New Perspective on Evolution of Northern Provinces of Offshore Sarawak Basin, Malaysia*

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Abstract

The offshore Sarawak Basin is located towards the southwestern part of South China Sea marginal basin and hosts many oil and gas fields. The present paper summarizes the tectono-stratigraphic framework and a conceptual evolution model developed for the northern part of the Sarawak Basin and is based on a comprehensive study of seismic, gravity, and well data.

Basins in the study area initiated as intracratonic rifts on attenuated continental crust, on a foreland bulge part of offshore Sarawak, ensuing from Phase-I NW-SE to N-S extension, during Late Cretaceous (?) to late Eocene. Gravity modeling results suggest attenuated continental crust, with a thickness range of 15 to 20 km in the study area. The general structural style during this stage is characterized by N-S and NE-SW-trending half-grabens, dipping to the east and southeast. Sequence-A/Pre Cycle-I filled the early formed half-grabens. The phase of extension continued (Phase-II), with opening of South China Sea during early Oligocene, and also during subsequent drift phase up to early mid-Miocene. Unequal subsidence in the half-grabens during this stage, accommodated variable thickness of infill sequences B and C, represented by Cycles I to III, showing diverse facies distribution as evidenced by the wells. Well results suggest nonmarine to transitional environment for the older section of Cycle I to Lower Cycle II, and outer neritic to bathyal setting for Cycle III, indicating progressive deepening of the basin. Subsequent regional uplift in the area associated with plate convergence during late Early Miocene to mddle Miocene, resulted in regional unconformity, designated Middle Miocene Unconformity (MMU). Cycle I subcropping MMU towards western part of the study area substantiated by seismic sequence mapping suggests possible early Miocene age for MMU, associated with uplift and erosion, also aided by major tilt to the east from East Natuna hinge zone. Age of MMU progressively becomes younger towards east. A major NW-SE transtension close to MMU time along SW Luconia fault zone transecting the study area resulted in the formation of West Luconia Trough, accommodating huge pile of post-unconformity section. Northeasterly sag of the basin through late Miocene to Recent led to a deep-water setting, resulting in deposition of hemipelagics, overlain by mass-transport-dominated sequence. The present study paved the way for better understanding of the petroleum system elements.

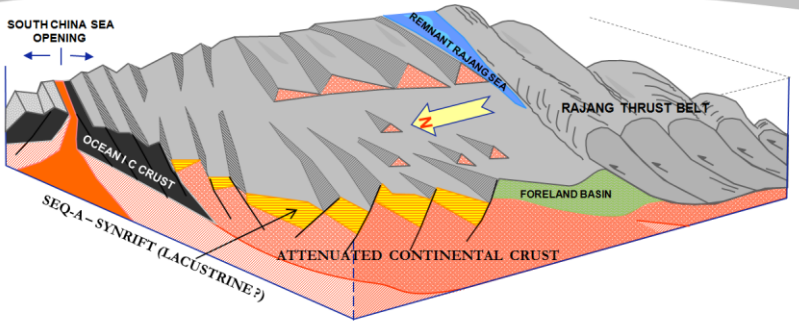
Selected References

Iyer, S.R., H. Rosidah, and A. S. Amar, 2012, Maturation of a new play concept in northern provinces of offshore Sarawak Basin, Malaysia: Petroleum Geoscience Conference & Exhibition, Kuala Lumpur, Malaysia, 4 p.

Madon, M., K.C. Ly, and R. Wong, 2007, The structure and stratigraphy of deepwater Sarawak, Malyasia; implications for the tectonic evolution of the NW Borneo continental margin: AAPG Annual Meeting Abstracts, p. 87.

NEW PERSPECTIVE ON EVOLUTION OF NORTHERN PROVINCES OF OFFSHORE SARAWAK BASIN, MALAYSIA

PETRONAS



IYER, 2009

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AAPG ICE 2012 – Singapore, 19th September 2012

Theme 1: Petroleum Geology Vietnam, East Malaysia, Brunei & Philppines (AAPG/AP Region)

