

# **Transgressive Events in the Lower and Middle Miocene of the Gulf of Thailand: Implications for Reservoir Characterization\***

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## **Abstract**

The lower to middle Miocene, late syn-rift to early post-rift, sandstone-dominant succession in the Gulf of Thailand hosts many important petroleum reservoirs and is traditionally viewed as nearly all fluvial deposits with minor estuarine sediments. However, recent studies indicate that marine strata are far more common than previously recognized. The succession includes shallow marine shale and relatively common, thin “coals” previously interpreted as floodplain swamp deposits and used extensively for stratigraphic correlation based on their wireline log signatures. Conventional cores from 9 wells across 200 km of the Pattani Basin integrated with biostratigraphic and petrographic data, indicate that the “coals” actually comprise three distinct facies, two of which are marine. Based on well log to core calibration plus log correlation of 157 wells, each of the three facies also has a different wireline signature and areal distribution. Shallow marine coaly mudstones are 0.6 - 5.0 m thick, laminated clayey siltstones with interbedded thin coals. They have gradational contacts with various adjacent tide-dominant sandy facies and burrows, organic matter and inner neritic foraminifera are common. Their log signature features low resistivity and moderately high-density values that can be correlated regionally. The third coaly facies is non-marine coaly mudstones, which are 0.2 - 0.6 m thick that have gradational upper and lower contacts with floodplain deposits. Plant debris is abundant and thin coal beds are common.

The geographic and stratigraphic distribution of the coaly mudstones indicates that there were multiple minor transgressive events, plus at least two significant marine transgressions, within the fluvial-dominant lower and middle Miocene succession. Many of the sandstones stratigraphically adjacent to the shallow marine and marginal marine coaly mudstones are tide-dominant or strongly tide-influenced, which affects reservoir characterization significantly because the tidal sand bodies are smaller with very different geometries from fluvial sandstones, and porosity and permeability generally are lower in the tidal sandstones. Many of the transgressive successions include abundant fining-upward, stacked channel sandstones previously interpreted as braided stream, meandering river or distributary successions. The sedimentary character of the channel fill varies considerably; some feature increasingly marine conditions upward from near their base while others have only minor marine influence near the top of the channel sand, although all become finer-grained and exhibit increasingly lower-energy sedimentary structures upward. Near the paleo-shoreline, distributaries were filled with a strongly marine succession that is similar to

progradational tidal point bar successions except that marine influence increases upward. Further upstream, marine indicators first appear much higher in the succession and the stratigraphic column closely resembles fining-upward fluvial point bar successions deposited by meandering rivers.

Proximal channel-fill successions exhibit much less fining-upward and resemble braided stream deposits. They can include relatively fine sandstones that look like sandy braided stream deposits except they have minor marine influence and grade laterally upstream into coarse, often pebbly sandstones with minimal, if any, marine influence. Accurate reservoir characterization requires careful determination of the depositional

### **Selected References**

Jardine, E., 1997, Dual Petroleum Systems Governing the Prolific Pattani Basin, Offshore Thailand: Proceedings of the International Conference on Stratigraphic and Tectonic Evolution of Southeast Asia and the South Pacific (Geothai'97), 19-24 August 1997, Department of Mineral Resources, Bangkok, p. 525-534.

Turner, R.E., J.J. Baustian, E.M. Swenson, and J.S. Spicer, 2006, Wetland Sedimentation from Hurricanes Katrina and Rita: Science, v. 314/5798, p. 449-452.

# **Transgressive Events in the Lower and Middle Miocene of the Gulf of Thailand: Implications for Reservoir Characterization**

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Chulalongkorn University*

# *Transgressive Events*

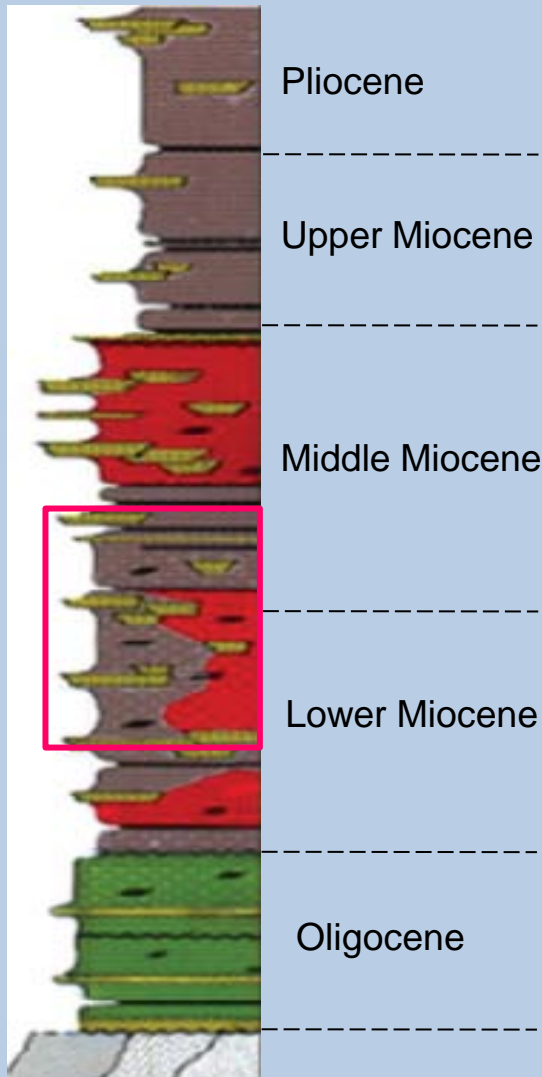
- Thin units deposited during short-lived transgressions are common in the lower Miocene and younger succession
- Two lines of evidence:
  1. Lower to middle Miocene marine and marginal marine coaly mudstones in Pattani Basin
  2. Sand-filled channels with marine influence of various ages in different basins around the Gulf of Thailand

# Marginal Marine Coaly Mudstones

(based on M.Sc. research projects by Khun Jittikan Narapan,  
Khun Patcharaporn Champasa and Khun Jirach Kamvan)

## Gulf of Thailand Stratigraphy

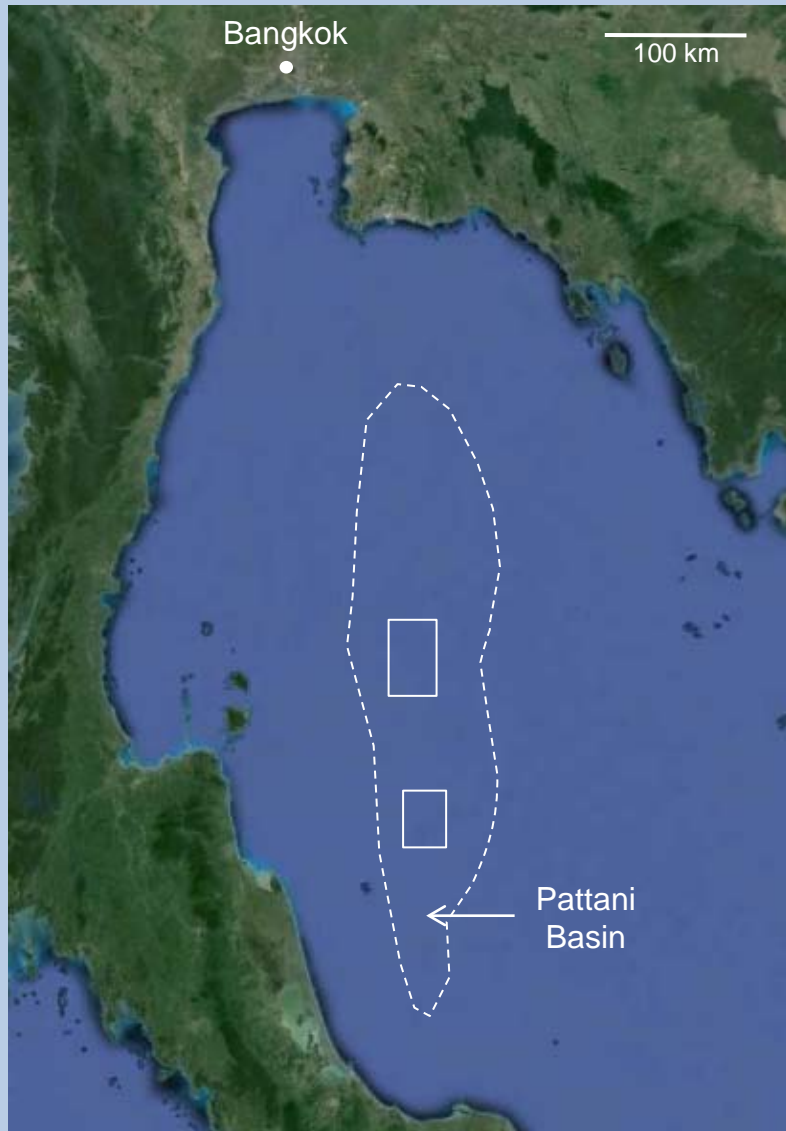
(after Jardine 1997)



