Controls on Depositional Systems and Sequence Stratigraphy of the Pliocene - Pleistocene Strata of Eastern Niger Delta, Nigeria*

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Abstract

The Niger Delta is a tectonically active progradational margin where structural collapse under a prograding deltaic wedge complicates depositional patterns and sequence stratigraphic signatures. A sequence stratigraphic analysis of the Pliocene-Pleistocene strata in the eastern part of Niger Delta based on 2D and 3D seismic data, as well as biostratigraphic and wireline data from 16 wells, documents the depositional patterns within five maximum flooding surface (MFS) bounded genetic sequences. While the Pliocene sequences shows a shelf-to-slope seismic facies association consisting of shallow marine deltaic sediments in proximal areas and hemipelagic shales basinwards, the Pleistocene sequences however, show a shelf-to-slope seismic facies association consisting of shallow marine deltaic sediments, shelf-margin deltas and deep water sediments. There is an overall basinward shift in axis of deposition from the Pliocene to the Pleistocene.

The main control on sequence development and preserved depositional patterns and facies is the interplay between accommodation and sediment supply. Time structural and isochore mapping suggests that accommodation is primarily controlled by fault-related subsidence. Variation in fault controlled accommodation on the shelf-margins and slope leads to an along strike variation in facies, sequence thickness and stacking patterns. This is especially important in the Pleistocene where there is a marked variation in the developed and preserved facies along strike. Whereas the eastern part of the study area is mainly aggradational and comprised of stacked shelf-margin deltas and an upper slope that is composed primarily of hemipelagic shales, the western and central part of the study area in contrast are mostly progradational and dominated by shelf-margin deltas and multiple submarine channel fills, canyon fill, slope fans, mass transport complex and collapsed slope sediments. Local fault controlled accommodation is a key component in

determining whether sediment is sequestered in a shale-cored fault mini-basin, or whether sediments are able to bypass the local fault-basin to deliver sediment to linked deepwater provinces.

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Outline

- *Objectives*
- *Data and Analysis*
- *Results*
- *Conclusions*

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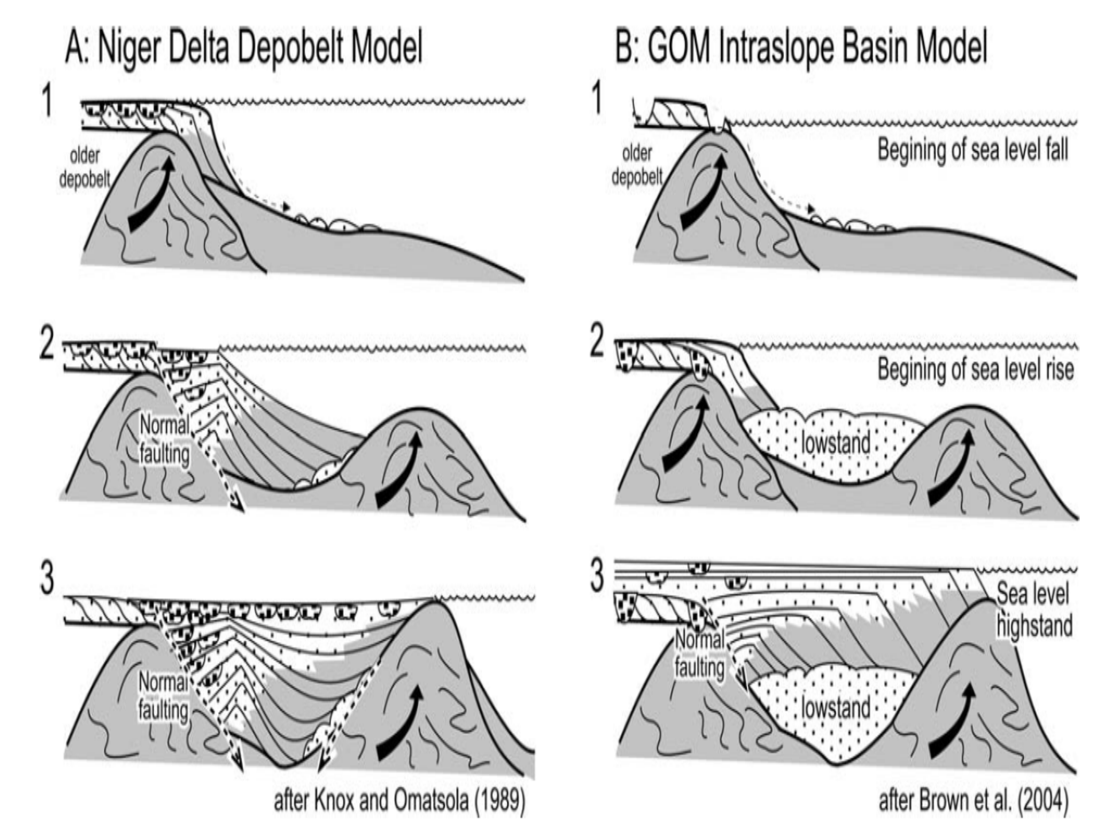
- *Nigeria National Petroleum Corporation (NNPC)/Shell Nigeria JV*

Objectives

1. Evaluate the 3rd order controls on depositional sequences and systems in a passive margin with shale tectonics from shelf-slope and along-strike

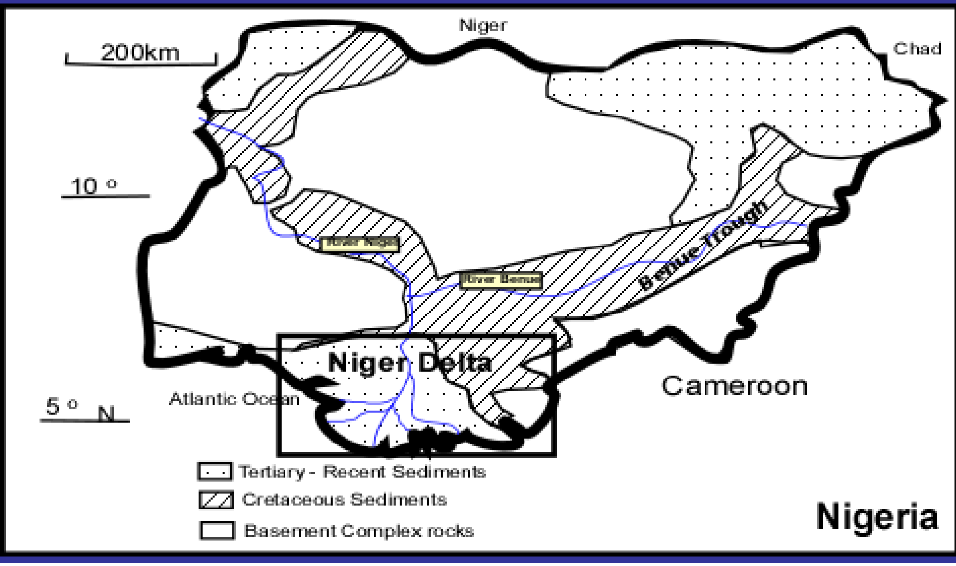


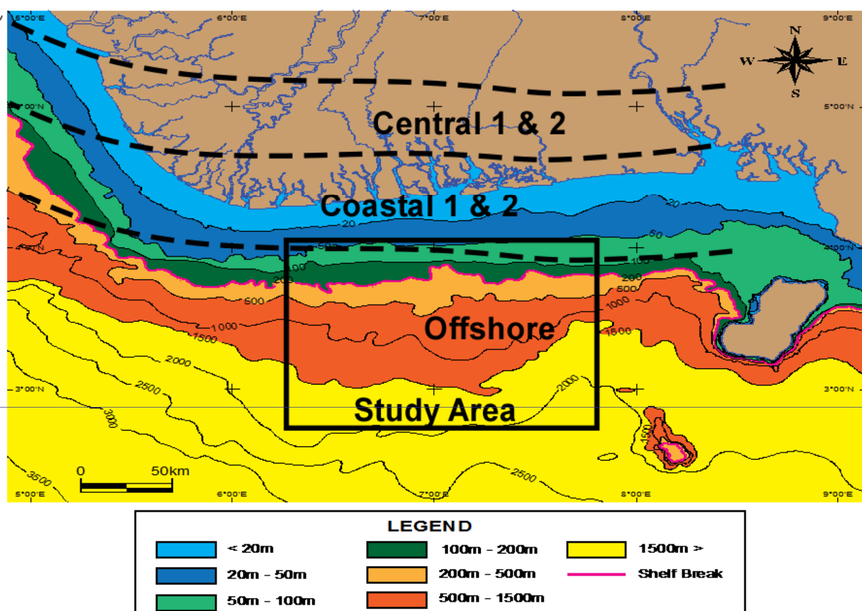
2. Evaluate the interplay between major down-to-basin fault and major counter regional fault and the effect on sequences, depositional systems and depobelt (sub-basin development)

