

Sediment Supply Systems of the Champion "Delta" of NW Borneo: Implications for the Distribution and Reservoir Quality of Associated Deepwater Sandstones*

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Abstract

Middle Miocene to Pliocene sedimentation on the NW Borneo margin has long been interpreted as the product of one relatively large deltaic system, the Champion Delta. However, several lines of evidence indicate that the Champion system was not a simple, large delta; its drainage basin was too small, several structurally active sub-basins, each with its own stratigraphic succession, comprised the area covered by the "delta" and structurally-generated topography segregated the Champion shallow marine strata into thick, wave-dominant and tide-dominant successions. Seismic stratigraphic and fluvial outcrop observations indicate that multiple modest-sized rivers comprise the Champion system, of which the Padas and Limbang appear to be the largest, longest-lived and most important with respect to sediment supply. The mineralogy and texture of the sand delivered to the shelf edge by these rivers was diverse owing to contrasting bedrock lithologies in the different catchment areas; reservoir quality of the resulting deepwater sands is expected to be comparably diverse.

Structurally-evolving topography continually modified the number and location of rivers reaching the paleo-shoreline. Growth faults, rapidly subsiding synclines, inversion anticlines and shale ridges trapped sand on the shelf resulting in a variable sand supply to the shelf edge. Because of the Champion system's multiple sources and frequently-changing sediment supply, the spatial and temporal distribution of its deepwater sand accumulations are not only expected to be less related to sea level fluctuations than those sourced from a single, large shelf edge delta, but should also be smaller in size with a more scattered geographic and stratigraphic distribution. The complex sediment supply pathways and variable provenance of the Champion system appear to explain some of the stratigraphic and geographic variability that occurs in the reservoirs of the deepwater Gumusut and Kikeh fields, despite their geographic proximity.

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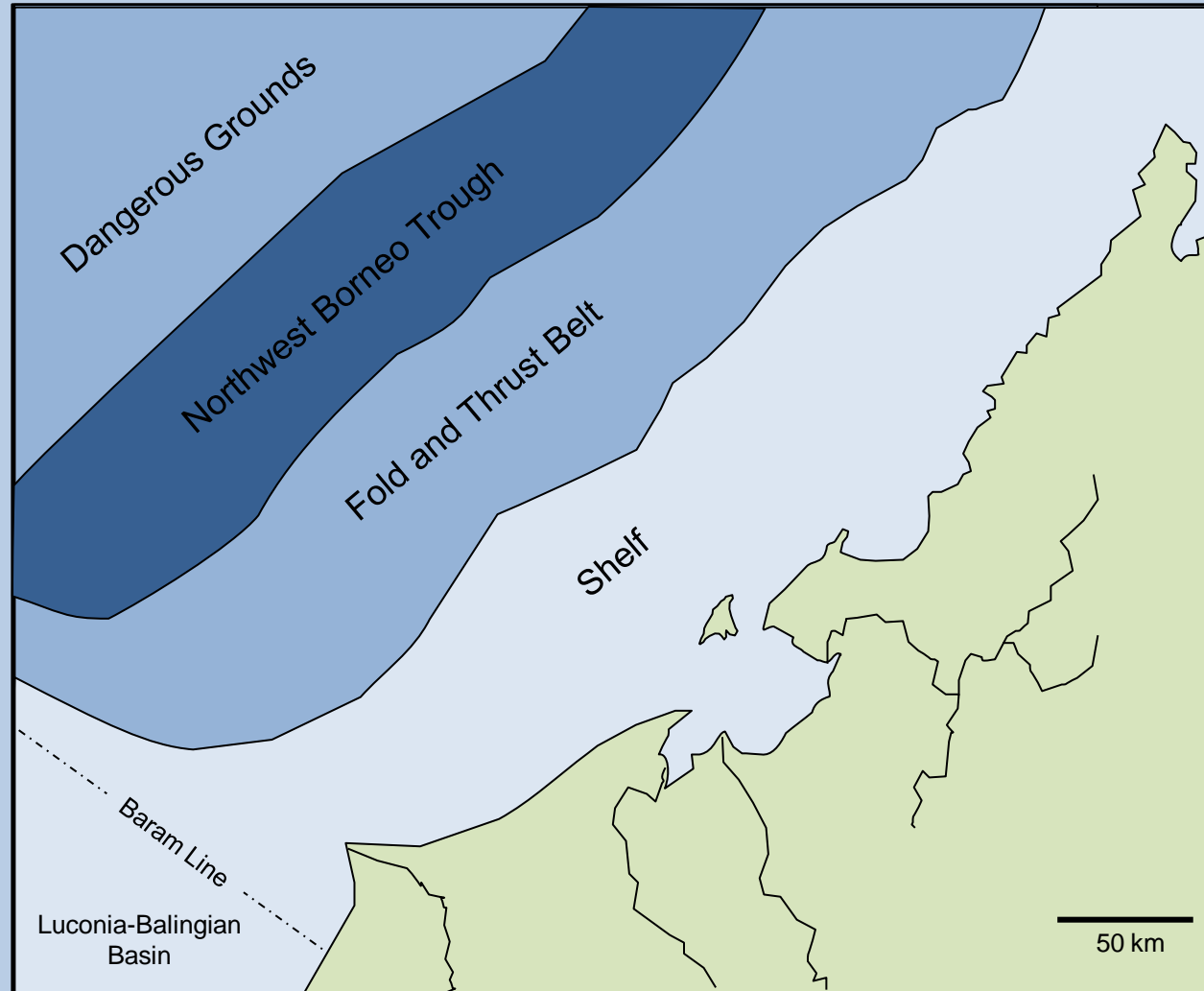
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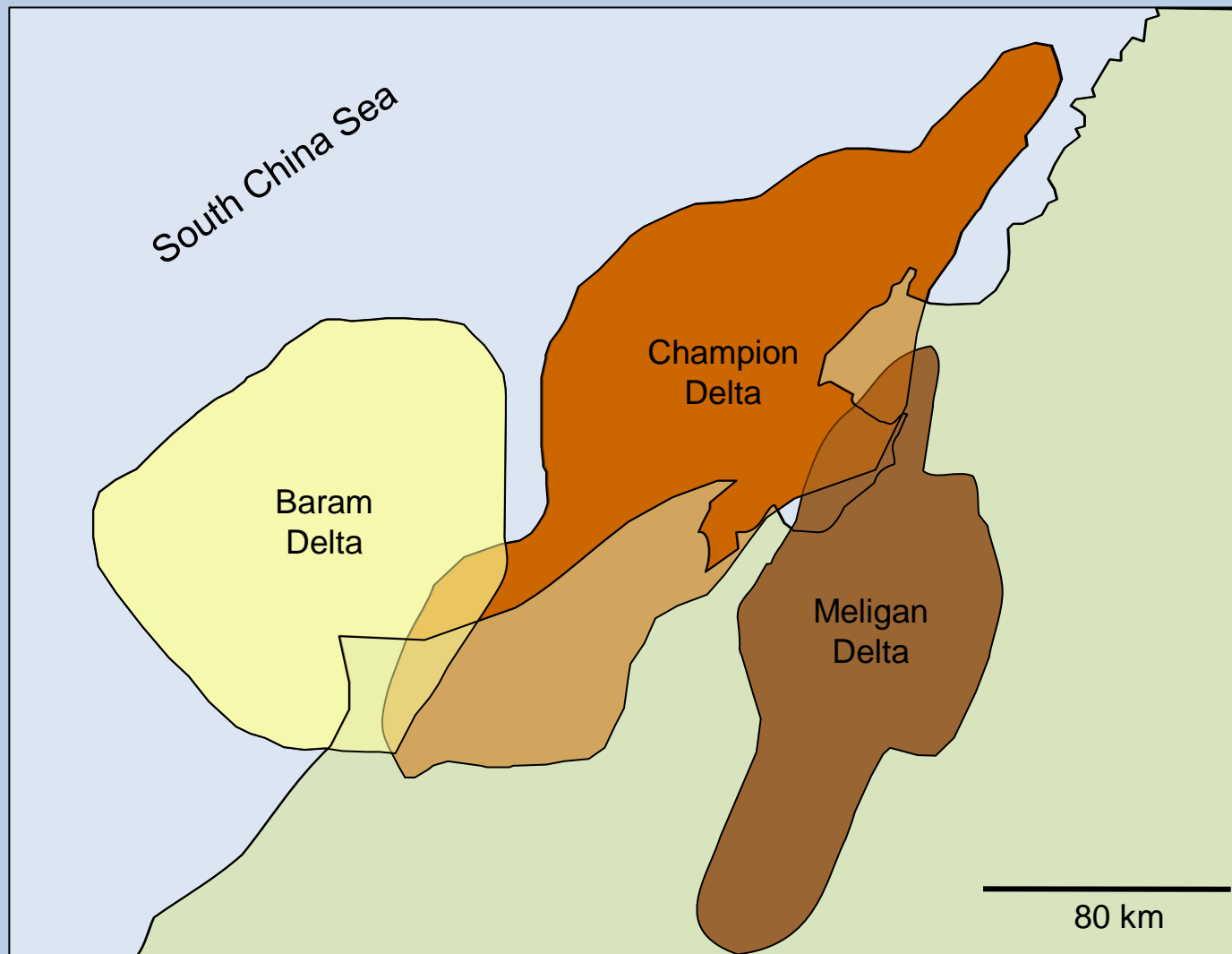
Baram Delta Province



- Mid-Miocene to Recent progradation
- Narrow shelf
- Steep muddy slope
- Deep water toe thrusts