## *Stratigraphic Interval*

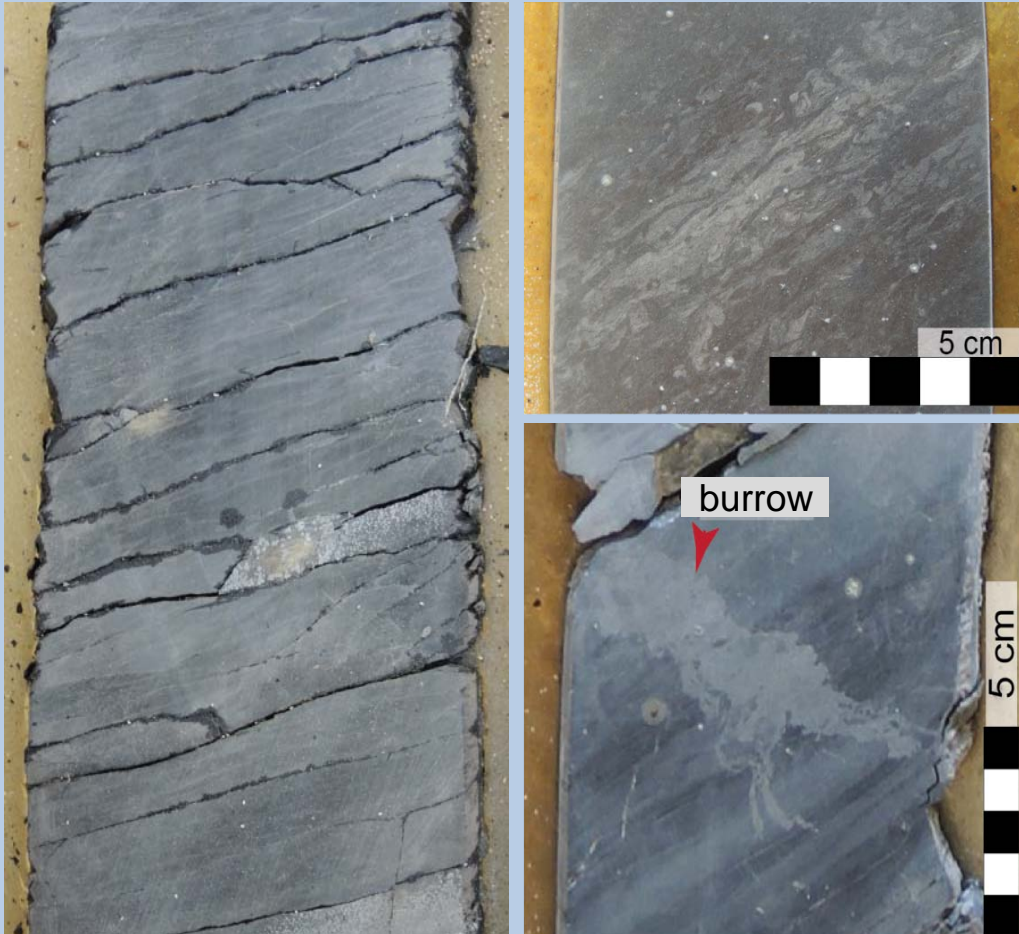
- Lower to middle Miocene, late syn-rift to early post-rift, sand-dominant succession
- Economically significant as it includes important petroleum reservoirs
- Traditionally interpreted as mostly fluvial sediments with minor estuarine deposits
- Includes relatively common, thin "coals" regarded as floodplain swamp deposits
- "Coals" used for stratigraphic correlation based on wireline log signature

# *Study Area and Database*



- Northern and southern areas within Pattani Basin
- Conventional cores from 9 wells
- Wireline logs from 157 wells
- Integrated with biostratigraphic and petrographic data
- "Coals" comprise three distinct facies of coaly mudstone
- Each facies has a different wireline log signature

# *Shallow Marine Coaly Mudstone*

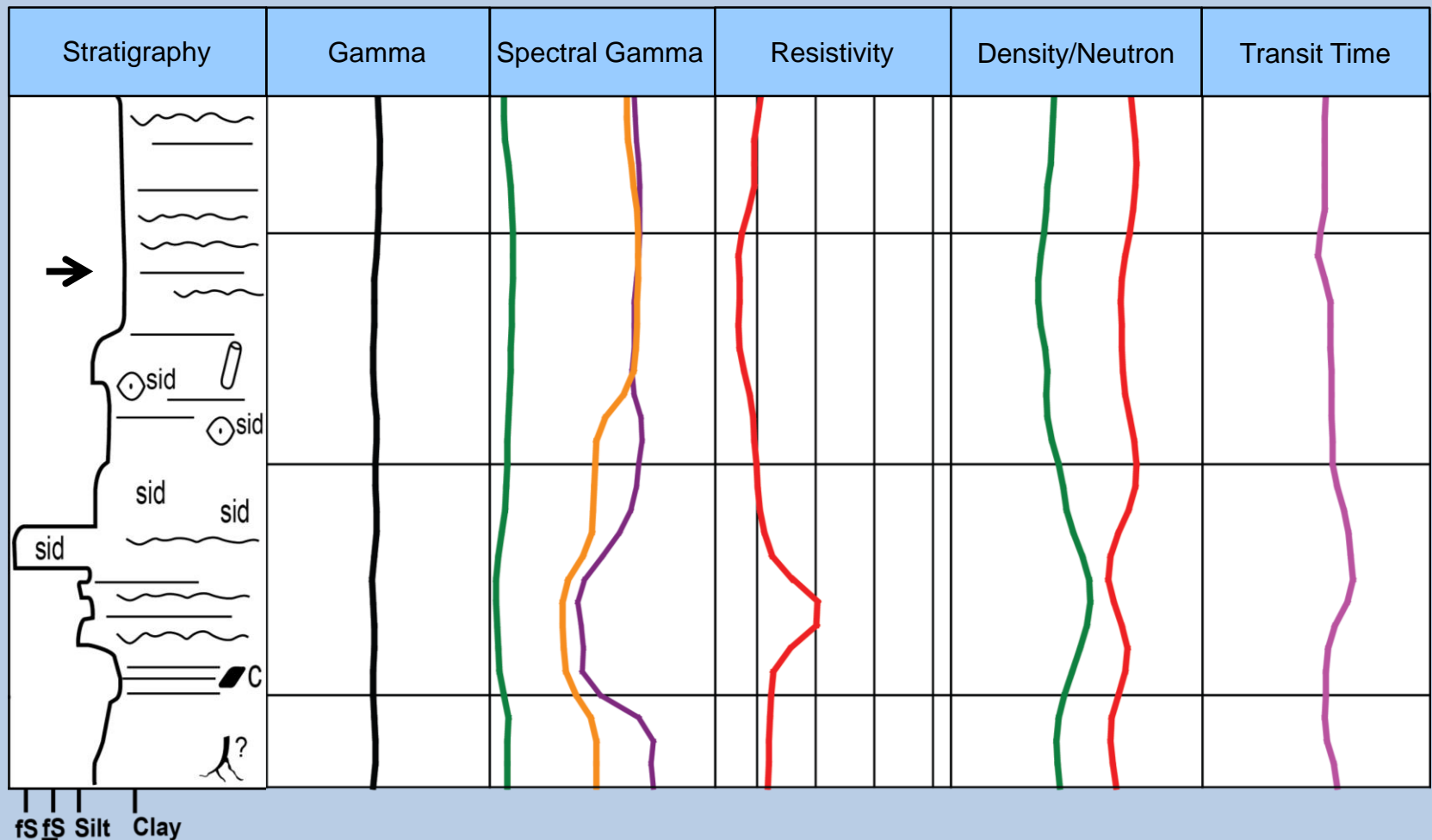


- 0.6 - 5.0 m thick laminated clayey siltstones
- Interbedded thin coals and coaly mudstones
- Burrows and organic matter are common
- Inner neritic foraminifera
- Gradational contacts with tidal sandstones

