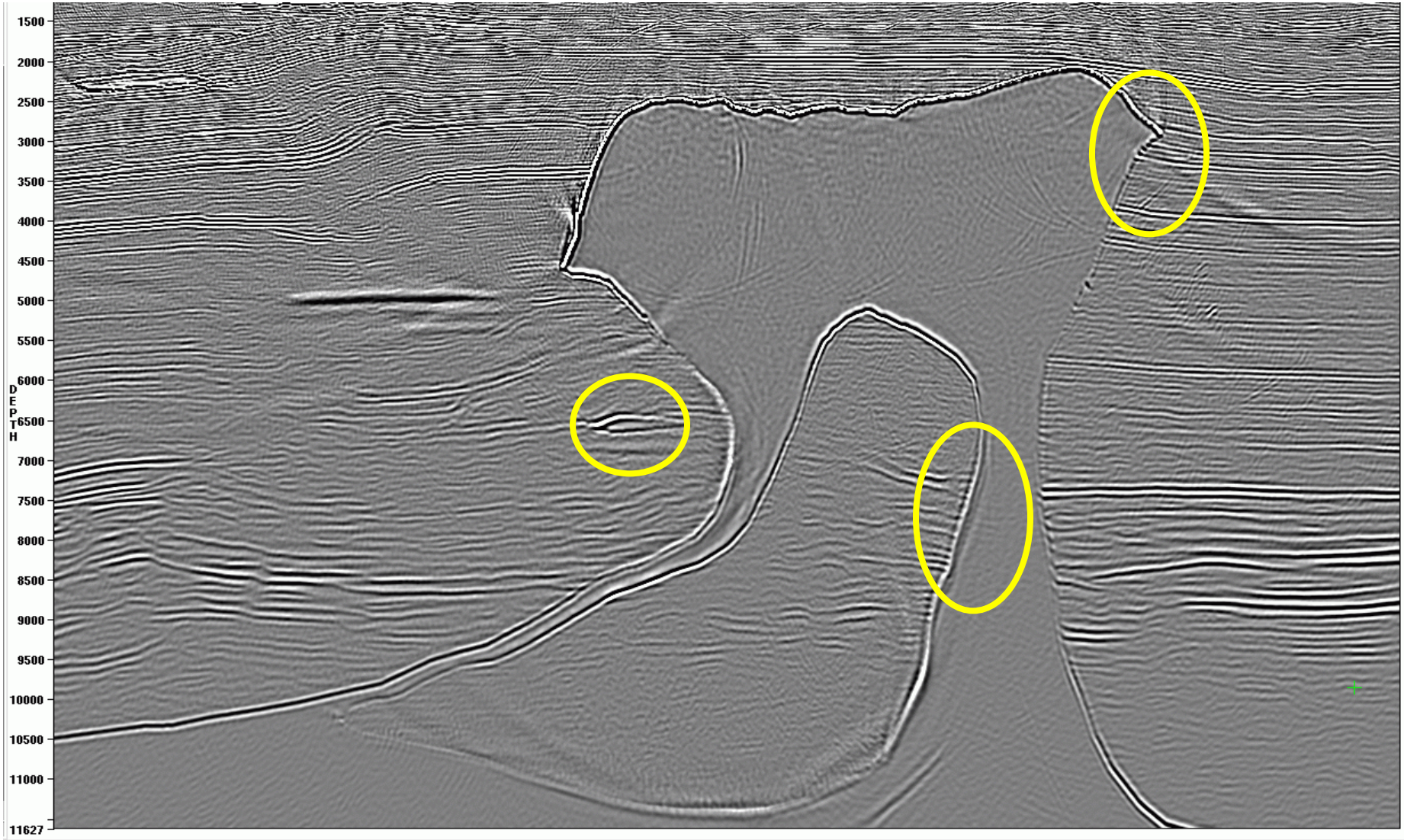
Pre-Stack Depth Migration Method

Algorithm vs. Criteria	Illumination Fidelity	Steep Dips	Multi-Pathing	Speed	Output Flexibility	Limitations
Kirchhoff	no	yes	no	yes	yes	limited by ray theory
Beam	no	yes	qualified yes	yes	yes	limited by ray theory
WEM	qualified yes	no	yes	yes	yes	
RTM	yes	yes	yes	yes	yes	

Wave Equation Migration (WEM)

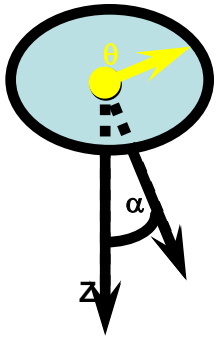


ION-GXT Reverse Time Migration (RTM)



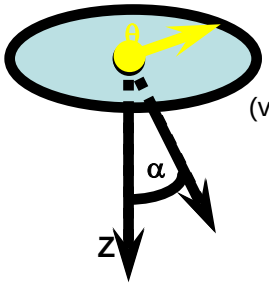
Isotropic, VTI & TTI in the RTM Imaging Flow

- Anisotropy and the Velocity model
  -
  - TTI and VTI models are parameterized in terms of ξ and δ
  - Supported in tomography
  - Properties can be output as grids
- All GXT migrations support TTI & VTI
  - RTM
  - Kirchhoff
  - Beam
  - WEM
- Geology dictates the options
  - GXT has strong experience with both TTI and VTI
  -



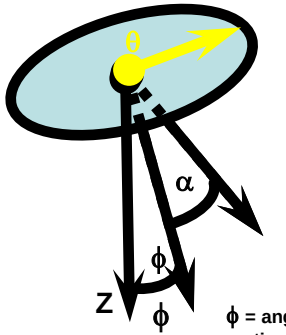
θ = azimuth

In the Isotropic case The velocity does not change with α, or θ



α = angle of raypath to the (vertical) polar axis

For VTI, the velocity changes with α, but not with θ



α = angle of raypath to the tilted polar axis

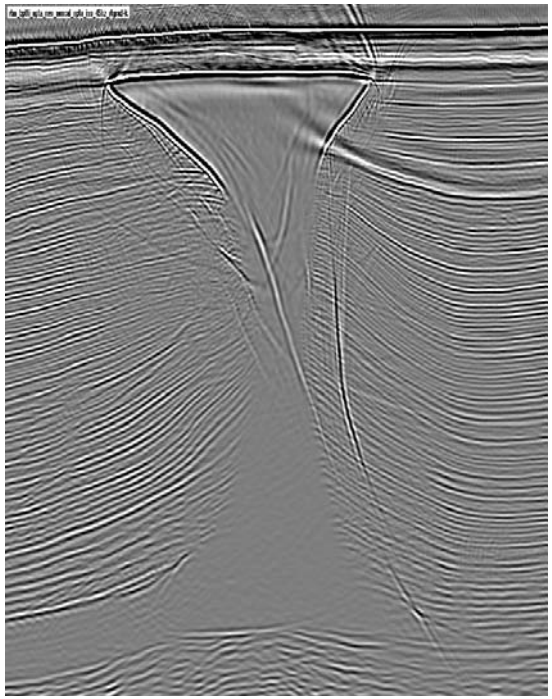
ϕ = angle of tilt axis to the vertical

If the axis of symmetry is tilted, and the velocity changes with α, but not with θ it is called TTI

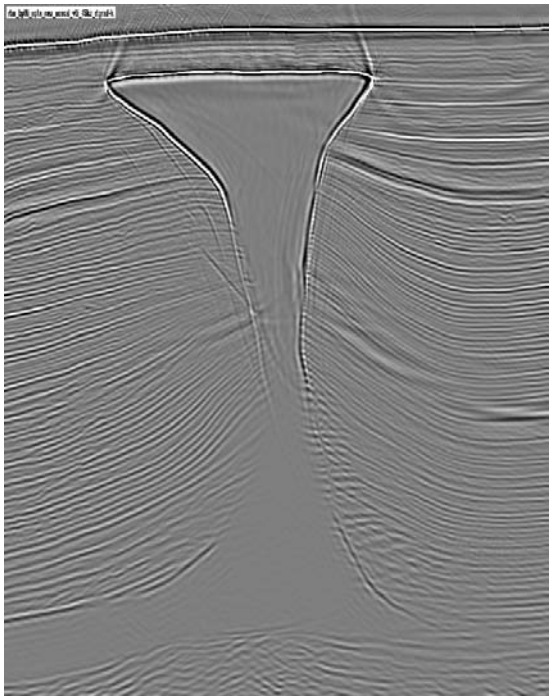
Please note that the above images are cartoons, and are exaggerated to show isotropy