Presenter : Dr. Subramania Iyer

PRESENTATION OUTLNE

1) Introduction & Objective

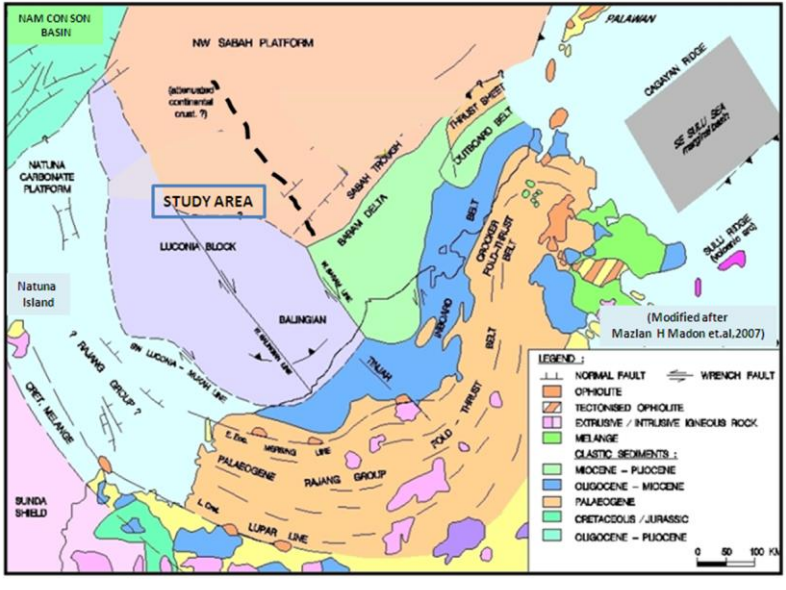
2) Basin Setting, Stratigraphy & Sequence Mapping

3) New Perspective on Basin Evolution - Summary

4) Basin Evolution – Stages 1 To 7

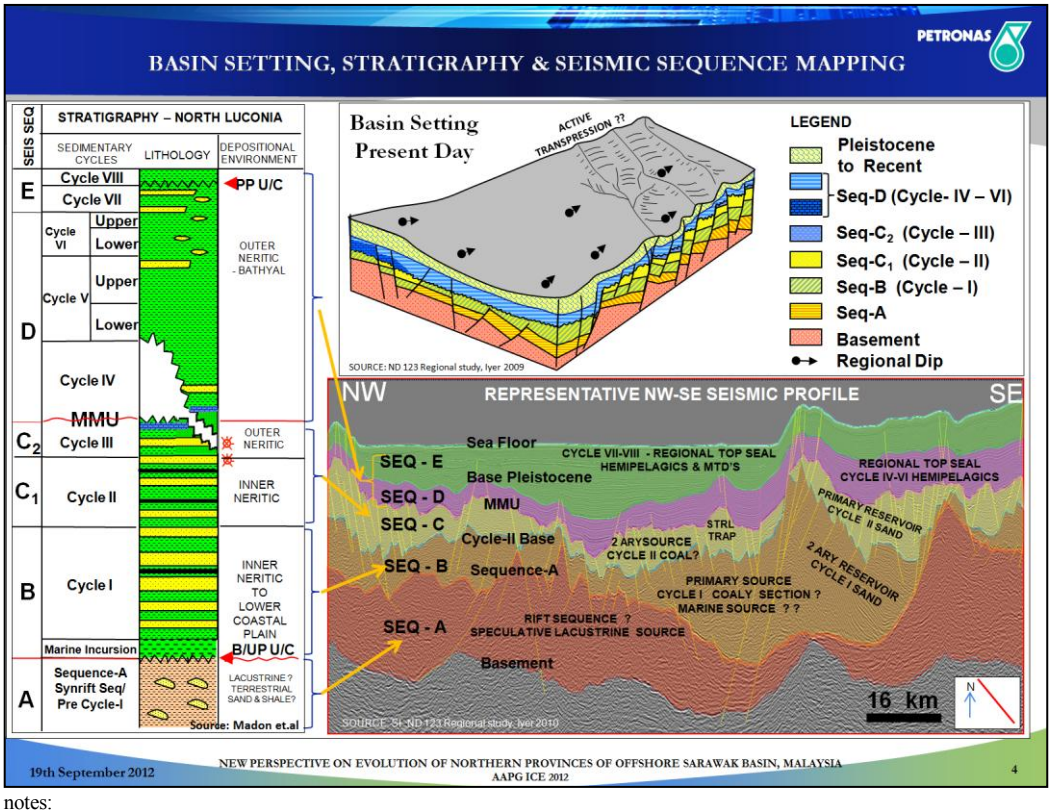
5) Conclusions

6) Acknowledgement



Presenter's notes:

- Study area is located in the North & West Luconia provinces in both NW Sabah Platform & Luconia tectonic blocks in the Northern Offshore Sarawak Basin.
- Extent of the study area is about 40000 sq.km, and the data used are 2D/3D seismic, gravity, and well results.
- A comprehensive regional study integrating seismic, gravity and well data facilitated the building of tectono-stratigraphic framework and conceptual evolution model of the area, leading to a better understanding of the petroleum system.
- Objective of this paper is to share the findings for integration into the understanding of the region.