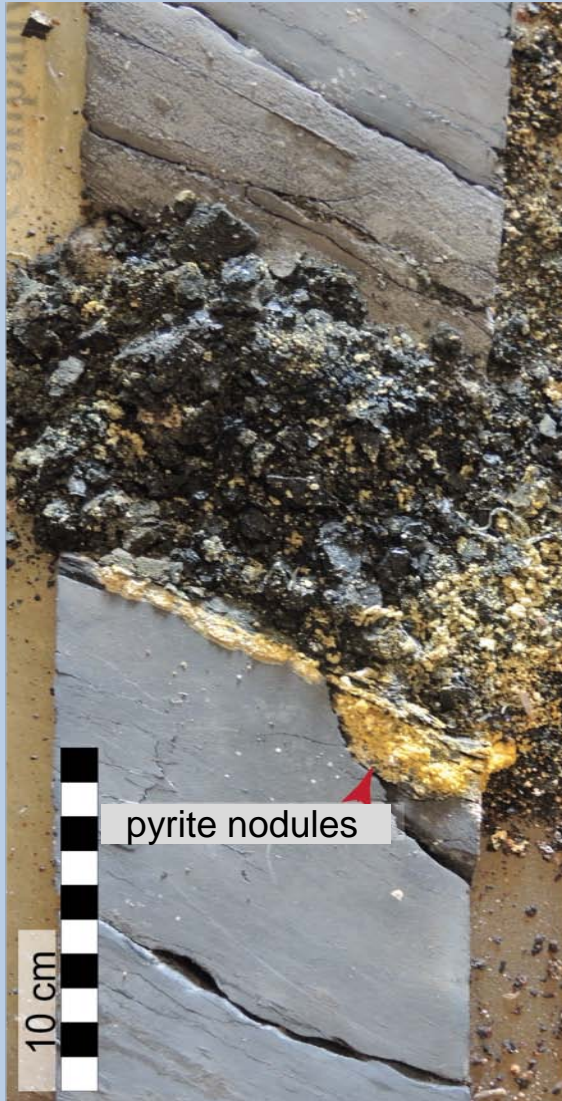


# Shallow Marine Coaly Mudstone Log Signature

- Low resistivity and moderately high density
- Can be easily correlated
- Good regional markers



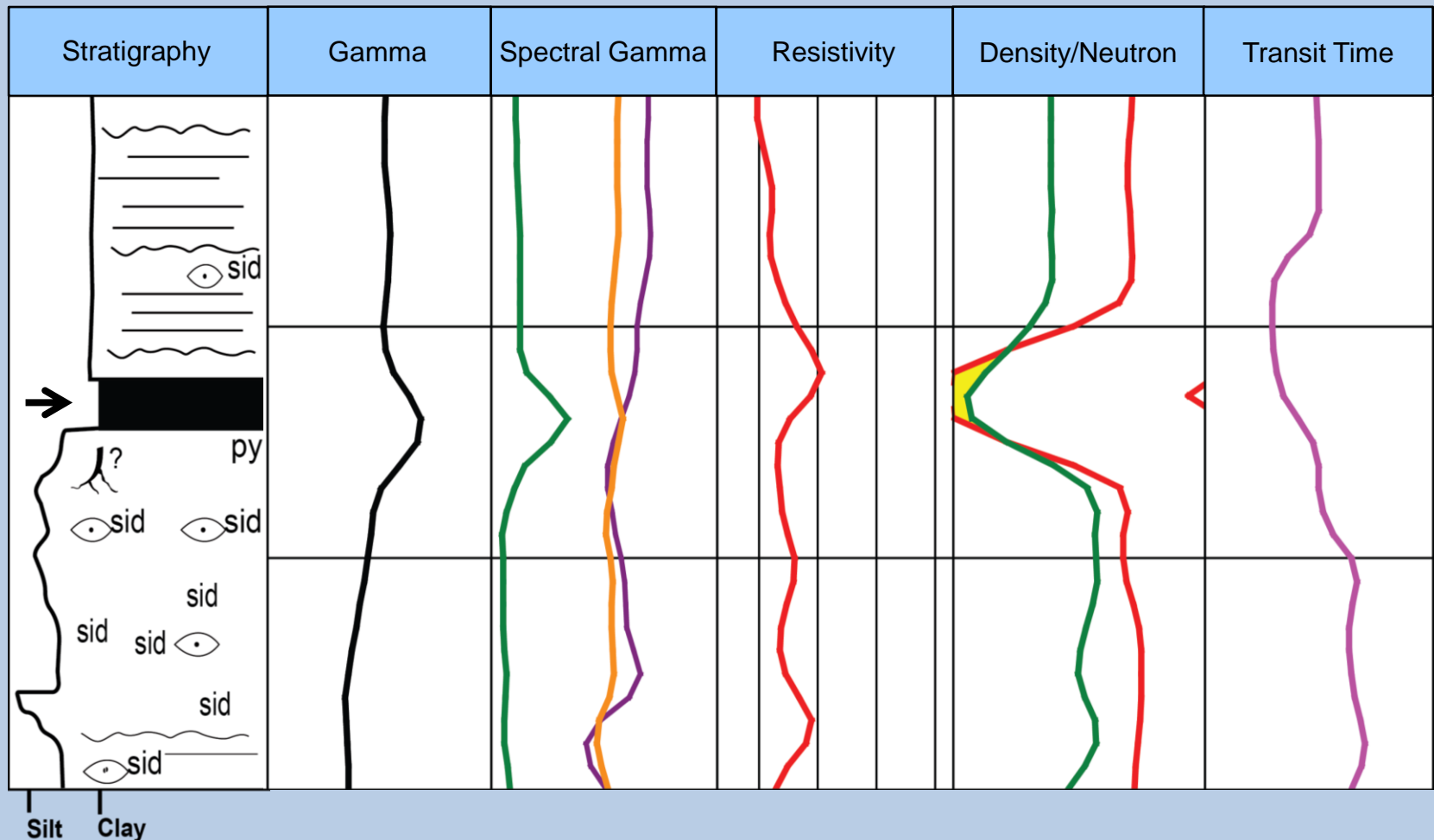
# *Marginal Marine Coaly Mudstone*



- 0.3 - 1.1 m thick interbedded mudstones and coals
- Abundant pyrite nodules
- Gradational contacts with tidal sandstone and/or estuarine deposits

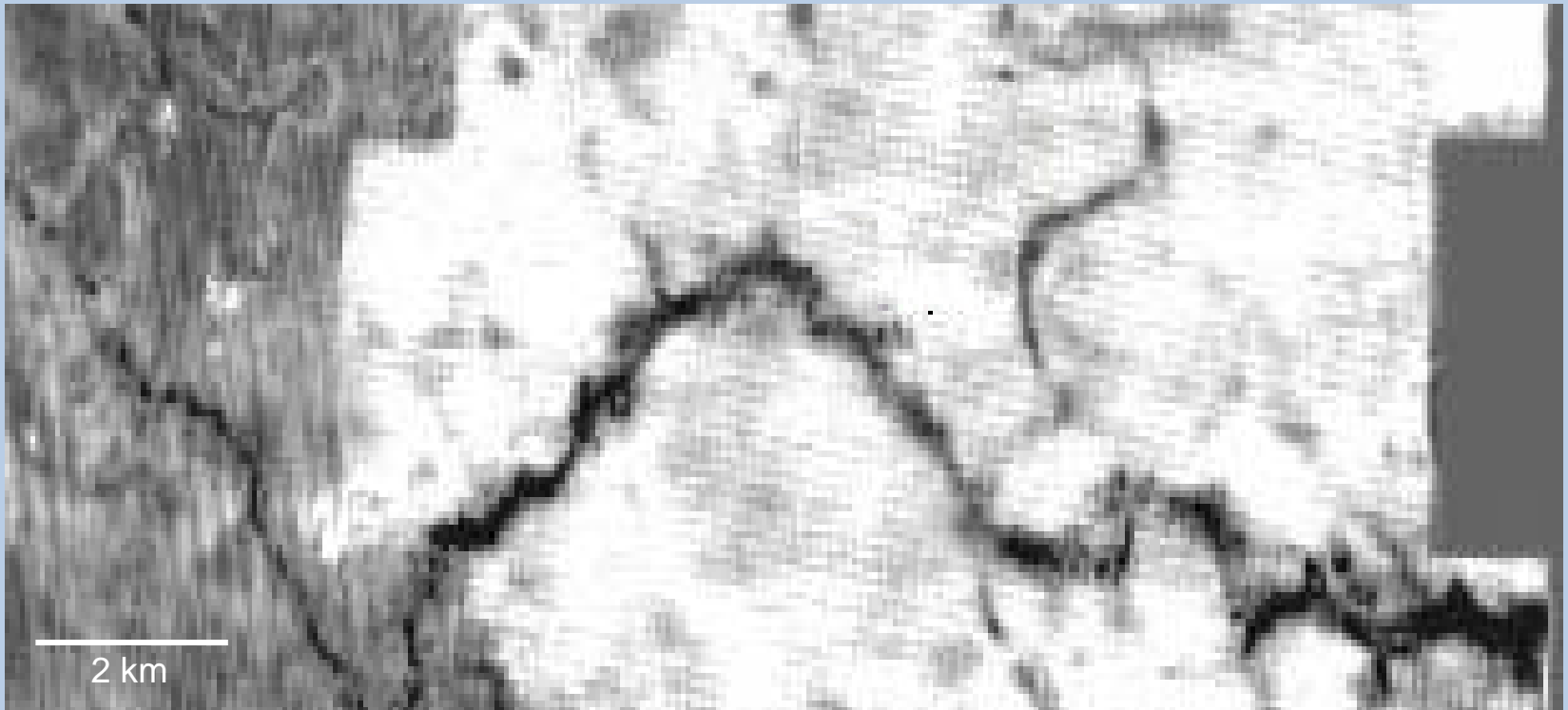
# Marginal Marine Coaly Mudstone Log Signature