TTI in the RTM Imaging Flow

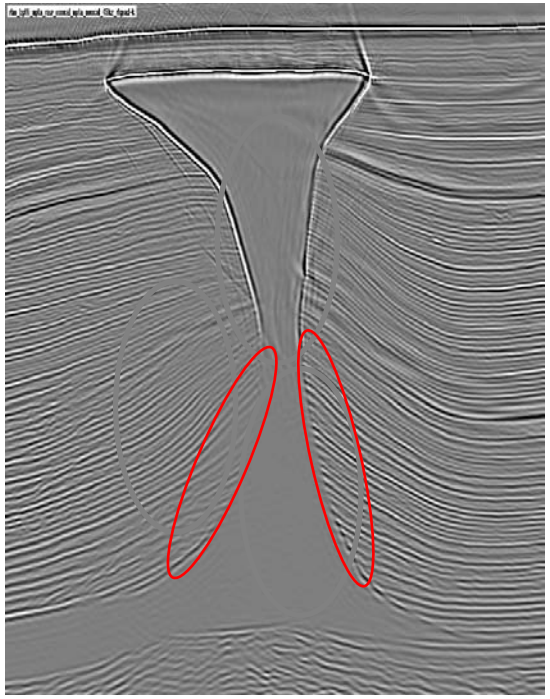
Isotropic



VTI



TTI



U.S. Gulf of Mexico Subsalt Potential

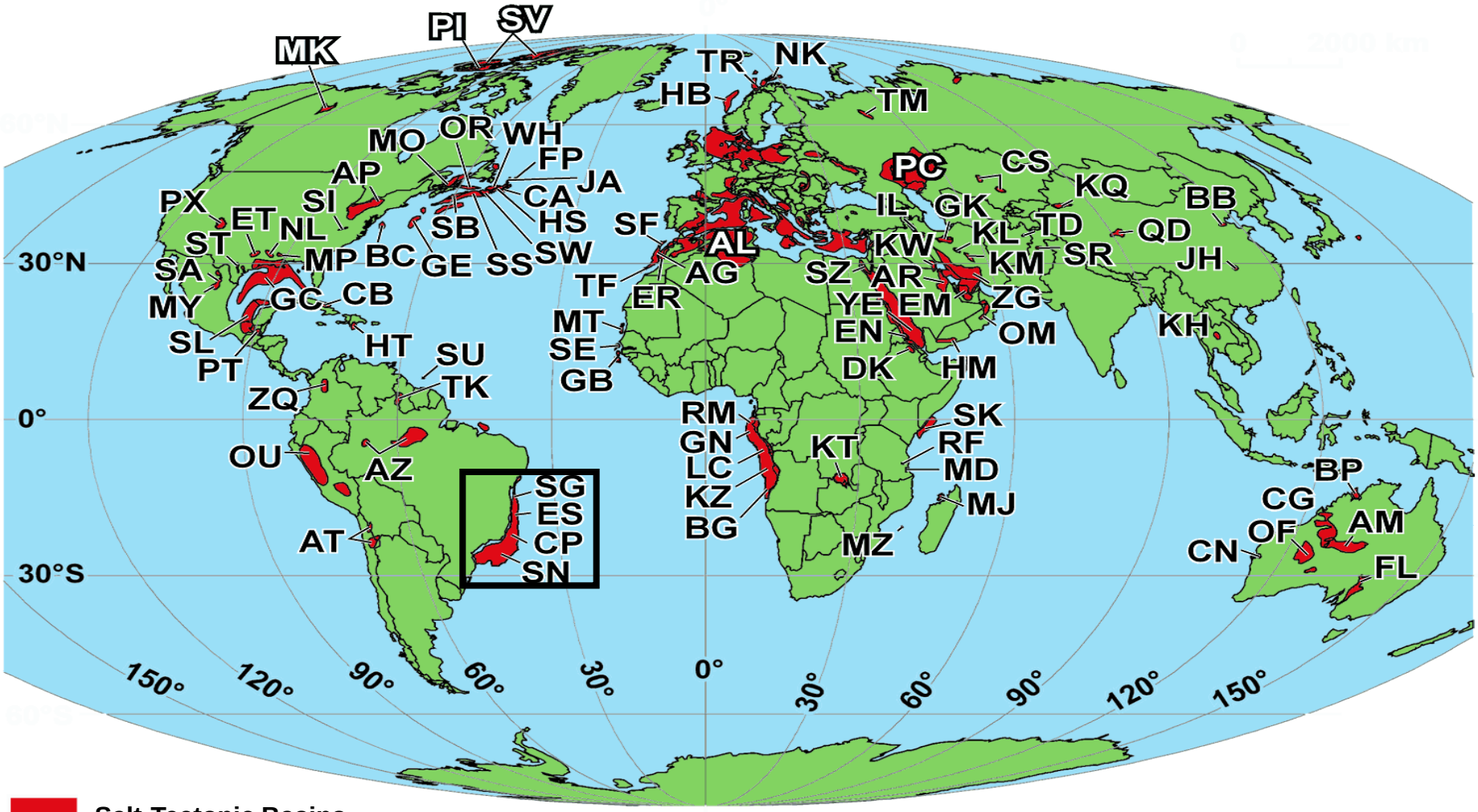
Over 40+ Apparent Subsalt Fields Discovered To Date

Subsalt Play below Allochthonous Salt Canopies & Welds
Projected Potential Recoverable Reserves – 7 to 18+ BBOE
(per published reports)

2000-2009 Subsalt Fields Discovered

75+ New Field Wildcats
40+% apparent wildcat discovery rate
Water Depths = 1,000' – 8,500' feet
Reservoir Depths = 8,000' – 32,000' feet
Latest discovery - "Lucius" – announced November 2009 by APC