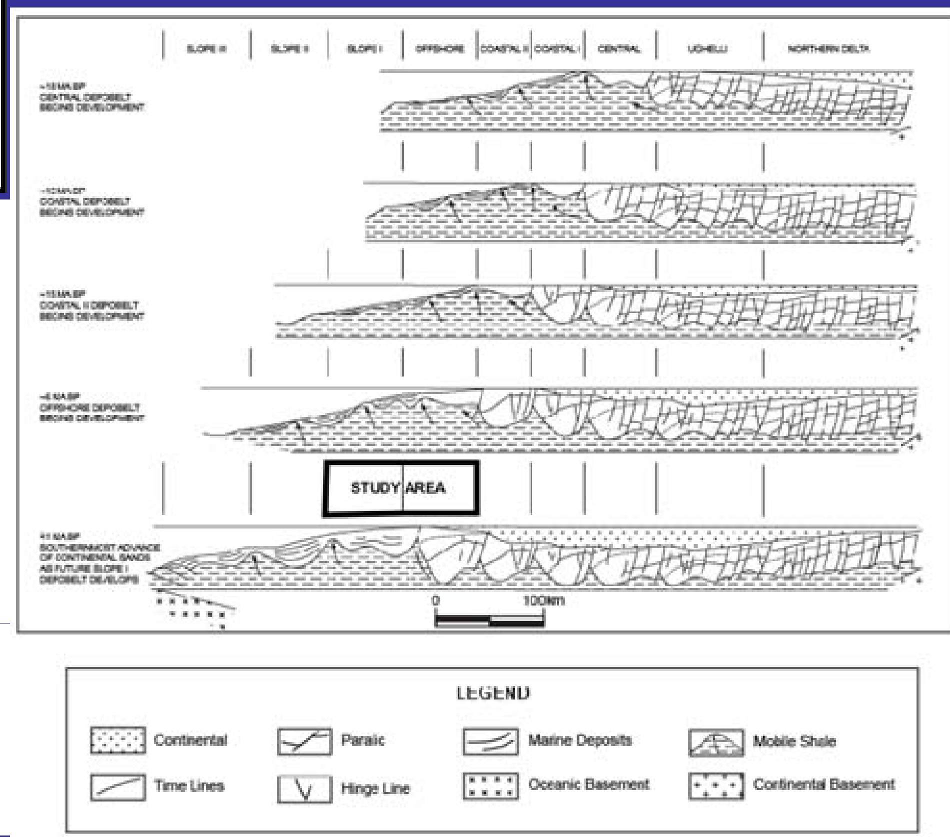
From Owoyemi and Willis 2006

Location

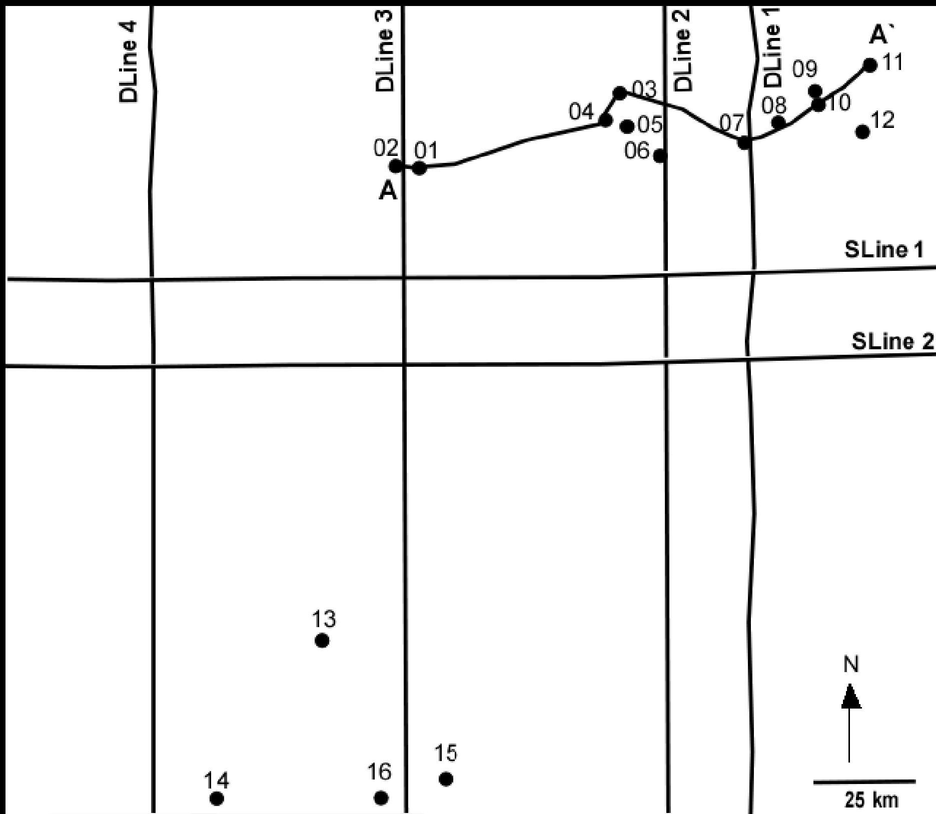
Stratigraphic cross section from the north to the south showing the progradational geometry of the Niger Delta deposits and location of study area (modified from Knox and Omatsola 1987)

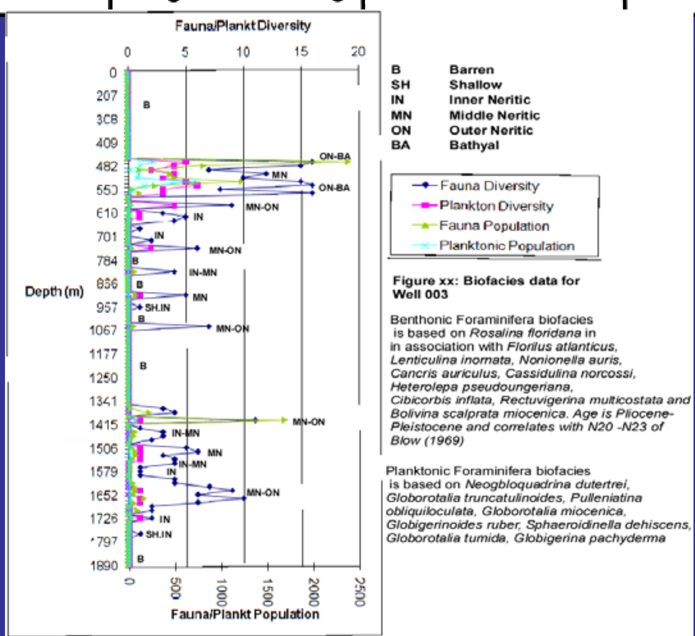






Study Area ~ 70,000km2



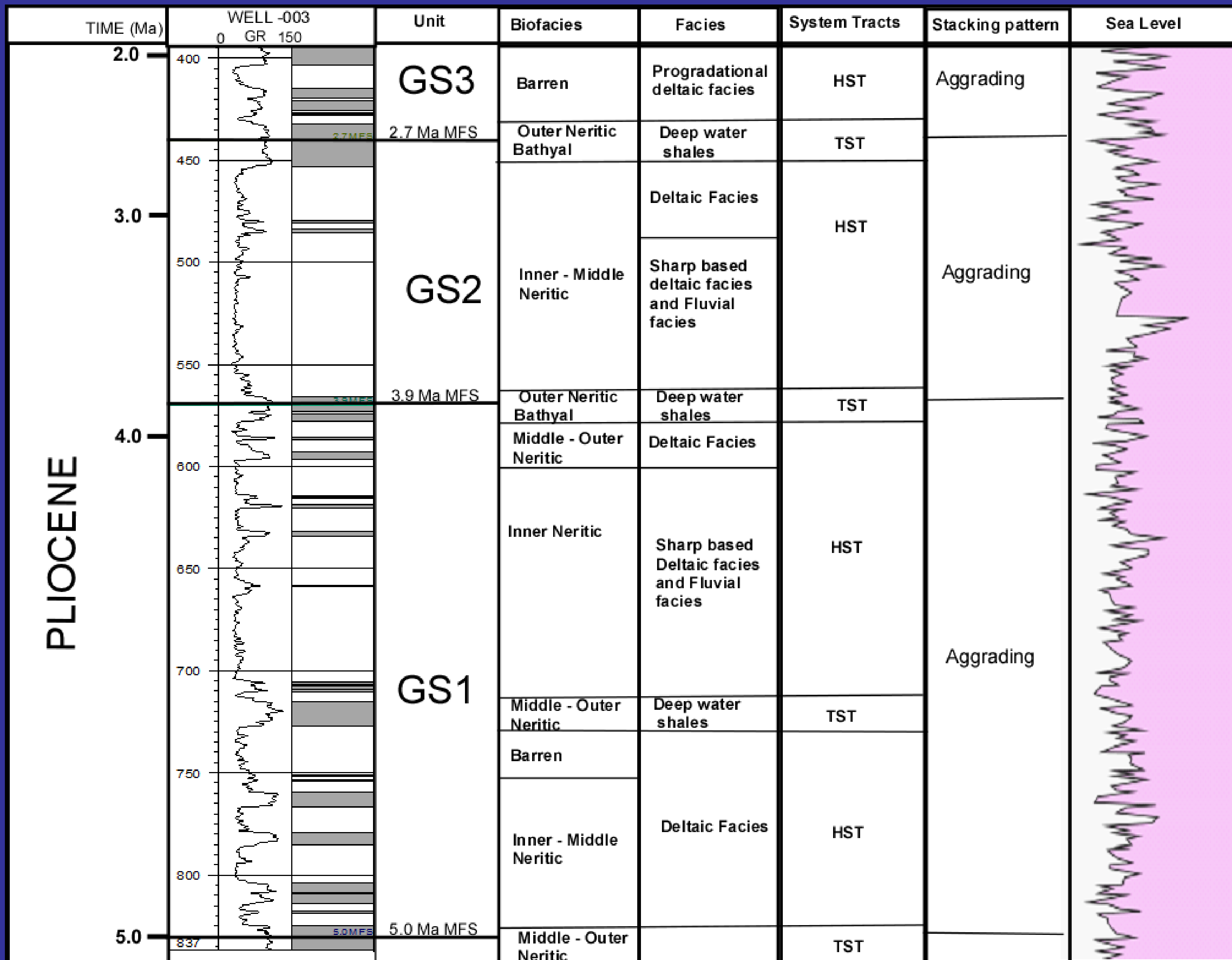


Data

- Wireline Log data (GR) from 16 wells
- Biostratigraphic data
- 24,000 km of High Resolution 2D Seismic data
- Five age constrained 3rd order MFS (5.0 Ma, 3.9 Ma, 2.7 Ma, 2.0 Ma and 1.3 Ma,) and Seafloor

