# Deepwater Subsalt-Suprasalt Middle to Lower Slope Sands and Reservoirs of the U.S. Gulf of Mexico: The Evolution of an Exciting Giant Field Concept*

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Search and Discovery Article #42048 (2017)**
Posted March 30, 2017

*Unsolicited manuscript submitted by senior author March 21, 2017, accepted March 27, 2017, and adapted from oral presentation at GCAGS 65th Annual Convention, Houston, Texas, September 20-22, 2015. Abstract copyrighted 2015 by GCAGS, Houston, Texas. Please refer to closely related article by these authors, Search and Discovery Article #42047 (2017).


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## Abstract

For almost 70 years, the U.S. Gulf of Mexico (GOM) has been an incubator of new depositional system models, and more recently, the focus for complex and dynamic subsalt-sediment trapping styles.

Early passive margin models applied to the GOM suggested short slopes between delta fronts and basin floors and concluded that most slopes were sand "bypass" areas. However, subsequent study of the GOM's present-day salt-supported slope, which extends nearly 125 miles from its present-day shelf edge to the basin floor, suggested possible new sand depositional models applicable to the Cenozoic sediments below, if the slope was similarly salt-supported at time of deposition. Today, well control has dispelled this sand "bypass" thinking by demonstrating the presence of thick sand sequences and, when combined with seismic stratigraphy and depth imaging that shows the ancestral salt sheets, yields a robust potential for both lowstand and highstand sands in many subsalt Cenozoic cycles. Most importantly, the Miocene confined mini-basin sand bodies of amalgamated fans, amalgamated channels, and amalgamated channel levees of the ancestral mid-lower slopes, have proven sandstone reservoirs that have produced significant oil and gas fields. Undoubtedly, there are more of these to be discovered and developed.

This is not the first time that geologists in the GOM have pioneered new depositional concepts. When the authors started their GOM geoscience careers in the 1970s, industry was starting to apply Miocene delta depositional models seaward. In the 1950s and 1960s, these models had been pioneered in the nearshore. By 1970, Plio-Pleistocene deltas were hypothesized seaward of the Miocene deltaic fields, and billions of dollars of lease bonus monies were invested in the 1970s lease sales. Those massive Plio-Pleistocene deltaic sandstone reservoirs deposited in the last million years were discovered to contain billions of boe, all generated from oil and gas shale source rocks deposited in the Early Cretaceous Aptian (125-113 mya) and Late Jurassic Tithonian (152-145 mya). One of these most notable giants on the present-day outer shelf, Eugene Island (EI) 330 field (the 3rd largest single field in GOM per BOEM [EUR 770 mmboe]), was discovered and produced suprasalt, in about 300 ft of water just 20 miles north of the edge of the Outer Continental Shelf.

During the first 40 years of offshore GOM industry exploration, all petroleum reservoir objectives were "suprasalt", that is above all sheets or beds of salt, like EI 330. The original bedded deep salt (autochthonous) was first deposited soon after the opening of the GOM, during Mid-Jurassic Callovian "Louann" time (165-163 mya), and all horizontal salt sheets (allochthonous) originated from that Jurassic salt. The old concepts of vertical-only salt dome structuring have evolved toward dual-structuring models of both the traditional vertical doming AND the concept of horizontal translation of salt sheets across broad areas of the ancestral shelf and slope, similar to today's salt-supported slope.

Exploratory drilling, both on the shelf and in deepwater, has demonstrated that most salt bodies in the Gulf of Mexico are part of these extensive allochthonous salt sheets that have translated more horizontally than vertically throughout the ancestral shelves and slopes. Much of what the mobilized salt has covered are thick untested sedimentary sections containing reservoir quality sand bodies and effective sealing shales. Preservation of petroleum liquids is also greatly assisted by the heat transfer properties of these extensive, subsurface lateral salt sheets. Economically significant fields of oil, condensate, and natural gas have been discovered and produced from these high porosity-permeability sandstone reservoirs, despite 15,000-20,000 feet of "overburden," which contained these thick salt sheets.

Today, the present-day outermost shelf and uppermost slope of the Louisiana GOM is well understood as a renewed exploration area of high potential, building on the fields discovered (1993-2003) in the early days of poor seismically-imaged GOM subsalt traps. Over 300 mmboe has been produced to date (400+ mmboe EUR) from Conger, Hickory, Mahogany, Tanzanite, and Tarantula fields, all in 300-1500-ft water depth, near the present-day shelf-slope break.

Explorers have always known the Gulf of Mexico to be a world class exploration basin with tremendous potential. The thousands of explorers that have worked its complex geology over the last 70 years know that it has always been a great incubator for all forms of innovation that have then been adapted worldwide. The Gulf of Mexico has never been a "dead sea." In its latest report on future GOM petroleum potential, BOEM reported that the GOM has tremendous recoverable petroleum resources, with over 50 billion boe yet to be discovered. Much of it will be subsalt and found in slope-basin floor sand reservoirs.

The Offshore U.S. Gulf of Mexico is still a "Mother Lode" of petroleum, where new giant fields like these will continue to be discovered and produced.

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**Dwight "Clint" Moore & Bill Lefler**
**with Rich Heaney, Mike Neese, & Tom Uphoff**

GulfSlope Energy

**GCAGS 2015 – Houston, Texas**
**September 21, 2015**

# Objectives

- **Highlight depositional systems of reservoir sands in the ancestral middle and lower Miocene slope section of the Central LA GOM**
- **Describe these Conger-Mahogany-Hickory Miocene slope sands as proven highly productive reservoirs, with further potential in surrounding mini-basins**
- **Demonstrate that the Miocene ancestral middle and lower slope is <u>NOT</u> a “bypass” zone, but is a broad, widespread area of sand-filled confined mini-basins with amalgamated fans and channels as reservoir sands**

# Subsalt Miocene Slope Sand Production

## EUR 400+ MMboe were discovered in the 1990s

**Conger >250 MMBoe**
Discovered 1998
$1^{st}$ Prod 2000

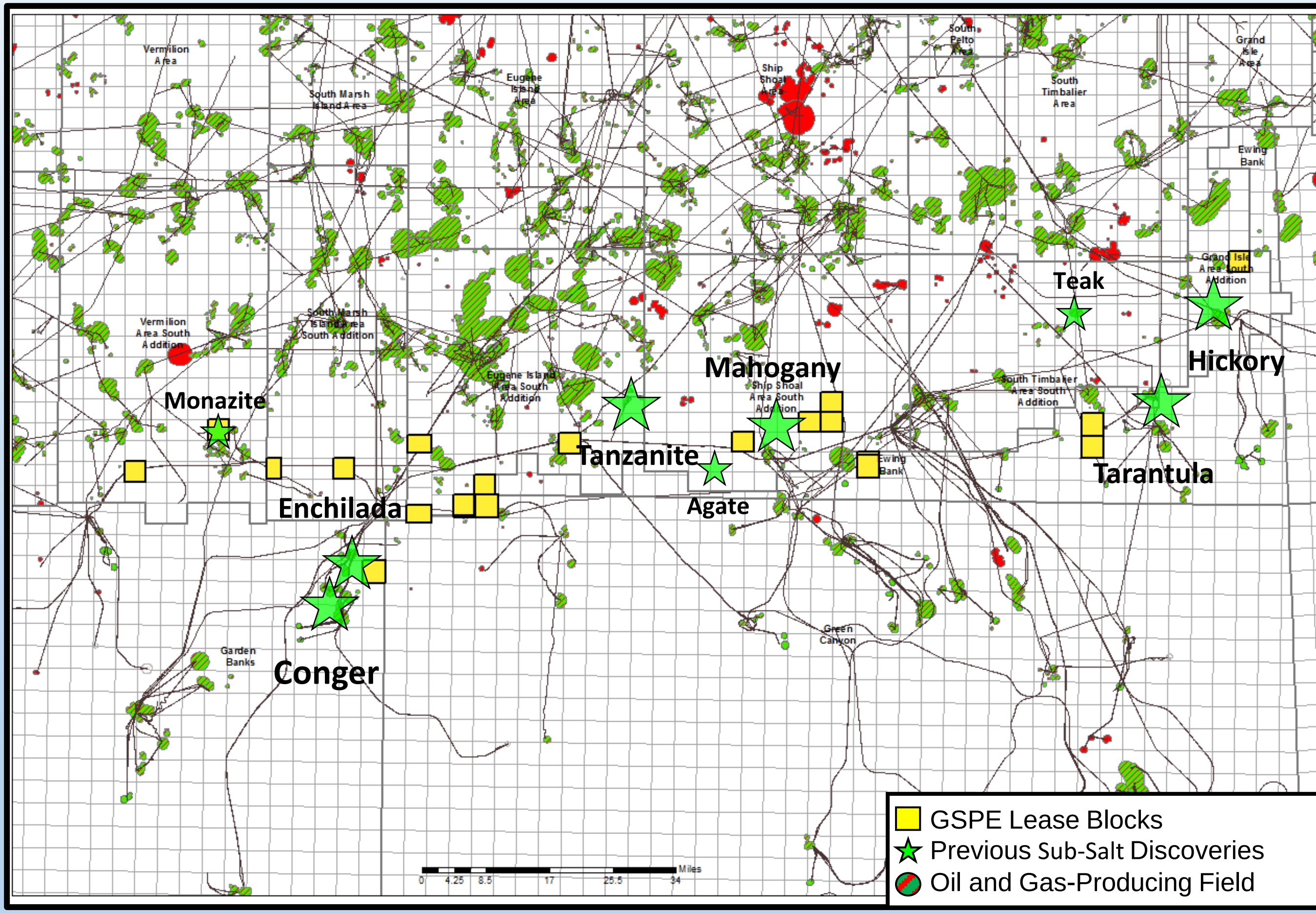
**Hickory >55+ MMBoe**
Discovered 1998
$1^{st}$ Prod 2000