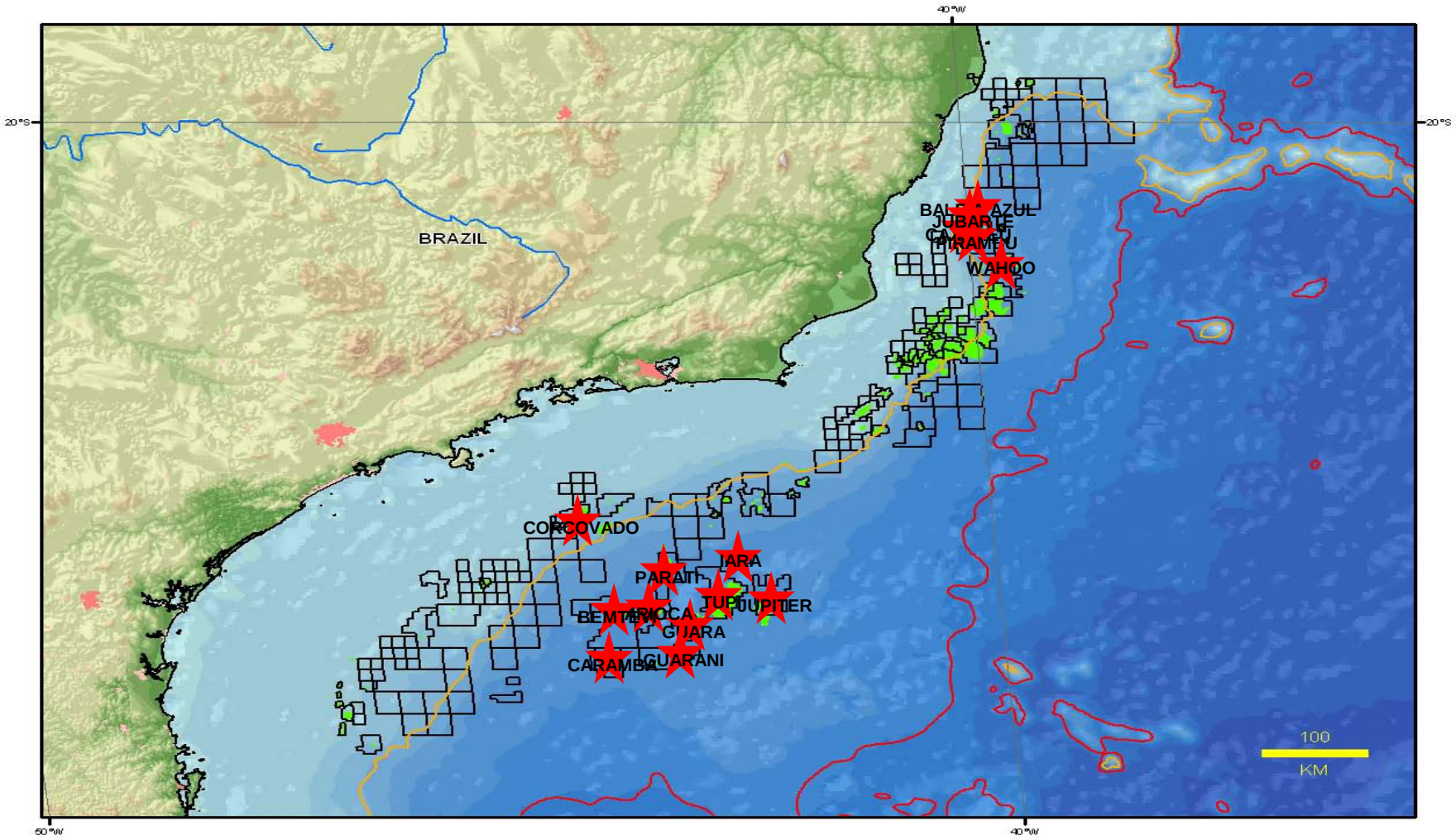
Brazil Offshore Salt Basins



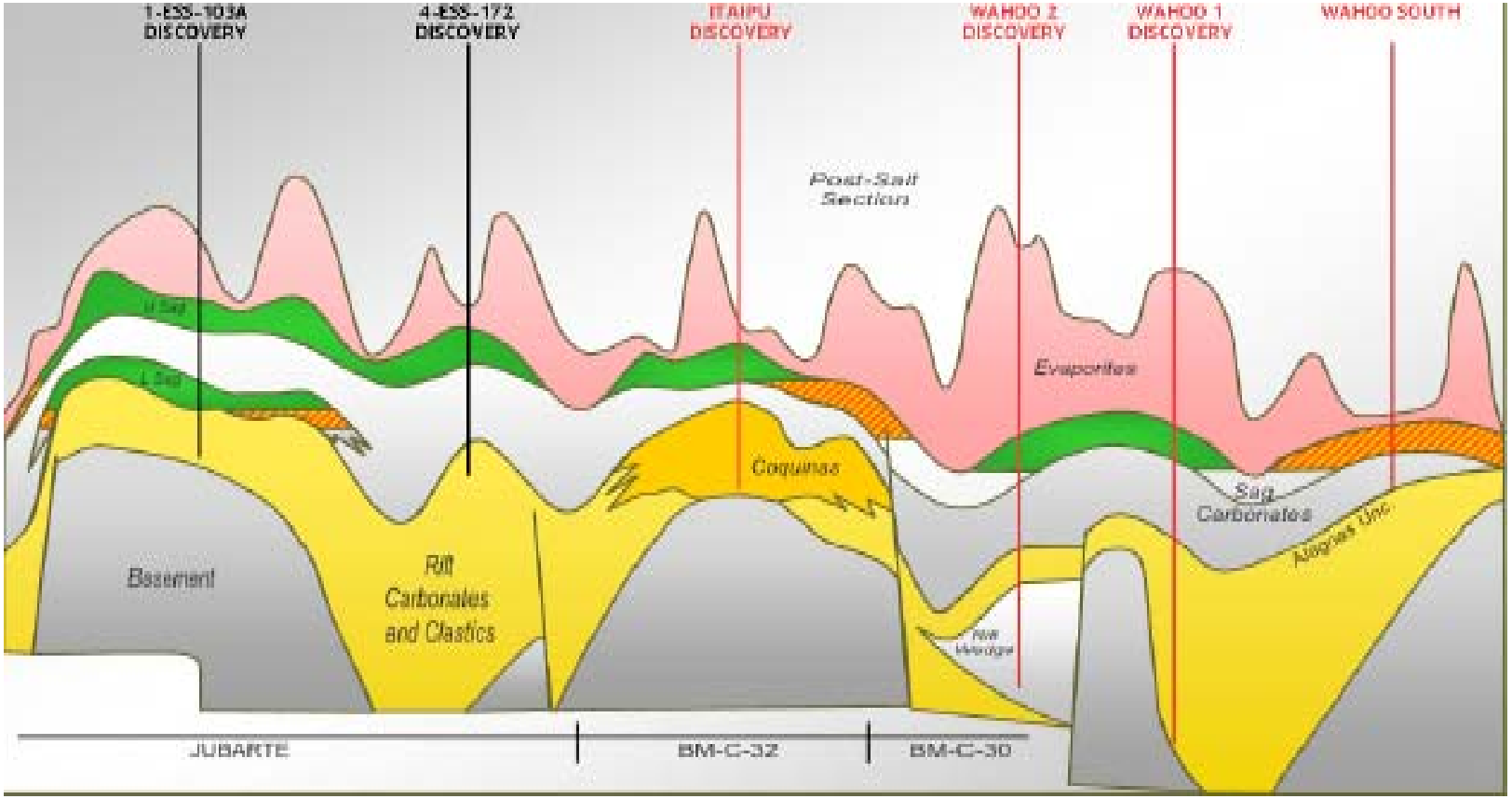
Salt-Tectonic Basins

Source: Martin P. A. Jackson, 2007

Santos, Campos, & Espirito Santo Basins



Campos Basin – Anadarko's X-Section



Source: Anadarko Investor Relation Presentation

Brazil Presalt Potential

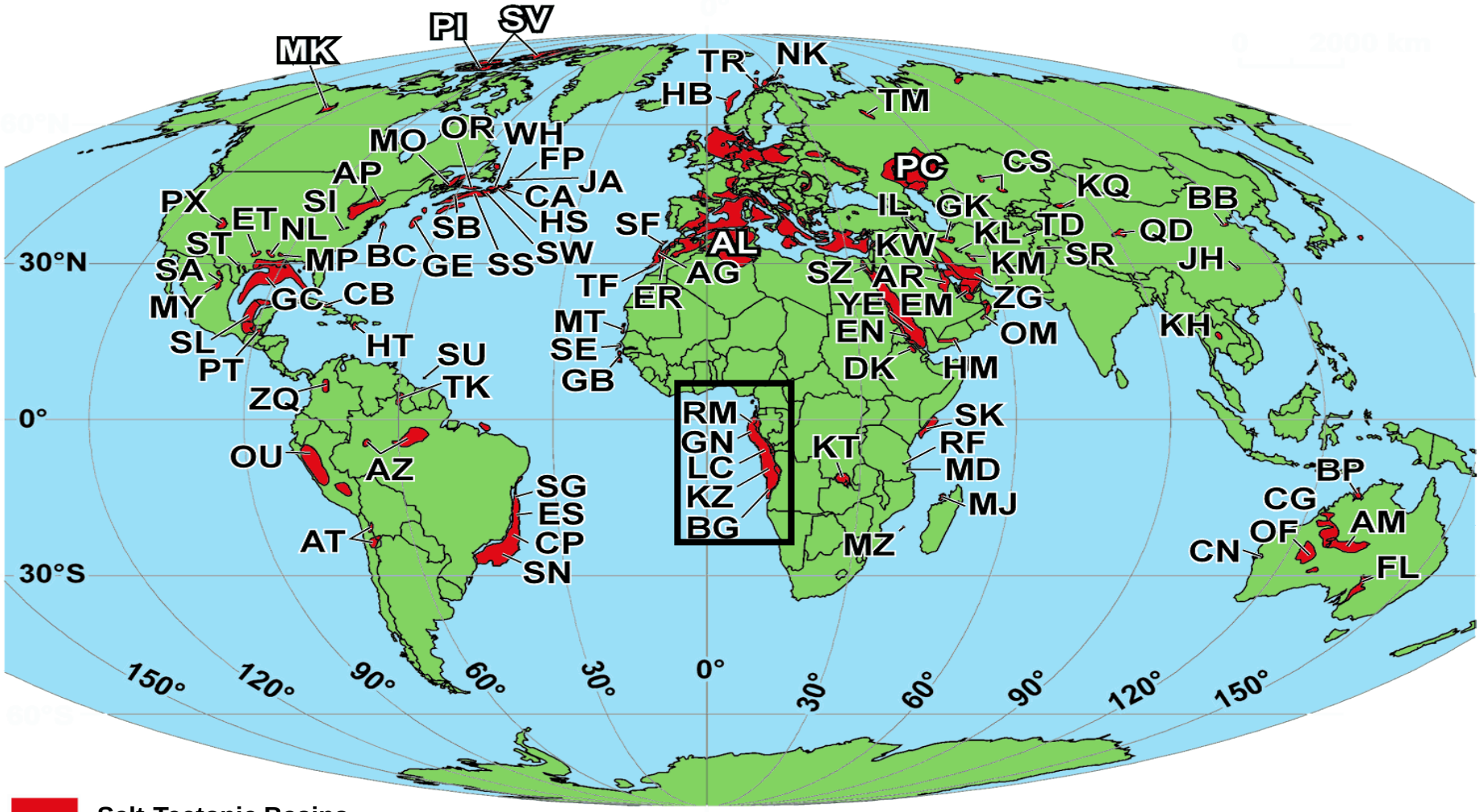
Over 20+ Apparent Presalt Fields Discovered To Date

Presalt Play below Autochthonous Salt Layer
Projected Recoverable Reserves = 15 BBOE to 50+ BBOE
(per published reports)

2000-2009 Presalt Fields

25+ New Field Pool Wildcats
80+% apparent wildcat discovery rate
Water Depths – 250' – 7,000+'
Reservoir Depths – 10,000' – 20,000+'