- Distinctive high gamma ray (especially high uranium)
- Spiky transit time curves
- Easily correlated but not regionally extensive



# *Early Miocene Estuary*

- Drowned fluvial channel
- Decreased sinuosity
- Tidal scouring
- Flared mouth



(after Firmansyah 2011)

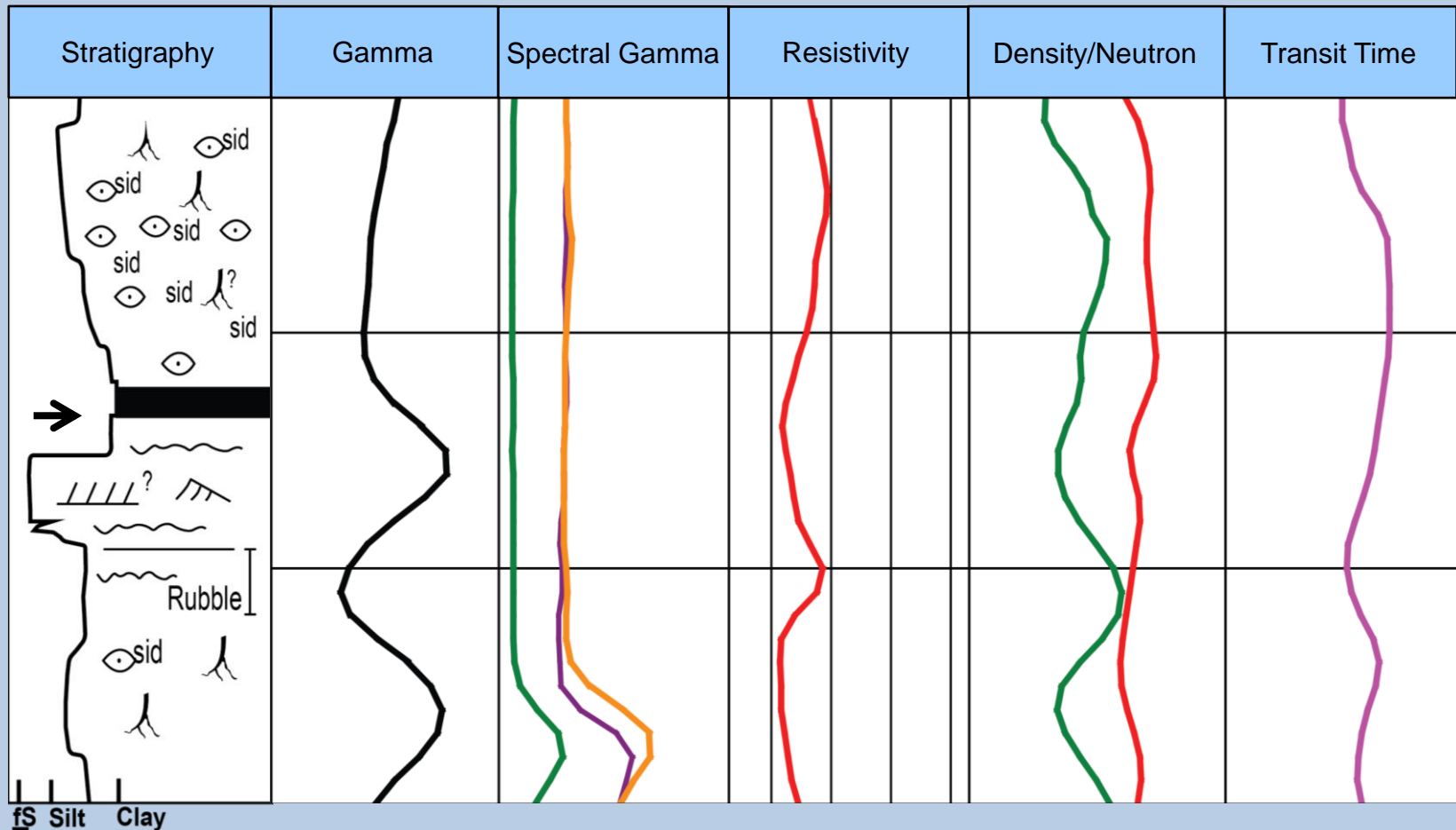
# *Non-Marine Coaly Mudstone*



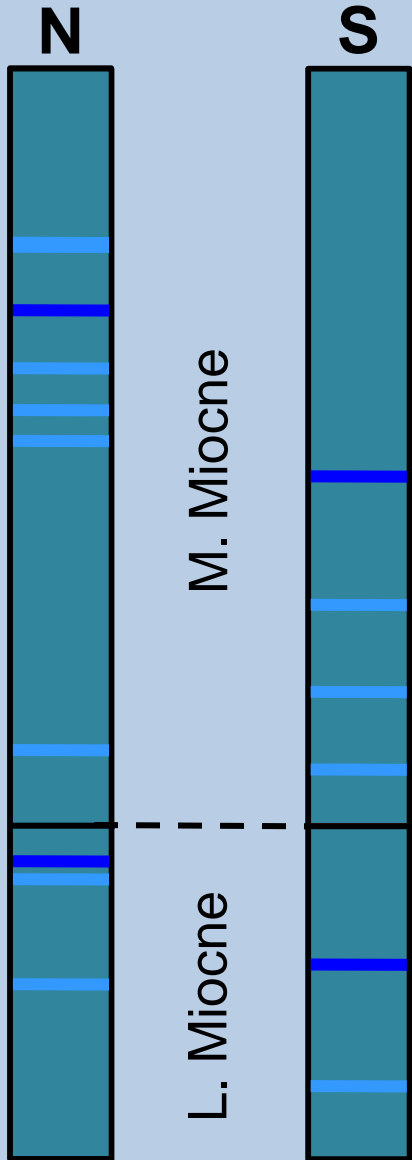
- 0.2 - 0.6 m thick mudstone
- Abundant plant debris
- Thin coal beds common
- Gradational contacts with floodplain mudstones

# *Non-Marine Coaly Mudstone Log Signature*

- Bed thickness is often below wireline log resolution
- Very similar to floodplain mudstones
- Difficult to identify and correlate



## Stratigraphic Abundance



- Available cores do not provide complete stratigraphic coverage
- Supplemented with wireline log correlation
- Marine strata are much more common than previously recognized
- At least 9 transgressive events in the northern study area and 6 in the south
- Several transgressions in the supposedly all non-marine lower Miocene
- At least one significant marine transgression in the late lower Miocene and another in the middle Miocene
- Abundance underestimated because wells are drilled on structural highs



# *Lower Miocene Transgression*



- Shallow marine coaly mudstone in the south
- Shallow marine coaly mudstone and marginal marine coaly mudstone in the north
- Up to 6 m thick in the north and 8 m thick in the south



# *Middle Miocene Transgression*



- Extended across most of Pattani Basin
- Shallow marine coaly mudstone in the north and south
- Up to 8 m thick in the south and 6 m thick in the north

# *Implications for Stratigraphic Development*



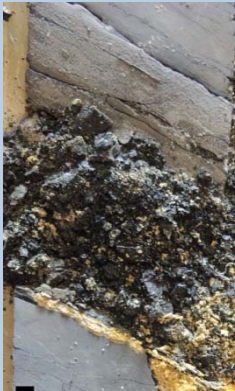
- Relatively thin transgressive successions are common
- They reflect minor, short-lived transgressions
- There may be several other significant transgressions that remain unrecognized
- Some may have effected the entire Gulf of Thailand from the late Oligocene onward