- 6 MFS surfaces defines 5 Genetic Stratigraphic Sequences (GS1 – GS5, Galloway 1989)
- 2 erosional surfaces or CSB's

Data/Analysis



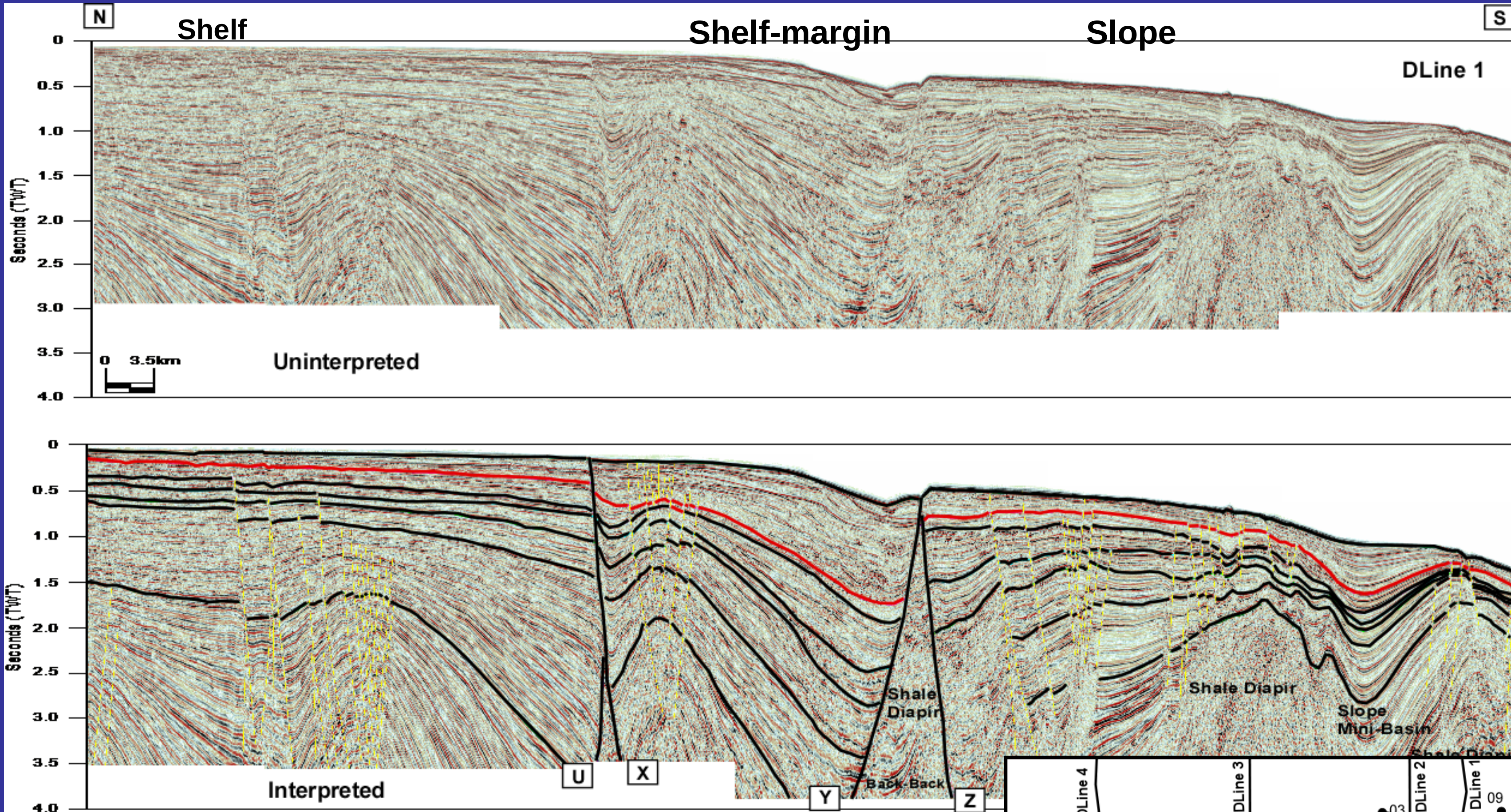
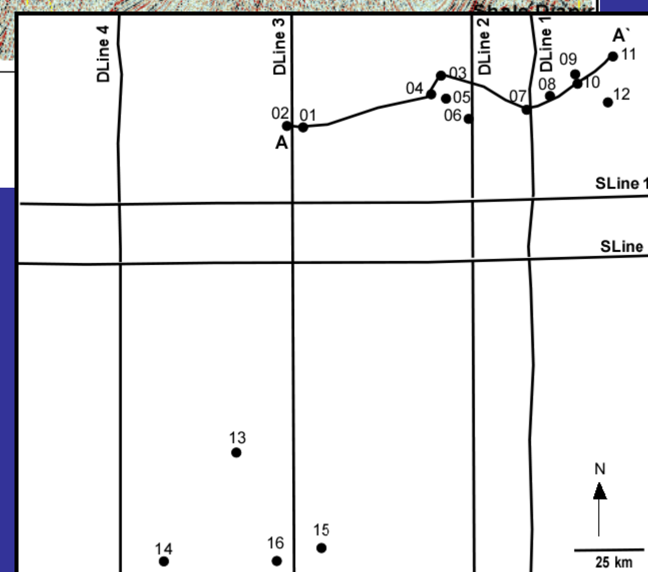
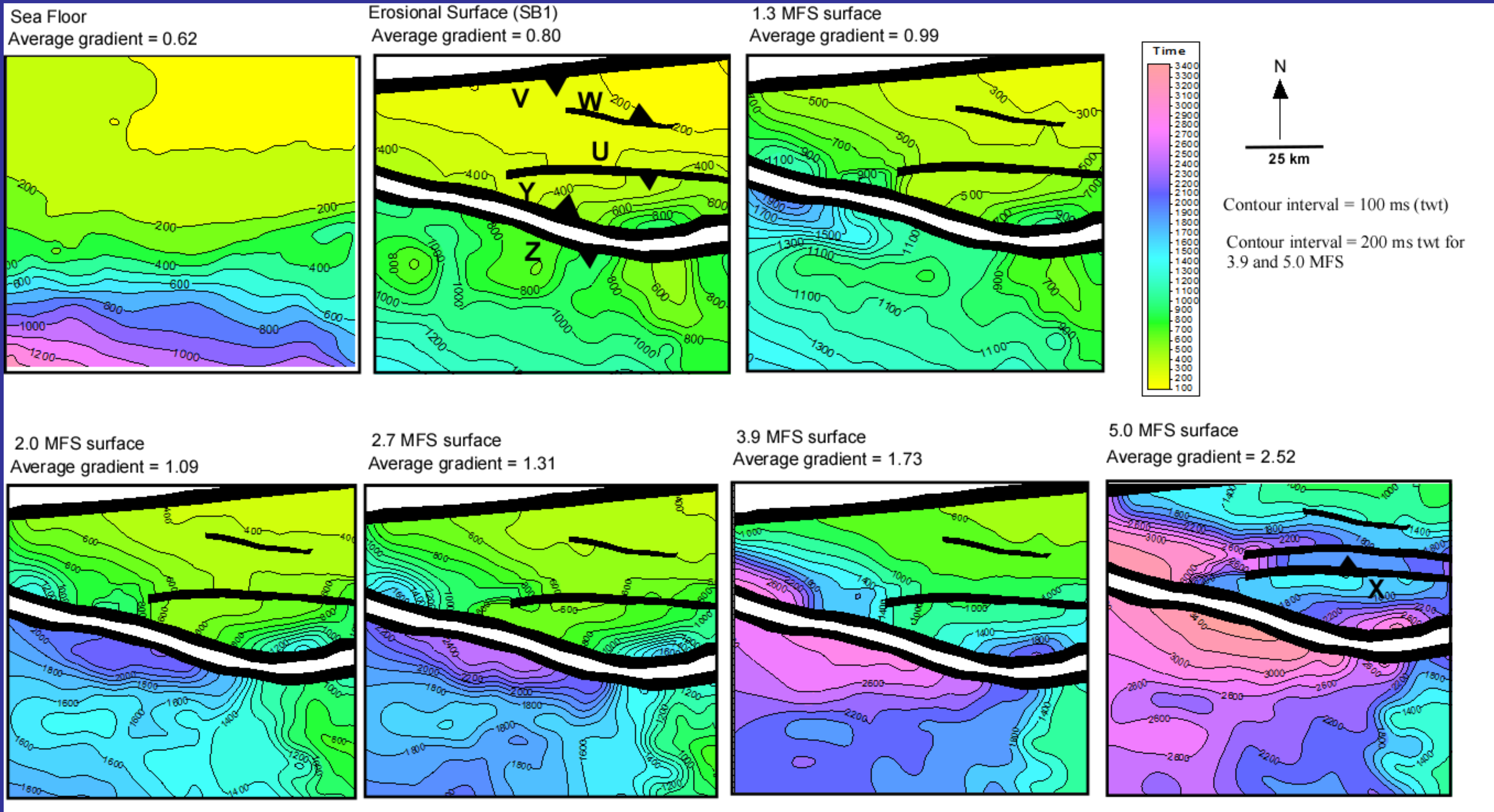


Fig. 7a: Seismic section showing the structural configuration of the study area
Horizon names from top to bottom: Sea floor, CSB1, 1.3 MFS, 2.0 MFS, 2.7 MFS, 3.9 MFS and 5.0 MFS
Letters represents fault names. Yellow lines represents other interpreted minor faults