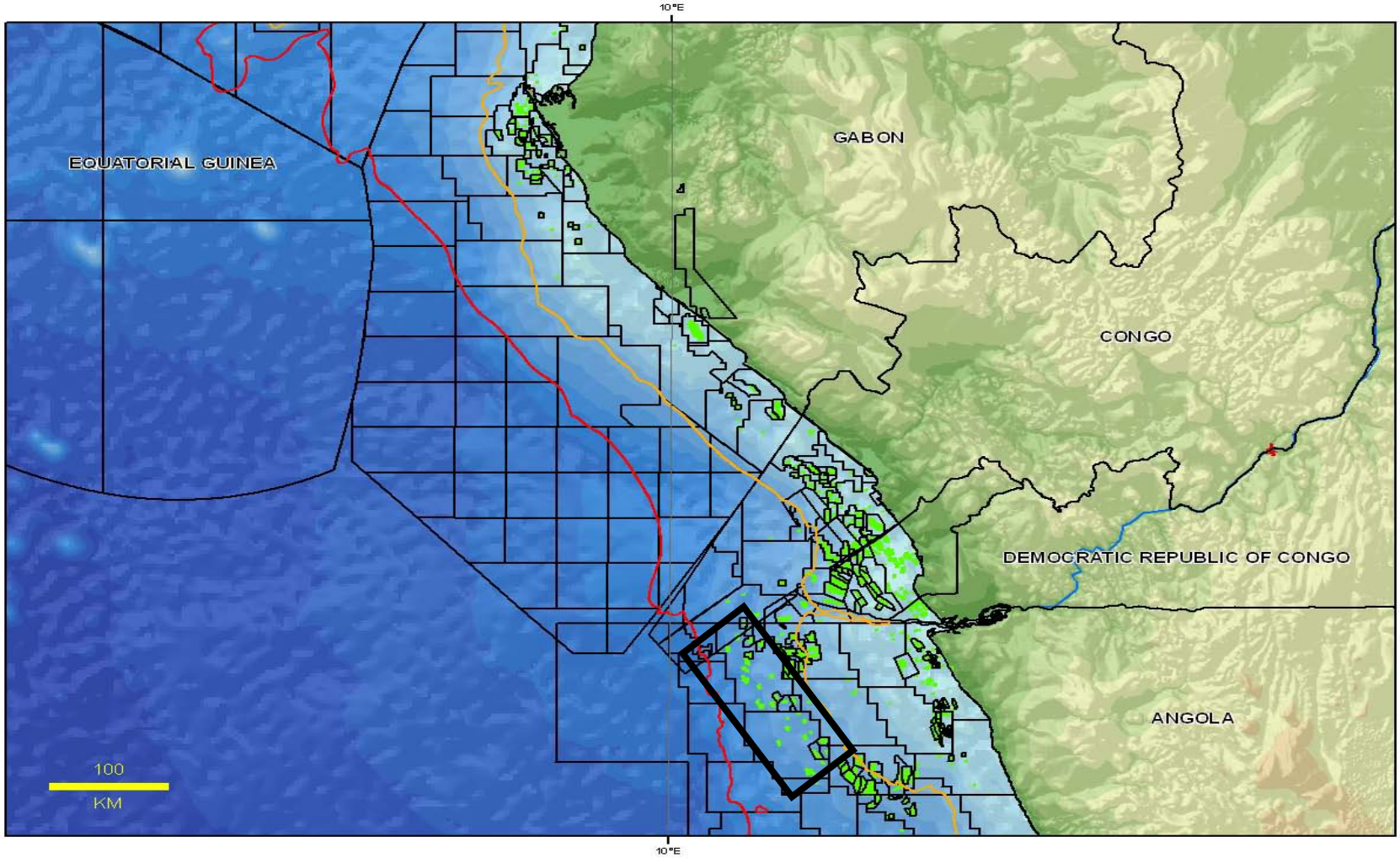
West Africa Offshore Salt Basins



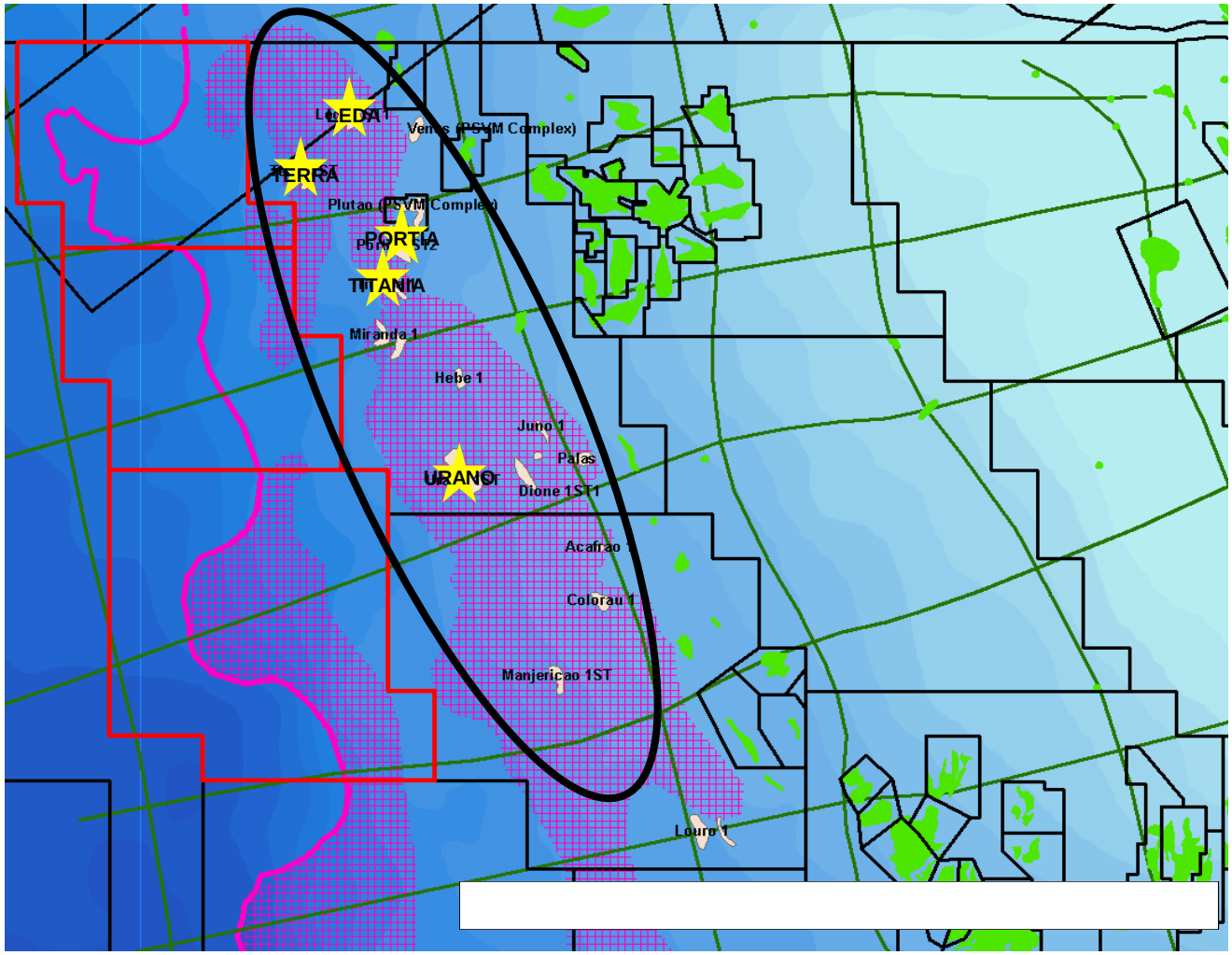
Salt-Tectonic Basins

Source: Martin P. A. Jackson, 2007

West Africa Offshore - Angola Subsalt

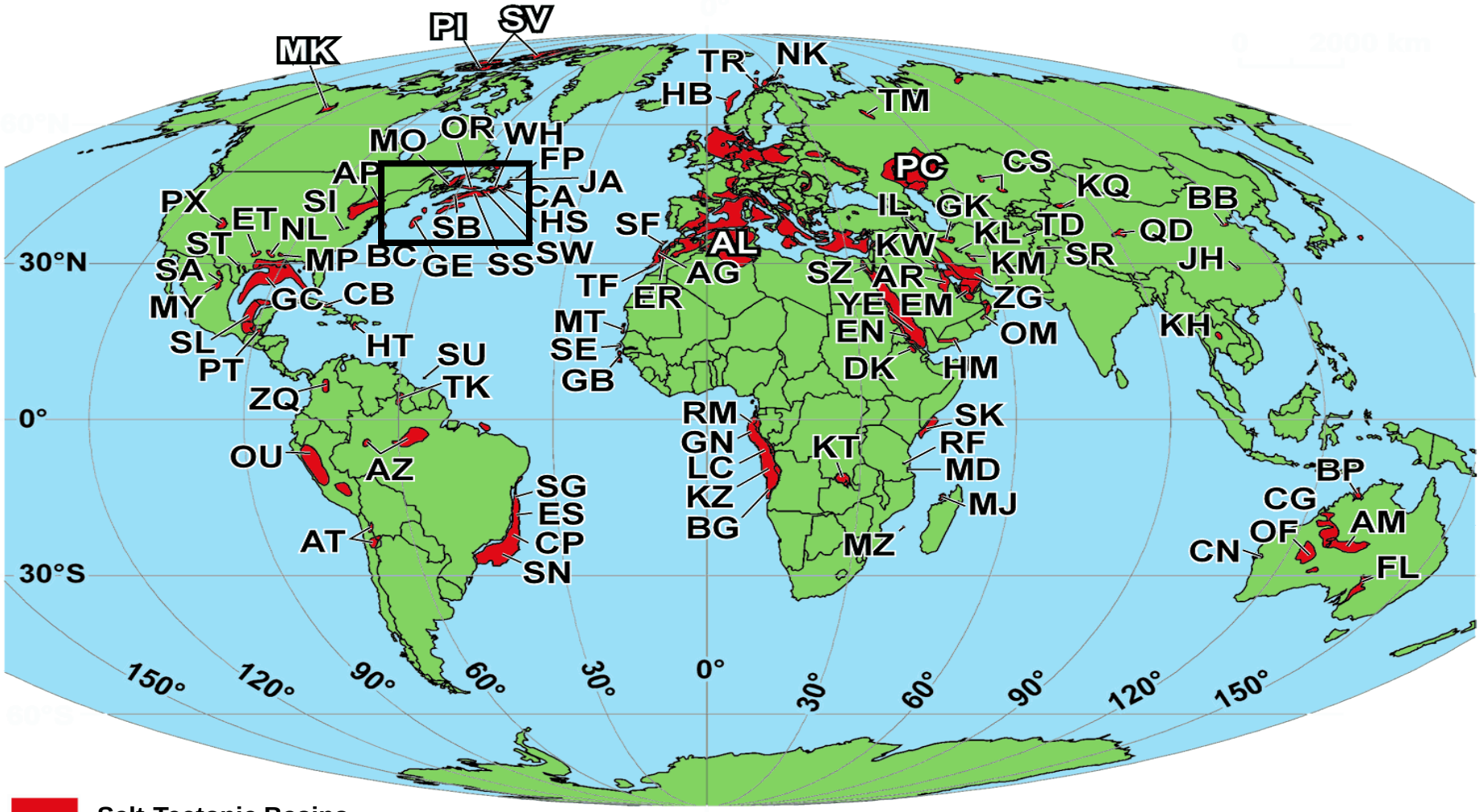


Angola Subsalt Field Discoveries



Source: Data ION GXT BrasilSpan; Interpretation: S. Henry, A. Danforth et al

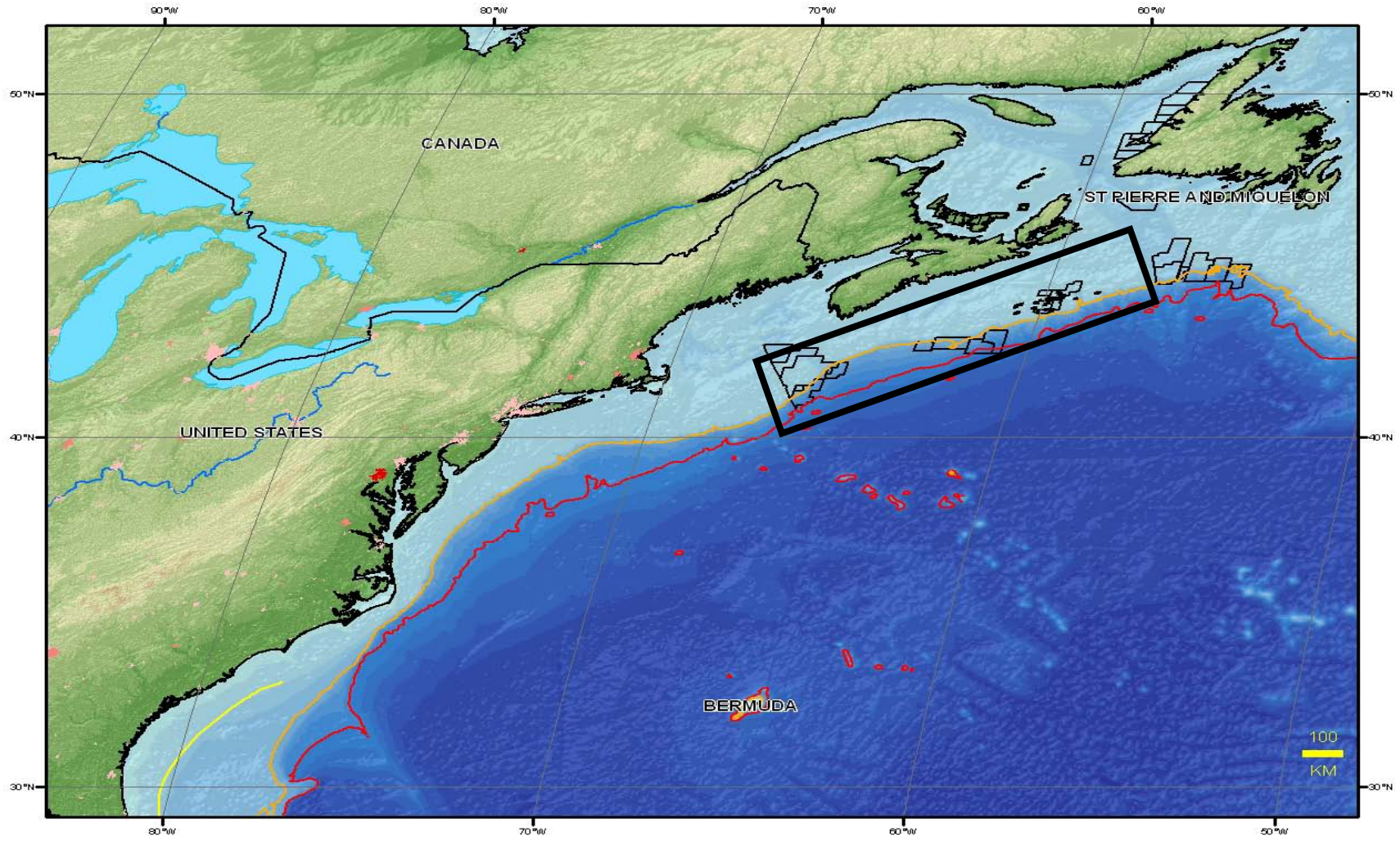
Eastern Canada Offshore Salt Basins