# *Implications for Well Correlation*



## Shallow Marine Coaly Mudstone

- Widely distributed and easy to correlate
- Good regional markers



## Marginal Marine Coaly Mudstone

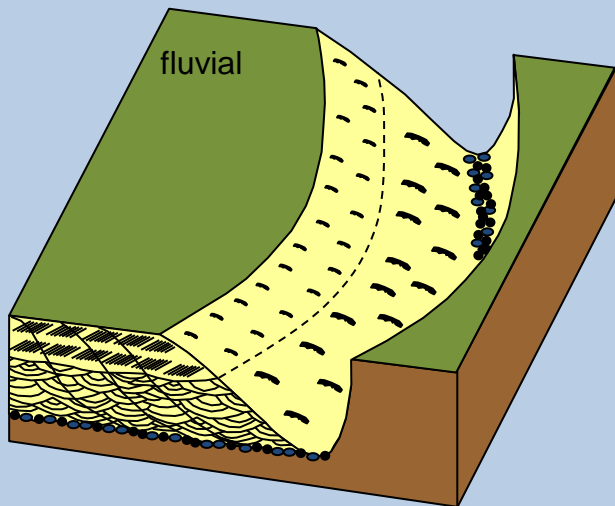
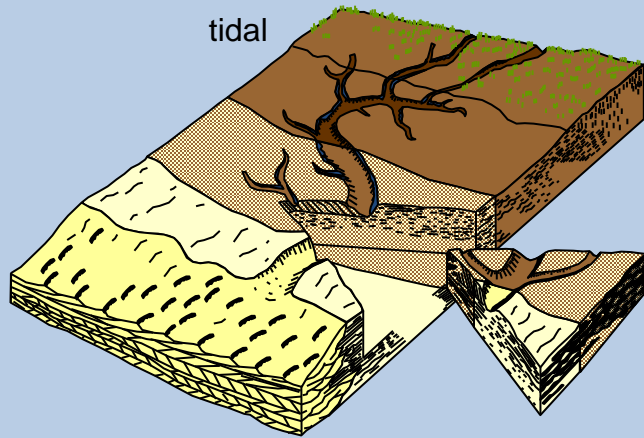
- Can have limited lateral extent and/or be laterally discontinuous
- Good local markers but not very good regionally



## Non-Marine Coaly Mudstone

- Limited lateral extent and/or laterally discontinuous
- Very similar to floodplain mudstones
- Difficult to identify and are poor markers

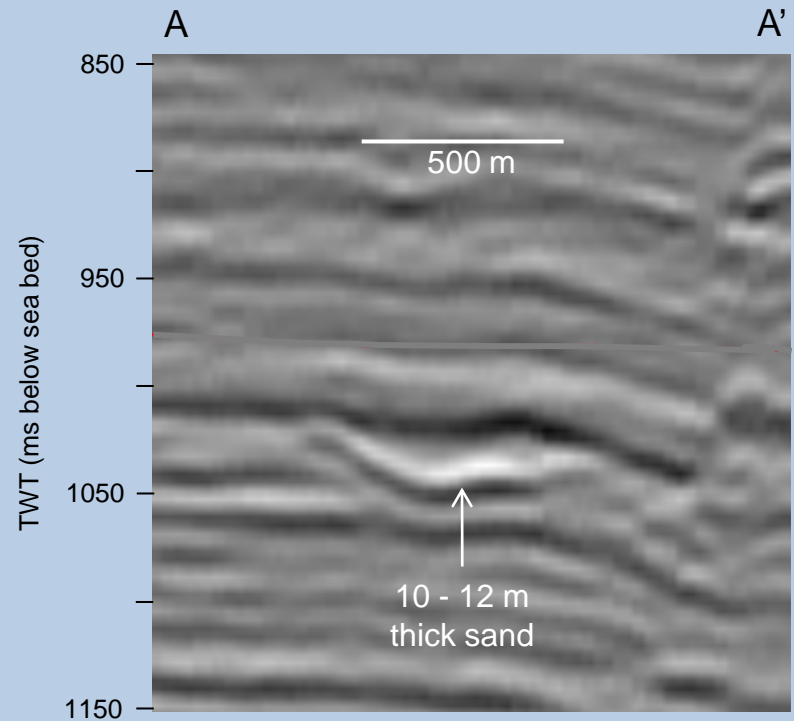
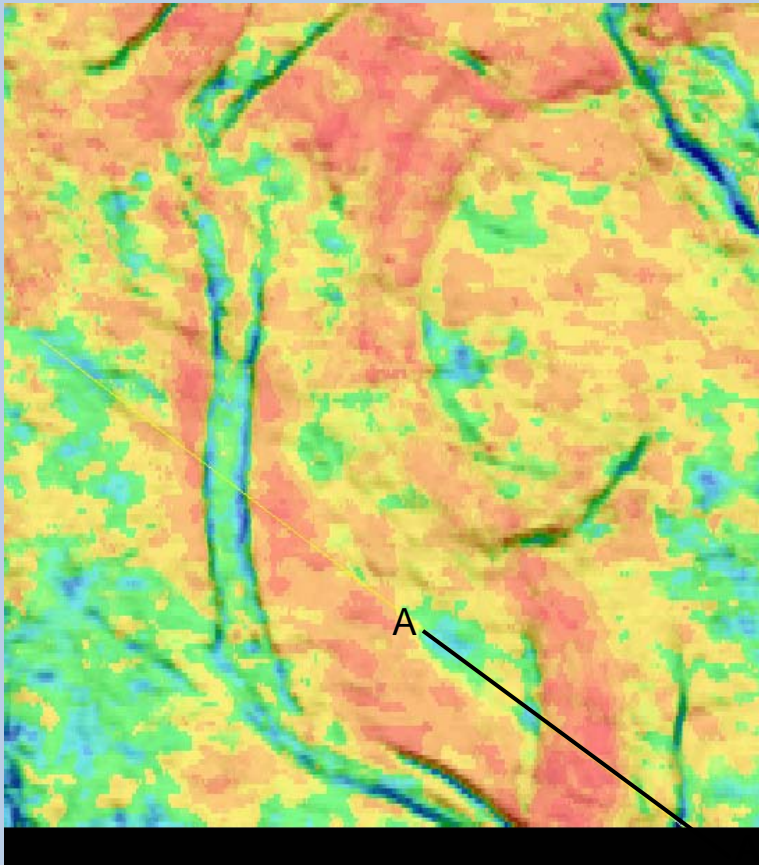
# *Implications for Reservoir Characterization*



- Many tidal sandstones stratigraphically adjacent to marine mudstones
- Tidal sandstones fine upward as do fluvial sandstones
- Sand body size and geometry in tidal sandstones is very different from fluvial point bar sandstones
- Porosity and permeability are usually lower in tidal sandstones
- Generally, fluvial sandstones are much better reservoirs than tidal sandstones

# Channel Sandstones

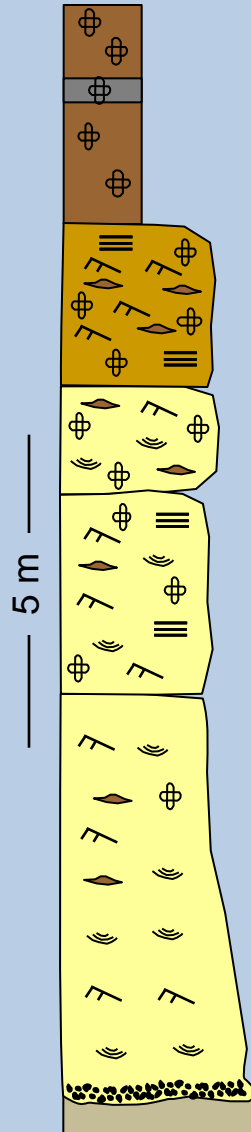
# *Sand-Filled Channels*





# Outcrop Example

- Fining-upward succession
- Onlapping bed geometry
- Increasingly marine upward
- Fluvial channels filled during transgression



# *Lateral Variation*

- Stratigraphic succession varies with distance from the shoreline
- Landward changes include:
  - marine influence decreases
  - grain size increases
  - variable discharge from river floods becomes increasingly more important