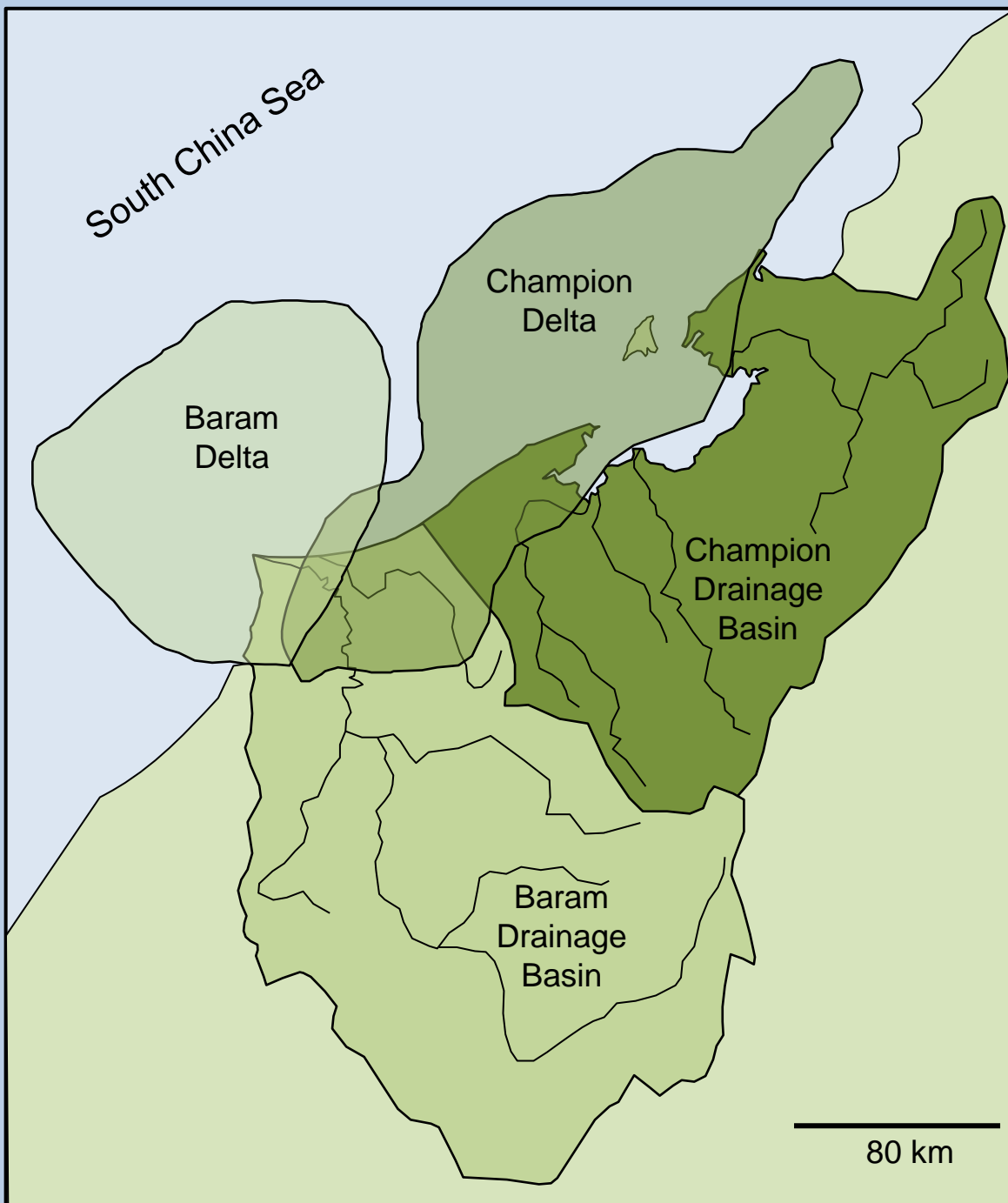


Traditional View



- Three wave-dominated deltas
- Early Miocene Meligan Delta
- Mid to late Miocene Champion Delta
- Pliocene to Recent Baram Delta

(after Koopman 1996)



Baram Delta

- One river system
- Large drainage basin
- Small delta

Champion Delta

- Multiple river systems
- Small drainage basin
- Large delta?

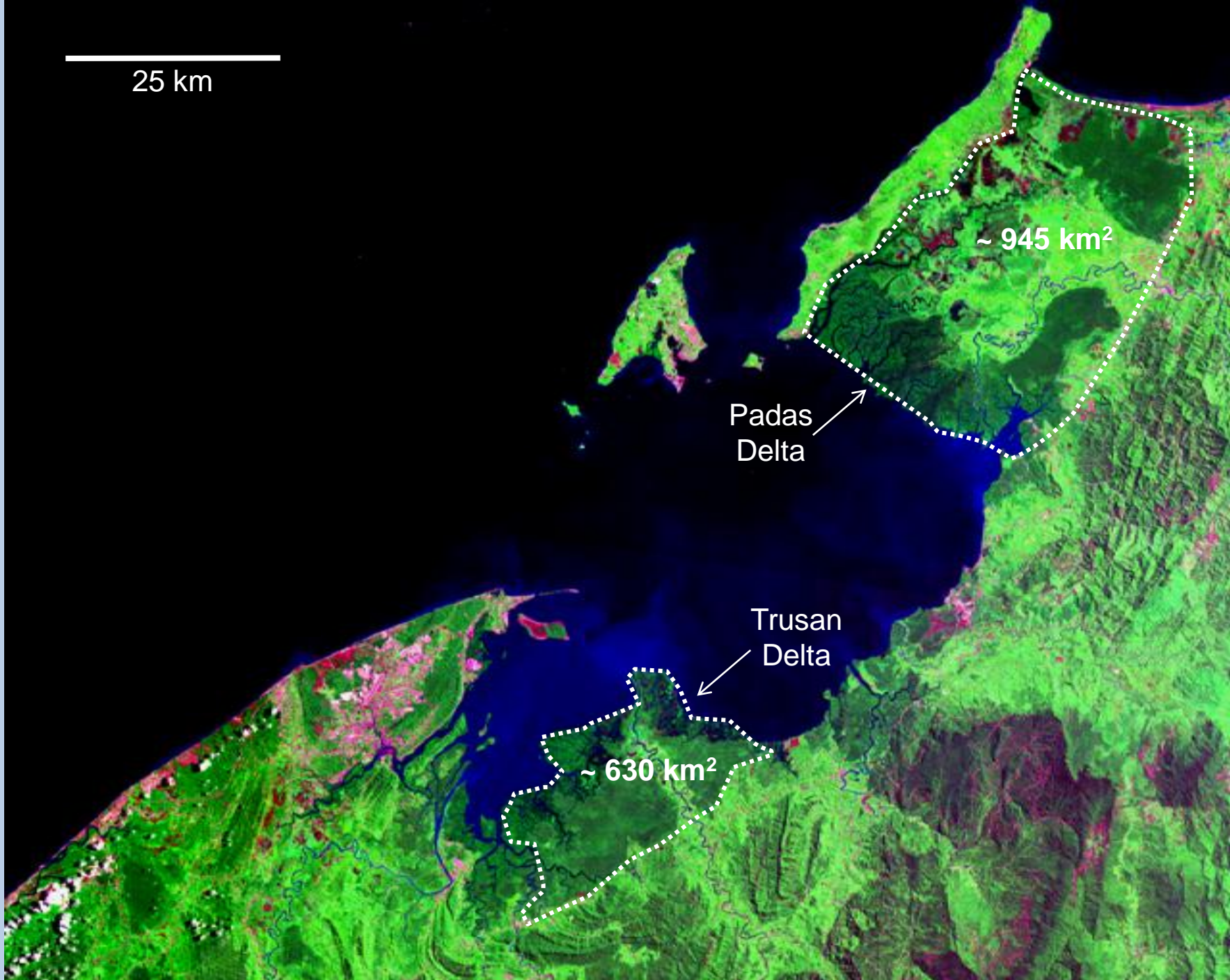
25 km

~ 945 km²

Padas
Delta

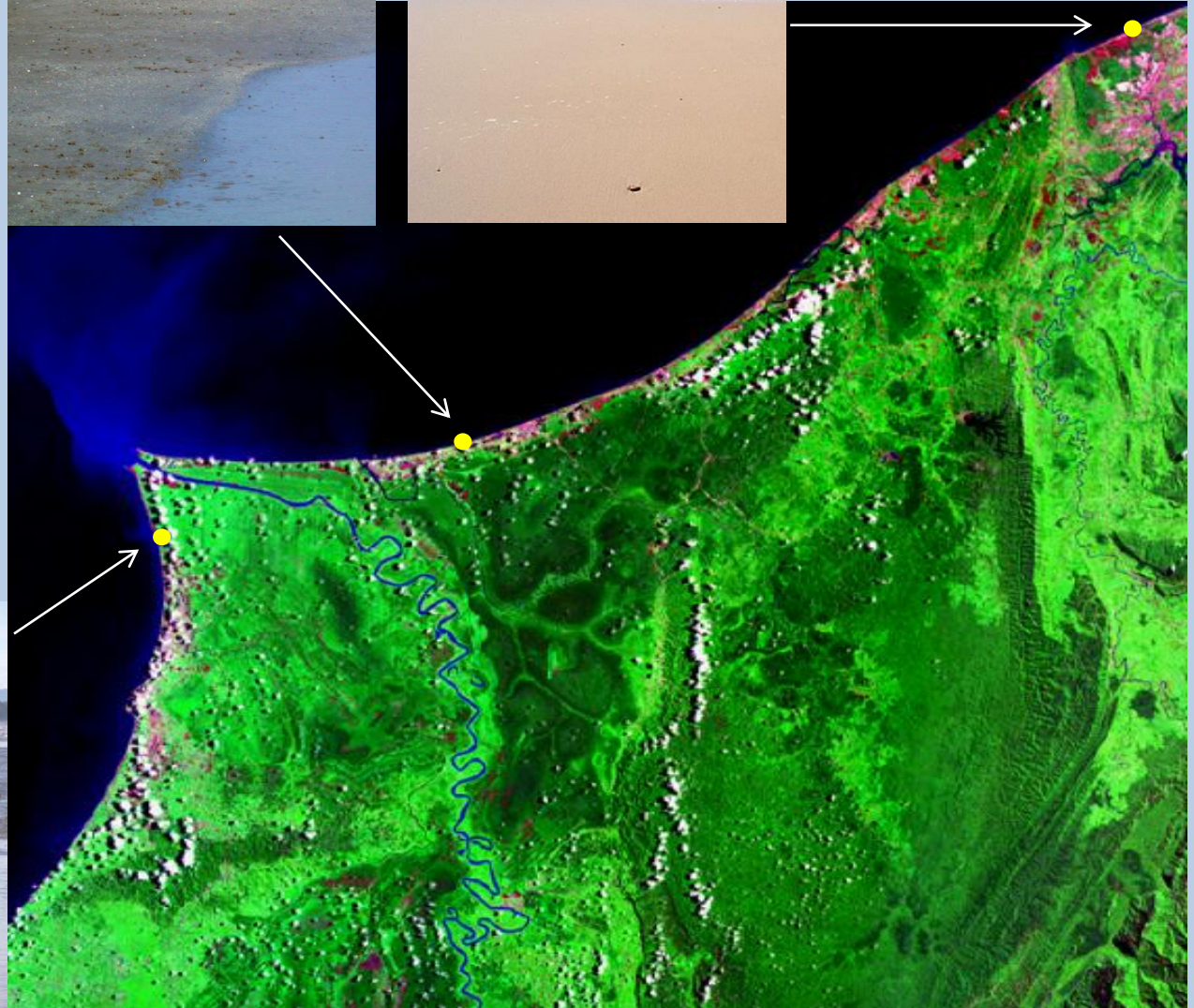
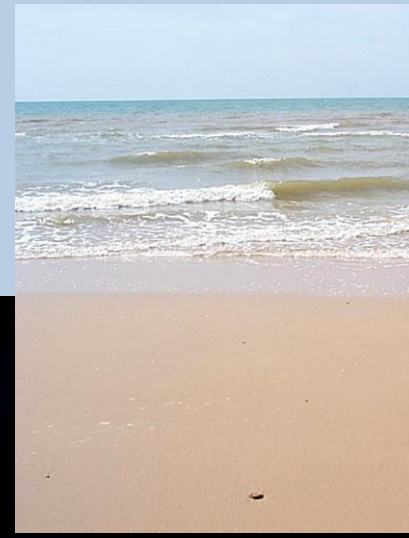
Trusan
Delta