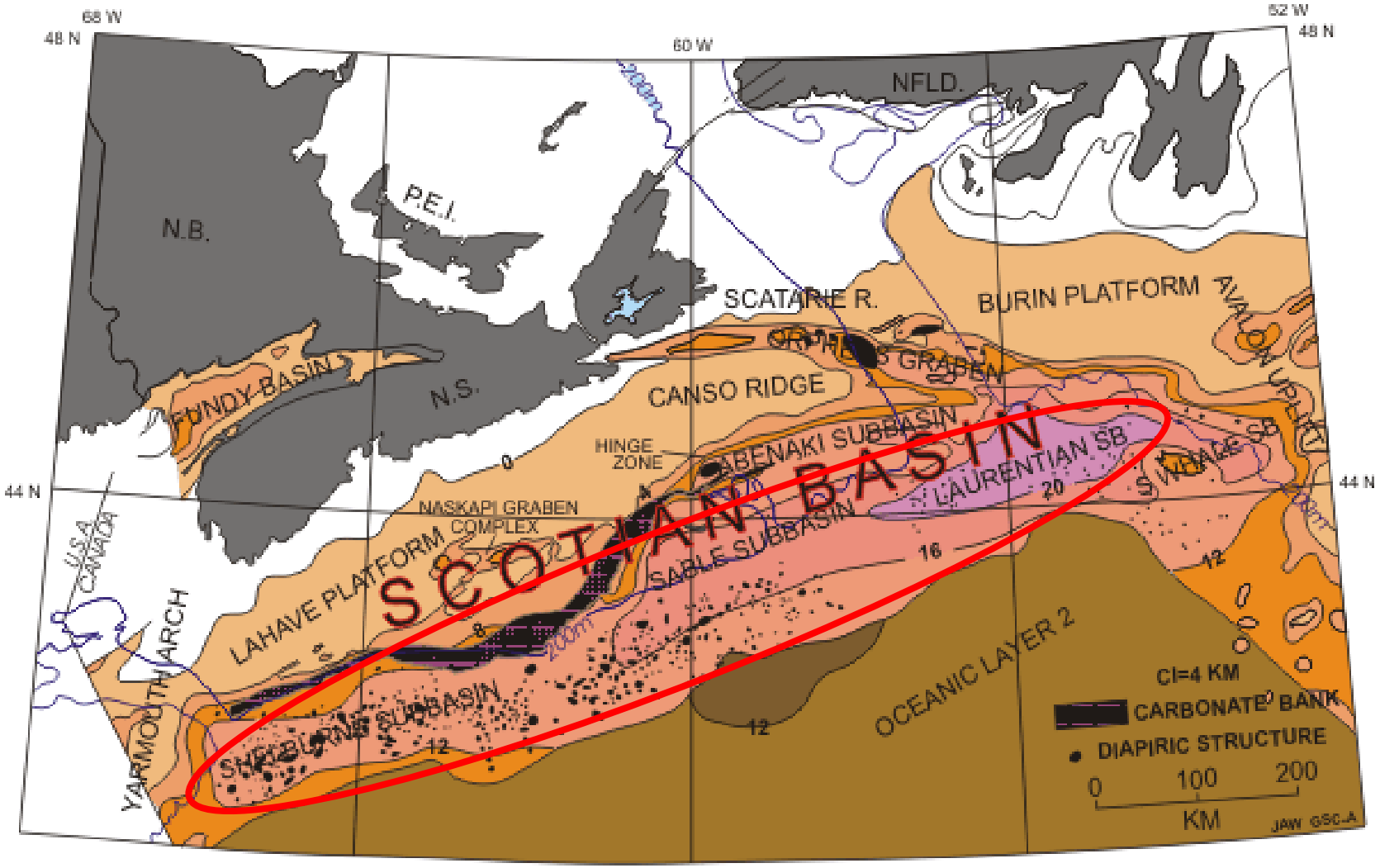
Salt-Tectonic Basins

Source: Martin P. A. Jackson, 2007

Eastern Canada - Scotian Basin

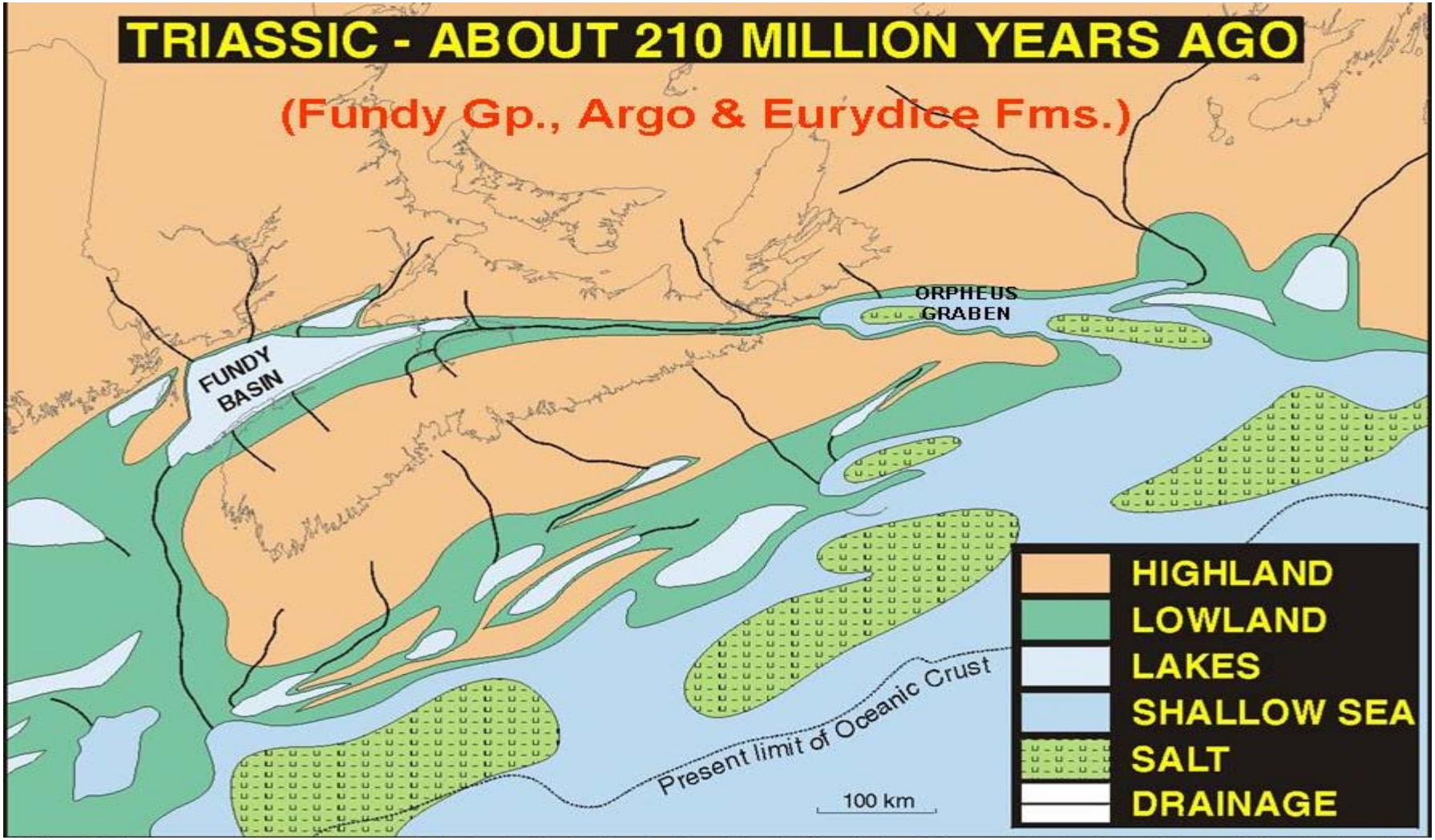


Nova Scotia Subsalt & Presalt



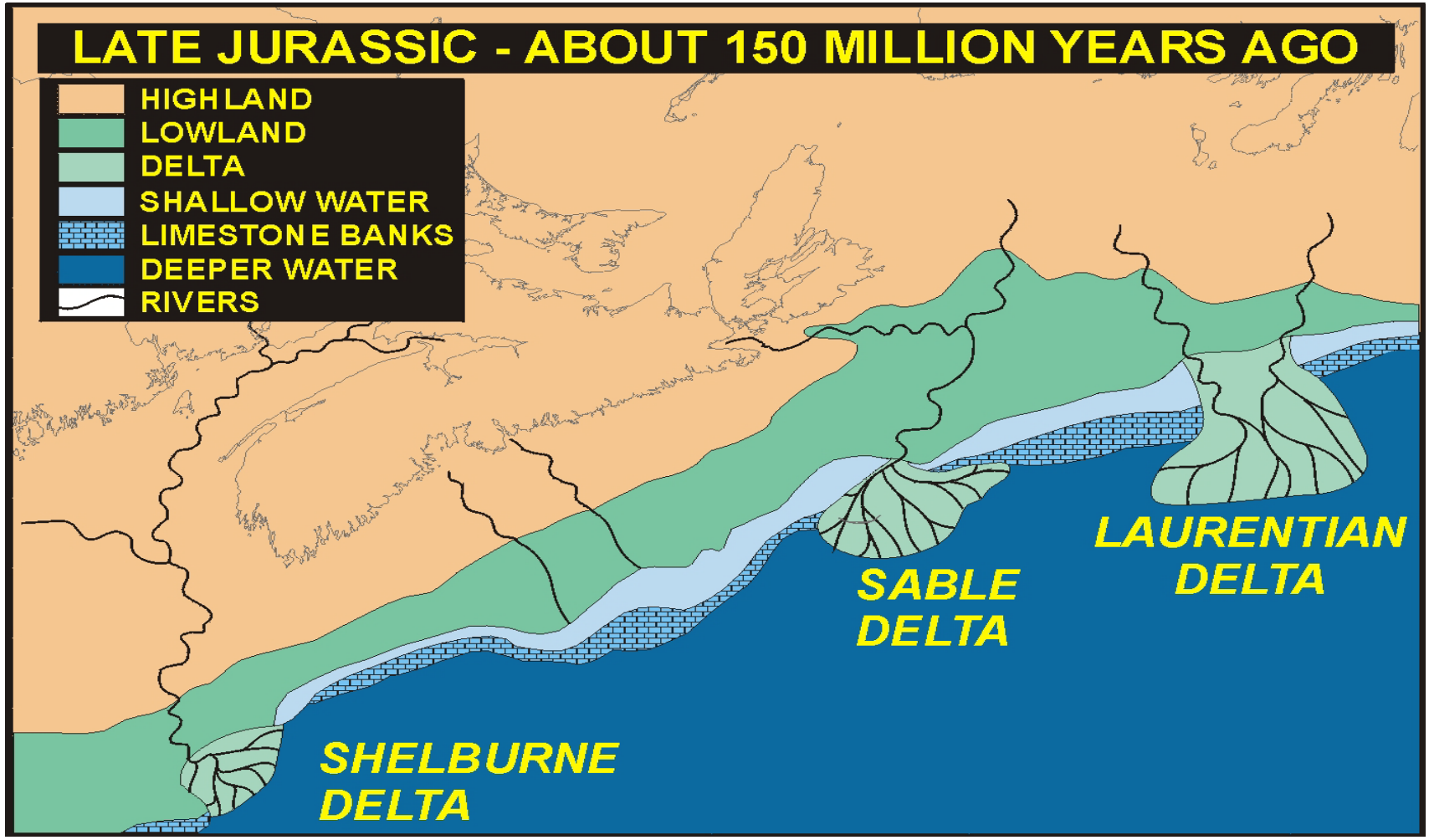
Source: Geological Survey of Canada

Formation of Scotian Basin - Salt Sub-basins



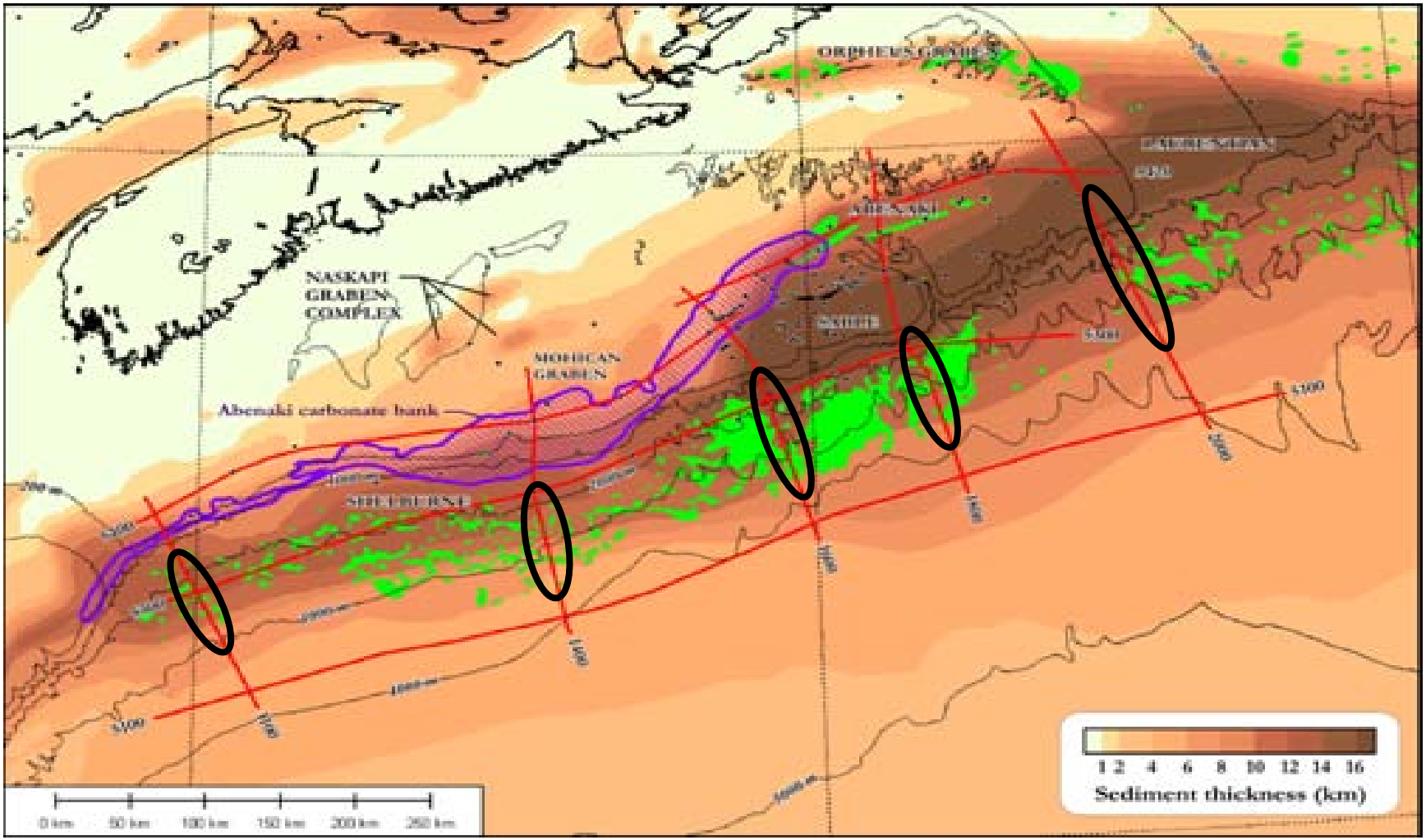
Source: Atlantic Geoscience Society