**Mahogany >50+ MMBoe**
Discovered 1993
$1^{st}$ Prod 1997

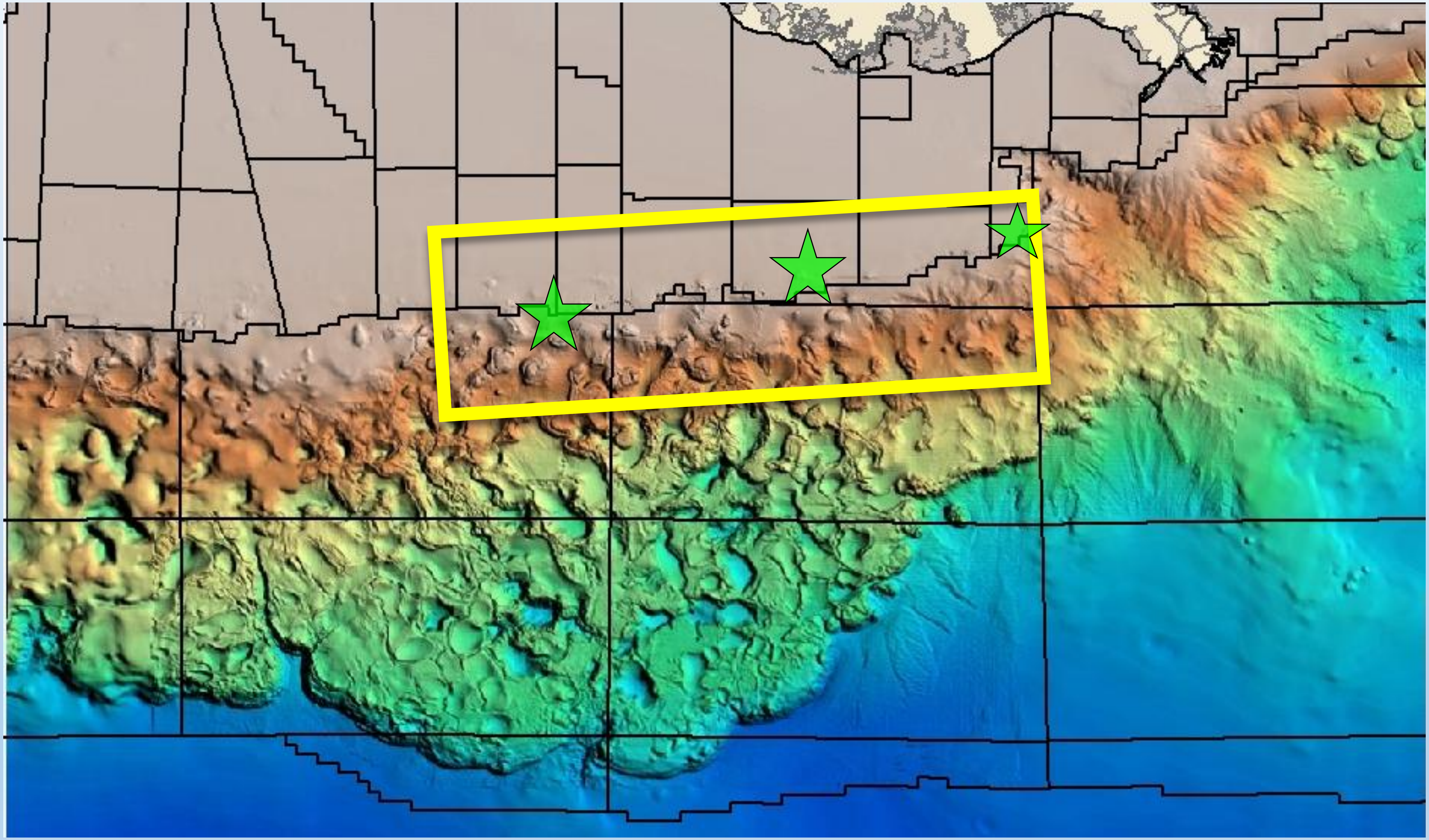
**Tanzanite >20 MMBoe**
Discovered 1998
$1^{st}$ Prod 1999

**Enchilada >30 MMBoe**
Discovered 1995
$1^{st}$ Prod 1997

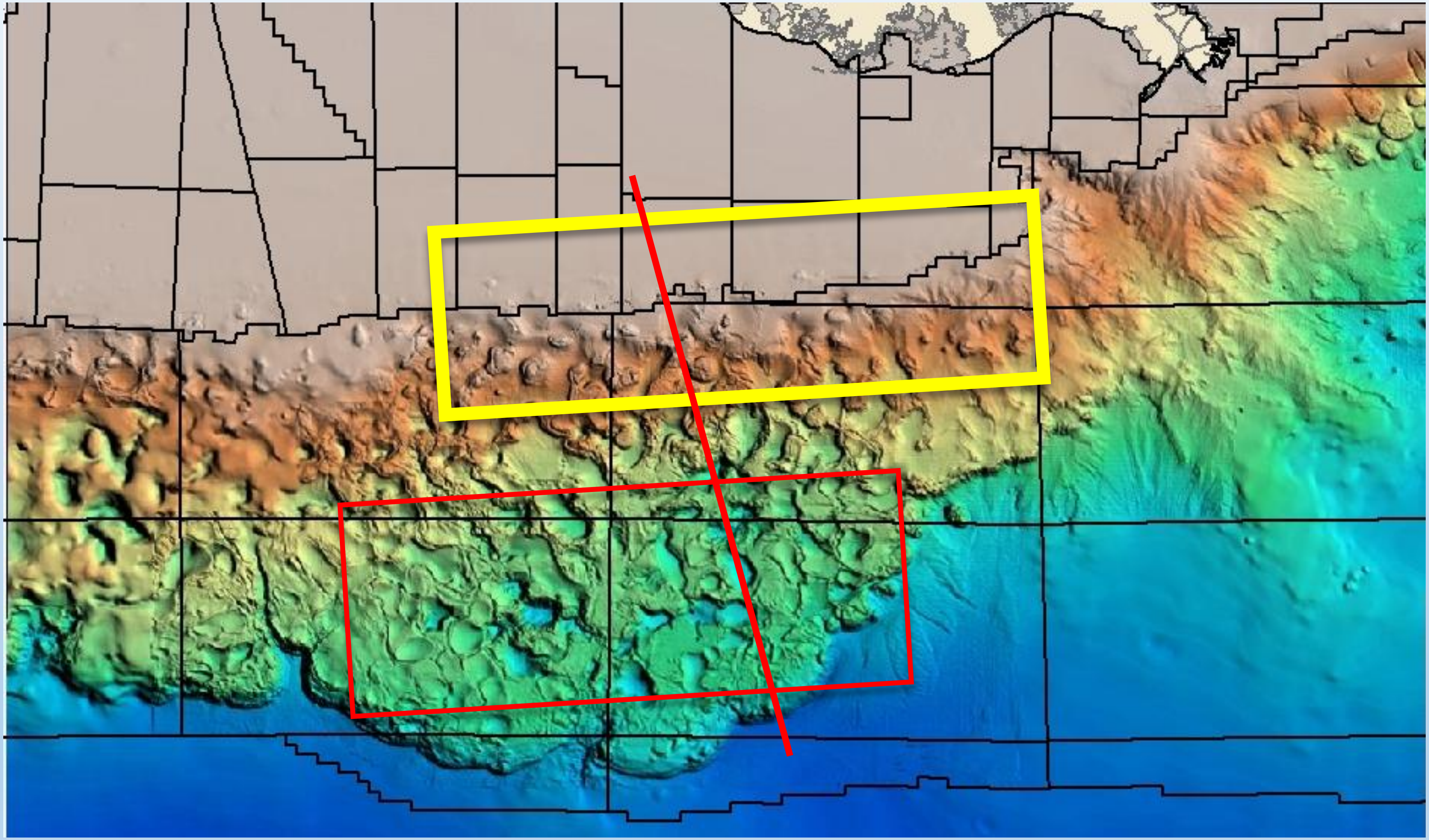
**Tarantula >15 MMBoe**
Discovered 2001
$1^{st}$ Prod 2004