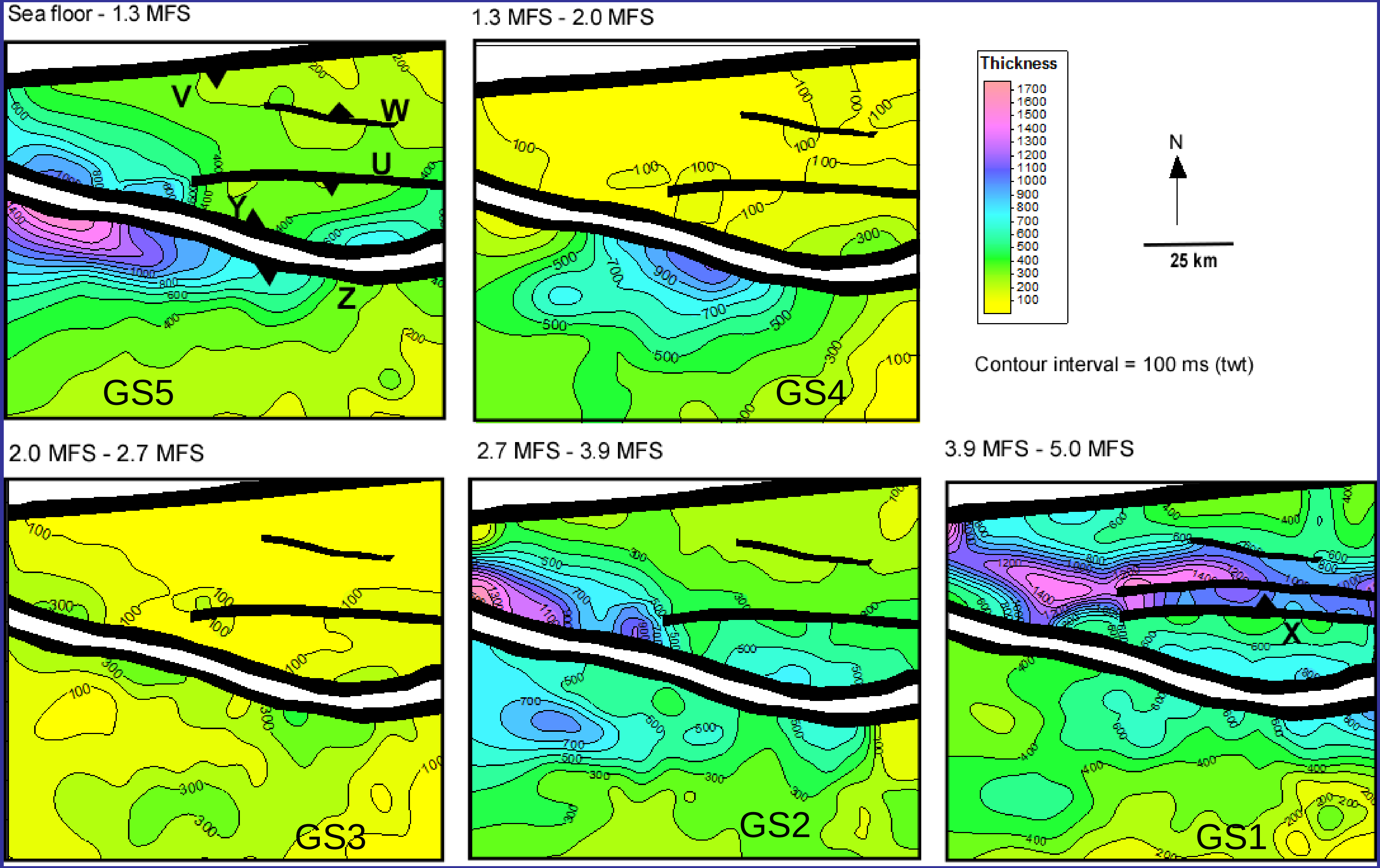


Horizon and Fault Interpretation

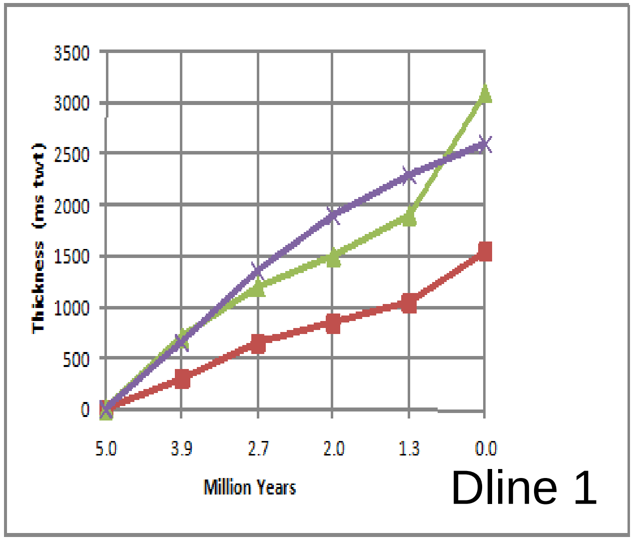
Time Structure Map

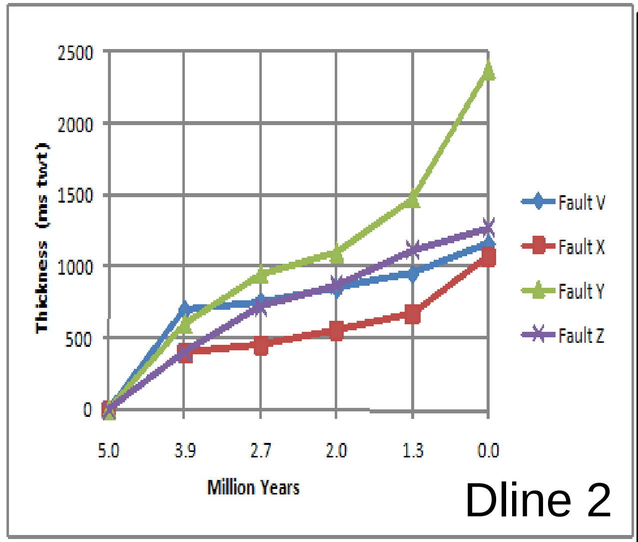


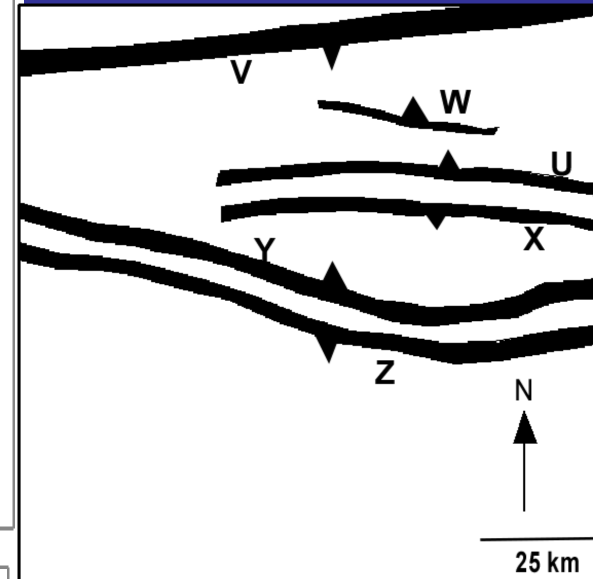
Time Isochore Map

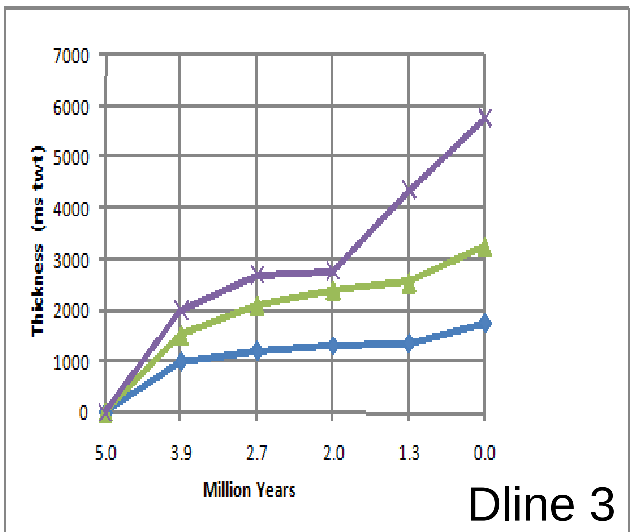


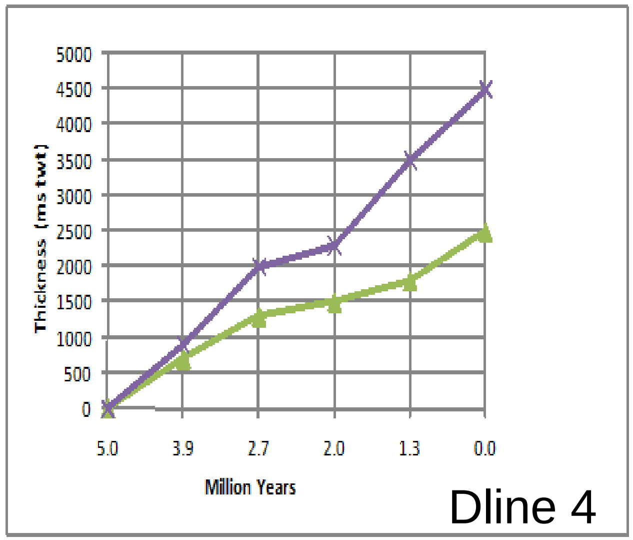
Fault Movement

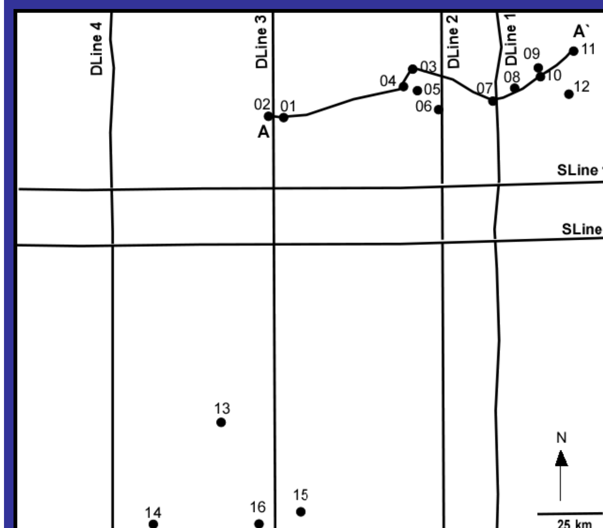




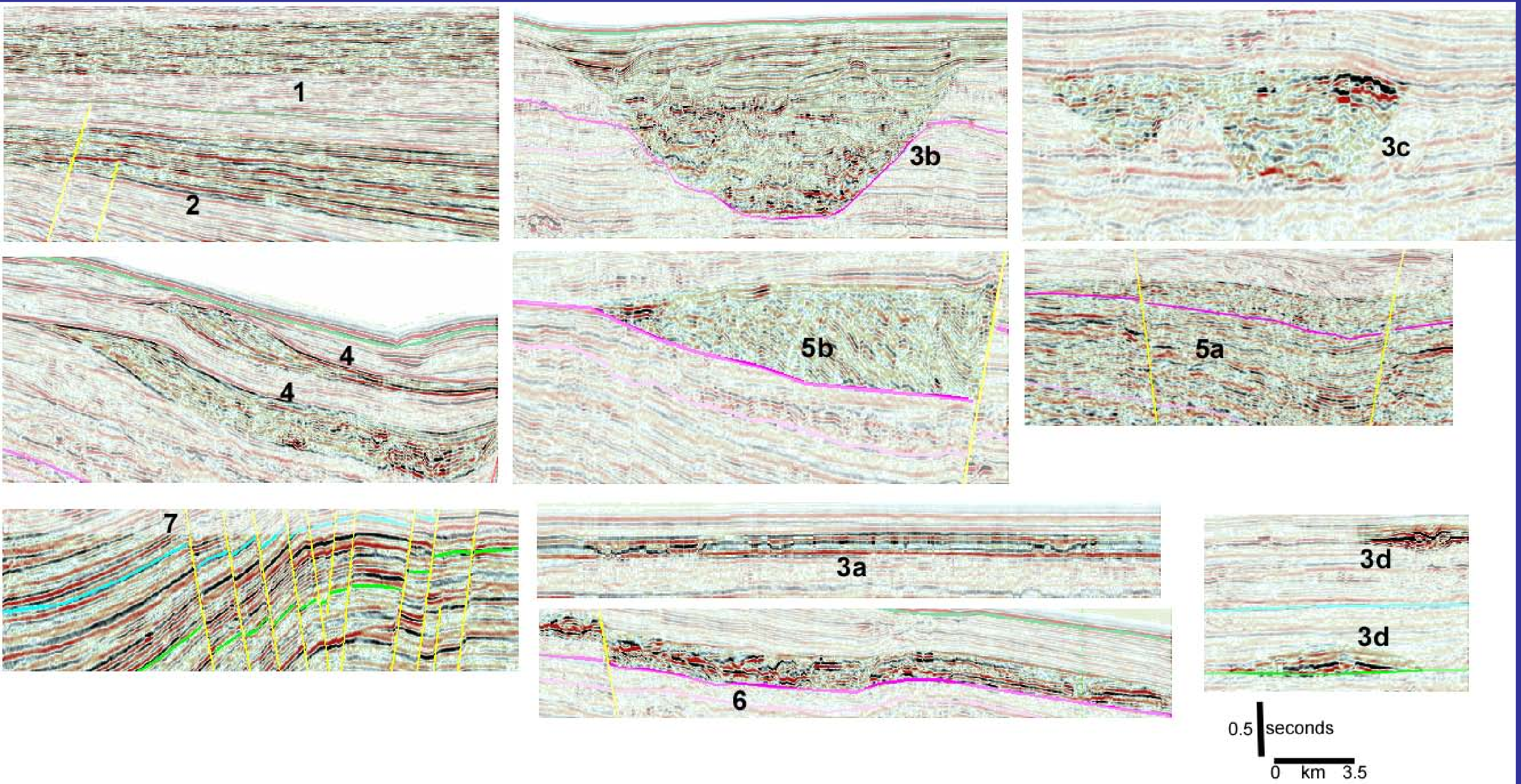








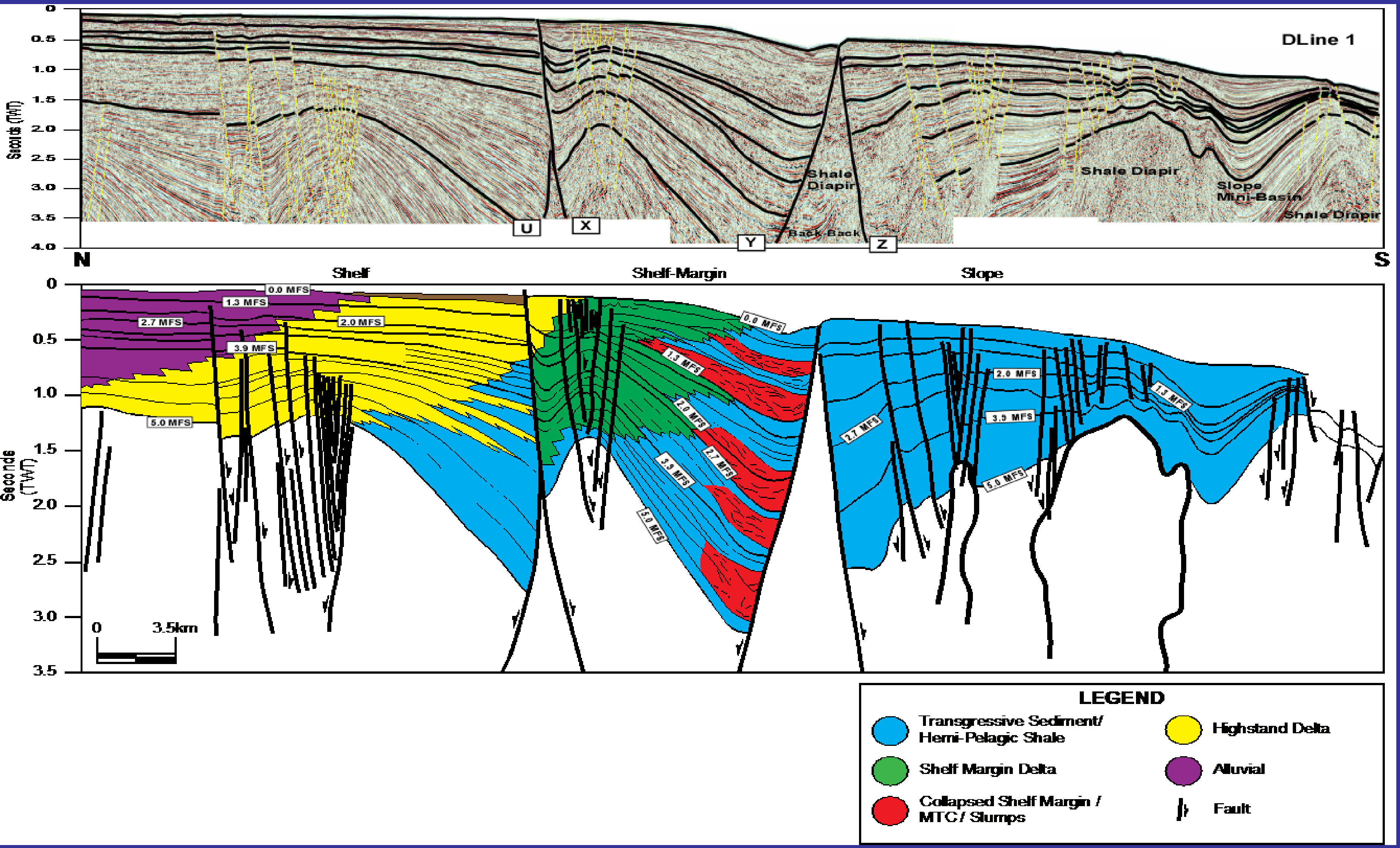