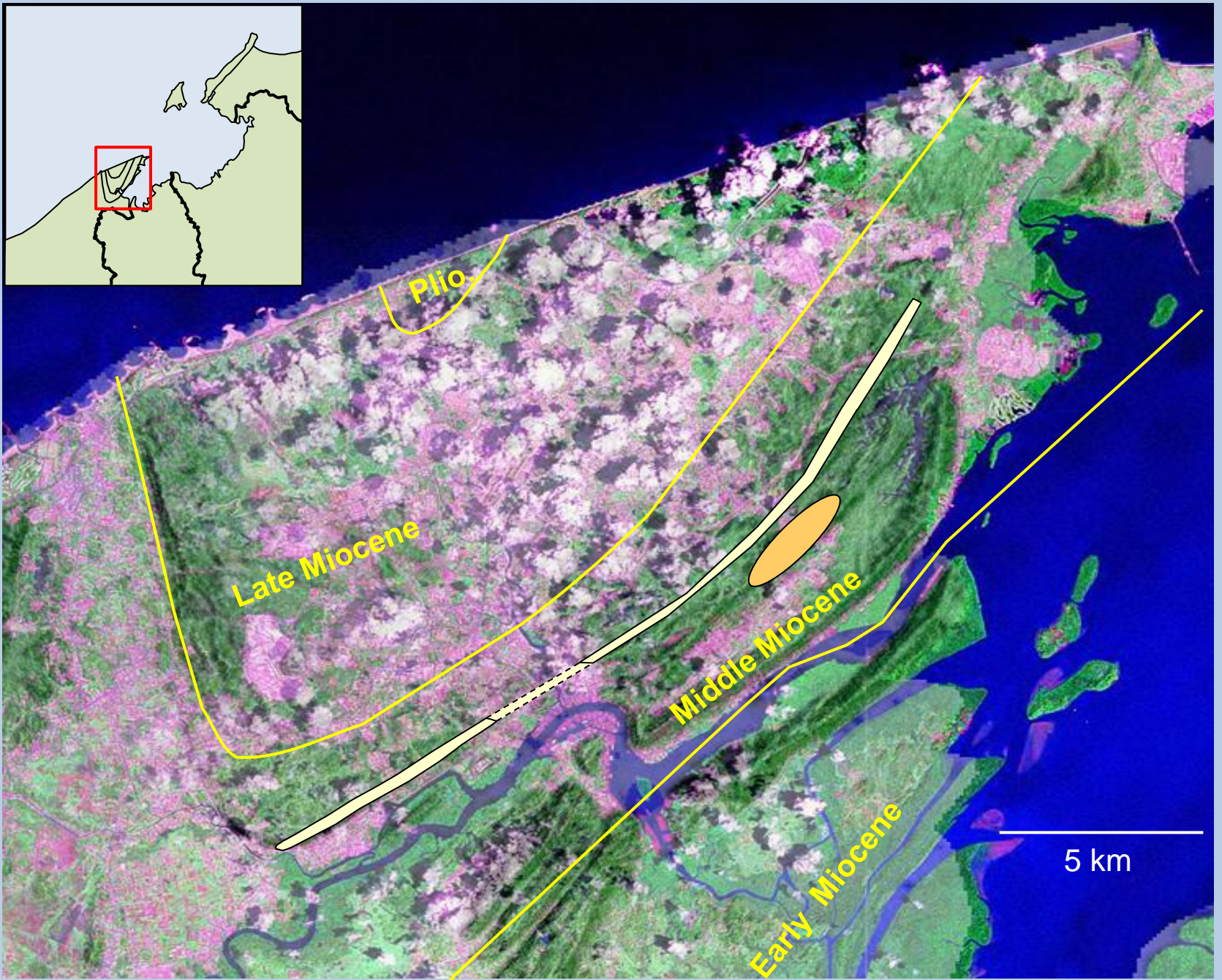
~ 630 km²



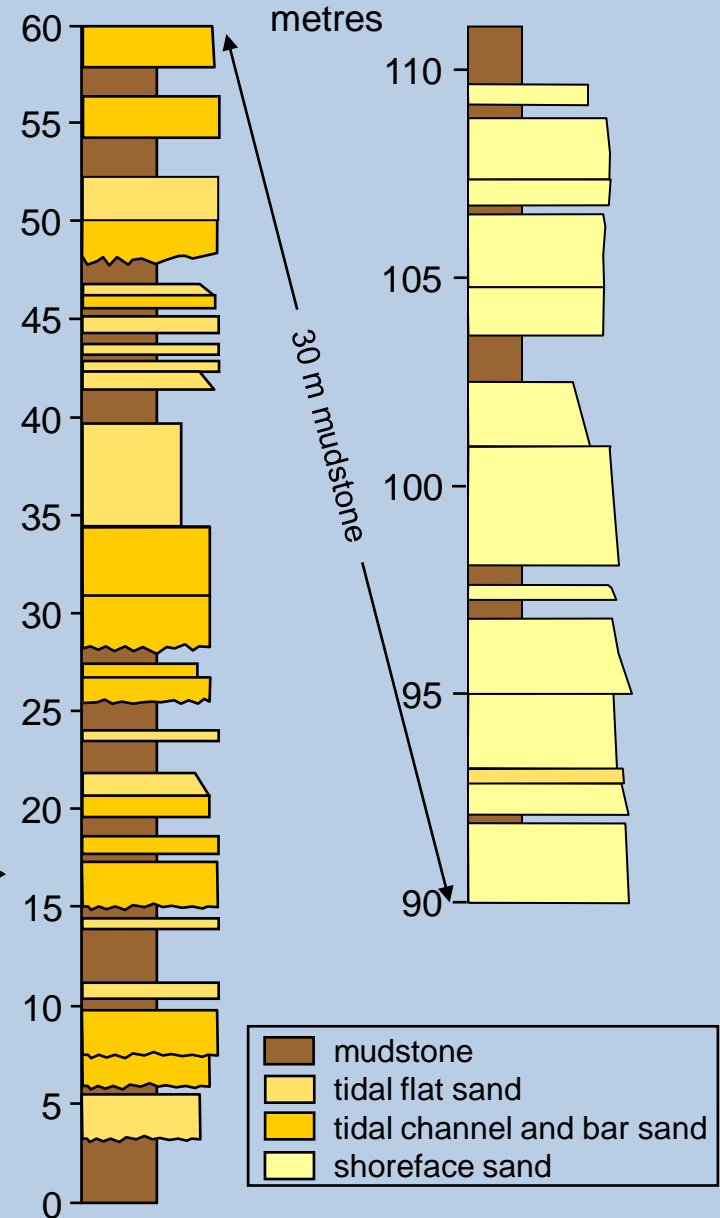
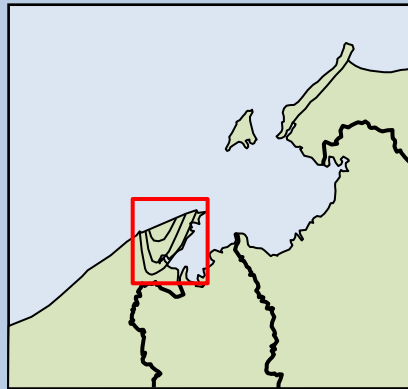
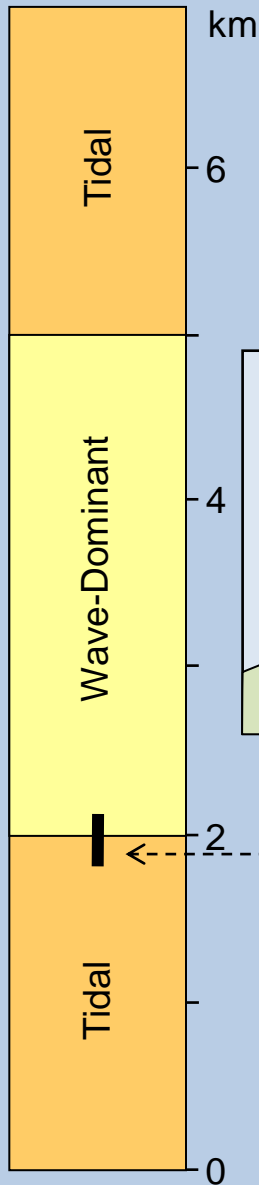
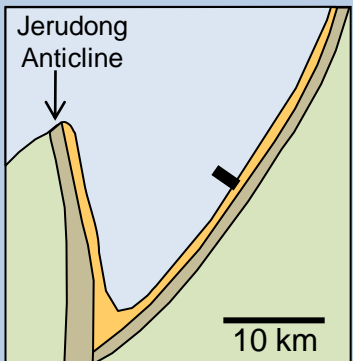
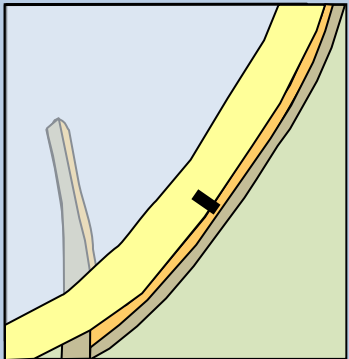
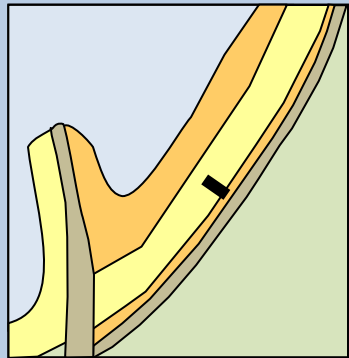
Baram Delta

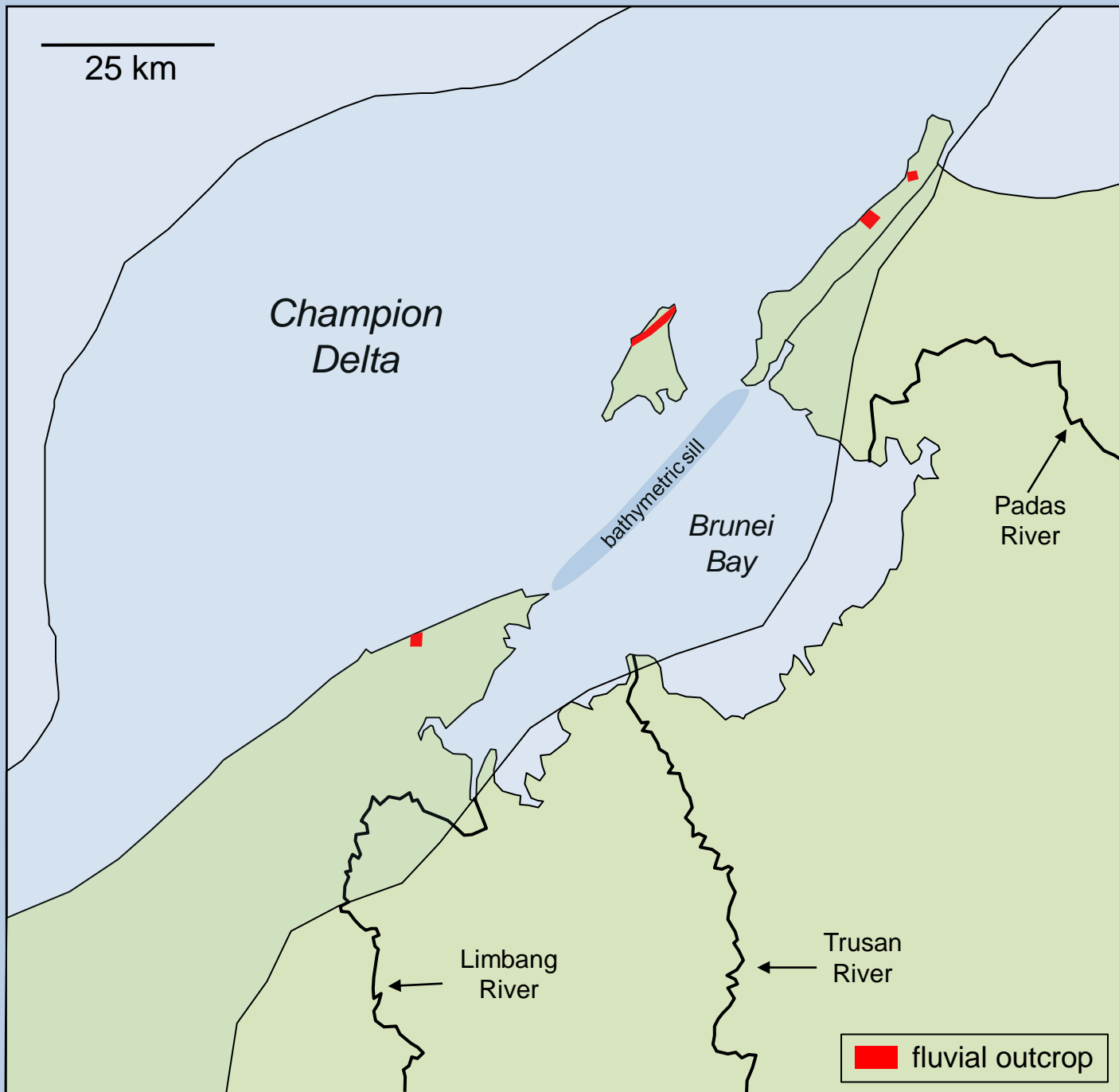
- erosional morphology
- muddy sands
- mixed tide and wave deposition
- wave-dominant delta may be impossible