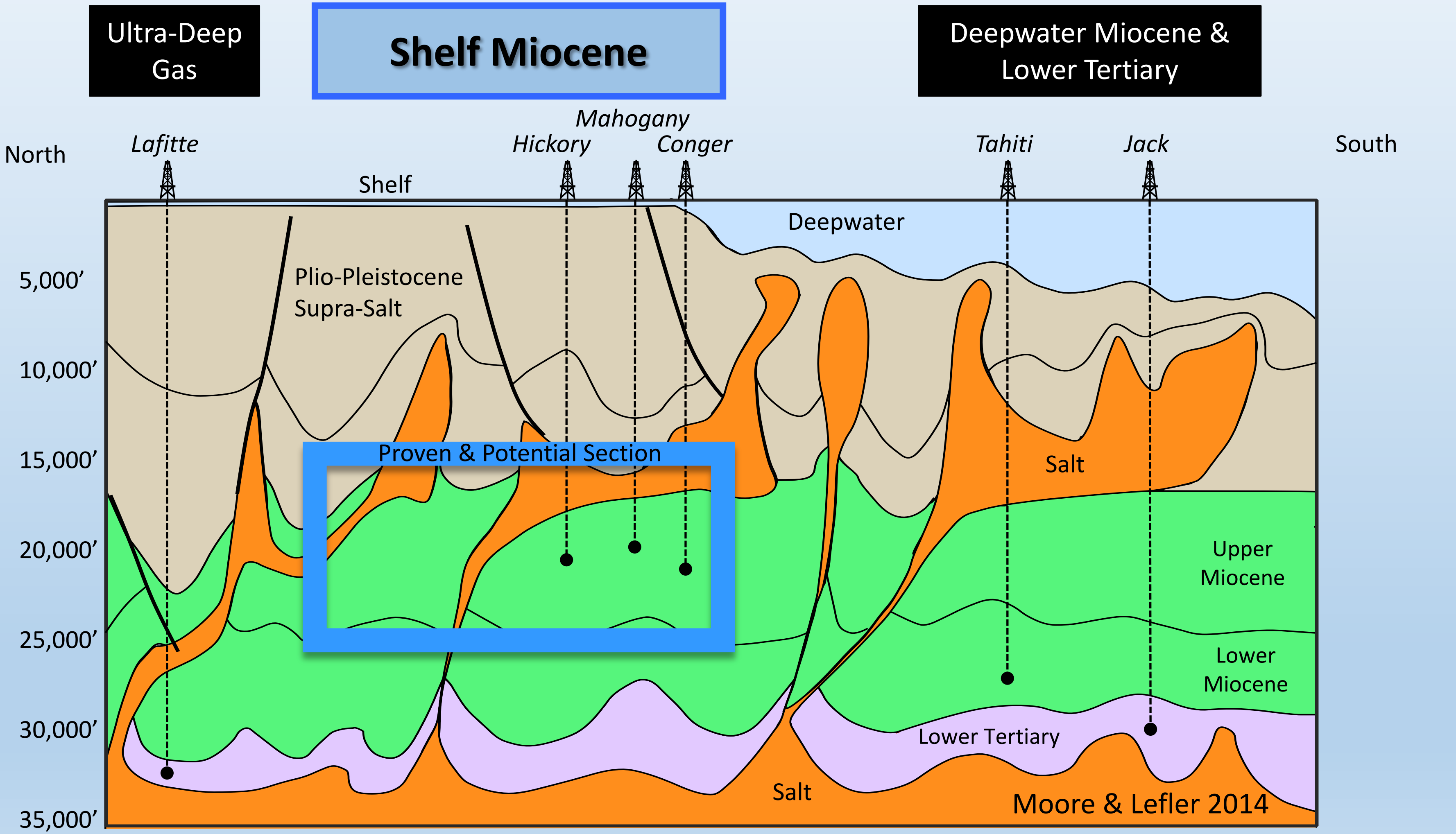
# Conger-Mahogany-Hickory Play Area



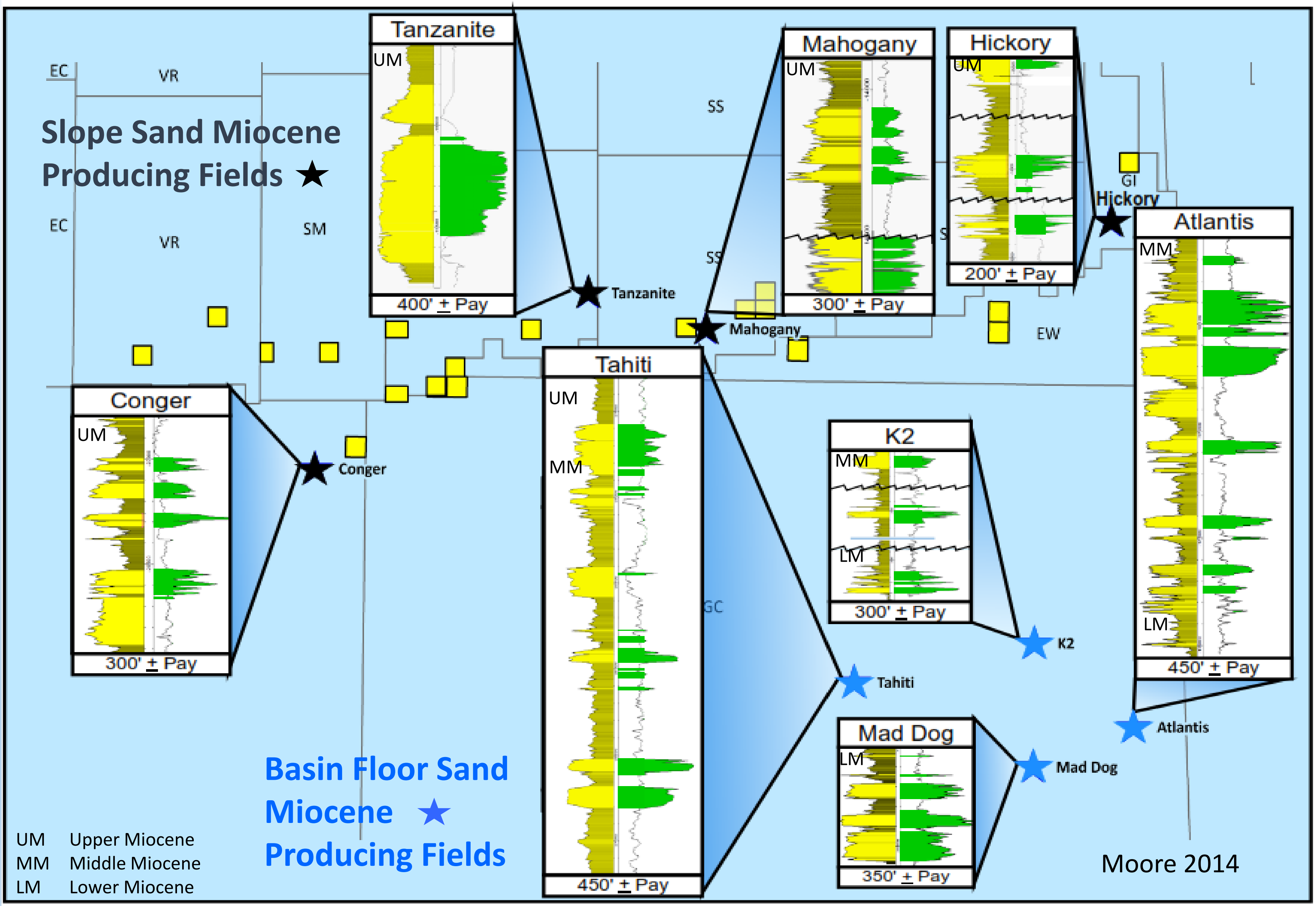
# Middle & Lower Slope Miocene Sand Area