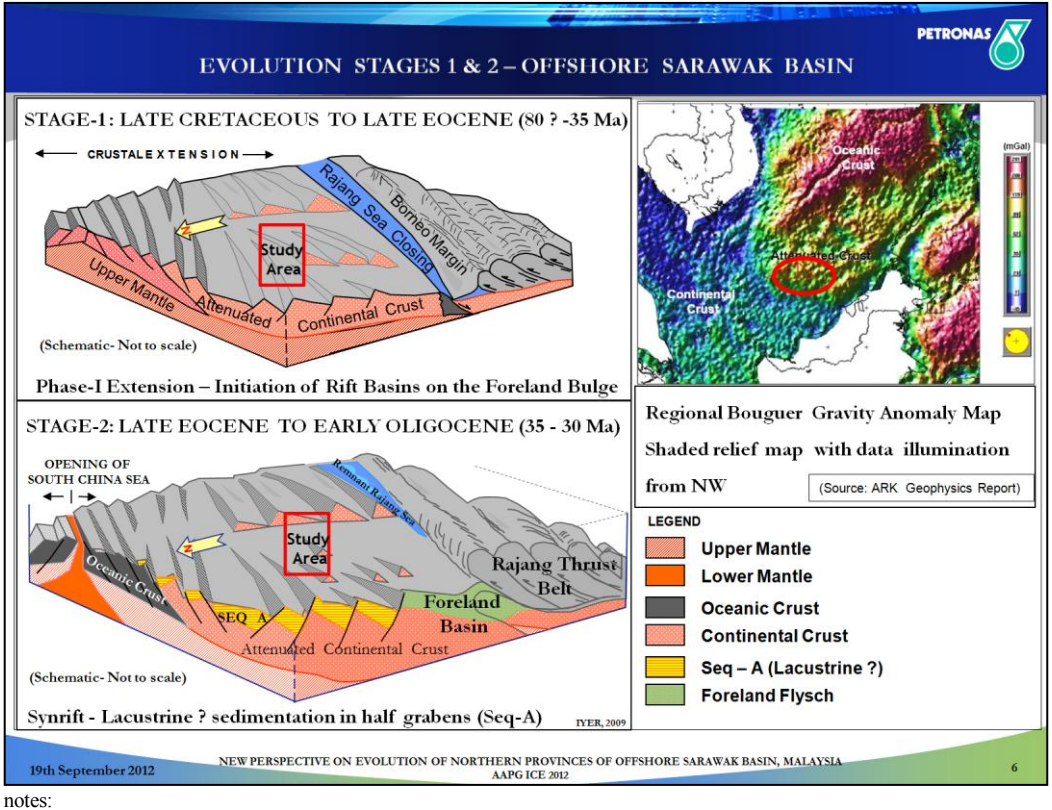


Presenter's notes:

- Block diagram shows the present-day basin setting, dip to the NE from Sarawak shelf to the south and East Natuna shelf to the west.
- Stratigraphy of the area is represented by 8 major sedimentary cycles based on earlier studies. Regional, middle Miocene unconformity (MMU) separates the lower synrift section of Cycles I to III, which consists of a deepening sequence (lower coastal plain at base to outer neritic at the top) from the post-unconformity marginal sag deep-water sequences (Cycles V to VIII). Deepest well penetration is to the upper part of Cycle I.
- NW-SE cross section across the basin depicts the six regional horizons mapped over the area in the present study with calibration from two of the deepest wells.
- Five Seismic Sequences (SS) - A to E have been identified with SS-A corresponding to Pre-Cycle I, SS-B to Cycle I, SS-C to Upper Cycle I to III, and SS-D & E to post-MMU deep water sediments. SS-B & C host the main petroleum system elements in the study area validated with well results.

NEW PERSPECTIVE ON BASIN EVOLUTION - SUMMARY

- Seven stages have been proposed for the evolution of Northern part of Offshore Sarawak Basin.
- Unequivocal evidences for the presence of an early rift section represented by Sequence-A have been brought out by this study based on regional seismic sequence mapping.
- New models based on evidences from new seismic and wells have been envisaged to revise the existing paleogeographic models and gross depositional environments.
- New model increases the probability of source rock in the North Luconia area.
- Regional unconformity (MMU) is more pronounced in the study area. Time gap (missing section) based on dating from existing wells varies from 2 Ma to 8.5 Ma (S to N). This has implication on HC maturation history and expulsion timing.



Presenter's notes:

•Regional Bouguer Gravity anomaly map indicates that the study area is located on attenuated continental crust.