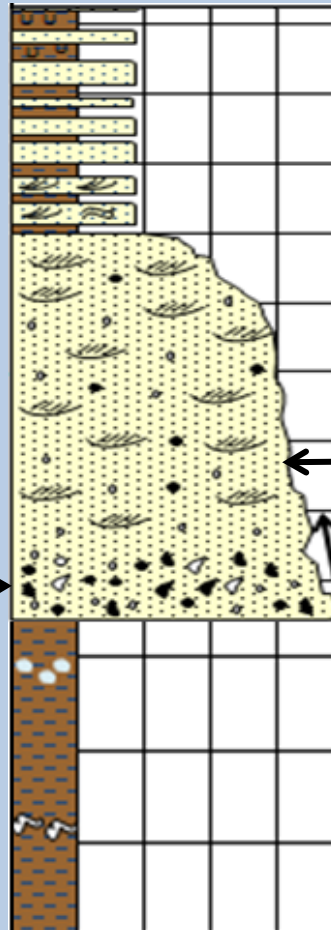
# Lower Coastal Plain



- Early post-rift channel sandstone
- Conglomeratic channel lag
- Cross-bedded, fining-upward sandstone



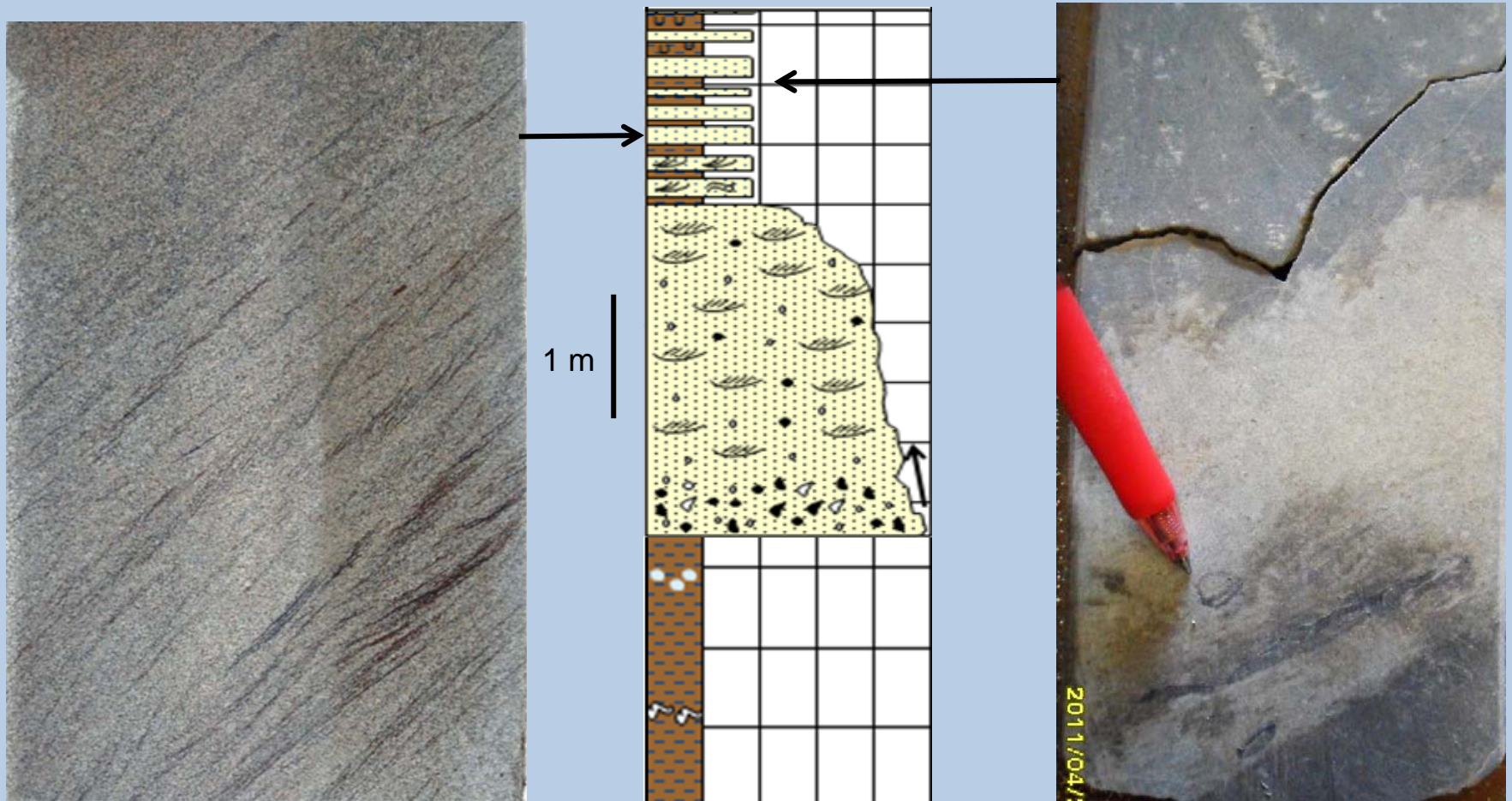
1 m



(after Veerapongwattana 2011)

# *Lower Coastal Plain*

- Tidal influence at the top (flasers, mud drapes, marine burrows)
- Increasingly marine upward
- Fluvial channel filled during transgression

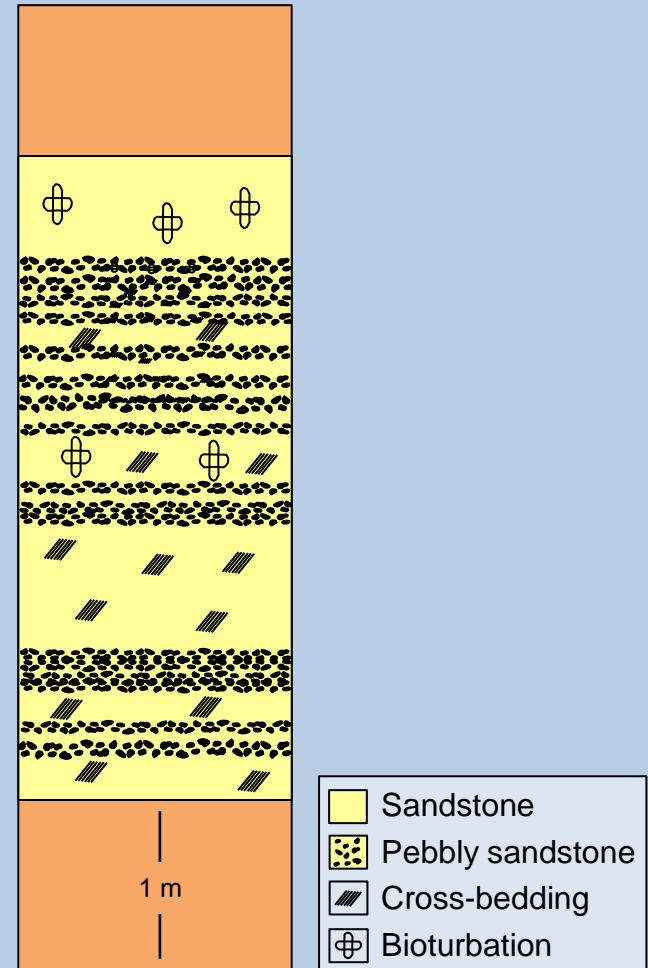


(after Veerapongwattana 2011)