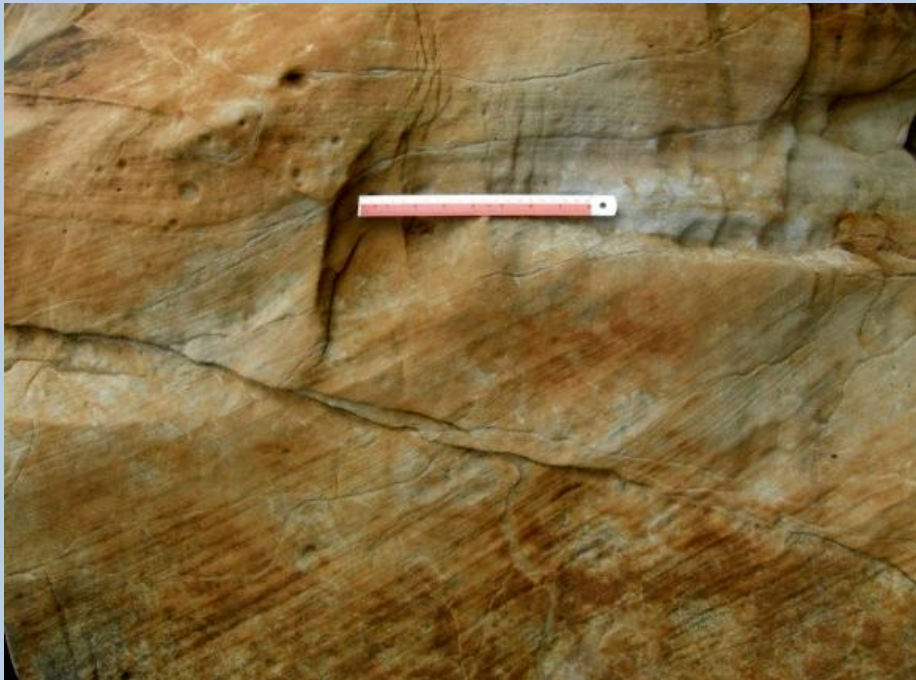
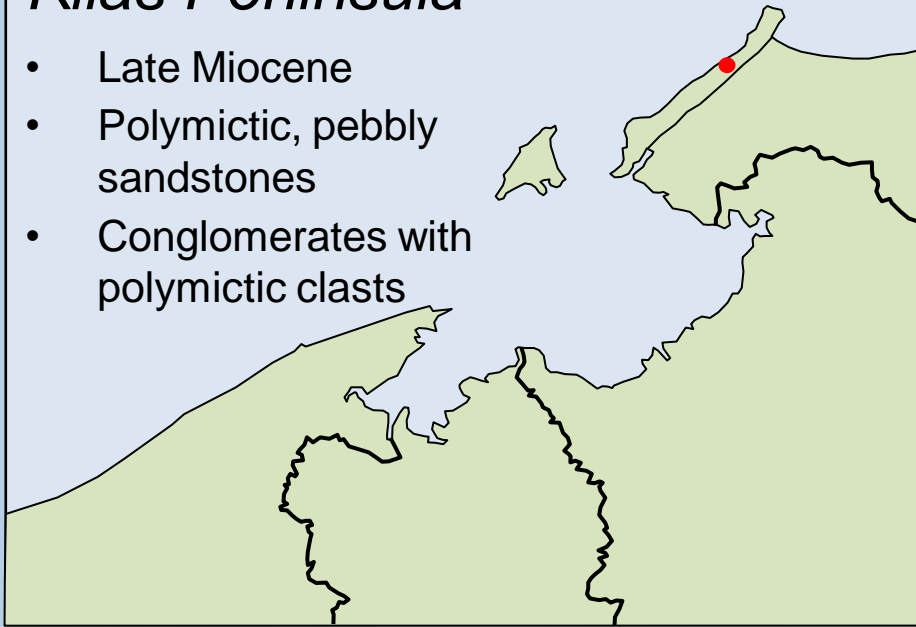
Berakas Syncline





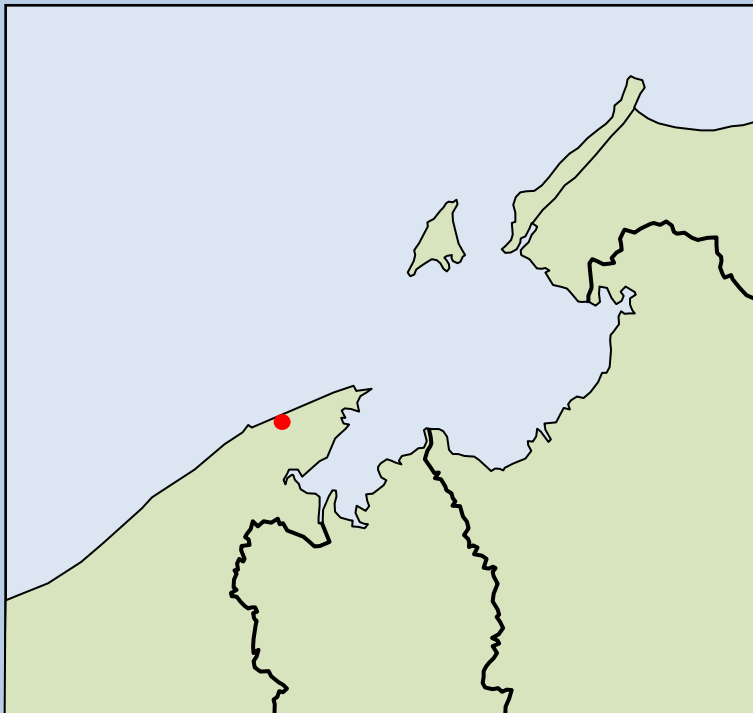
Klias Peninsula

- Late Miocene
- Polymictic, pebbly sandstones
- Conglomerates with polymictic clasts