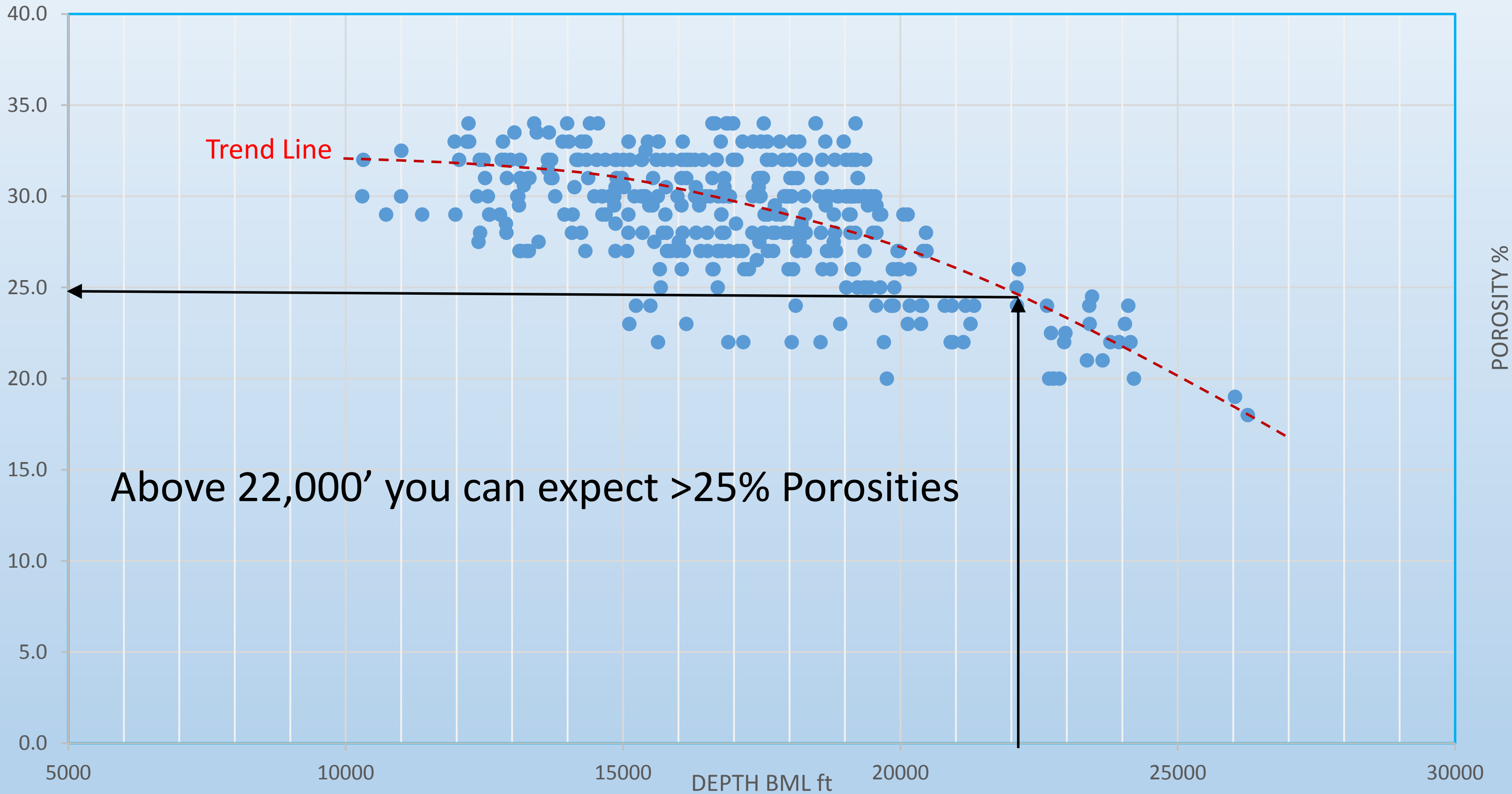
# Conger-Mahogany-Hickory Play Area



# Highly Productive Slope and Basin Floor Sands

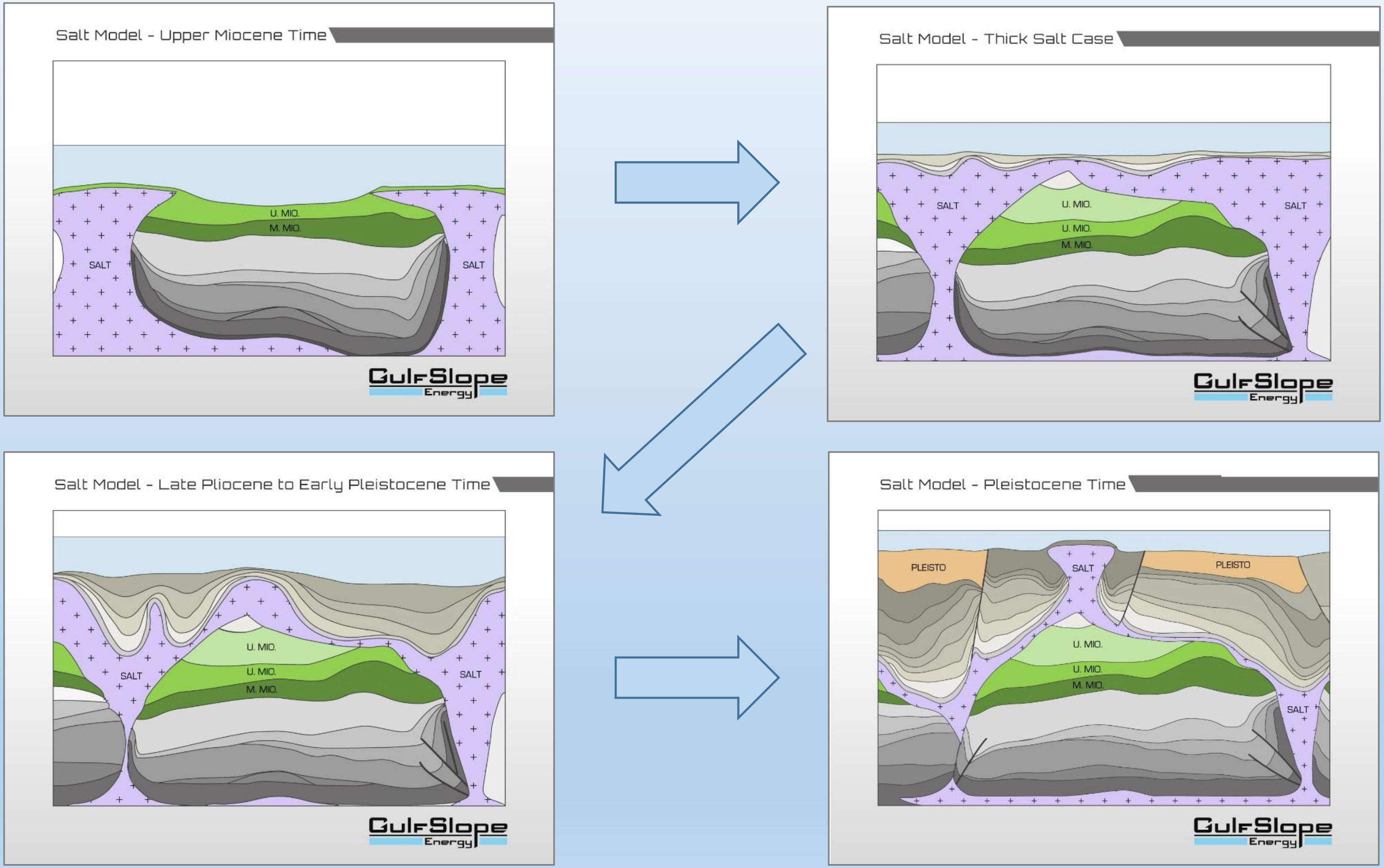


# Porosity vs Depth (BML) for Miocene Slope Sands




Lefler 2014

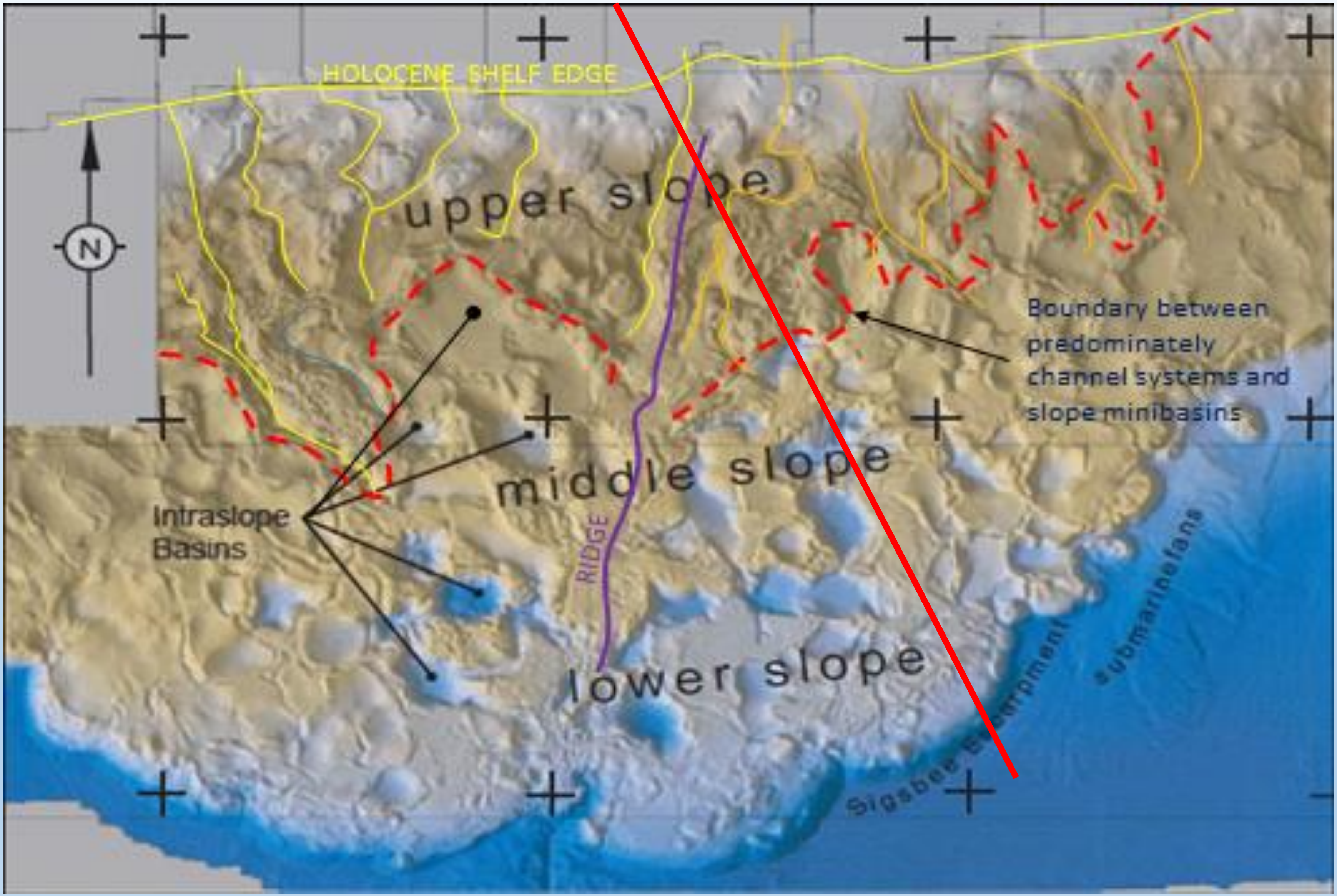
# Dynamic Salt & Sediment Model




Heaney 2014

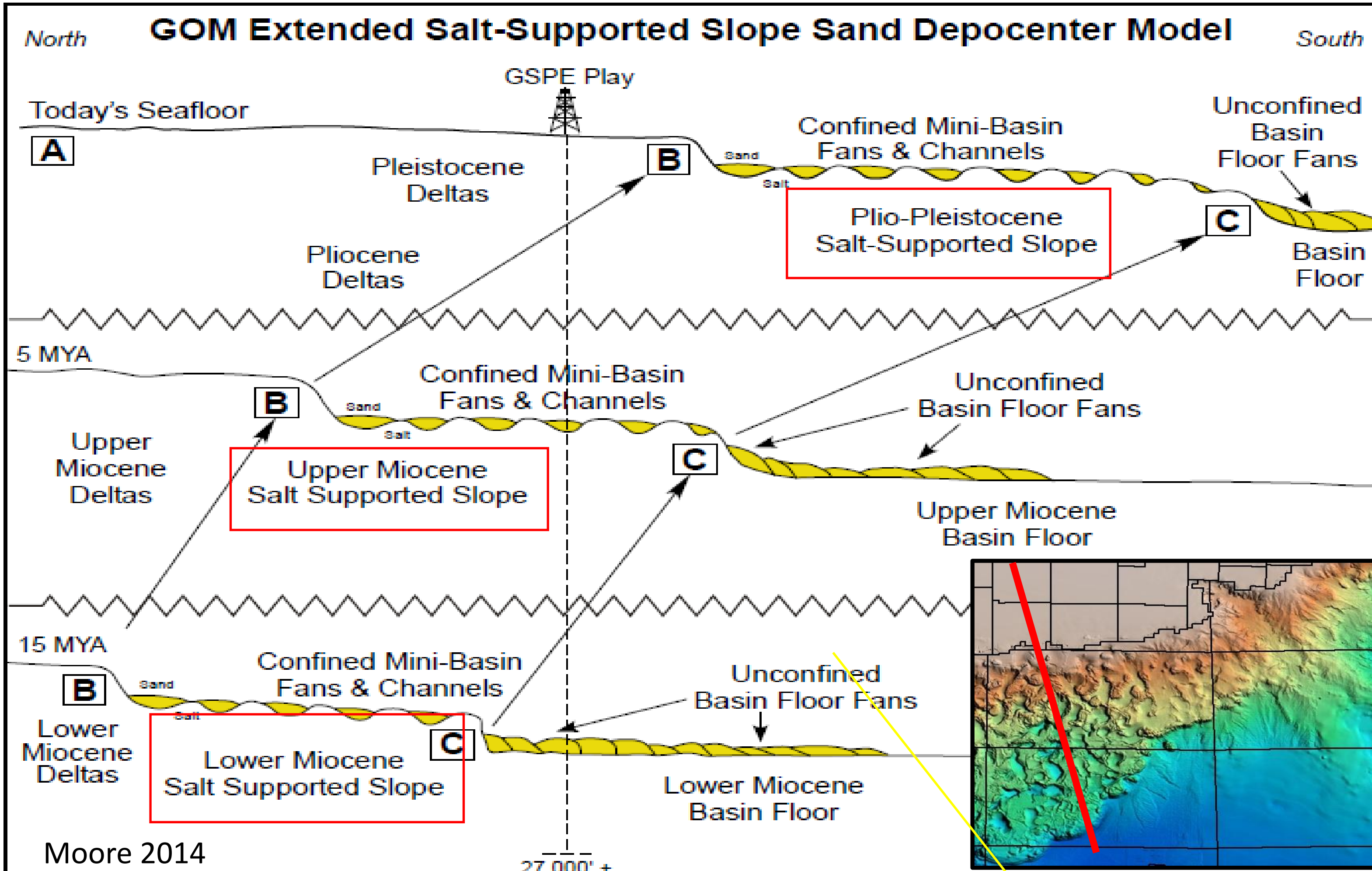