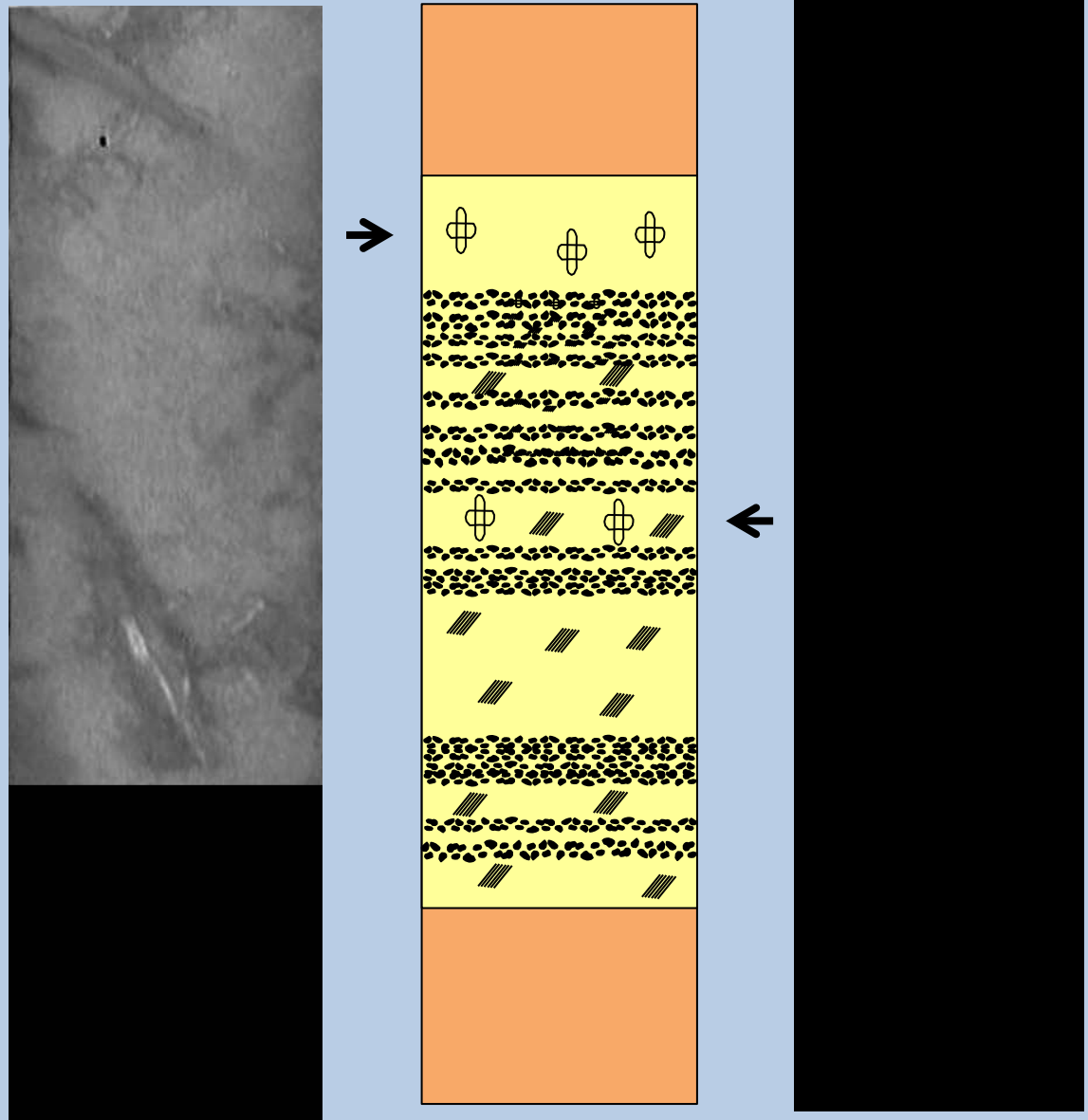
# *Upper Coastal Plain*

- Cross-bedded coarse sandstone intervals
- Pebbly sandstones occur as discrete, thin (0.1 m) beds
- Abrupt transition to overlying floodplain mudstone
- Minor marine influence in two intervals
- Burrowed, cross-bedded coarse sandstone near the middle of the core
- Homogenized fine to medium sandstone with large burrows at the top

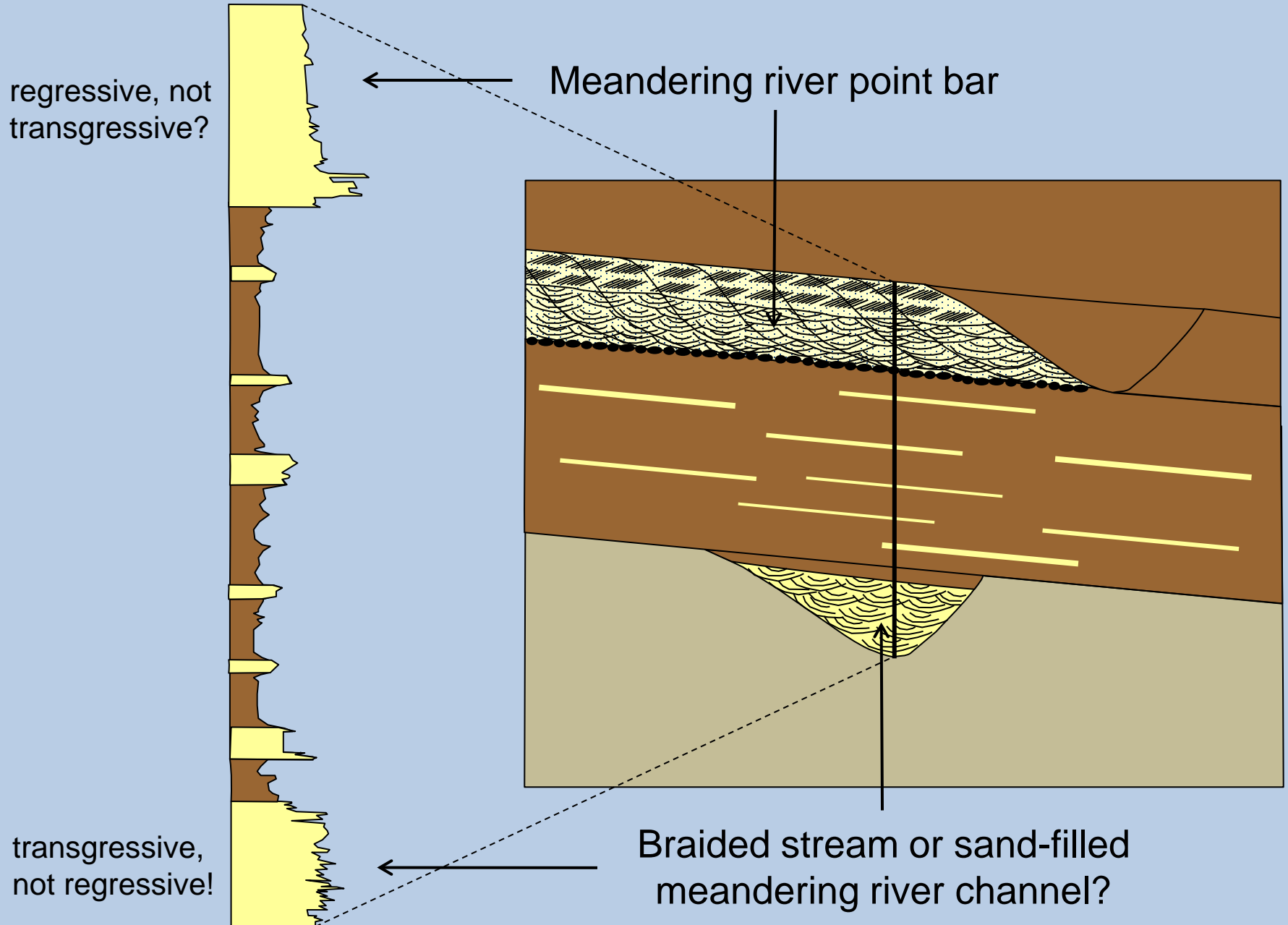


# *Upper Coastal Plain*

- Minor marine influence in two intervals
- Burrowed, cross-bedded coarse sandstone near the middle of the core
- Homogenized fine to medium sandstone with large burrows at the top

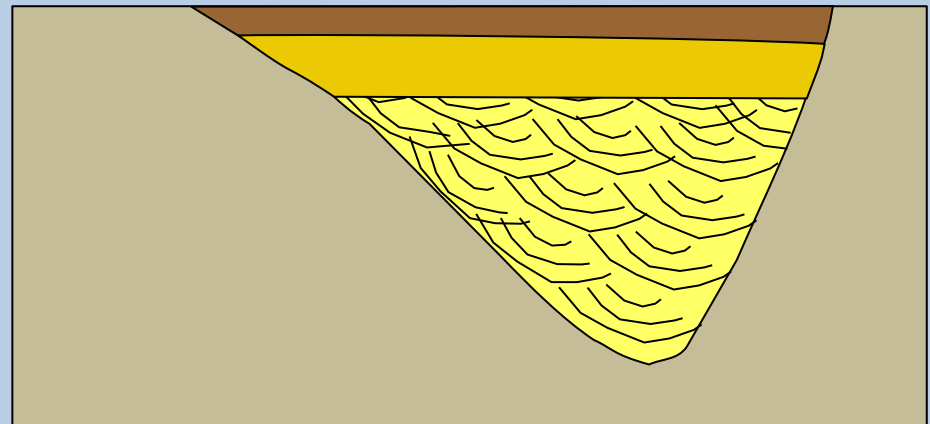
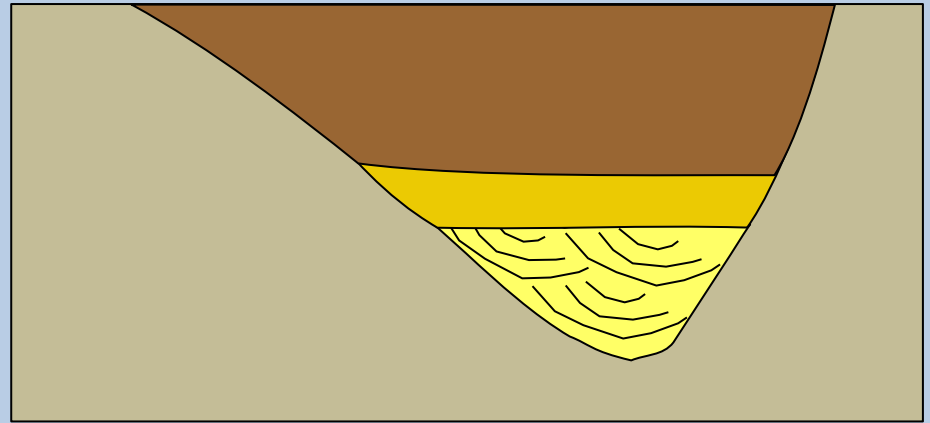