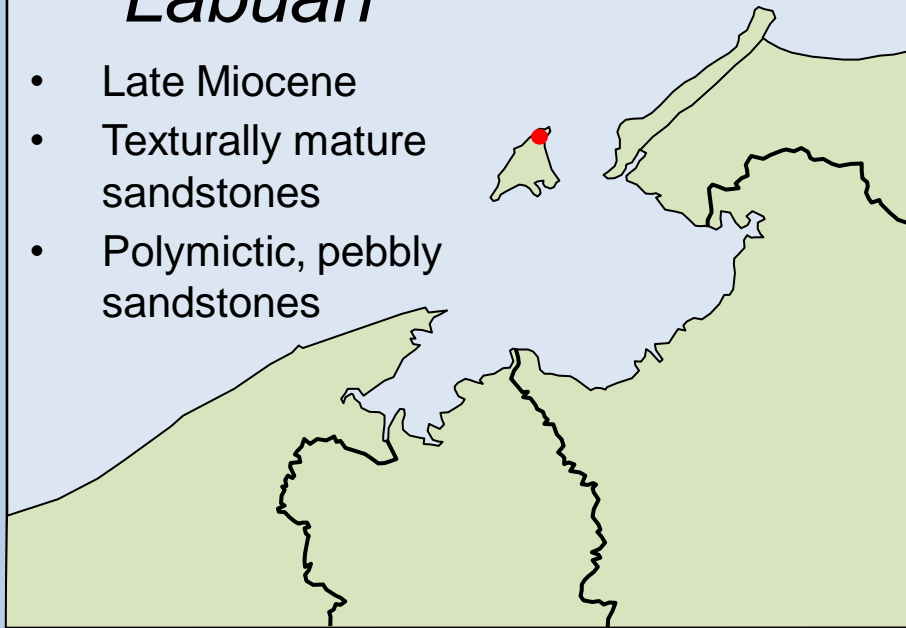
Berakas Syncline

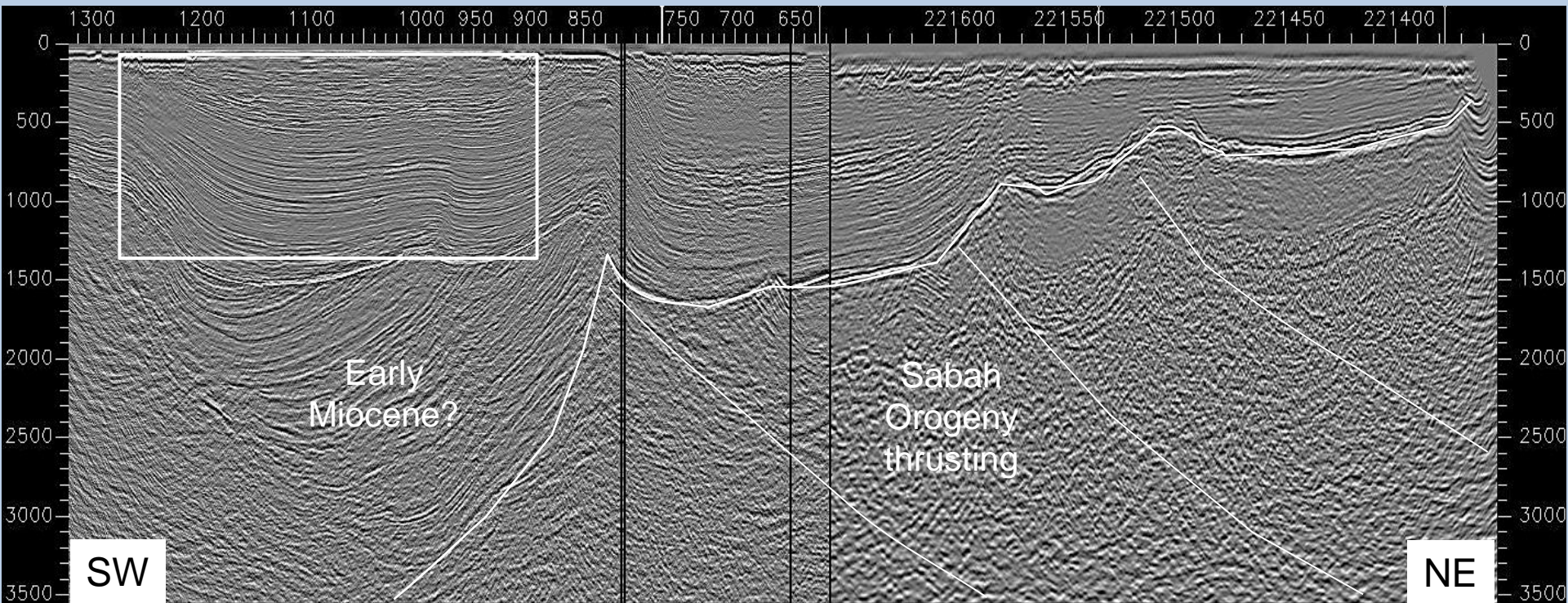
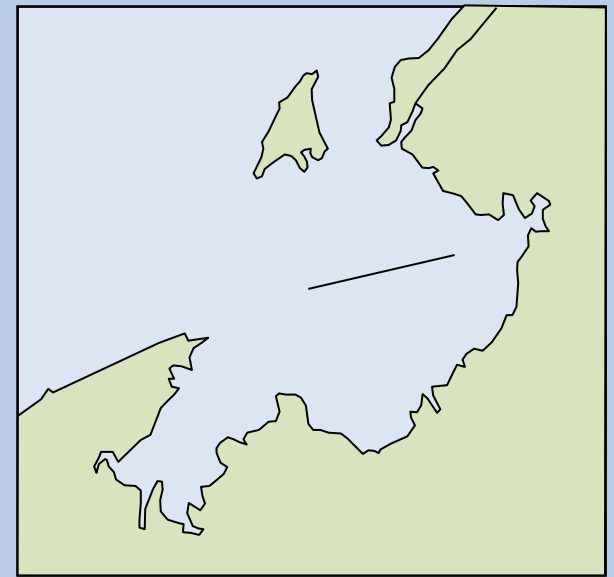
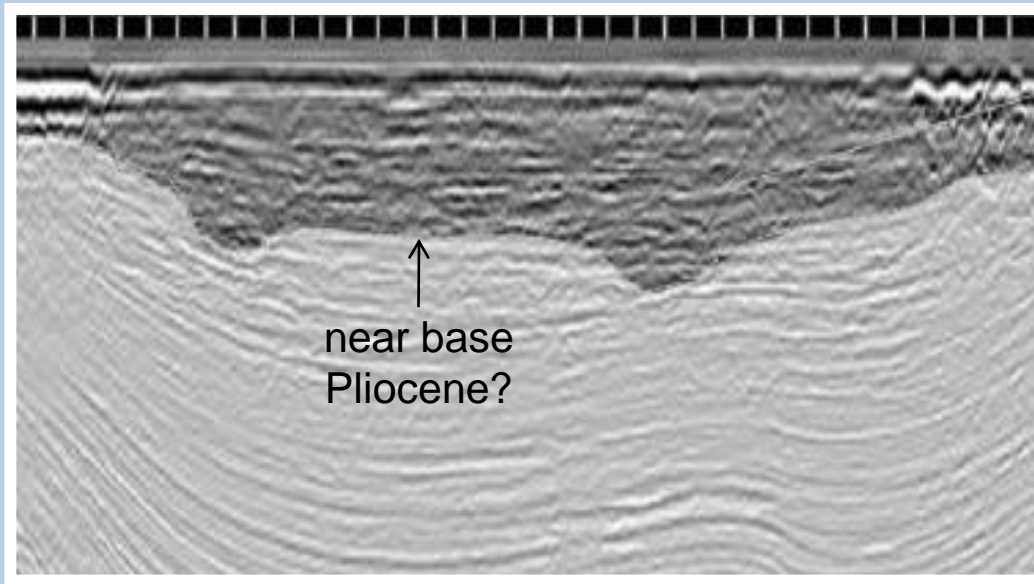
- Earliest Pliocene(?)
- Texturally mature fine sandstones
- Rounded, conglomeratic lag deposits
- Lag deposits are tightly-cemented, texturally mature fine sandstone



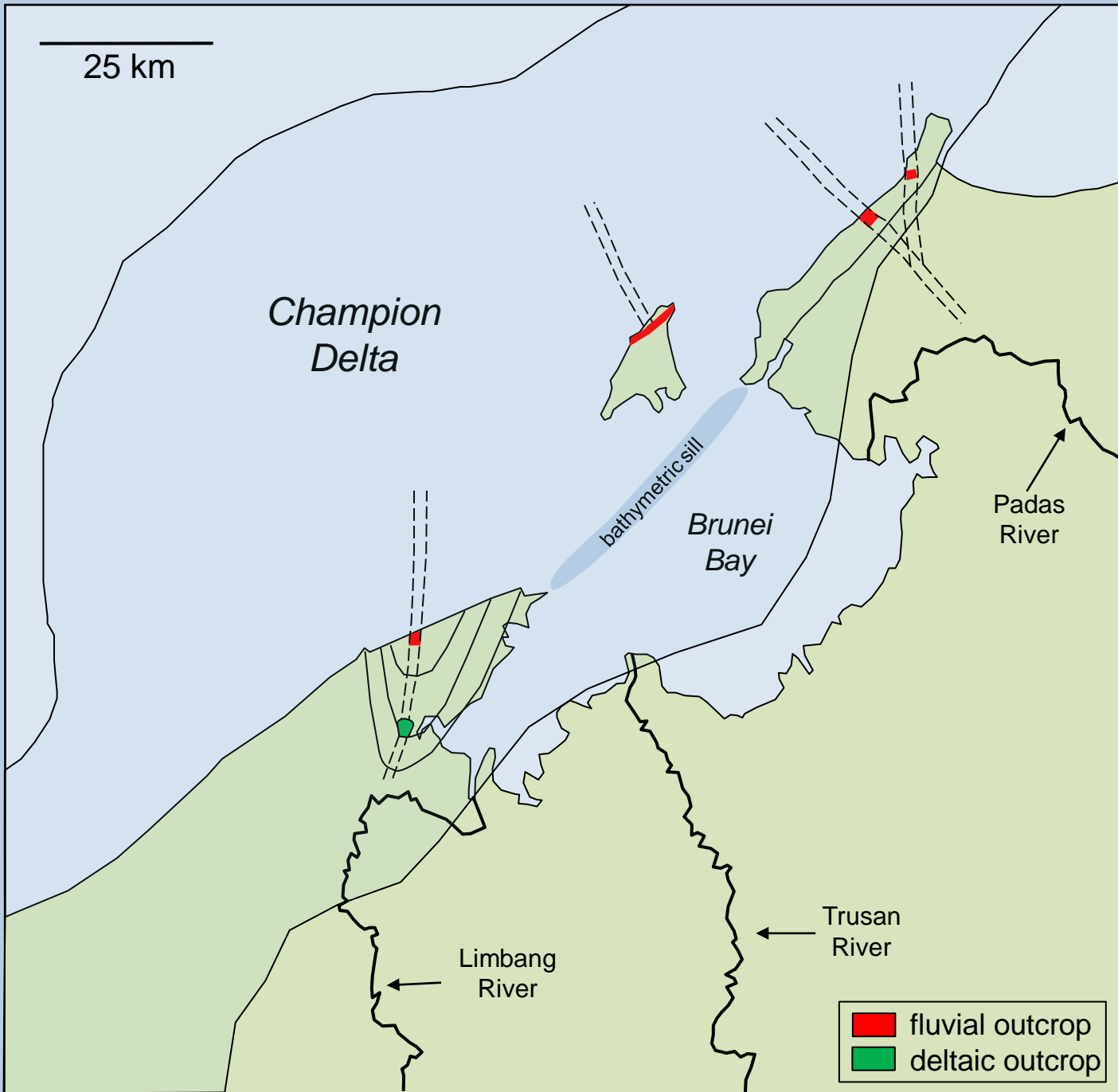
Labuan

- Late Miocene
- Texturally mature sandstones
- Polymictic, pebbly sandstones

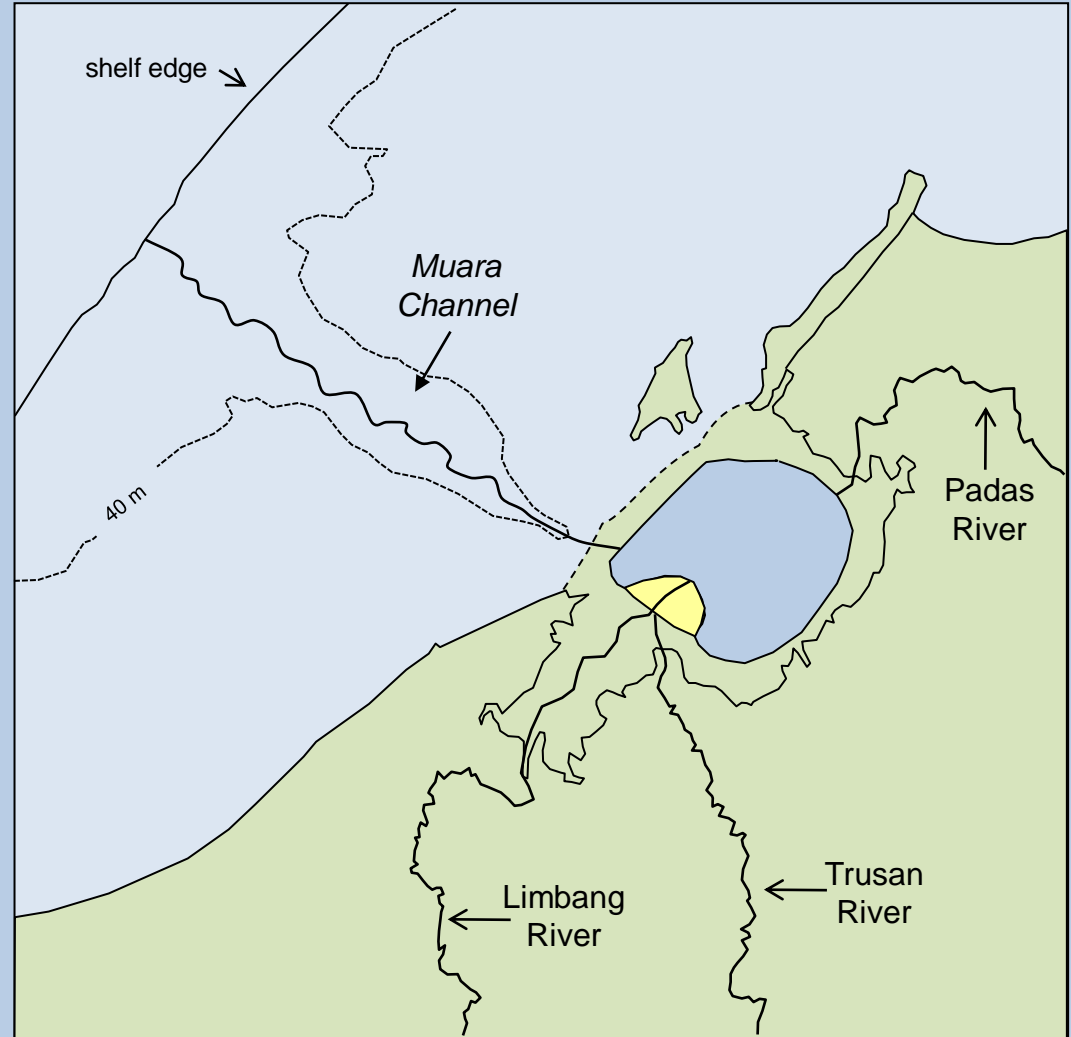
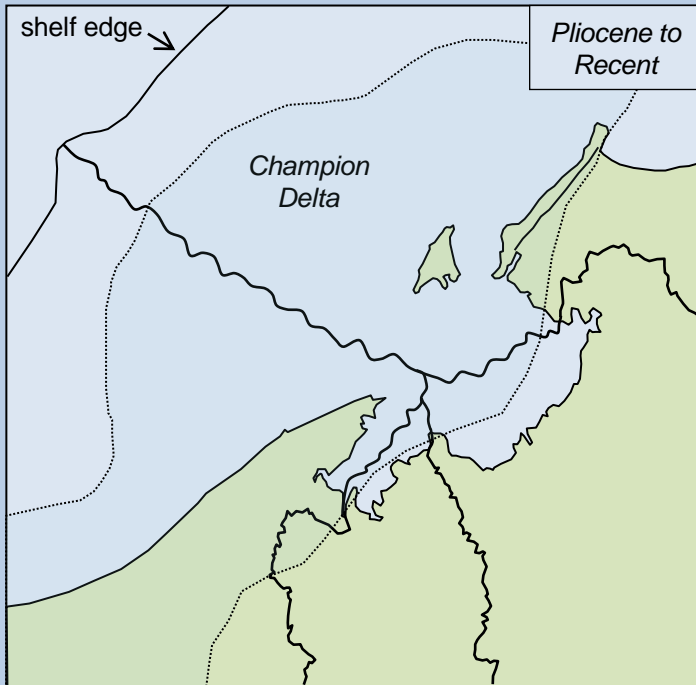
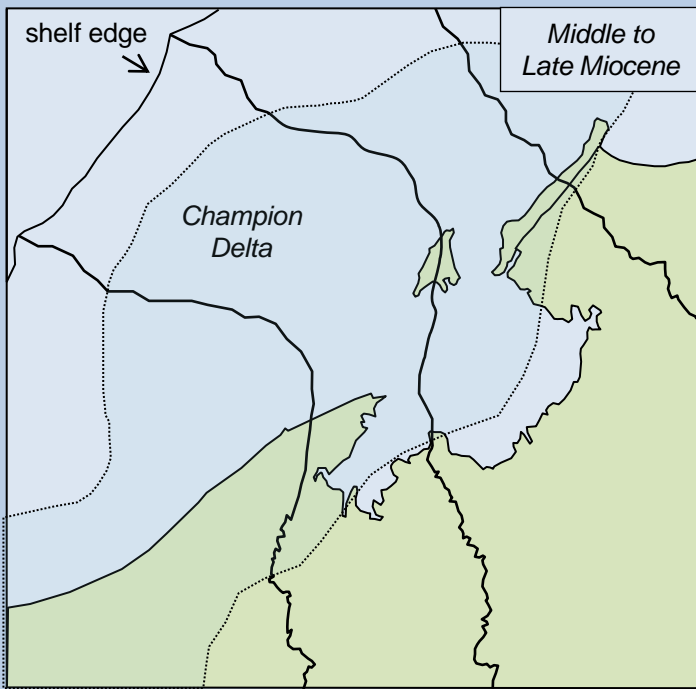