Seismic Facies



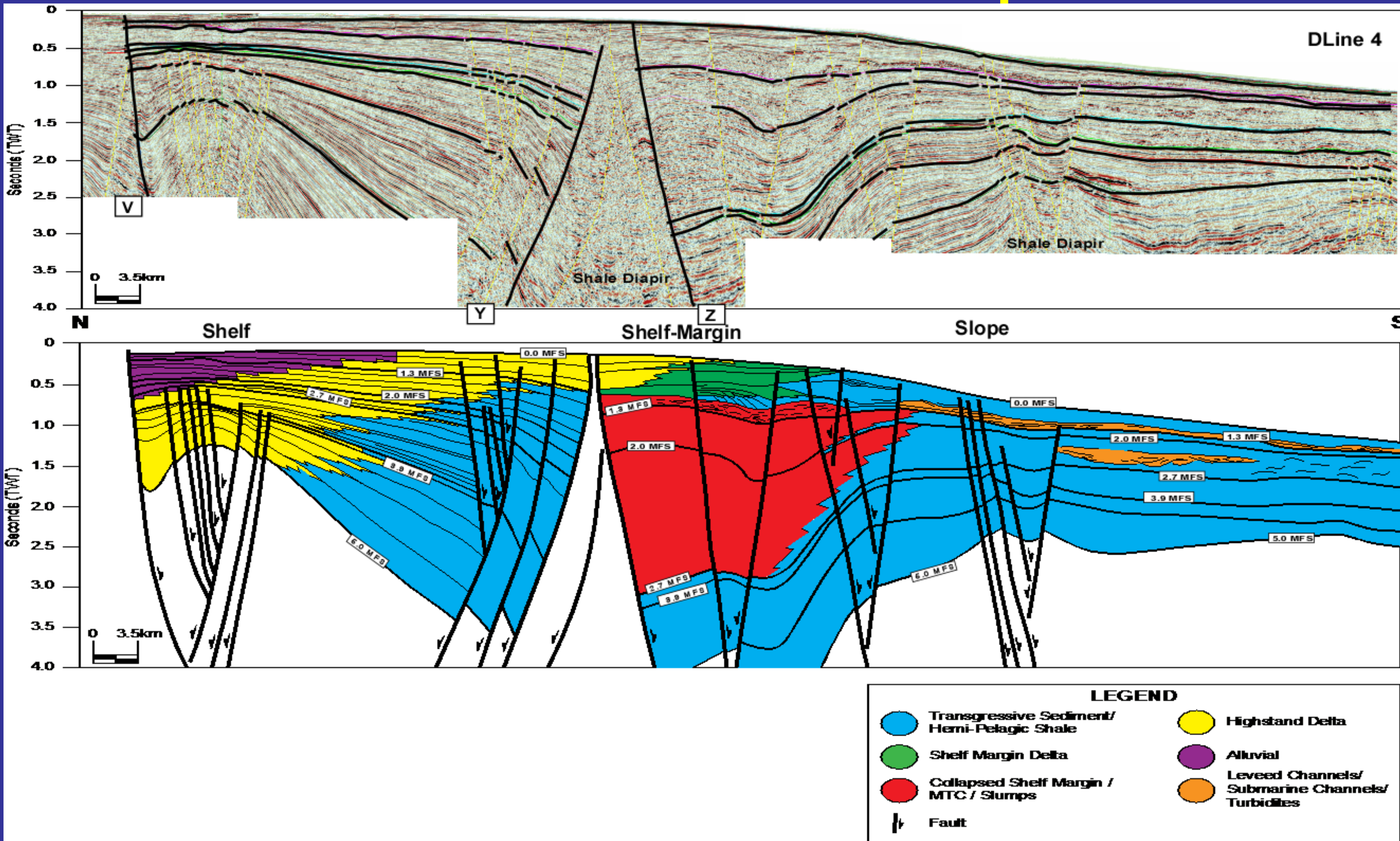
1. Continental Facies, 2. Deltaic Facies, 3a. Incised Valley, 3b. Canyon, 3c. Submarine channels, 3d. Leveed Channels, 4. Shelf-margin delta, 5a. Chaotic facies (slumps), 5b. chaotic facies (MTC), 6. Slope Fan, 7. Hemipelagic shales

Seismic facies were identified using techniques based on Sangree and Widmier (1977); Mitchum et al. 1977a, 1977b; Galloway (1998) and Krassay (2003).