Scotian Basin – Post-Salt Deposition

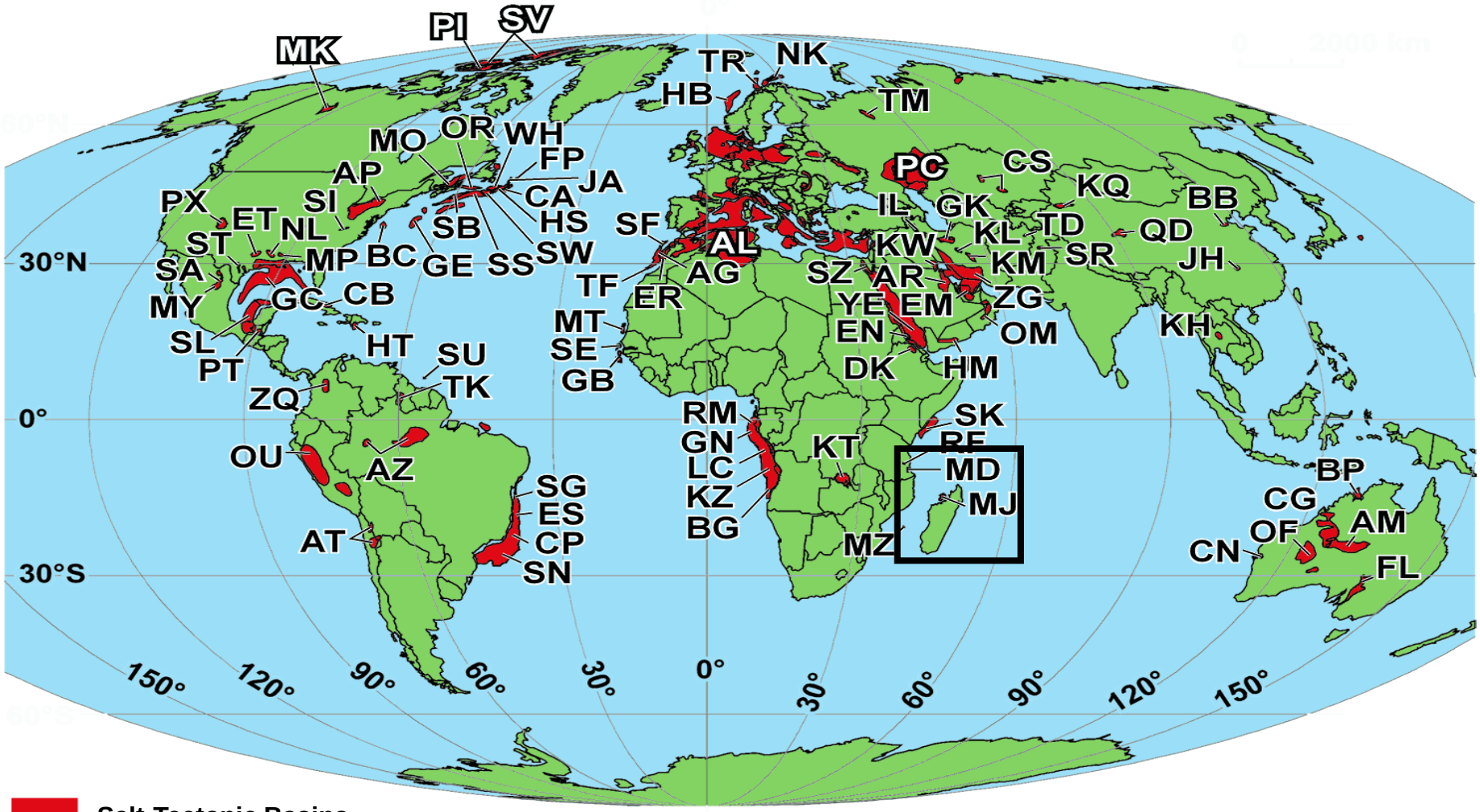


Source: D. Brown – CNSOPB, 2008

NovaSPAN - Scotian Basin Subsalt Potential



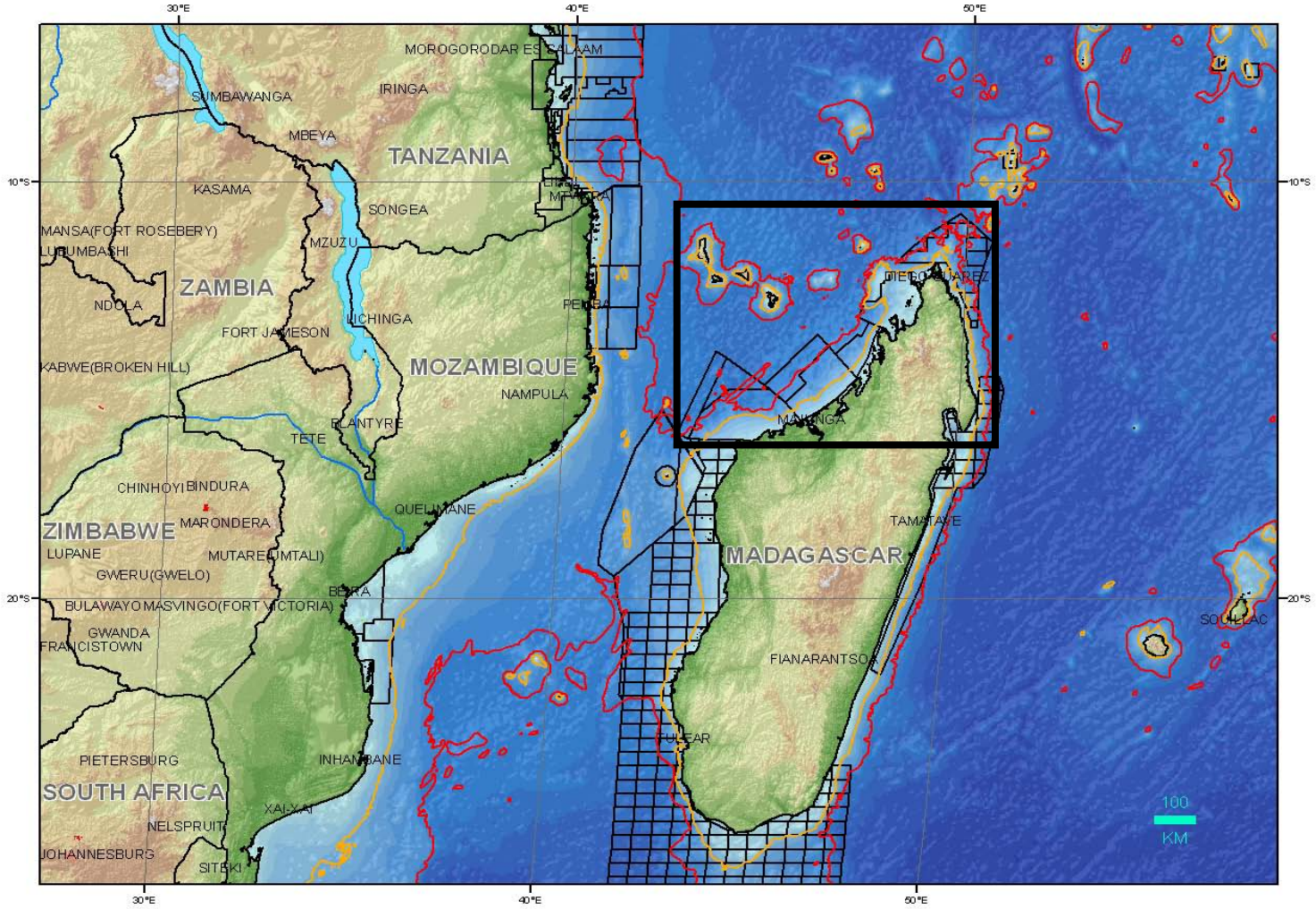
Madagascar Offshore Salt Basins



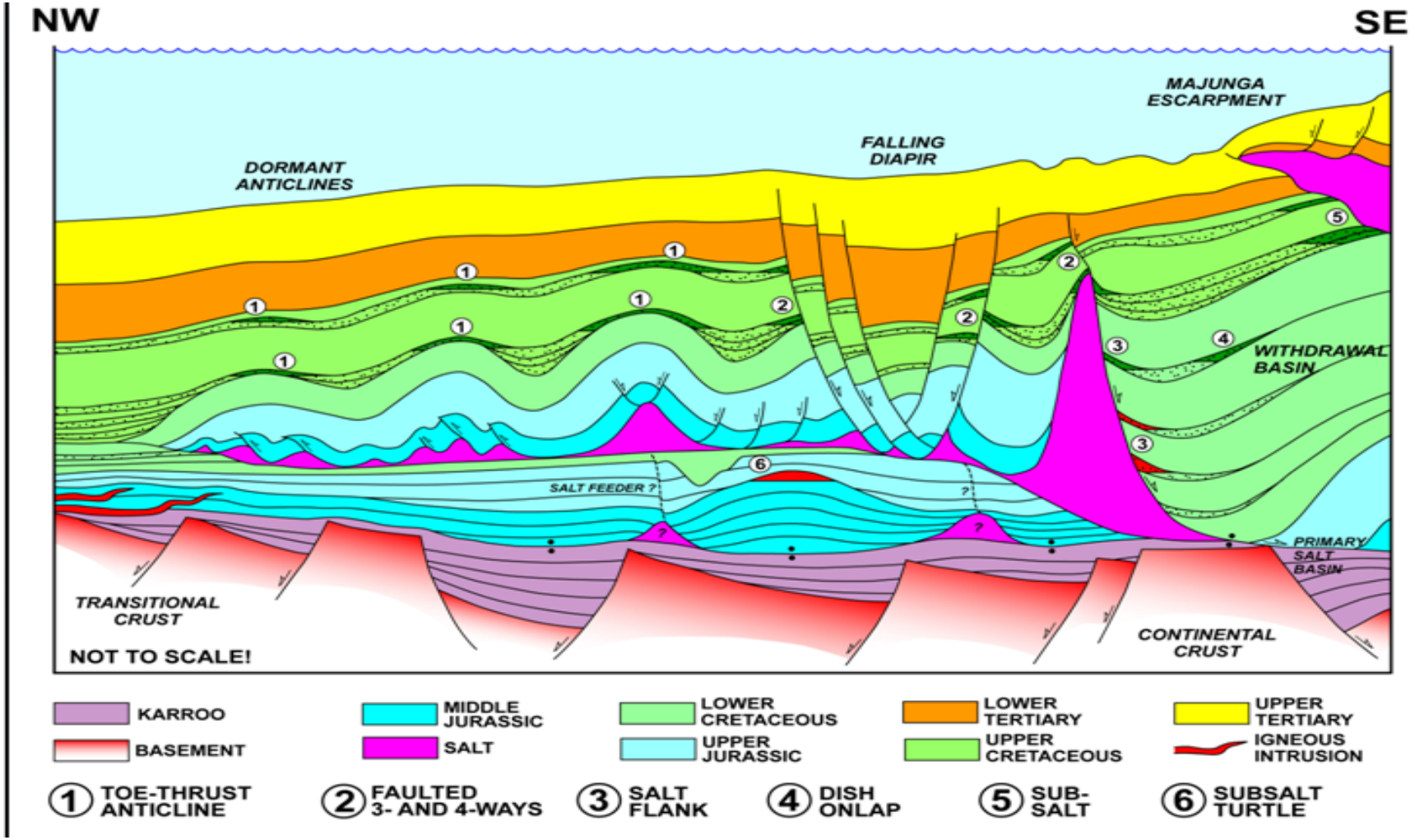
Salt-Tectonic Basins

Source: Martin P. A. Jackson, 2007

Madagascar – Majunga Basin

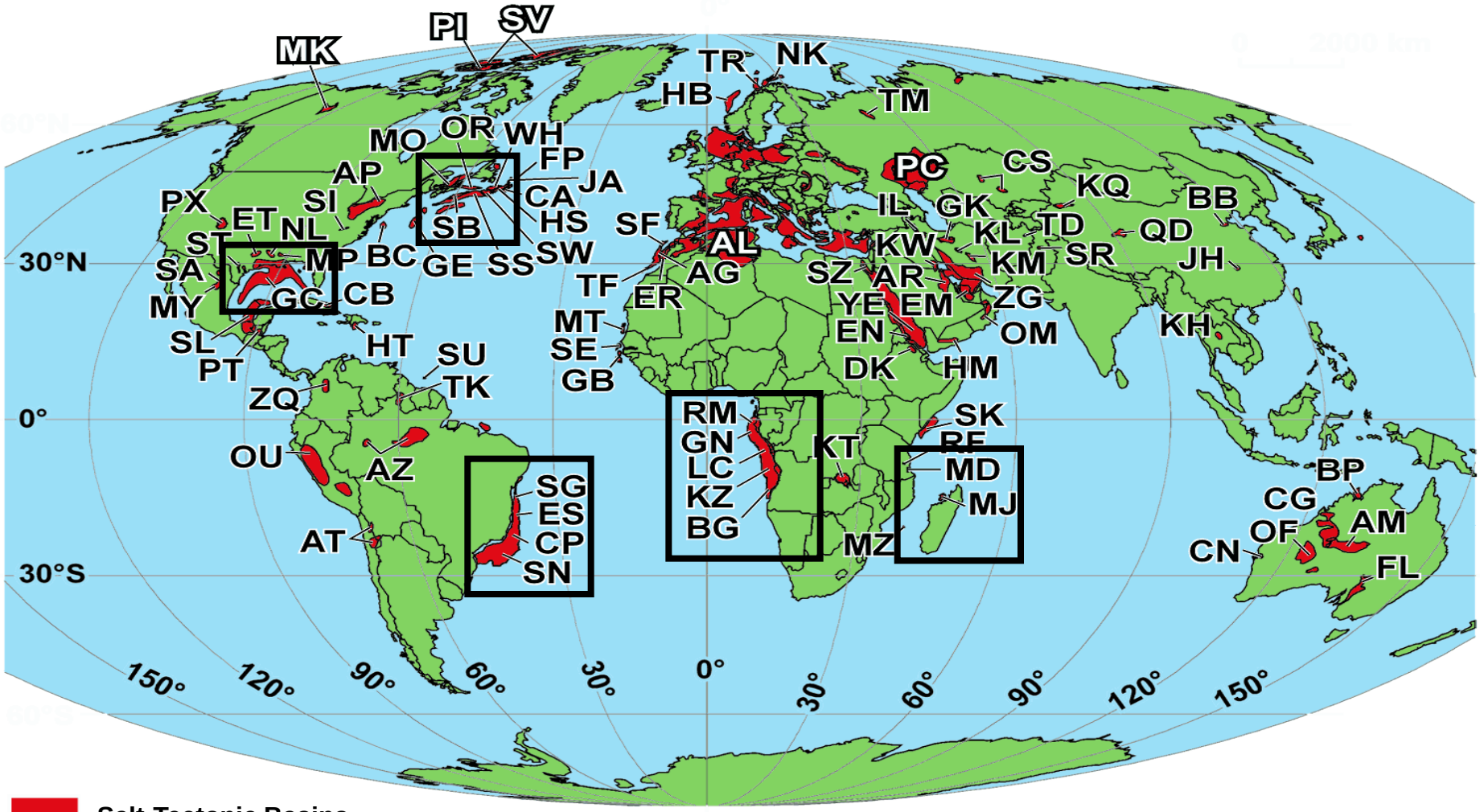


Madagascar Subsalt & Presalt