(after Cullen 2010 and Cullen *et al.* 2010)



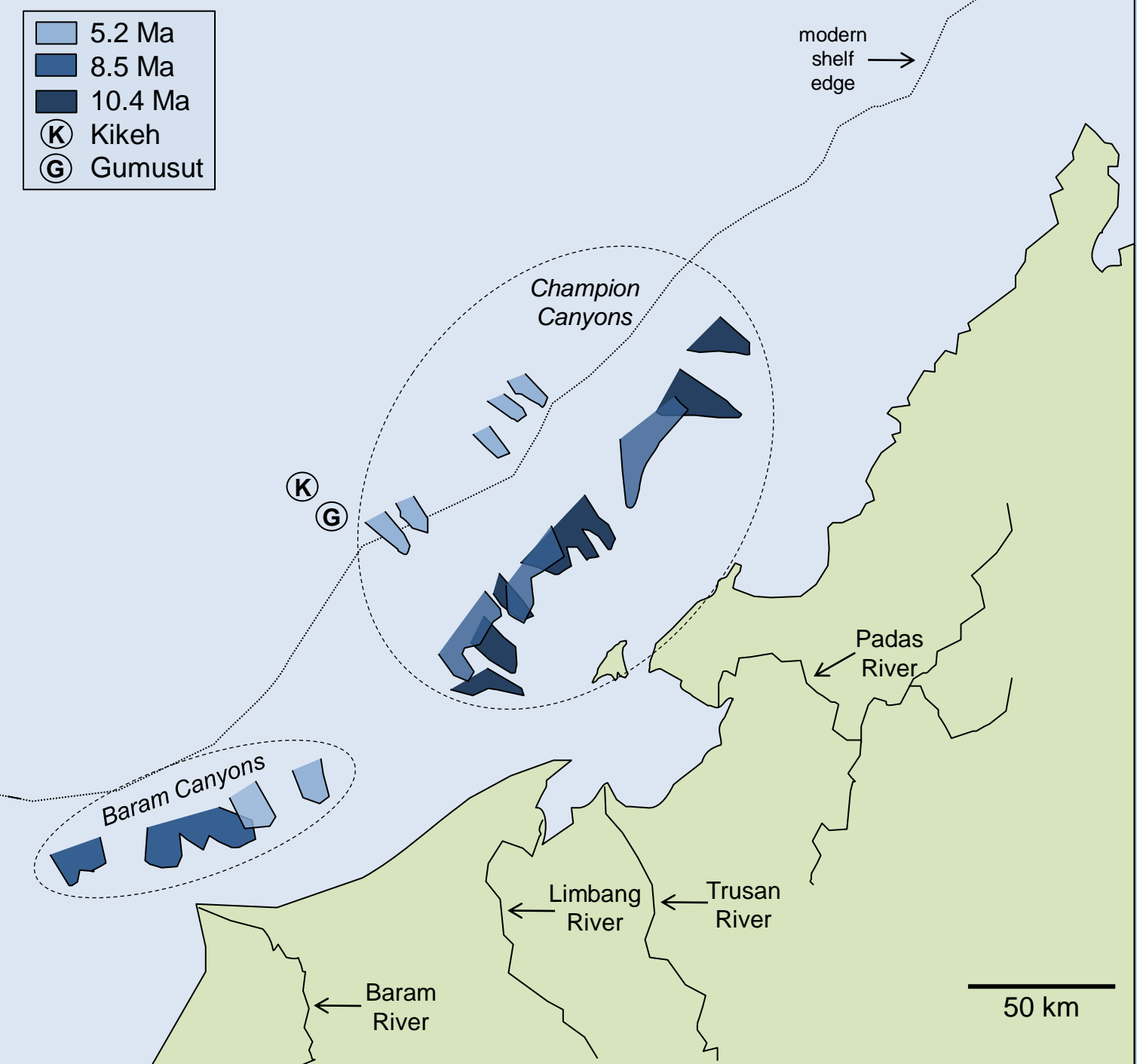
Variable Sediment Supply to the Shelf Edge