# Sequence Stratigraphic Implications



# *Implications for Reservoir Geometry*

- Sand thickness depends only on the amount of filling before avulsion
- No relationship between channel width and sand thickness
- Many reservoir sands are below seismic resolution
- Channel fill or point bar sand?
- Three dimensional sand body geometry can be easily misinterpreted



# *Implications for Reservoir Characterization*

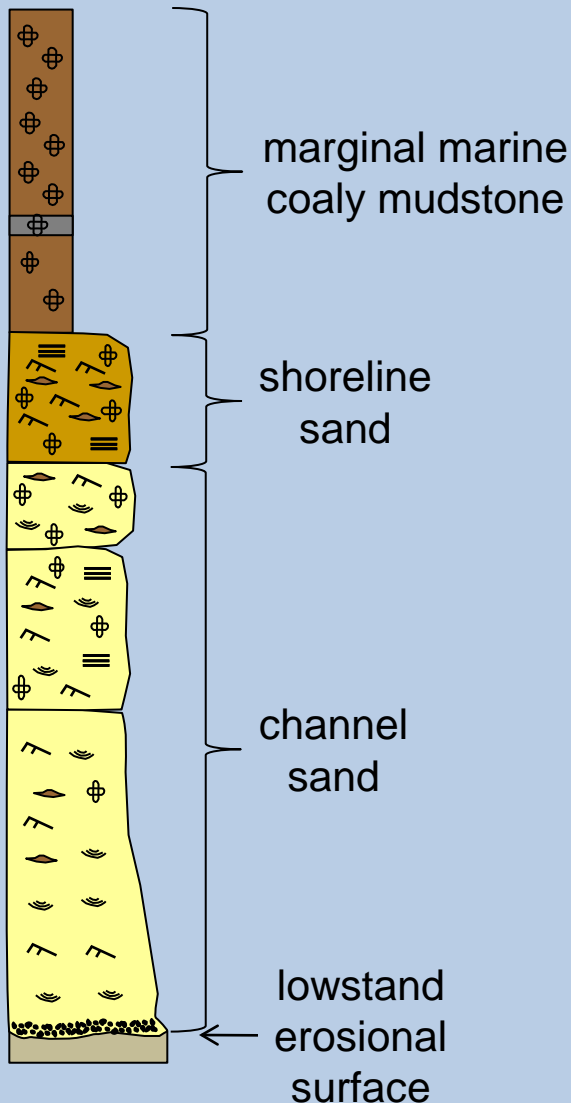


- Sand-filled channels are important petroleum reservoirs
- “Channel” sandstones are more abundant in transgressive successions
- Most (all?) channel sands were deposited during transgressive events
- Variable sedimentary character that reflects distance from the paleo-shoreline
- Equally variable sand body geometry, thickness, porosity and permeability

# Transgressive Successions

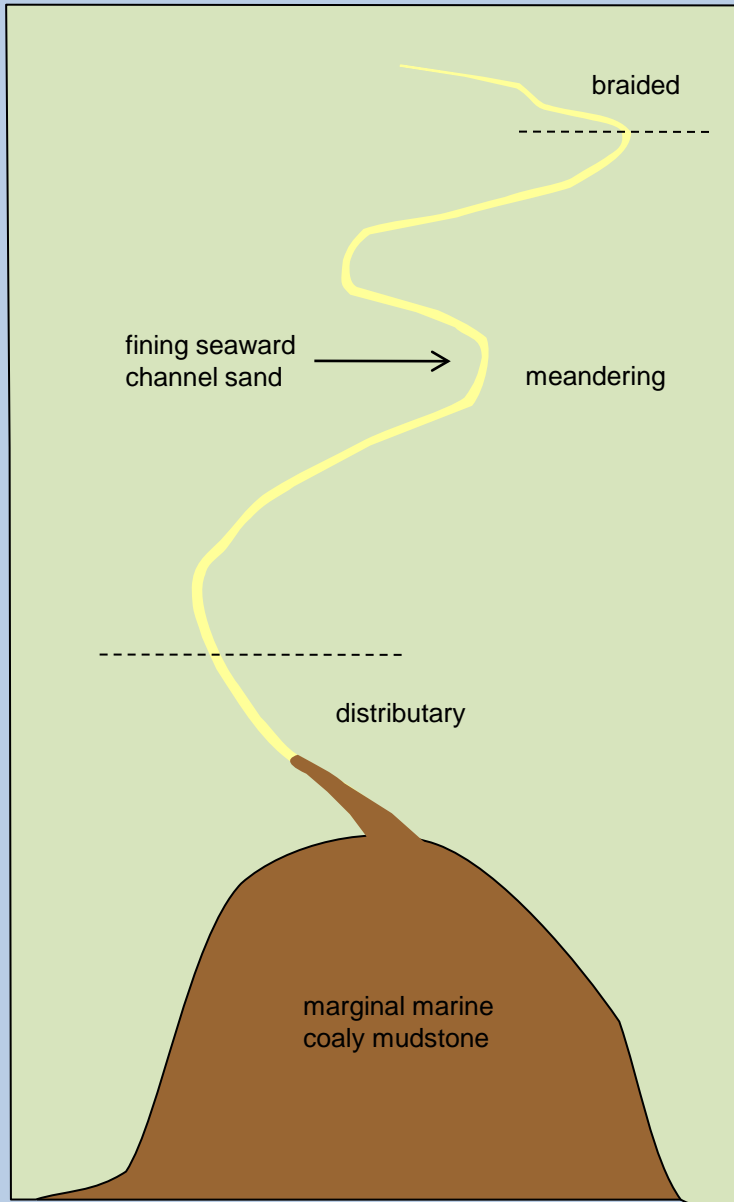


# *Vertical Facies Relationship*



- Channel sands and marginal marine coaly mudstones are different parts of a single transgressive succession
- Both facies are highly variable in thickness, as is the proportion of each
- Either facies can be absent in any one transgressive succession
- Channel sands are the first deposit above a lowstand channel base usually represented by an erosional surface
- Marginal marine coaly shales comprise the upper part of the succession
- There often is an intervening shoreline sandstone

# *Lateral Facies Relationship*



- Channel sands and marginal marine coaly mudstones are coeval, laterally adjacent facies
- Channel sands are more proximal and fine seaward
- Marginal marine coaly mudstone are more distal
- The two facies can be more than 100 km wide

# *Marine Transgressions in the GOT*



- Confirmed at several stratigraphic intervals within the lower Miocene and younger succession in Pattani Basin
- Also confirmed from the early Miocene and younger in the SW
- Reported to commonly occur from the early Miocene in the NW
- Channels sands common in most of the GOT

# *Conclusions*

- Transgressive successions occur from the early Miocene onward in the GOT and probably are much more abundant than currently recognized
- They often are relatively thin, reflecting minor, short-lived transgressions
- There was at least one significant marine transgression in the late lower Miocene and another in the middle Miocene
- Transgressive successions include channel sands and/or marginal marine mudstones and/or shoreline sandstones
- Marginal marine coaly mudstones are more common and more widely distributed than previously recognized and are good regional markers
- Channel fill sands are fining-upward successions that also fine seaward
- These successions can be easily mistaken for point bar and braided stream sands that have much different sand body geometries and sequence stratigraphic relationships

# *Acknowledgements*

- Contributions from former students Nadia Nirsal, Prateep Chaiwan, Pimlada Veerapongwattana, Rully Firmansyah, Jirach Kamvan, Jittikan Narapan and Patcharaporn Champasa
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- Access to subsurface data and images from Chevron Thailand Exploration and Production Ltd.