Source: Tari et al, 2004

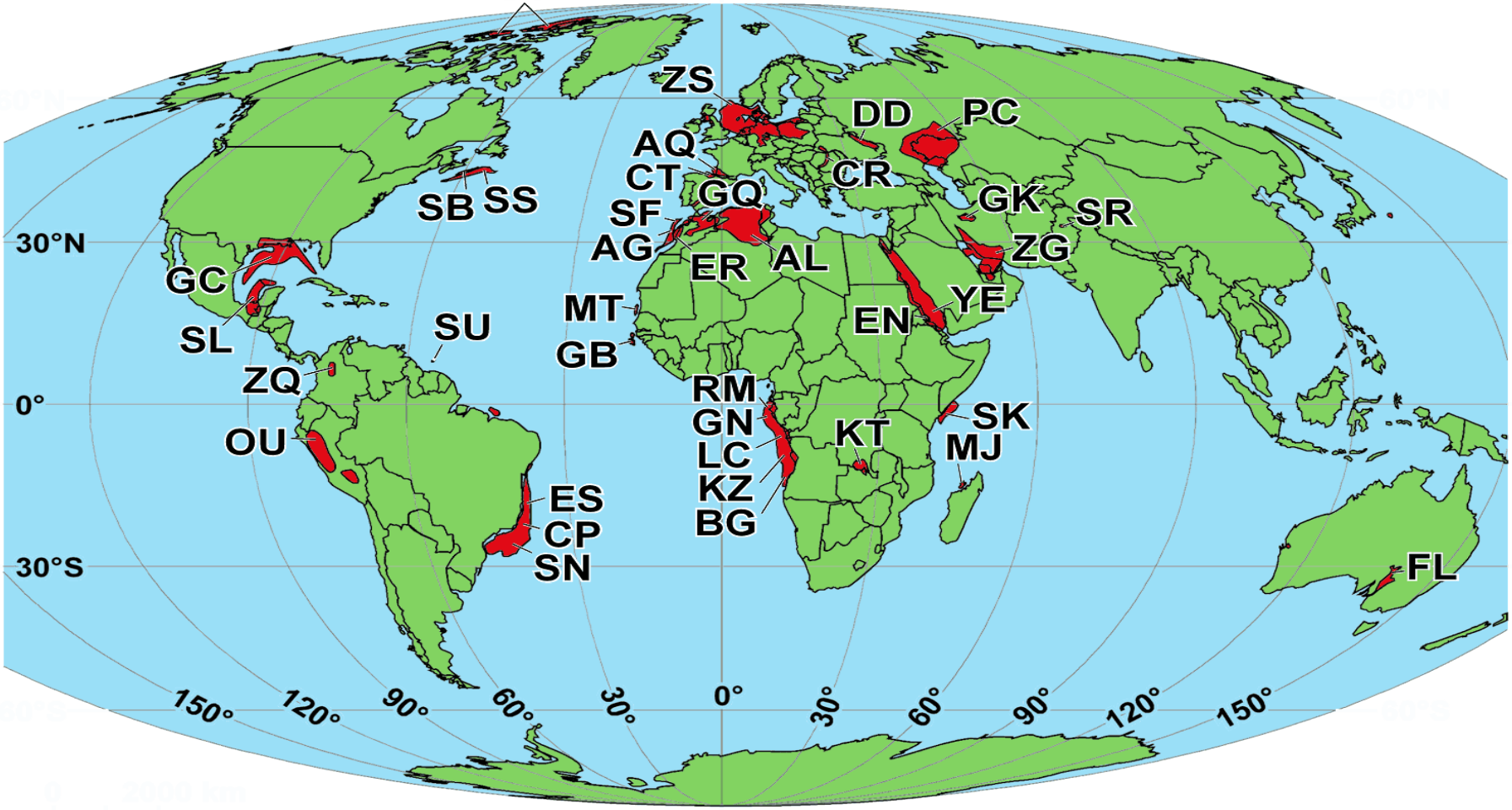
100+ Worldwide Salt Tectonic Basins



Salt-Tectonic Basins

Source: Martin P. A. Jackson, 2007

35+ Salt Tectonic Basins with Known Salt Sheets



Allochthonous Sheet Basins

Source: Martin P. A. Jackson, 2007

Key Tool for Future Subsalt & Presalt Success

Reverse Time Migration Technology:

A key tool leading
***Discovery Thinkers* to find tomorrow's**
Giant Subsalt & Presalt Fields

Into the Future

“Ultimately, there are few limits on future global oil & gas potential below salt. Whether it’s subsalt or presalt, we just need to accurately image below it.”

(Hart’s E&P Magazine, July 2009)

Thank You

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ION Geophysical Corporation
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Special thanks to Martin P. A. Jackson & Michael R. Hudec.