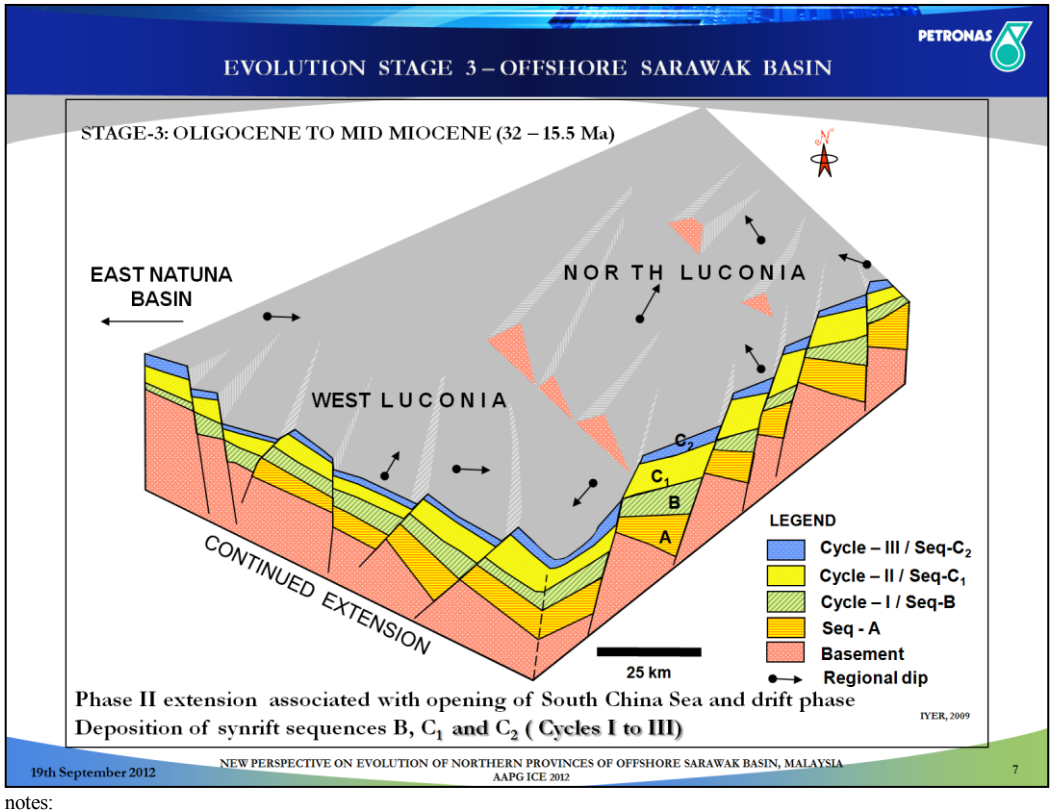
• Even though the study area is in the northern part, cartoons representing stages 1 and 2 have been linked to the overall evolutionary understanding of Offshore Sarawak Basin.

• Phase I NW-SE to N-S extension results in crustal attenuation & opening of SE-dipping half-grabens on the foreland bulge.

• Possible lacustrine sedimentation in the half-grabens is represented by SS- A.

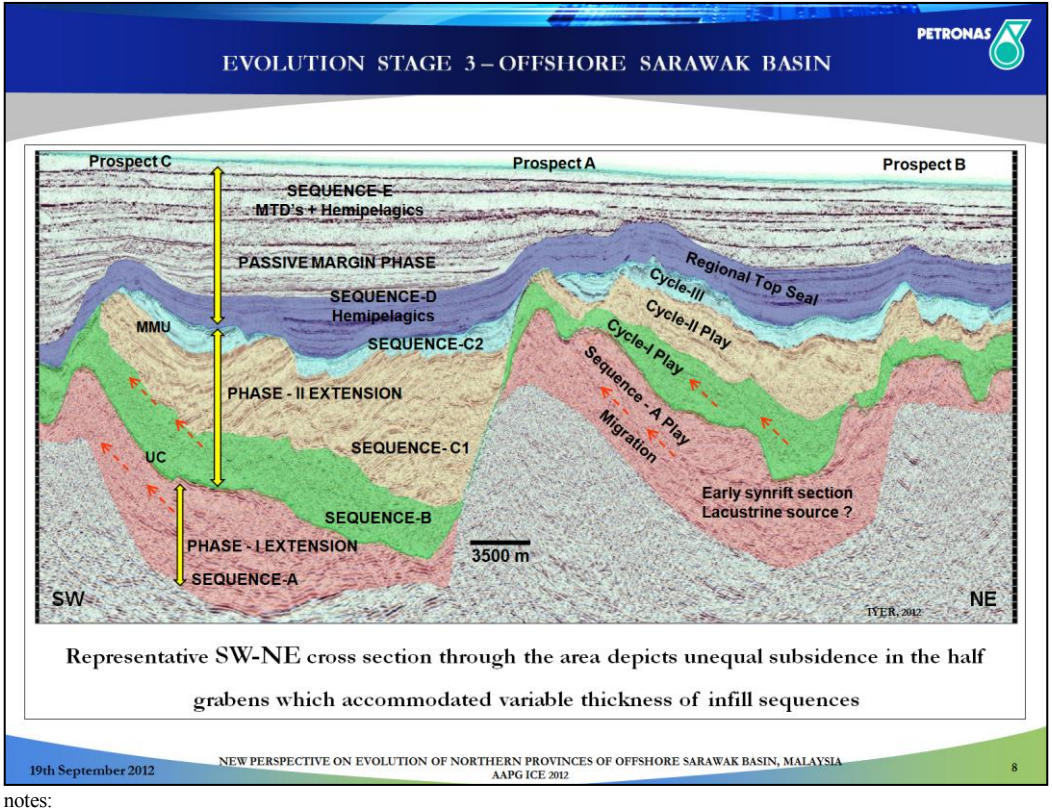
• Further convergence of Luconia block and NW Borneo margin led to oblique closing of Rajang Sea from SW to NE, uplift of Rajang thrust belt along Borneo margin, and formation of foreland basin.