# Bathymetry of Modern Sea Floor *

## An Analog for sediment fed Intraslope Basins



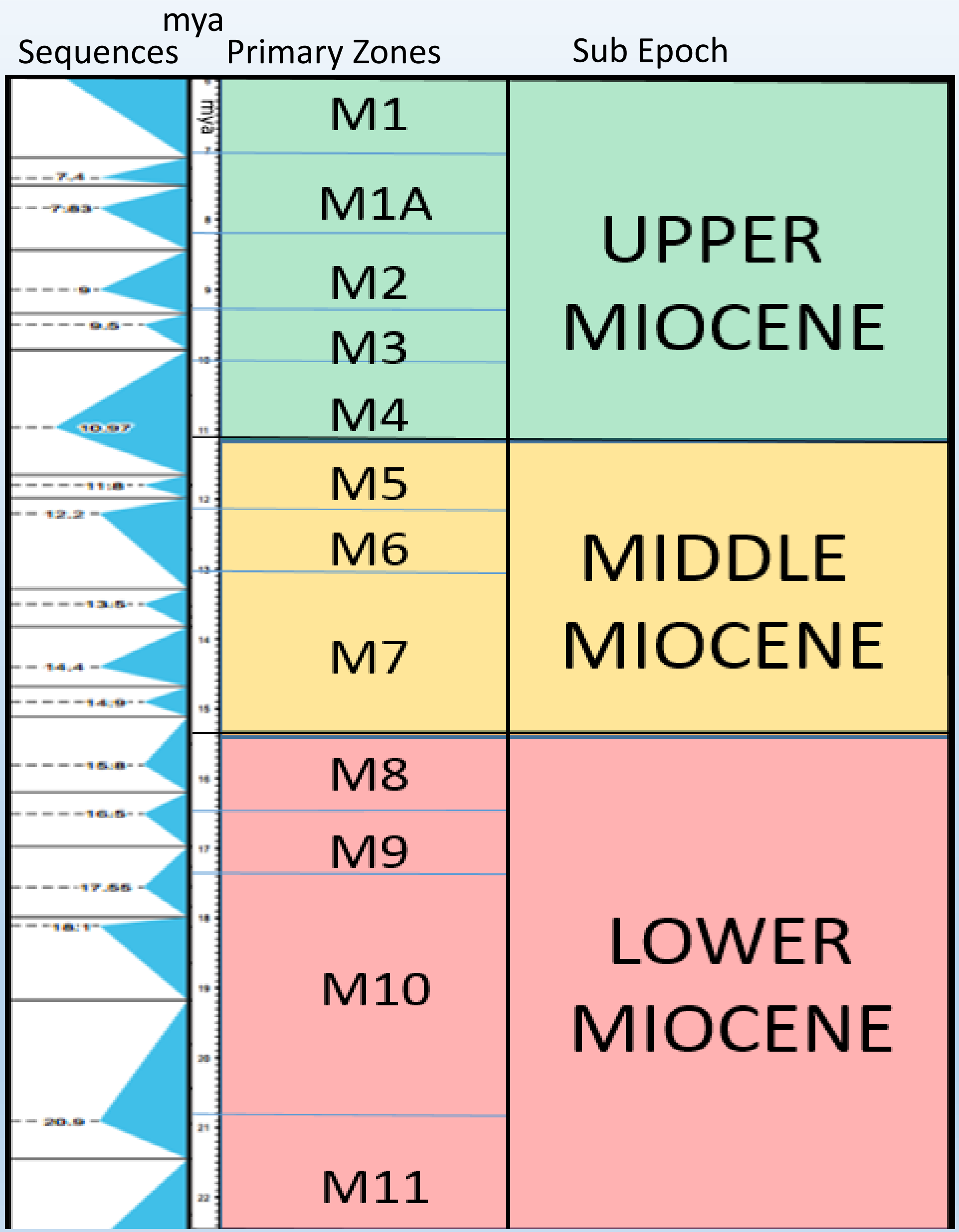

*Modified from Diegel et al., 1995, Prather et al., 1998

# Delta, Slope, & Basin Floor Prograde Seaward

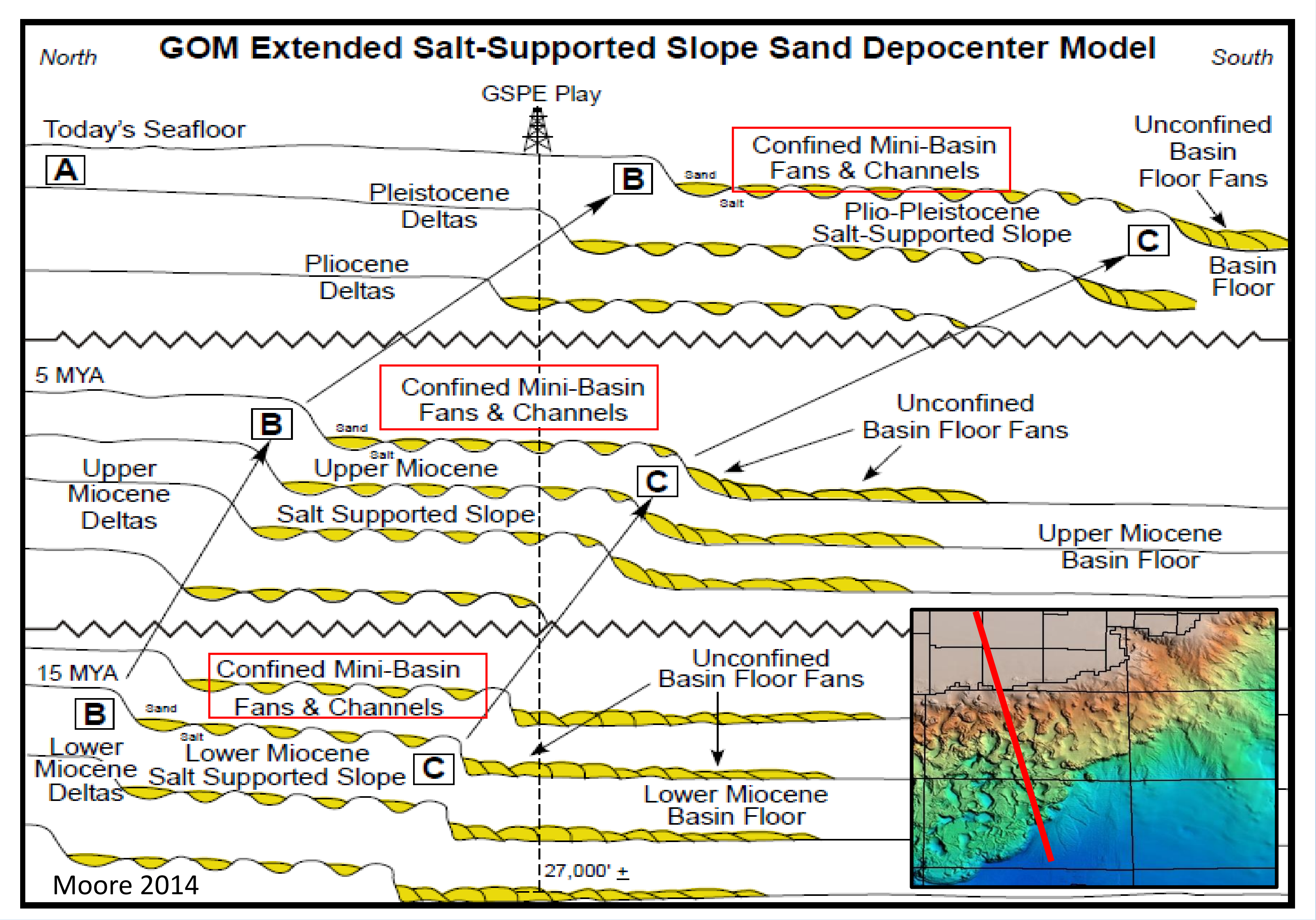



Moore 2014

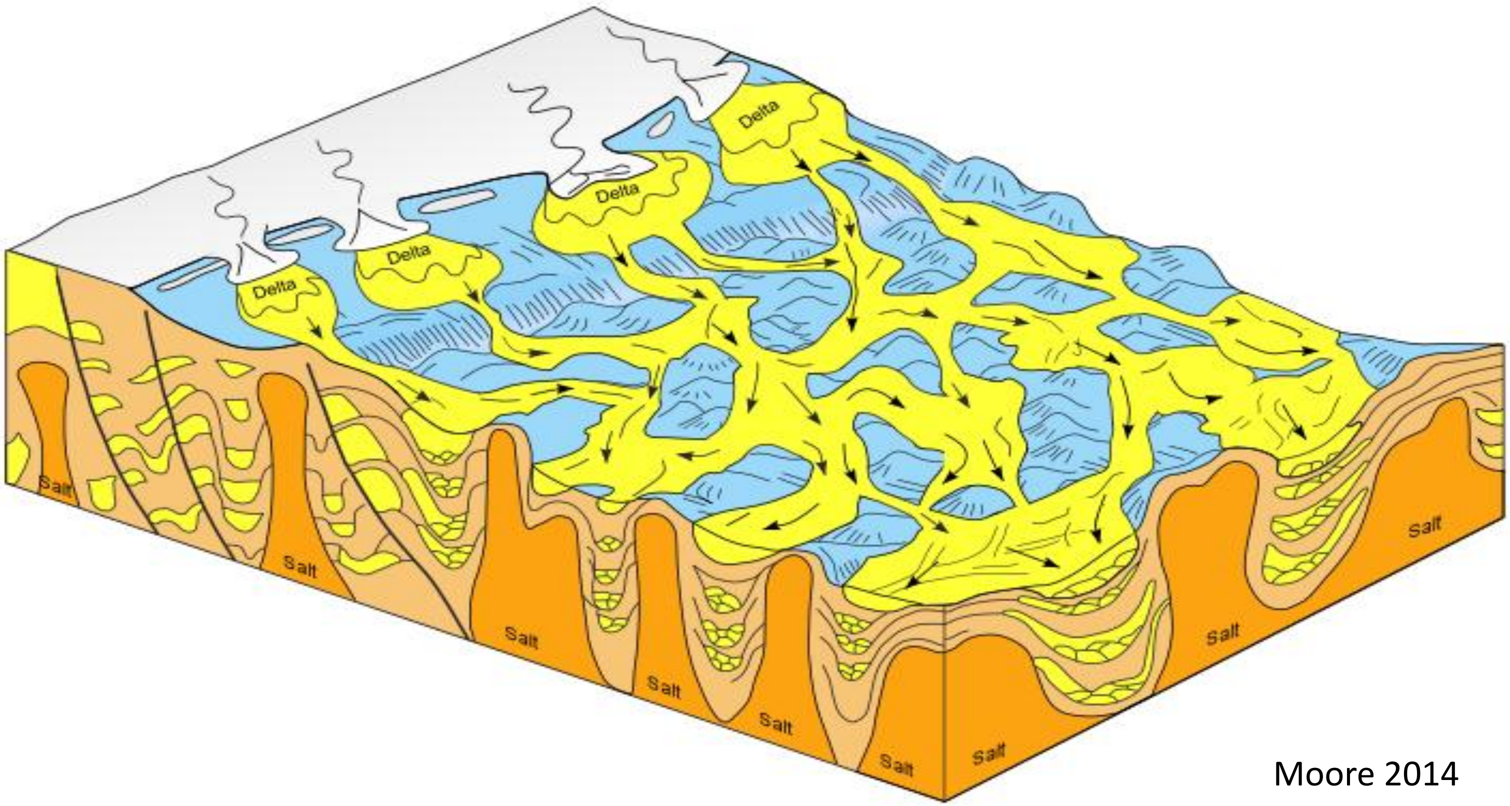
# 15+ Sequences - Lowstand Sand Potential