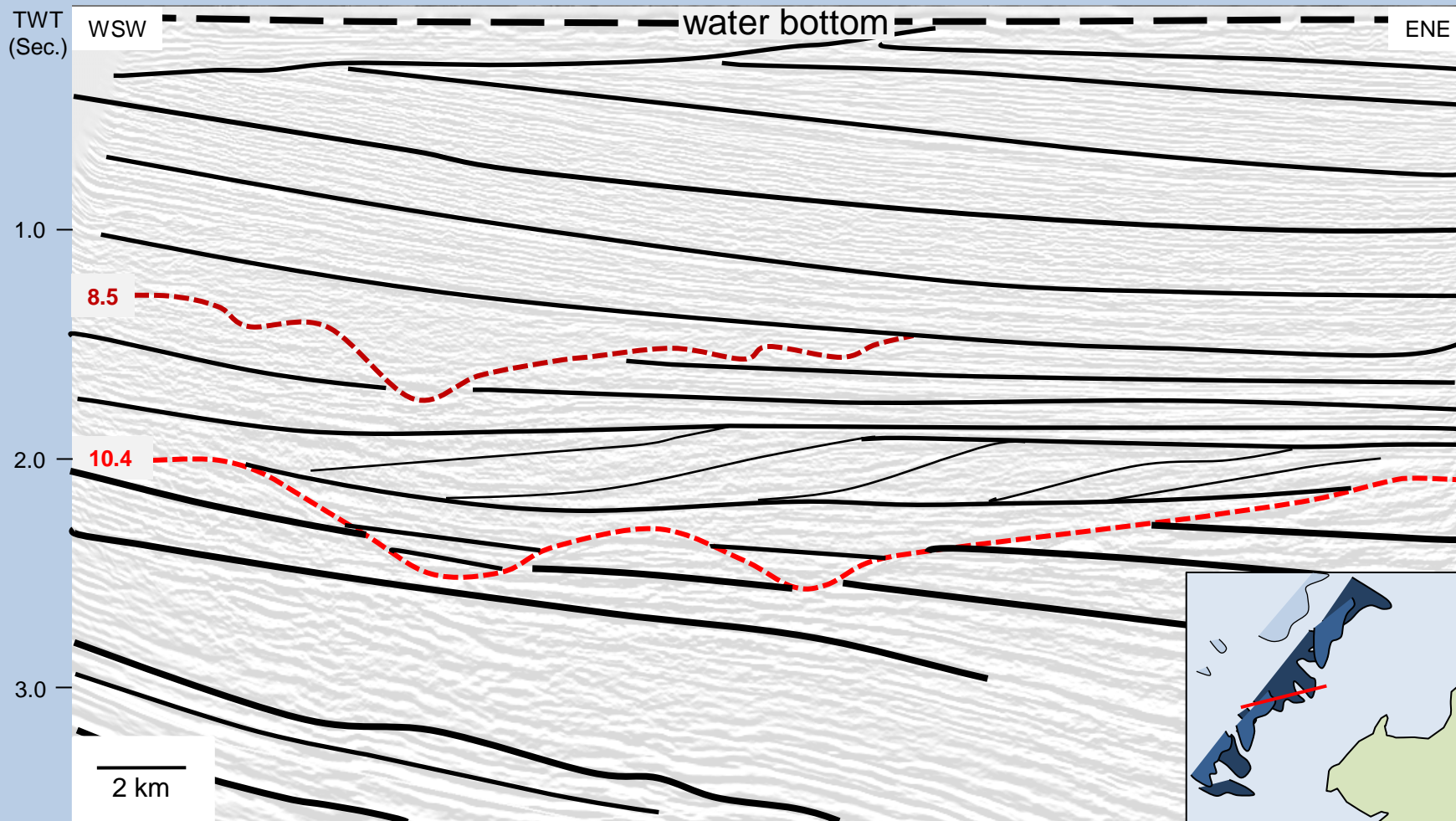
modern shelf edge →

Shelf Edge Canyons

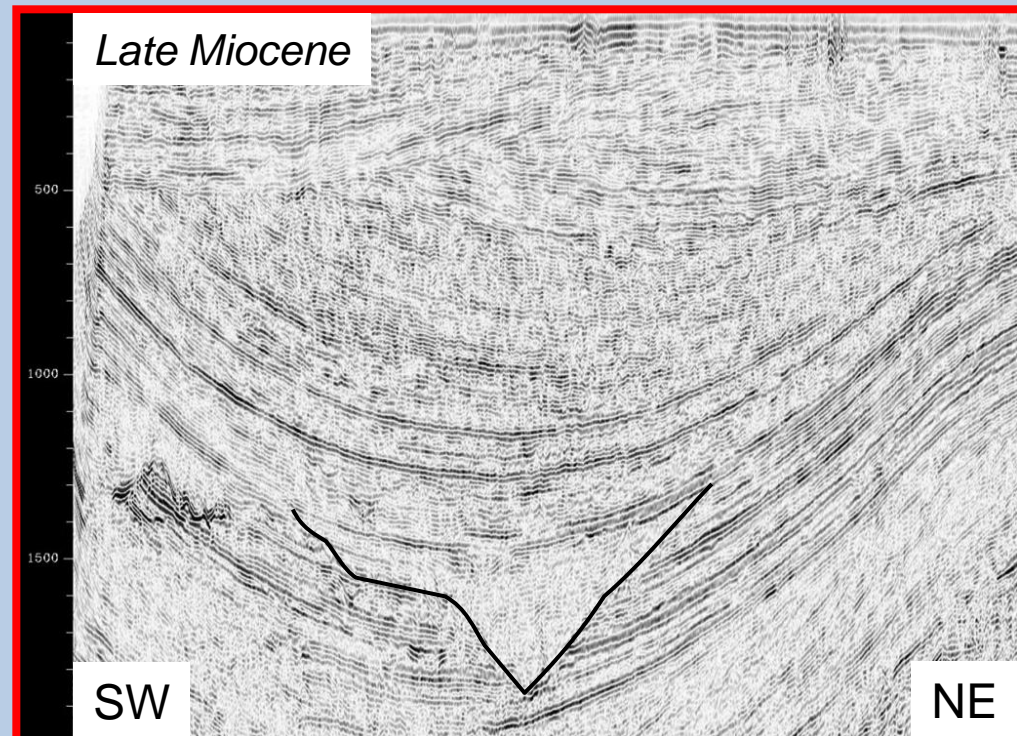
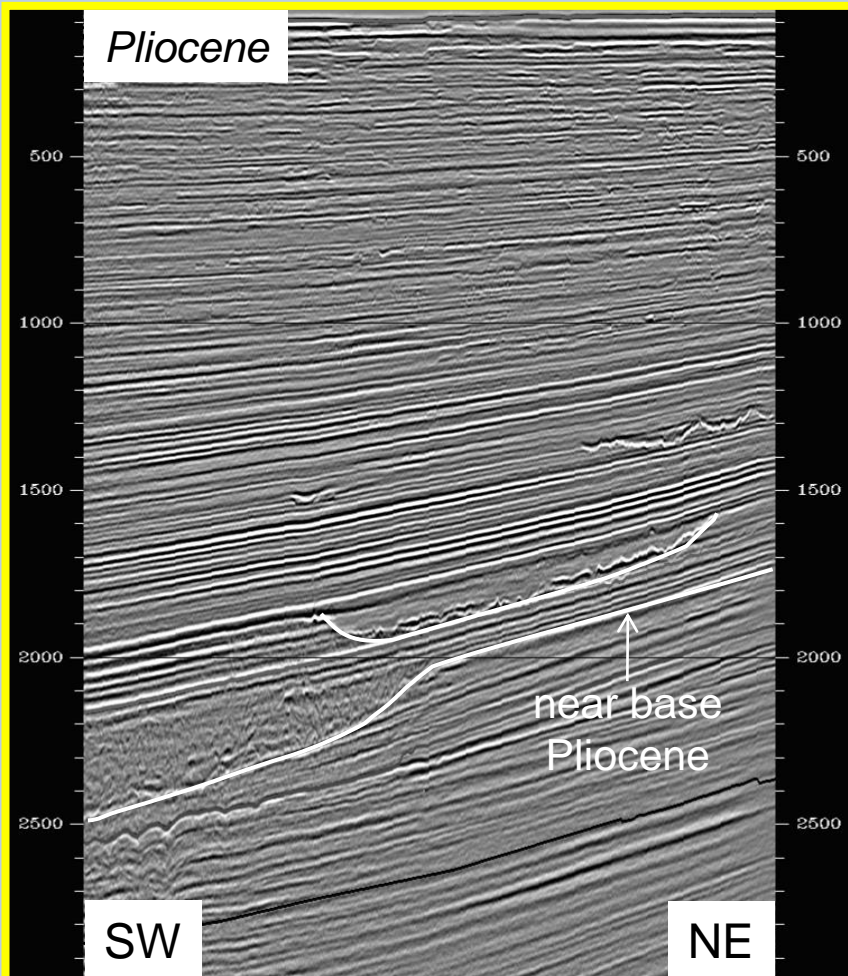
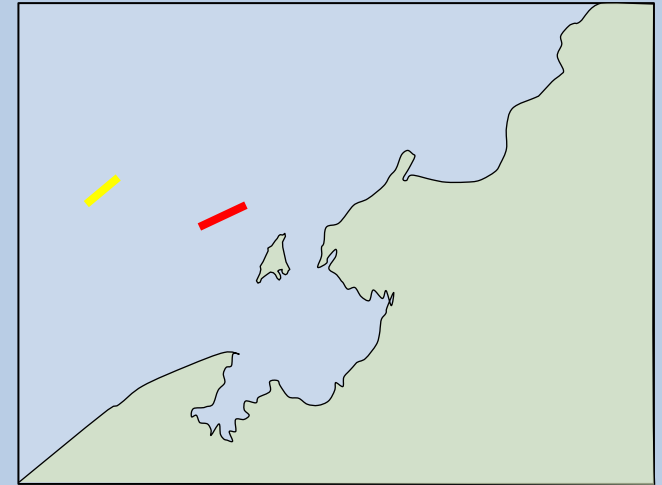


- 3 sets of Champion canyons
- each set related to a tectonic event
- multiple, shifting rivers

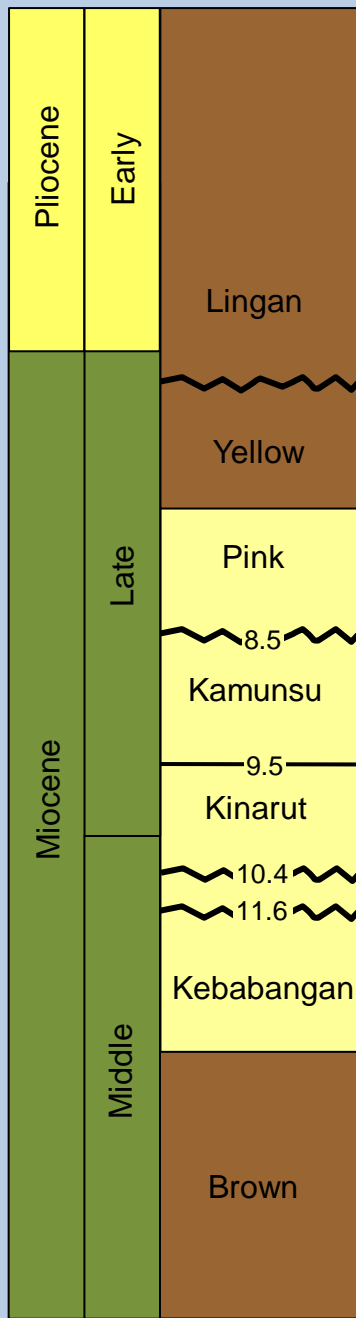
Champion Canyons



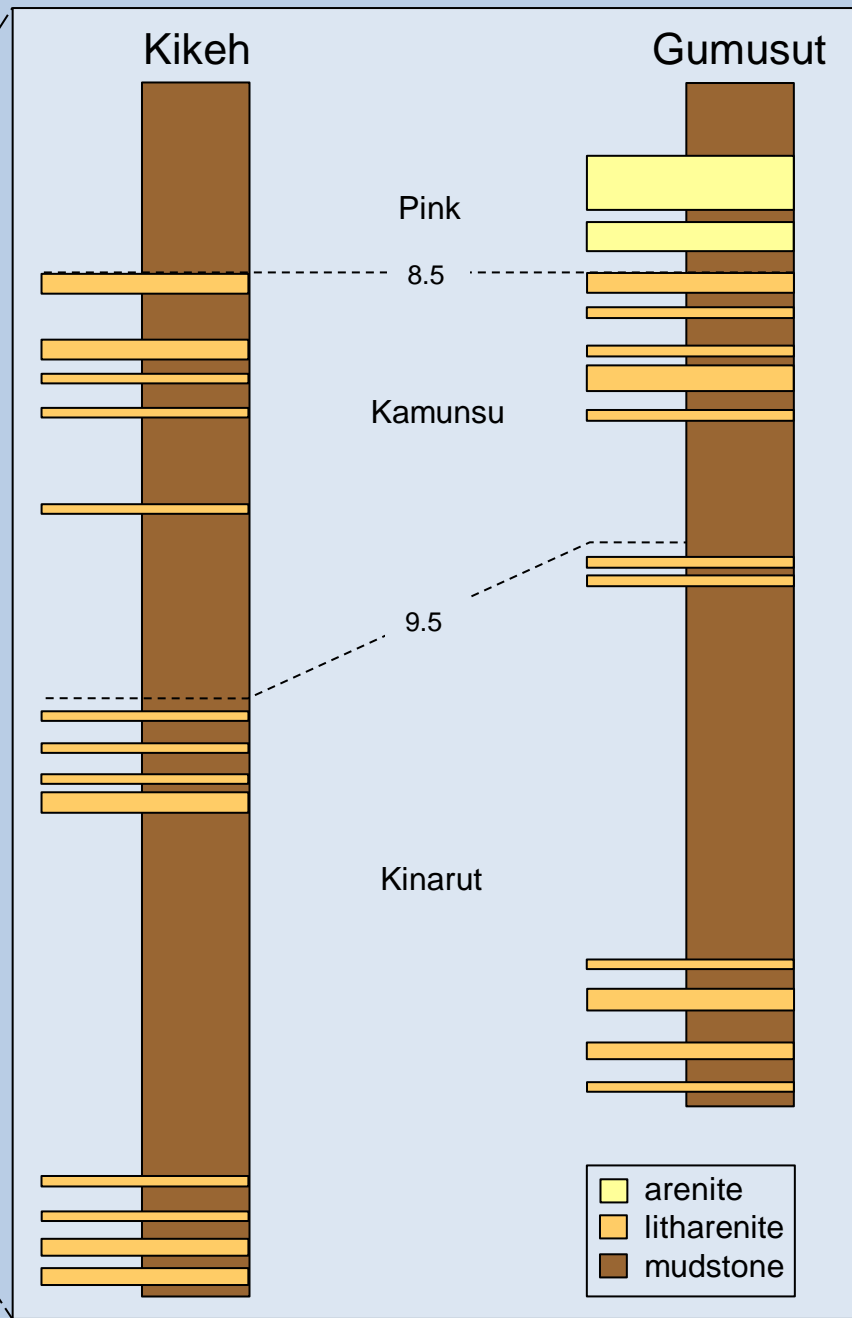
- Deep incision at 8.5 ma
- Multiple shallow incisions at 5.2 Ma



(after Cullen and Phillip 2006)

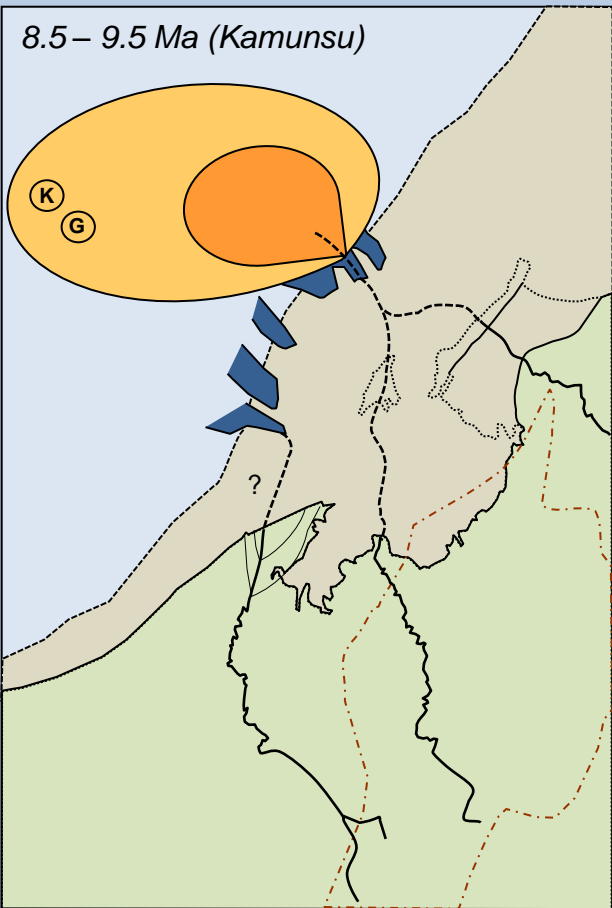


(modified from Krebs 2011)