• End of Phase I Extension is marked by a major regional unconformity on top of SS-A.



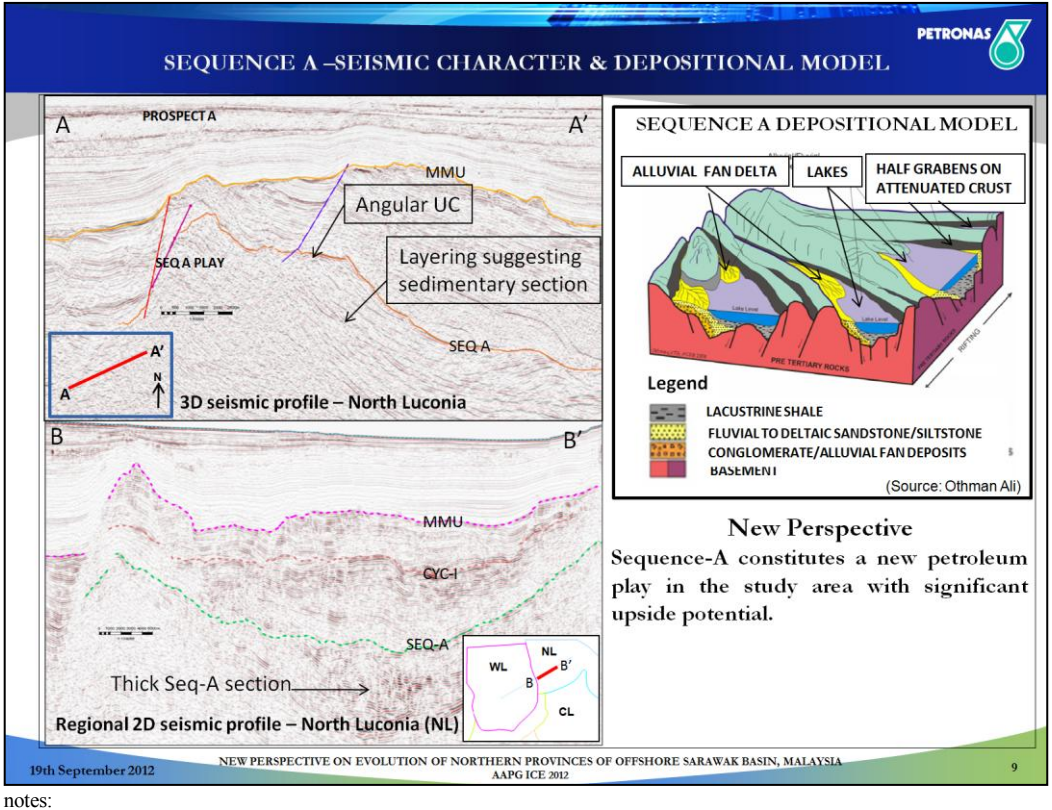
Presenter's notes:

- Cartoon of stage 3 pertains only to the study area in Northern Offshore Sarawak Basin.
- Phase II Extension initiated with the opening of South China Sea during early Oligocene and continued through the drift phase to early mid-Miocene.
- Unequal subsidence in the half-grabens accommodated variable thickness of synrift infill sequences B, C_1 & C_2 (representing Cycles I to III), showing diverse facies distribution over the area, as evidenced by wells.
- Well results suggest nonmarine to transitional environment for Sequences B & lower C_1.
- Marine incursion is thought to have commenced from E & NE during late early Miocene and progressively covered the whole basin during early mid-Miocene. The inference is based on deposition of upper C_1 in an inner neritic setting and the overlying C2 sequence in an outer neritic to bathyal setting.
- Phase II extension is truncated by a regional unconformity (MMU) associated with regional uplift resulting from plate convergence during late early Miocene to mid-Miocene.