# 15+ Successive Lowstand Cycles in Miocene



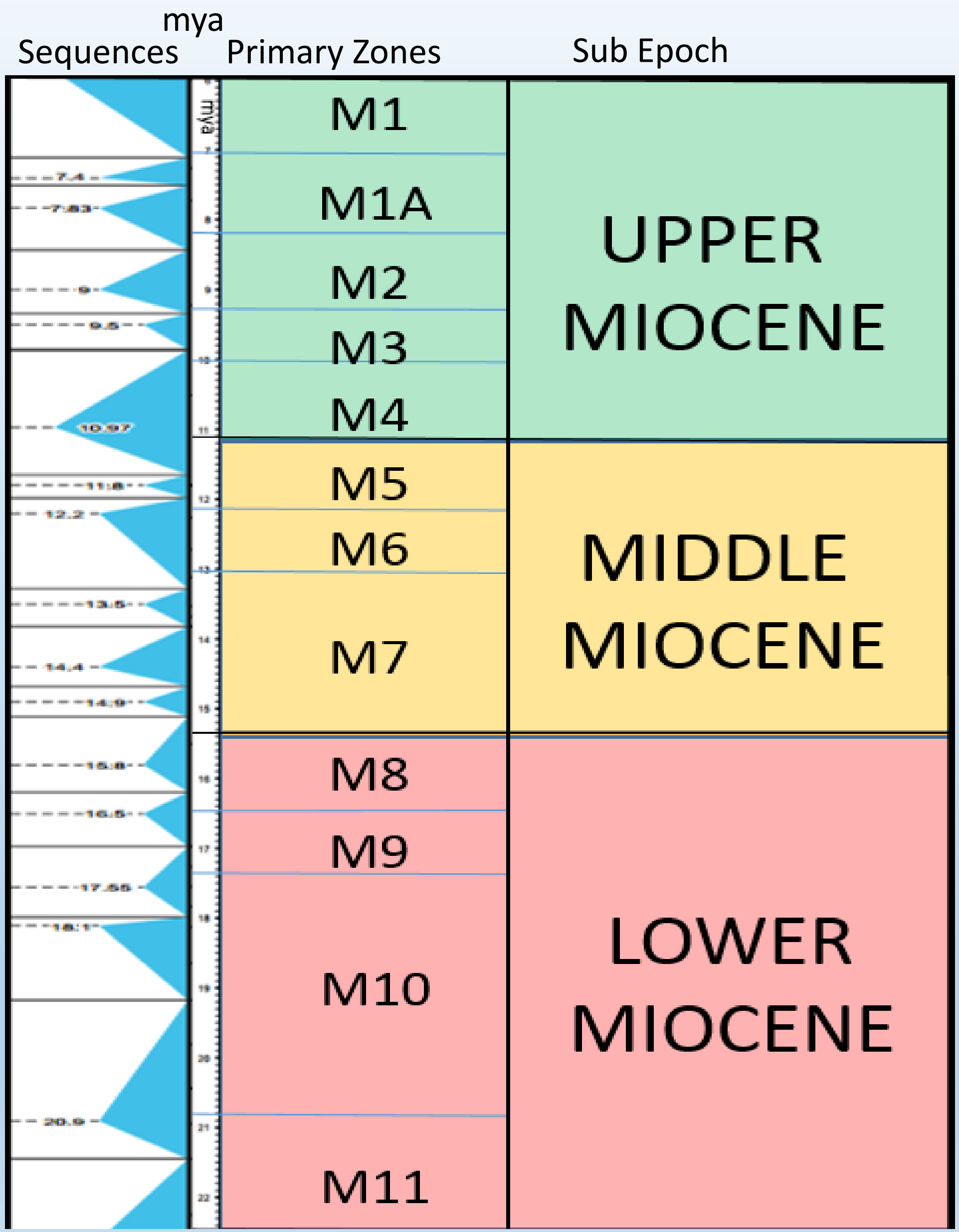
# Lowstand Deltas Fed the Salt-Supported Extended Slope, Creating Confined Mini-Basins with Amalgamated Fans & Channels