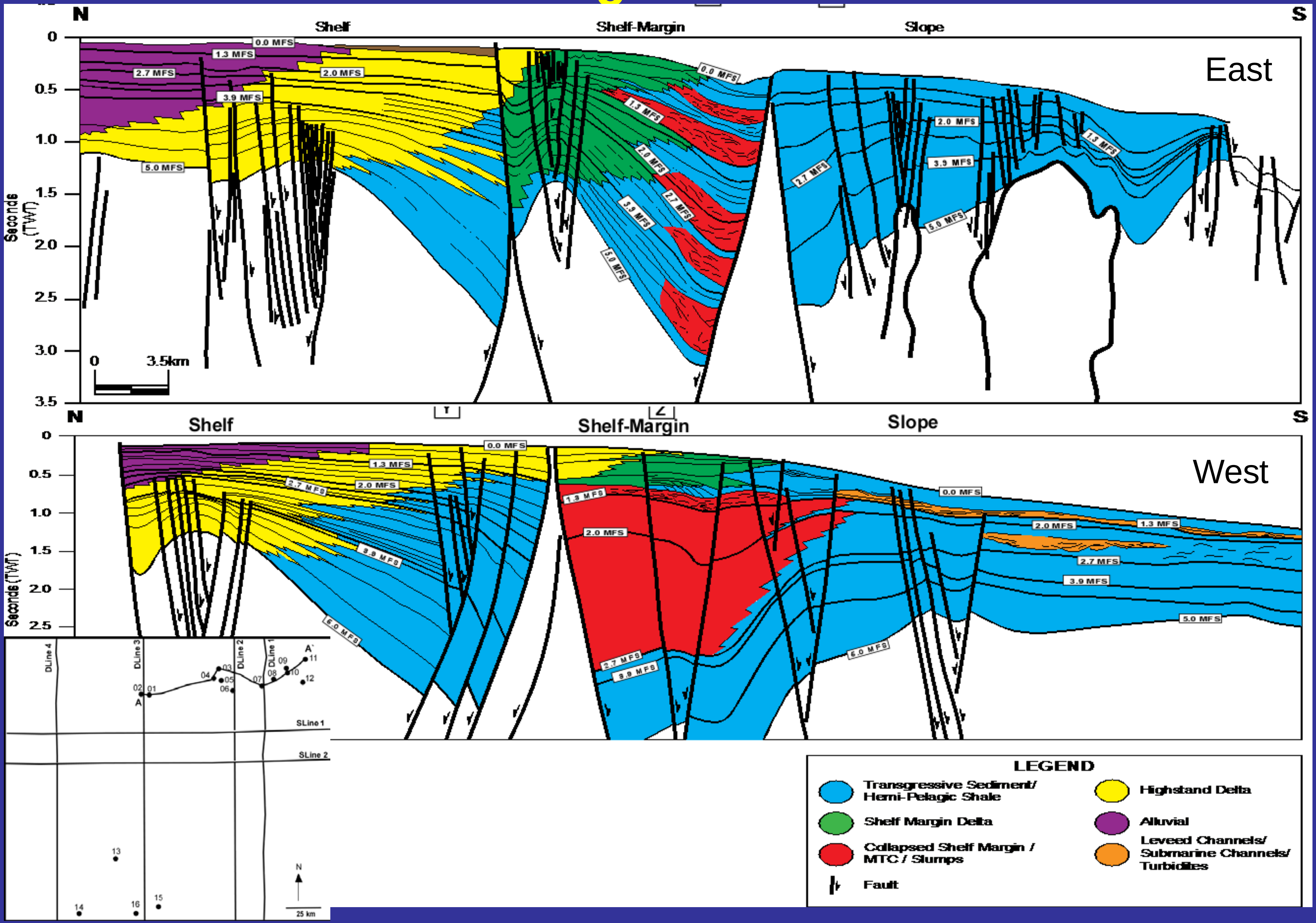
Facies variation from shelf-to-slope



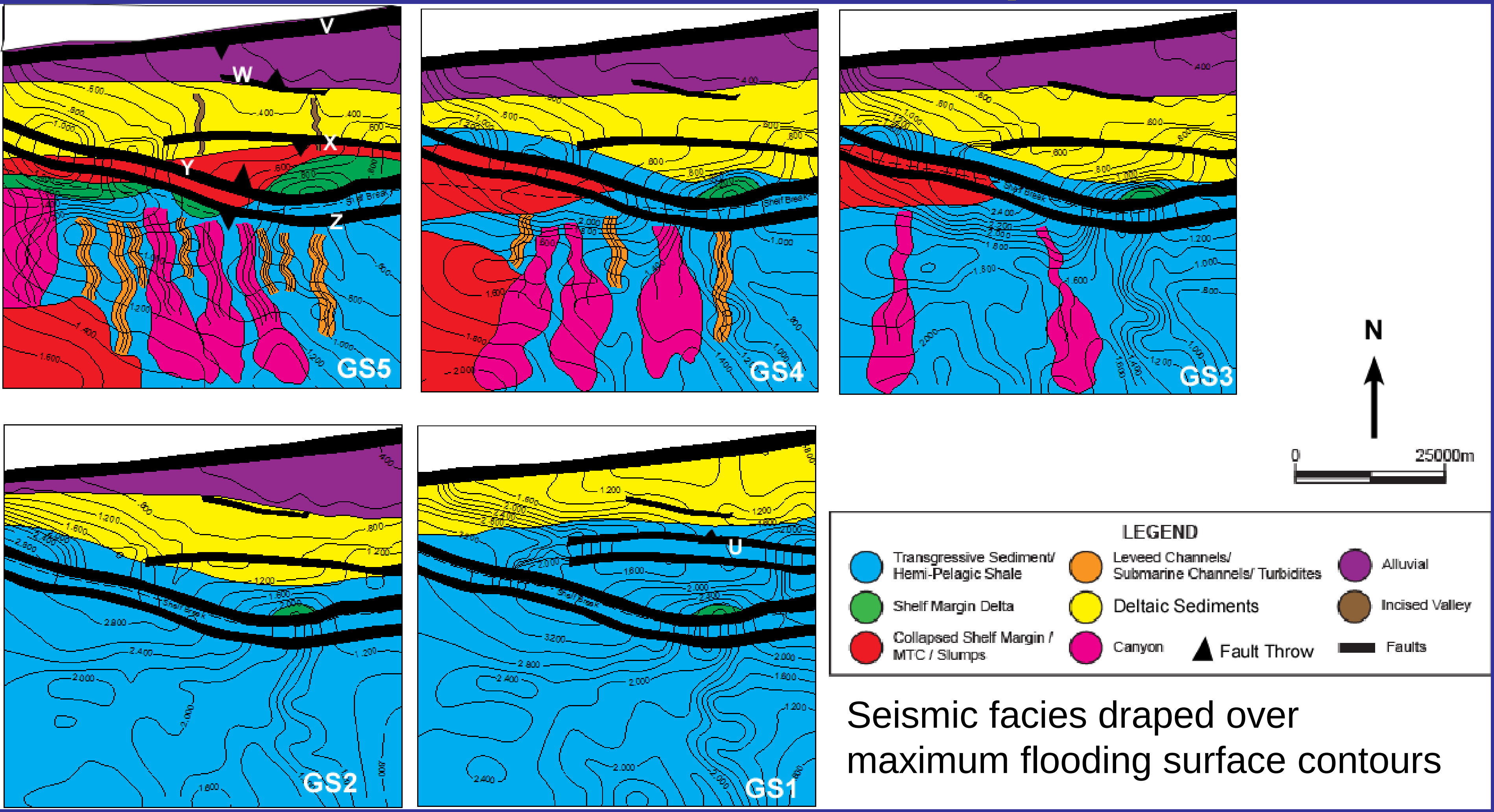
Facies variation from shelf-to-slope



Facies variation along strike

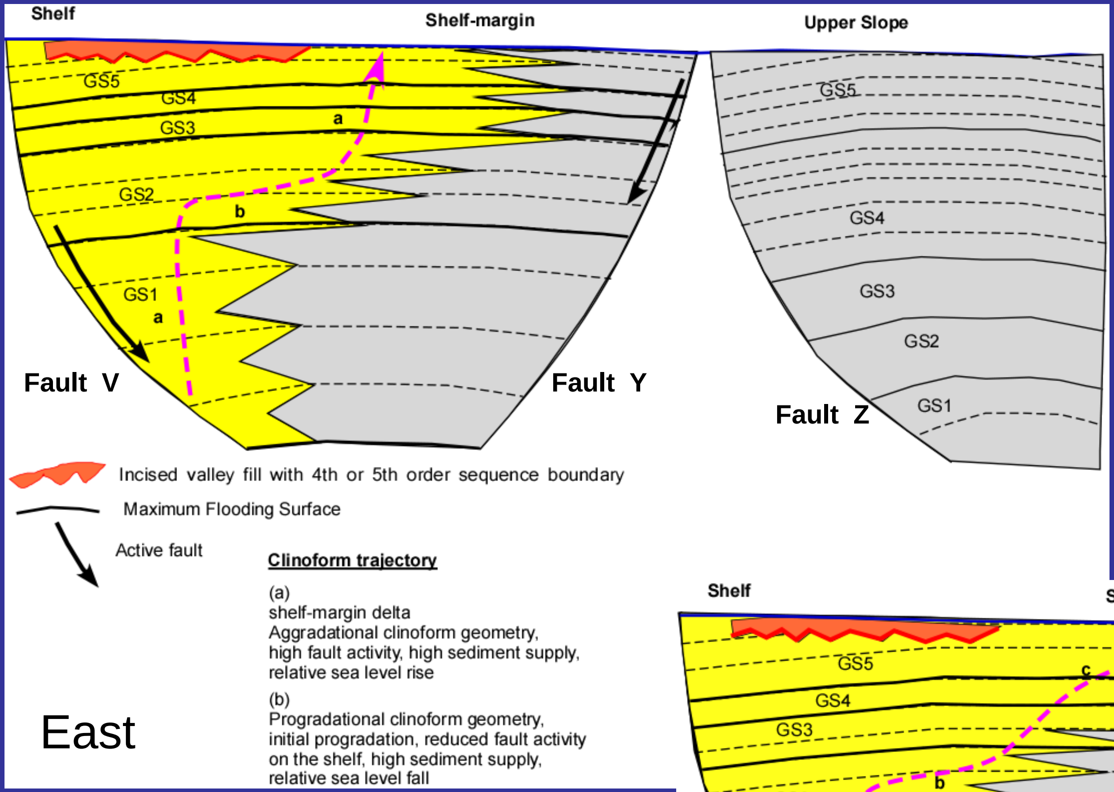


Seismic Facies Map

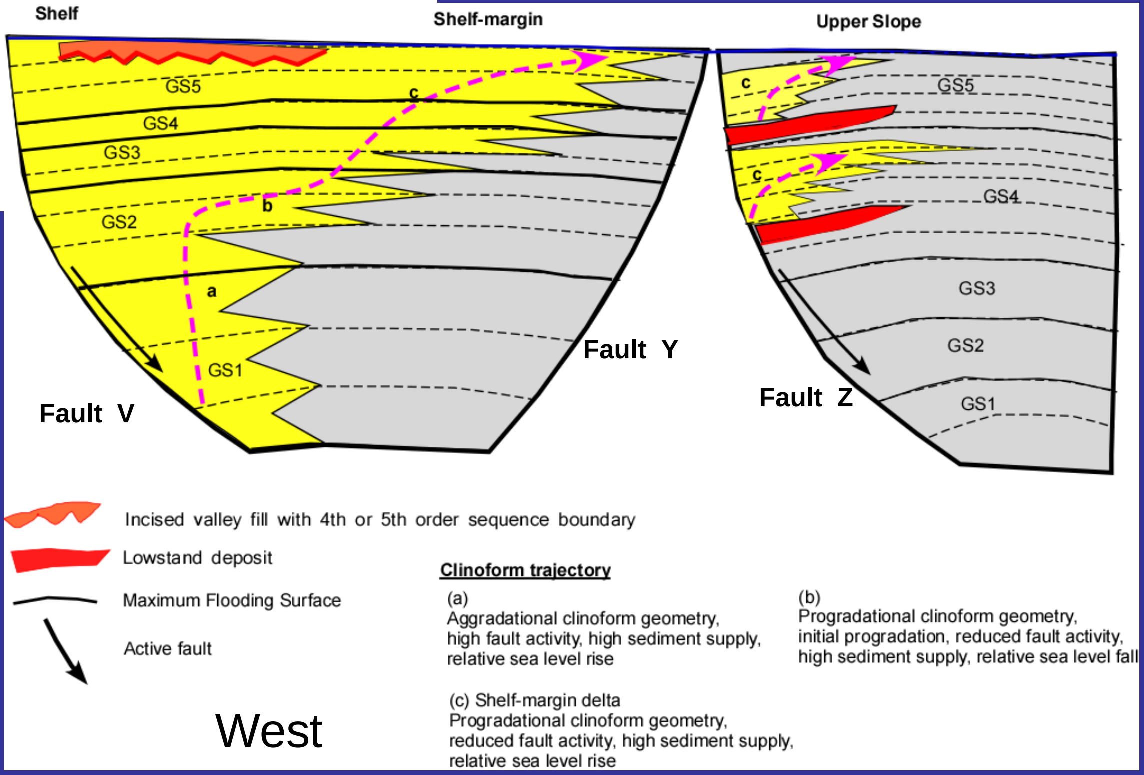


Seismic facies draped over maximum flooding surface contours

Sequence Stratigraphic Model



Slope sediments related to shelf-margin delta failure on fault-steepened slope (Ricketts and Evenchick 1999), rather than relative sea level fall.



Controls on sequence development and depositional systems

- Three factors identified to control sequences –sediment supply, tectonics and eustasy

- Fault created accommodation (Local Tectonics)
  - Variation in sequence development and depositional systems- along dip and strike