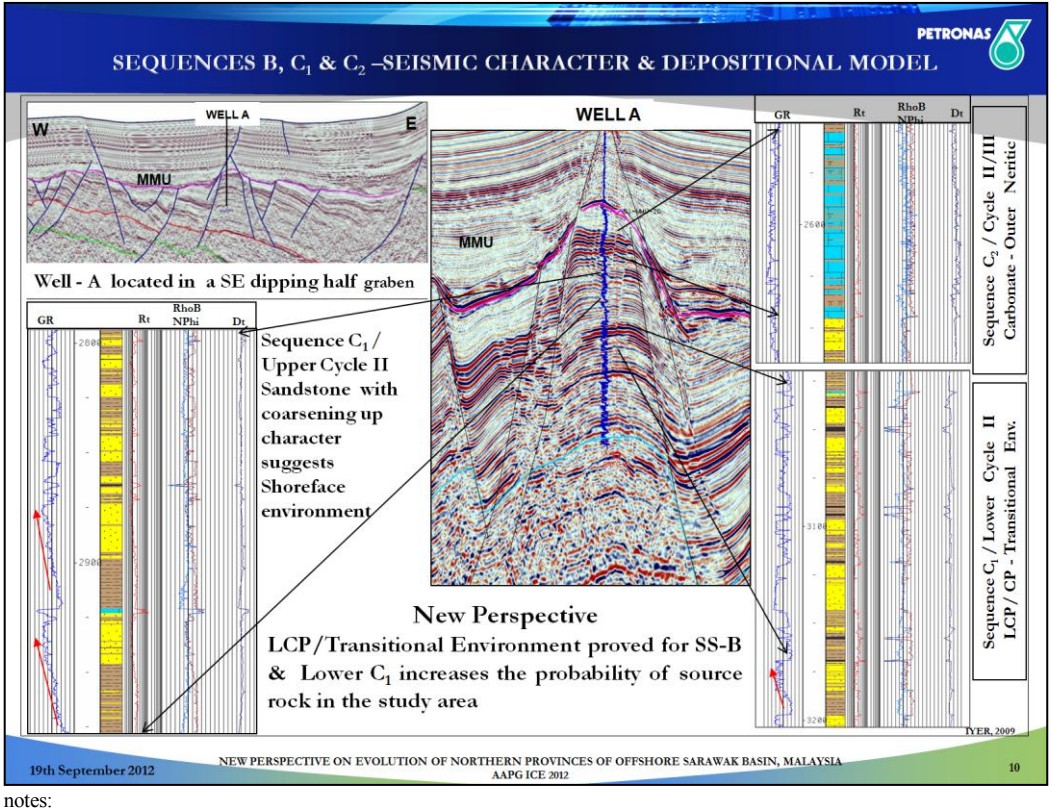
Presenter's notes:

- Representative SW-NE cross section through the area depicts unequal subsidence in the half-grabens which accommodated variable thickness of synrift infill sequences B, C_1 & C_2 (representing Cycles I to III), showing diverse facies distribution over the area, as evidenced by wells.
- These overlie the early rift Sequence-A over a regional unconformity.
- Phase II extension is truncated by a regional unconformity (MMU) associated with regional uplift resulting from plate convergence during late early Miocene to mid-Miocene.