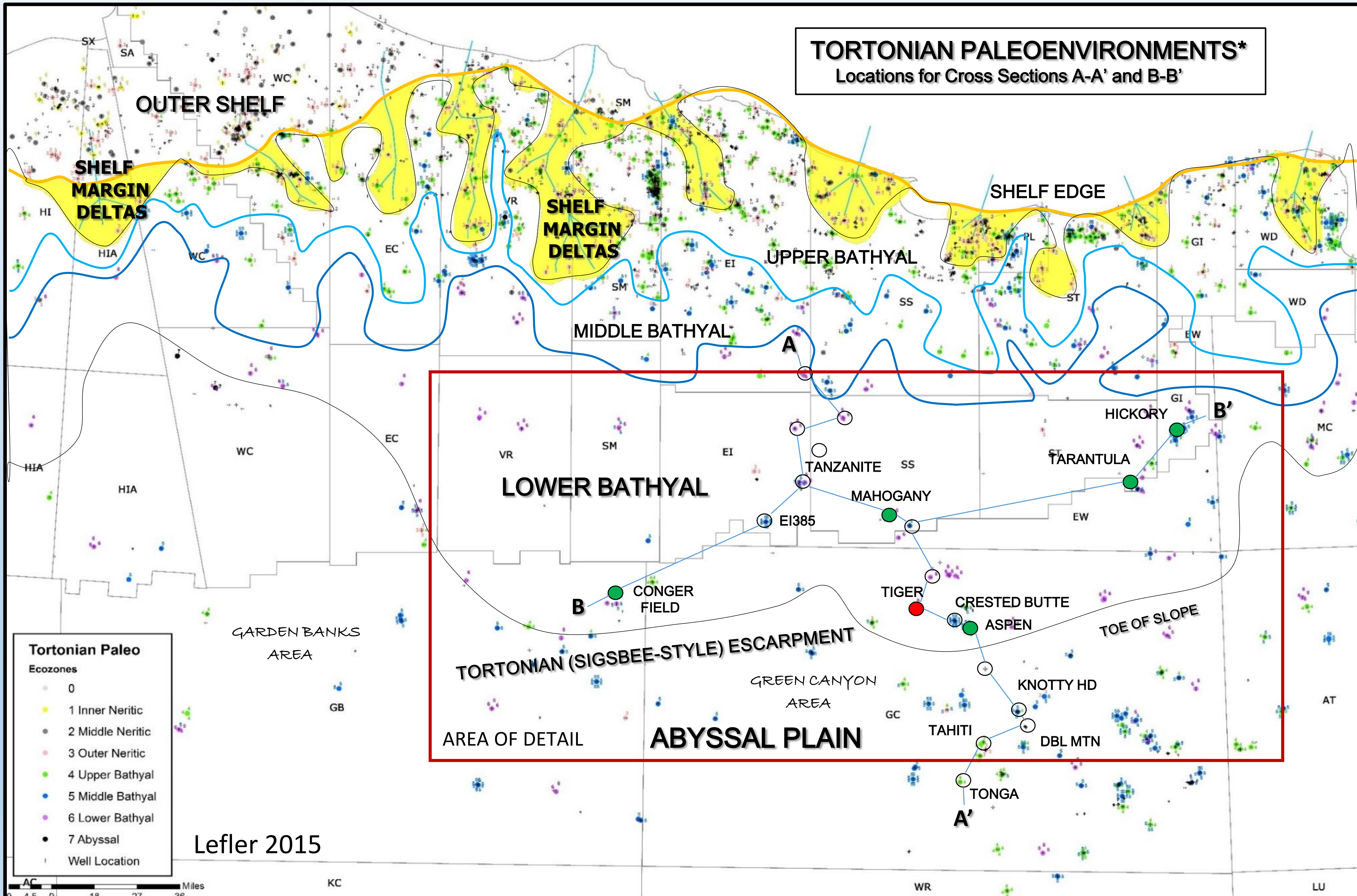

Moore 2014

# 15+ Sequences - Lowstand Sand Potential

**The 6+ LSTs of the Tortonian Stage**
7.0 – 11.6 MYA



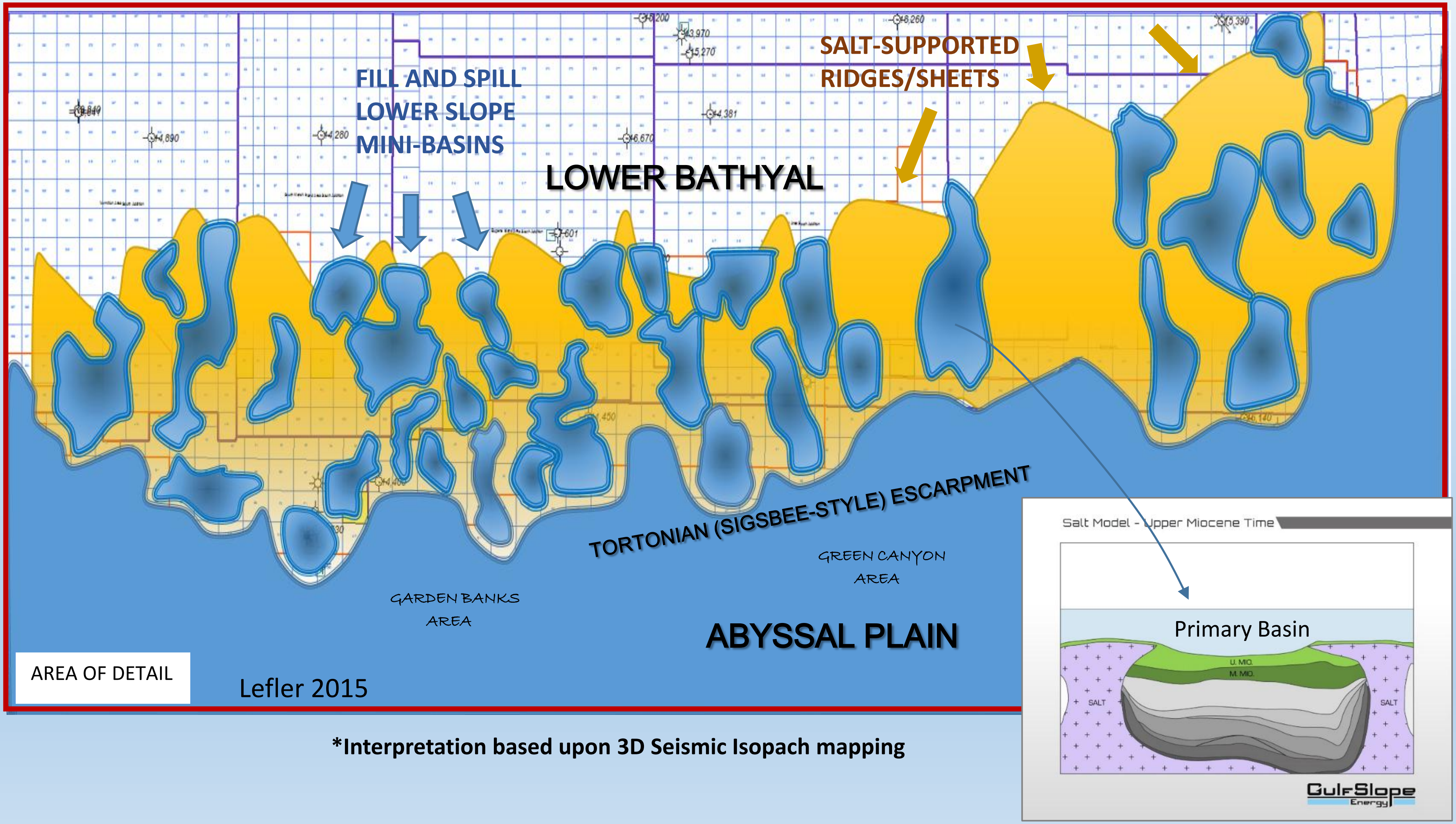
# Bathymetry of Upper Miocene "Tortonian" Stage




* Interpretation based upon BOEM Public Data

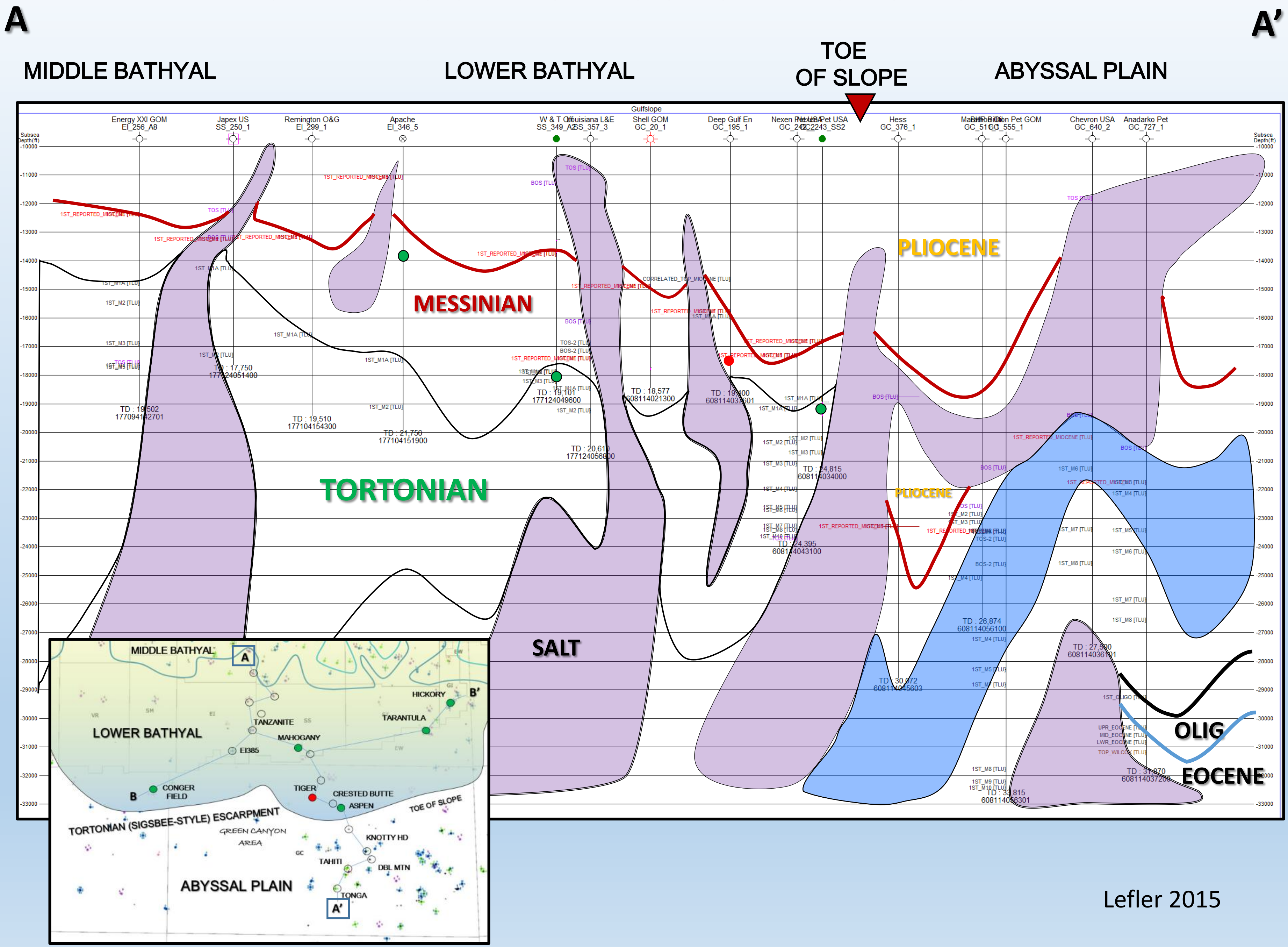
# Bathymetry of Upper Miocene "Tortonian"