- Sediment supply
  - High Sediment supply in the eastern Niger Delta (Short and Stauble, 1967; Whiteman, 1982)
    - Tectonic uplift in the catchment areas –e.g. uplift of the Cameroon volcanic highlands

- Eustatic sea level changes overwhelmed by fault subsidence
  - important at 4th and higher order within depobelts creating local shoreline transgression and regression

Conclusion: Implication for Sequence Stratigraphy

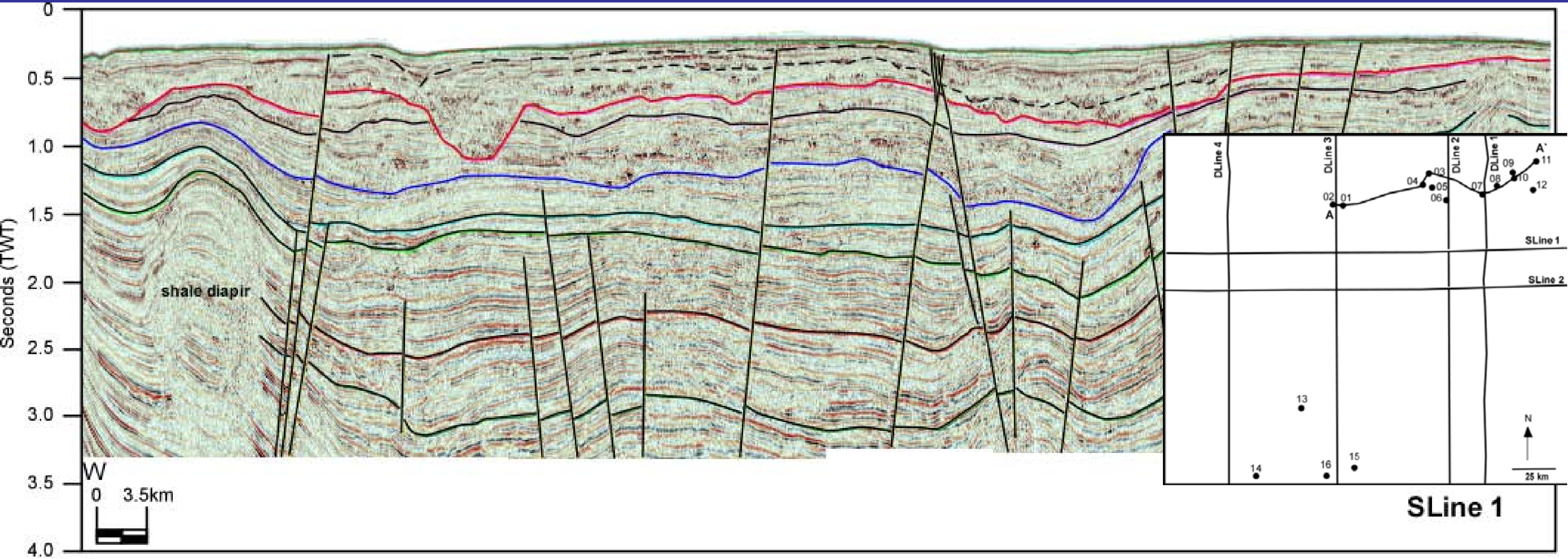
- Contrary to most sequence stratigraphic model of passive margins accommodation can be created in distal part of the basin by counter regional faults

- Differential rate of fault subsidence along strike can create co-eval systems with different stacking patterns and facies