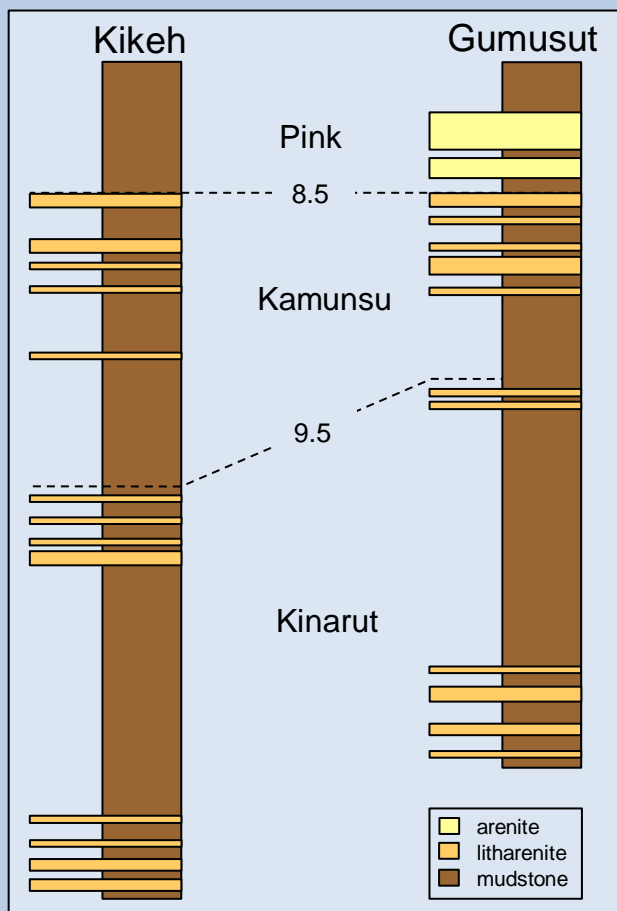
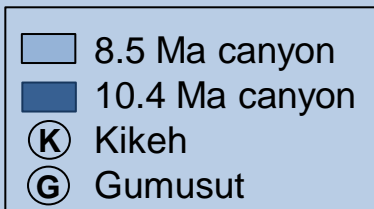
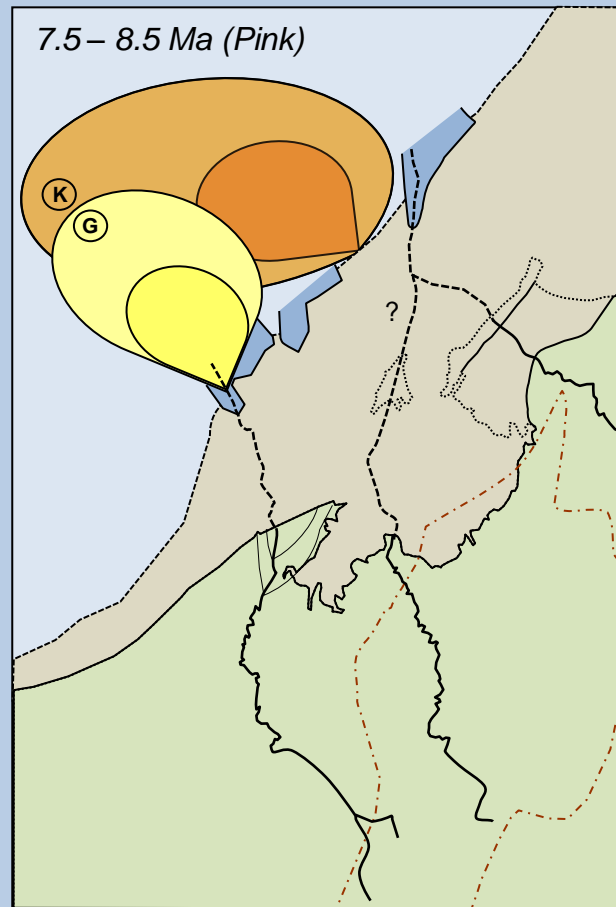


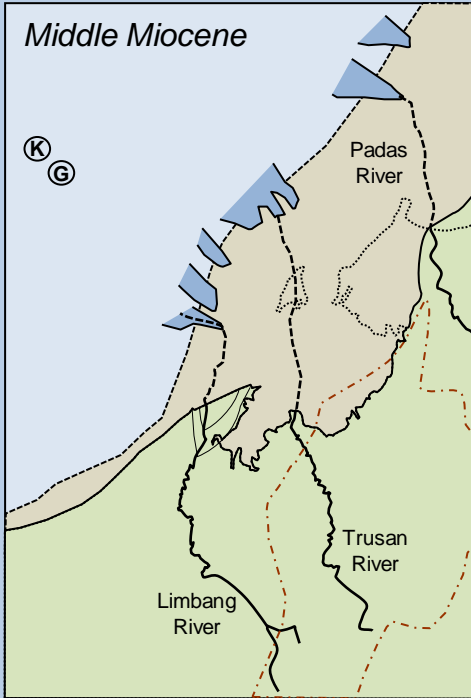
(synthesized from Grant (2003), Ingram *et al.* (2004) and Algar *et al.* (2011))

8.5 – 9.5 Ma (Kamunsu)

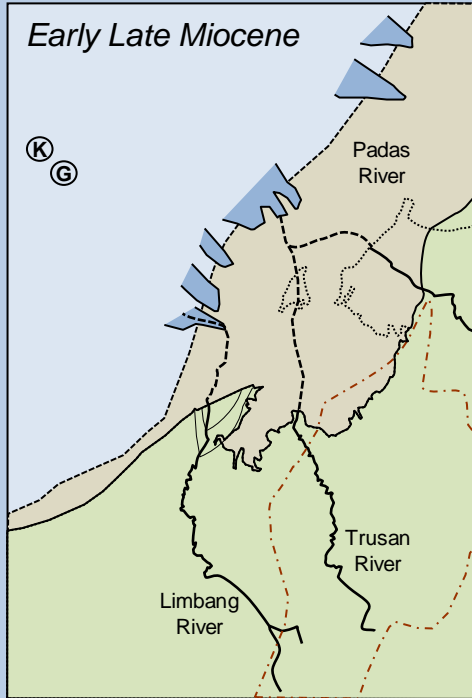


7.5 – 8.5 Ma (Pink)

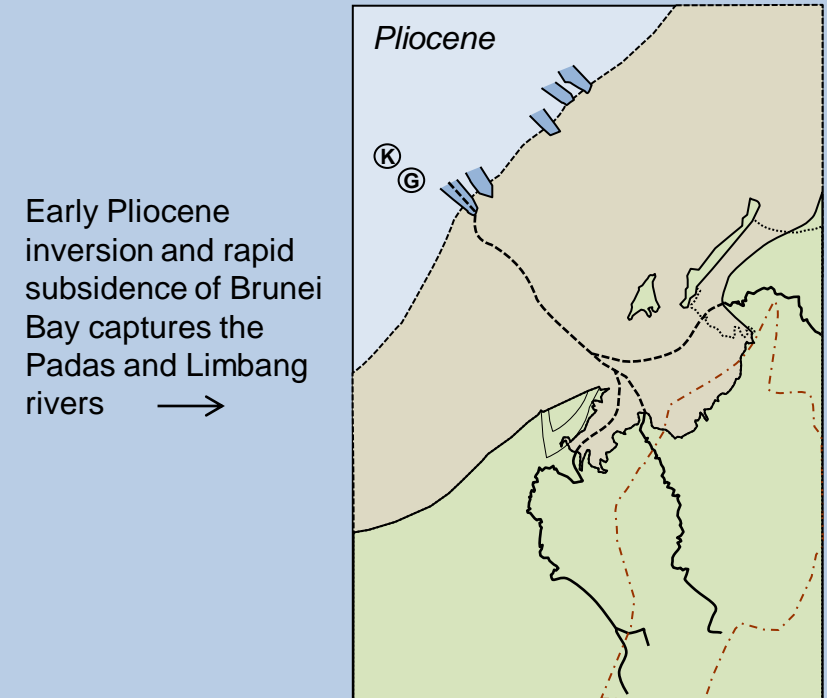
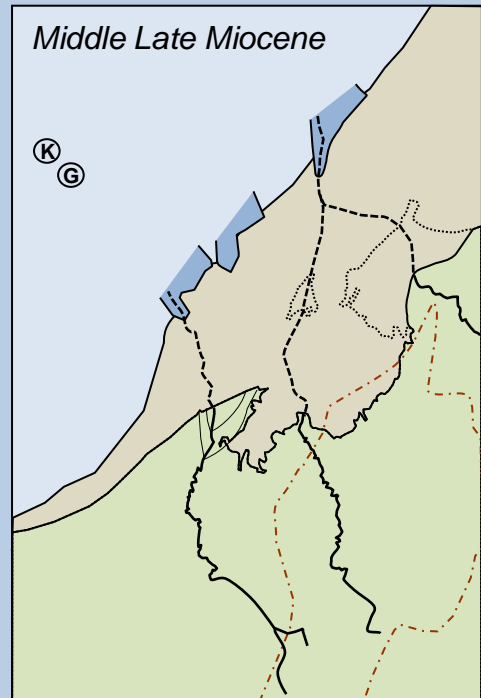




Multiple rivers reaching the shelf edge
←

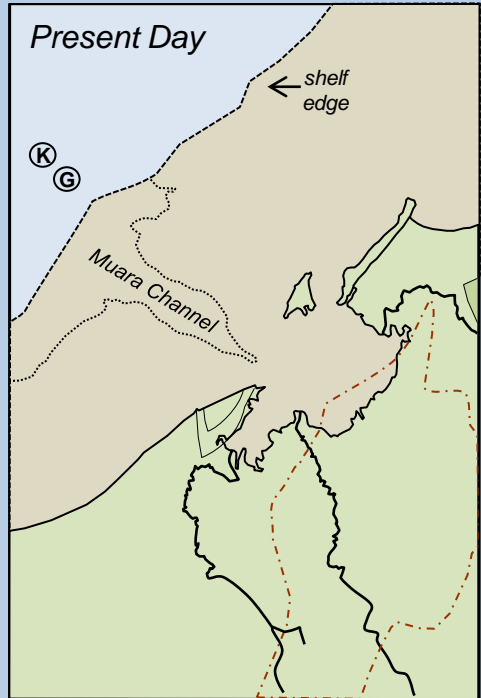


Limbang River supplies Kikeh reservoir sands
→



Early Pliocene inversion and rapid subsidence of Brunei Bay captures the Padas and Limbang rivers
→

↑
Padas/Trusan rivers supply Gumusut reservoir sands



shelf edge canyon
areal limit of Meligan Sandstone

Conclusions

- The Champion "Delta" is the product of diverse, shallow marine depositional systems
- Facies and stratigraphic architecture are controlled primarily by evolving topography
- The Padas, Limbang and Trusan rivers are important sources of sand, although most is trapped on the shelf
- Deepwater sands are relatively small and scattered with variable reservoir quality
- Kikeh and Gumusut reservoir sands probably were supplied by the Padas/Trusan and Limbang rivers, respectively