## Showing Lower Slope Mini-Basins as "Primary Basins"*



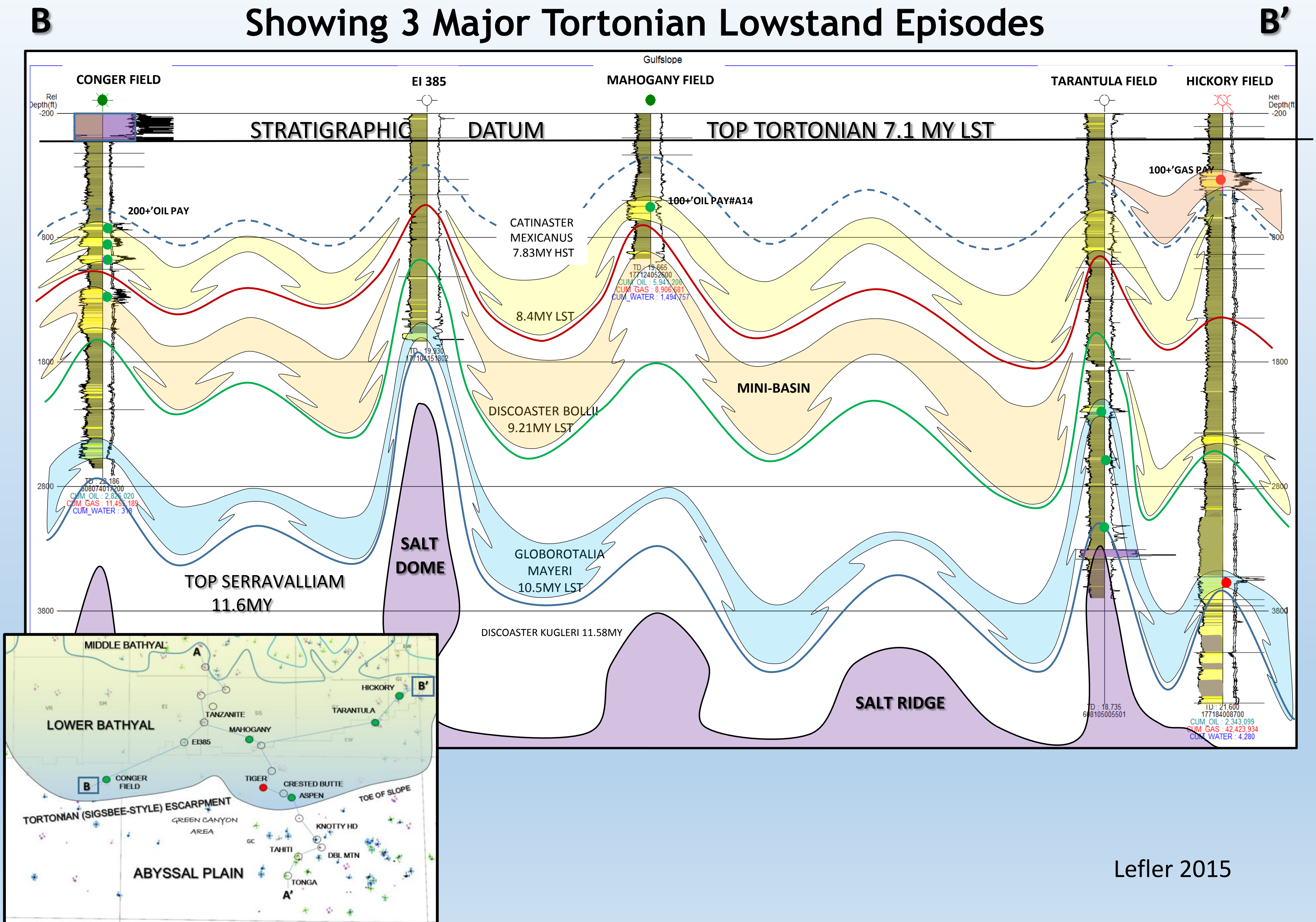

*Interpretation based upon 3D Seismic Isopach mapping

# NORTH-SOUTH STRUCTURAL SECTION



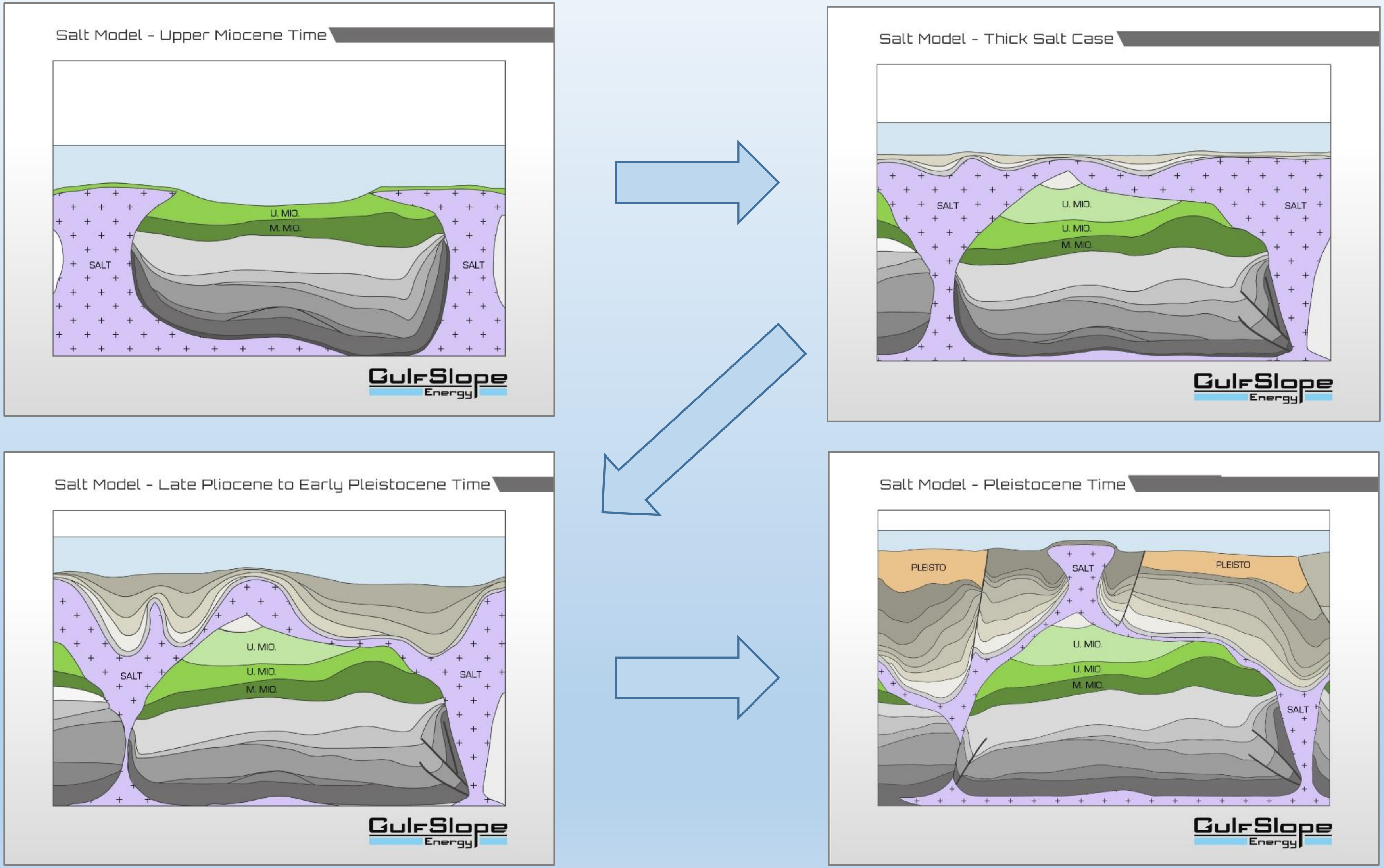

Lefler 2015

# WEST-EAST STRATIGRAPHIC SECTION
## Showing 3 Major Tortonian Lowstand Episodes



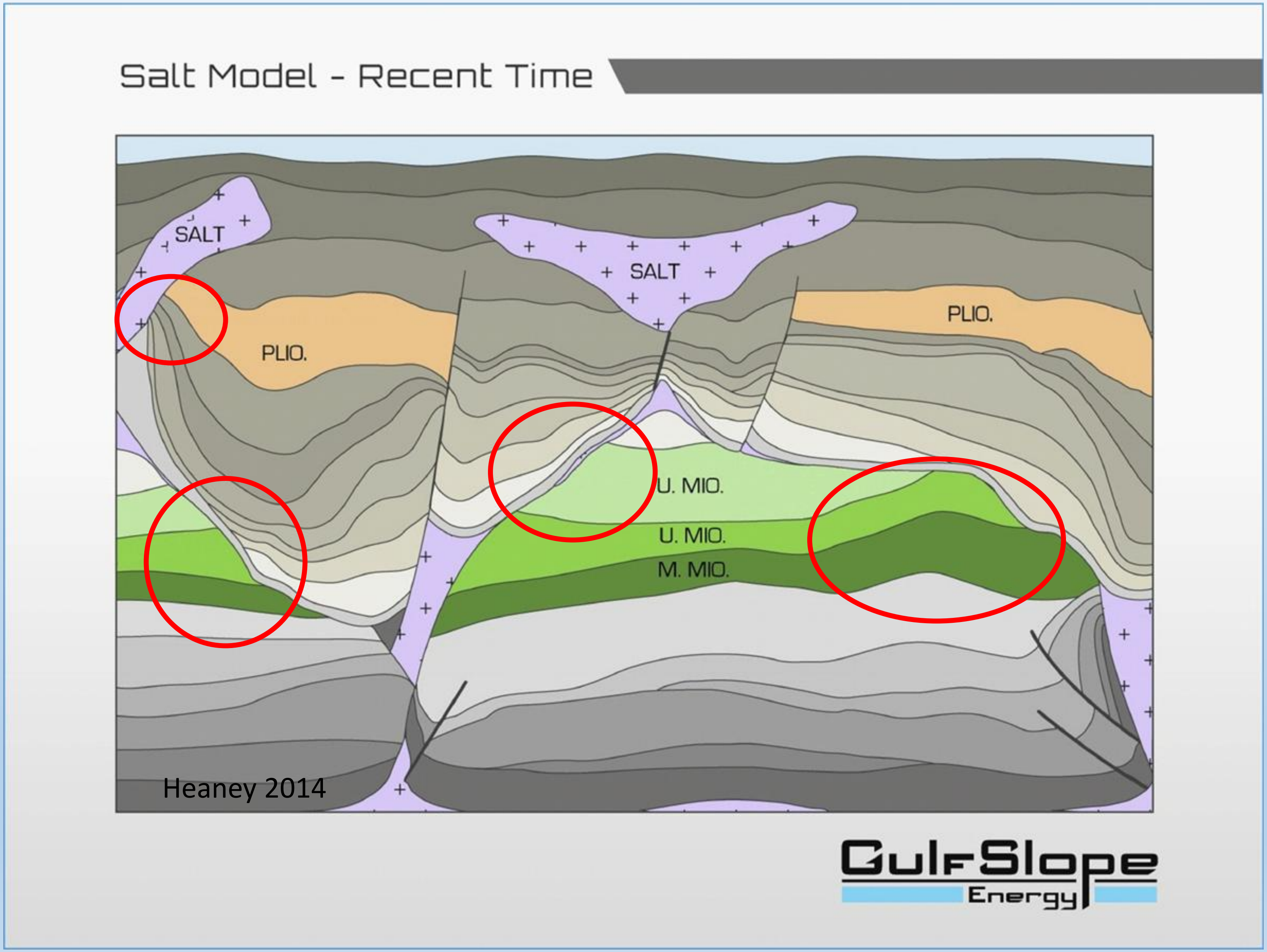

Lefler 2015

# Dynamic Salt & Sediment Model




Heaney 2014

# Trap Styles result from Salt & Sand Dynamics



# Conclusions

- **Lower slope sands are extensively deposited across the Miocene ancestral slope and are most commonly found as amalgamated fans and channels in confined mini-basins.**
- **Lower Slope Miocene sands have produced well in Conger-Mahogany-Tanzanite-Hickory reservoirs to date (350+ MMBOE produced – 400+ MMBOE EUR).**
- **GOM Miocene ancestral lower slope is NOT a "bypass" zone, but consists of widespread sand-filled confined mini-basins with sizeable untested field potential.**

## Geological & Geophysical Advantages

- Confined Mini-basin Fan Sands – Continuous Reservoirs
- Excellent Porosities – 25% to 30+%
- Key Fields – Conger, Mahogany Deep, Hickory, Tarantula, Aspen
- Proven Petroleum System – Reservoirs, Traps, Seals, Sources
- Advanced Seismic Processing (RTM+) Clarifes Sub-Salt Images

## Economic Advantages

- **Water Depths: 300-600’**
- Modern Drilling Technology below Salt
- Mostly Jack-up Rig Access - $70K/day - $20-40MM per Wildcat
- Mostly Conventional Platforms - $40-50 MM per Platform
- Extensive Existing Platform-Pipeline Infrastructure across Area

# Acknowledgements

The Authors would like to thank all their fellow members of the GulfSlope Energy Geoscience team, especially Sheila Wilkins Bruce.

We also gratefully acknowledge Petroleum Geo-Services ASA (PGS) for their permission to display their geophysical data in this presentation.