- Slope deposits can be related to sediment collapse, slumping and mass wasting and not sea level fall

- CSB identified in this study related to local slope collapse scarp, and not an expression of eustatic sea level fall

Sequence Boundary Issues



•Surface do not form a single, continuous chronostratigraphic surface

•No extensive incision on the shelf

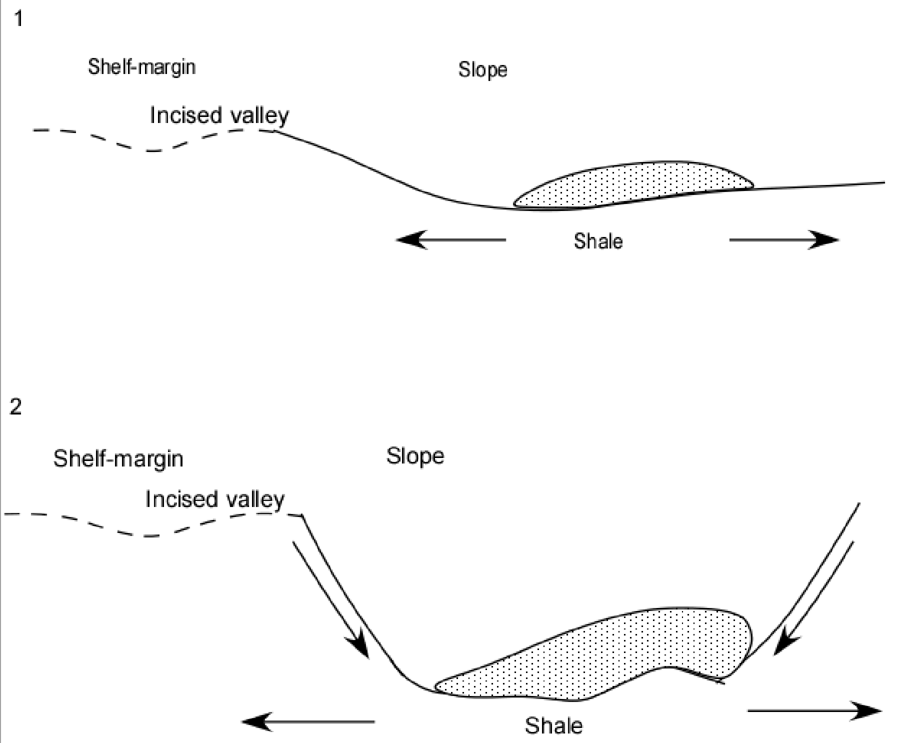
•Niger Delta depositional systems more supply driven than accommodation driven (Porebski and Steel 2006)- Sequence boundary may be absent to difficult to identify

•Presence of "Lowstand" facies does not necessarily mean sequence boundary –may be related to shelf-margin collapse on a fault-steepened slope (Ricketts and Evenchick 1999)

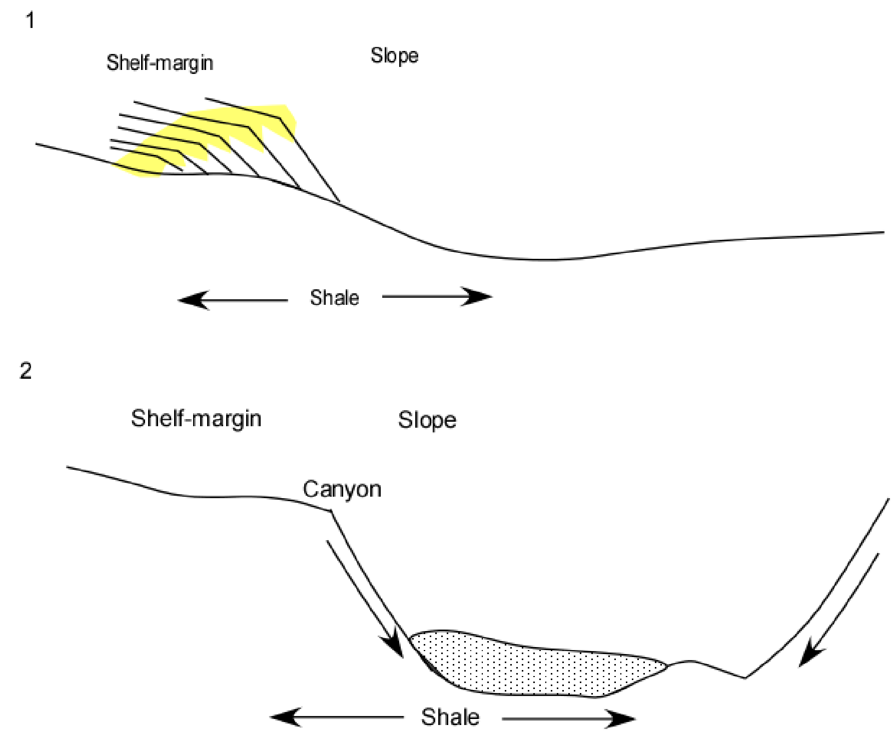
Conclusion: Implication for Depobelt development

	Previous Model (Brown et al. 2004)	Present Work
Process for Lowstand deposition	Sea level fall and incised valley fed lowstand systems	Sediment failure on fault steepened slope
Structural Collapse	Occur on slope and basin floor	Occur on shelf-edge and upper slope
Predicted facies	Lowstand facies and shallow marine systems with shale dominated distal areas	Lowstand facies, detached shelf-margin deltas in proximal and distal areas and shallow marine systems

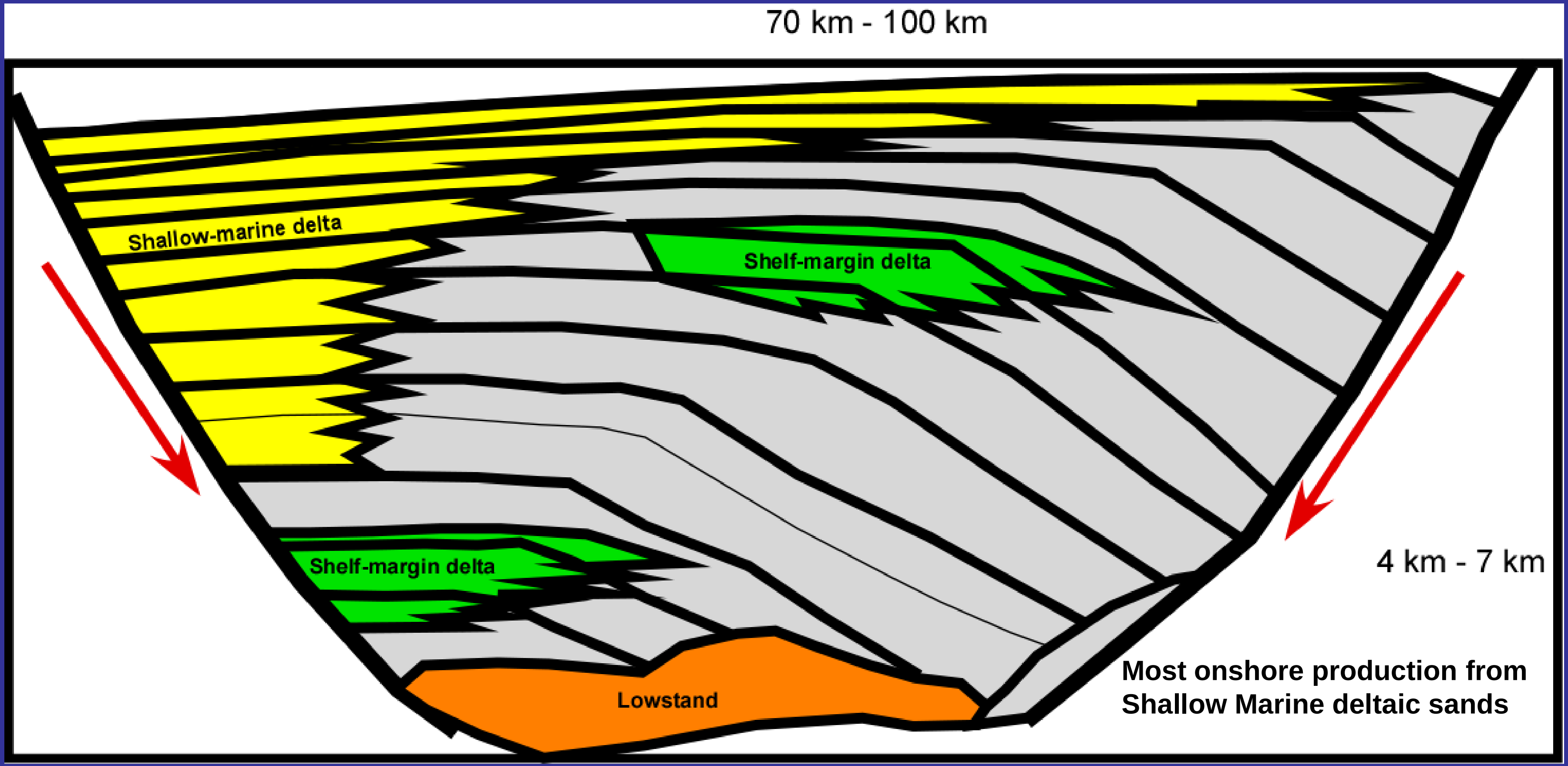
Previous model (Brown et al. 2004: Collapse on the slope and basin floor and highstand deltaic sediments filled the sub-basin)



Present work in supply-driven systems(Collapse on the shelf-edge and upper slope with forced/normal regressive and highstand deltaic sediments filling the sub-basin)



Conclusion: Implication for New Plays



- Deep exploration plays below the shelf
  - Lowstand facies (Slope facies) and shelf-margin delta

- Exploration play in distal location within depobelt
  - Shelf-margin delta
  - Shelf-margin delta is a proven play in other basins (Meckel 2003)

Thank You