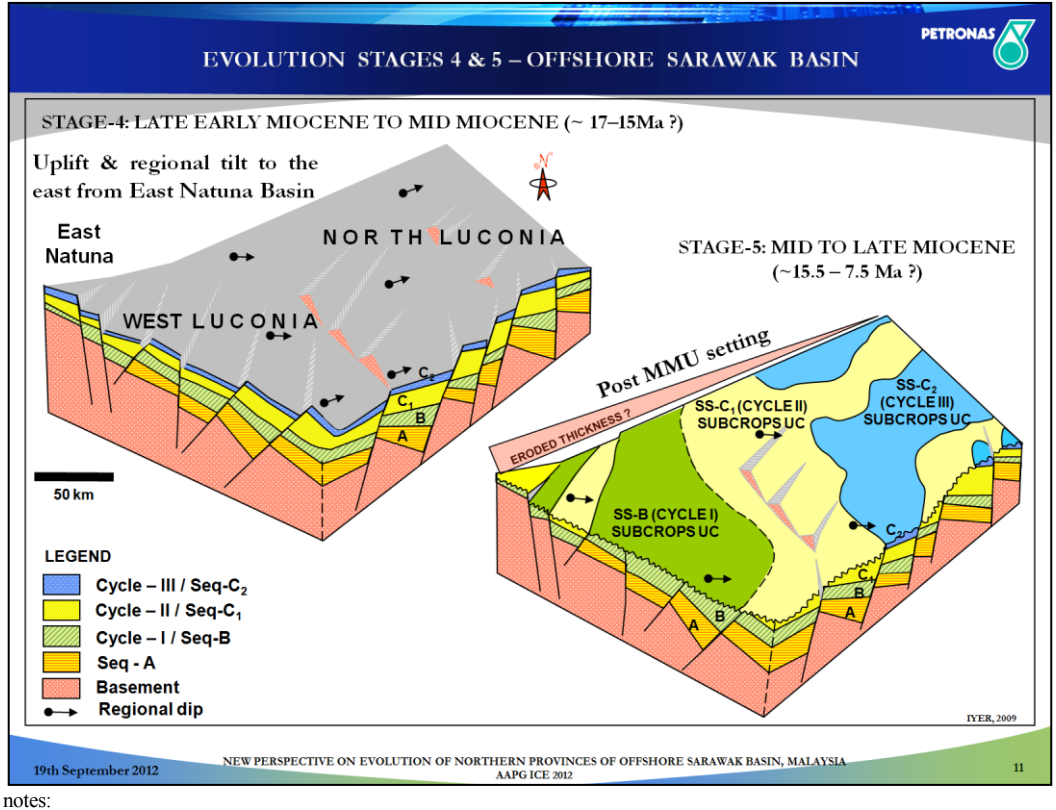
Presenter's notes:

- Representative 3D seismic profile from North Luconia reveals the unequivocal sedimentary character of Sequence–A, such as layering, angular unconformity over the highs, and mappable younger Sequence–A subunits in the grabens.
- Postulated depositional model for Sequence–A is a lacustrine environment with alluvial fan/ fluvial deltaic progradation into the half-grabens on attenuated continental crust.
- Presence of a thick SS-A unit in the North Luconia Province is also evidenced by the regional 2D profile to the south.
- To date, exploration in the study area has been focused on pre-MMU clastics / carbonate plays of sequences B, C_1 and C_2 (Cycles I to III).
- New perspective - Uplifted Sequence - A sections on footwall closures of rotated blocks are potential structural traps with charge from lacustrine (?) source in the adjoining grabens.
- Based on regional study, there is significant upside potential for this new play, if it is established through drilling of at least one prospect. .



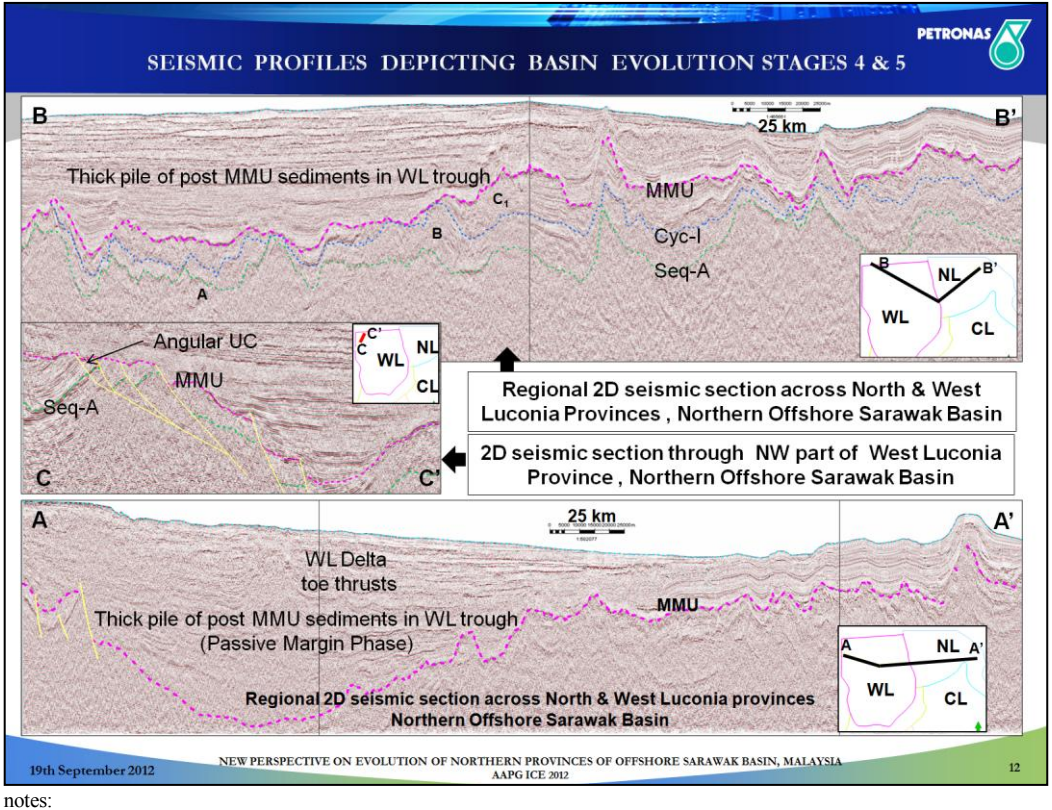
Presenter's notes:

- Well A is a representative well from North Luconia Province drilled on a horst block within a SE-dipping half-graben and penetrates to top of Sequence B.
- Well results suggest nonmarine to transitional environment for SS-B & lower C_1. Overlying SS-C_2 was deposited in an outer neritic to bathyal setting.
- Existing paleogeographic models indicate a bathyal setting for sequences B & C_1 in the study area.
- New perspective based on new well data - nonmarine to transitional environment is envisaged for sequences B and lower C_1 (Cycle I & lower Cycle II) in the northern part of the study area with the basin deepening towards south.
- Implication is that the new model increases the probability of source rock in the North Luconia area.



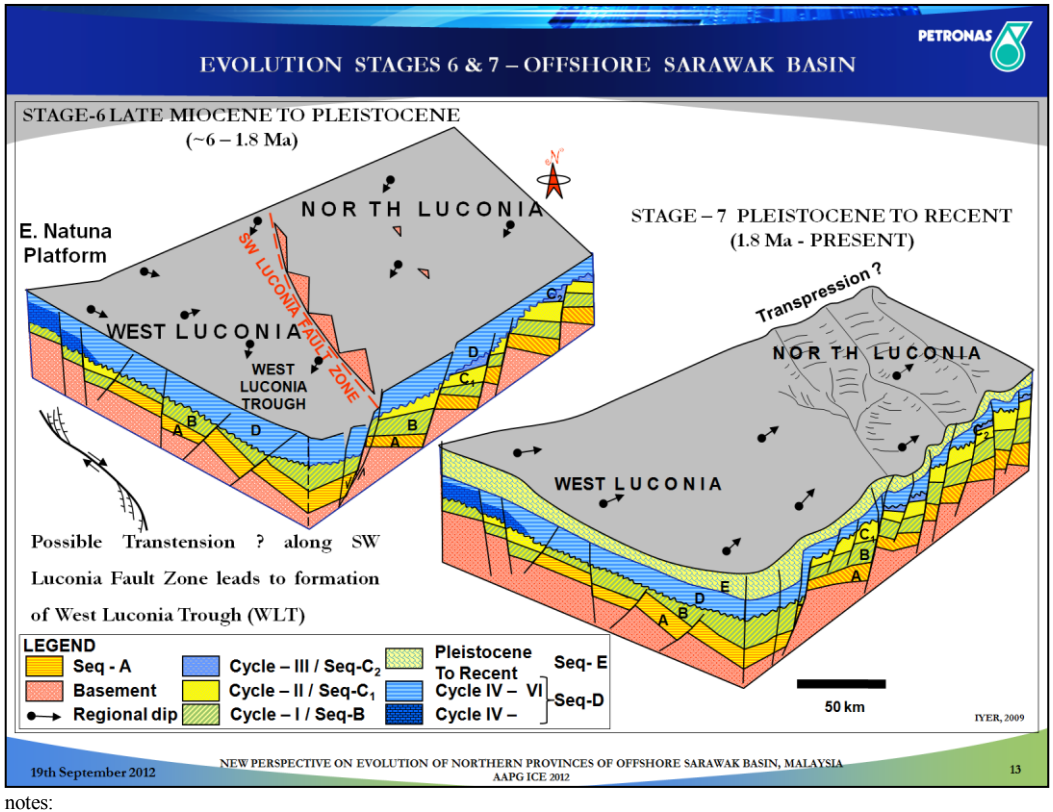
Presenter's notes:

- Cartoon of stage 4 depicts the regional uplift results from plate convergence during late early Miocene to mid-Miocene. An easterly tilt from East Natuna hinge zone is also reported for this period. This resulted in the regional unconformity (MMU) truncating Phase II extension.
- Stage 5 depicts the post-MMU setting. Maximum erosion is on the western part, probably removing entire sequences SS-C_1 & C_2, resulting in SS-B subcropping MMU.
- Eastern part of study area is characterized by less erosion, often with SS-C_2 below MMU.



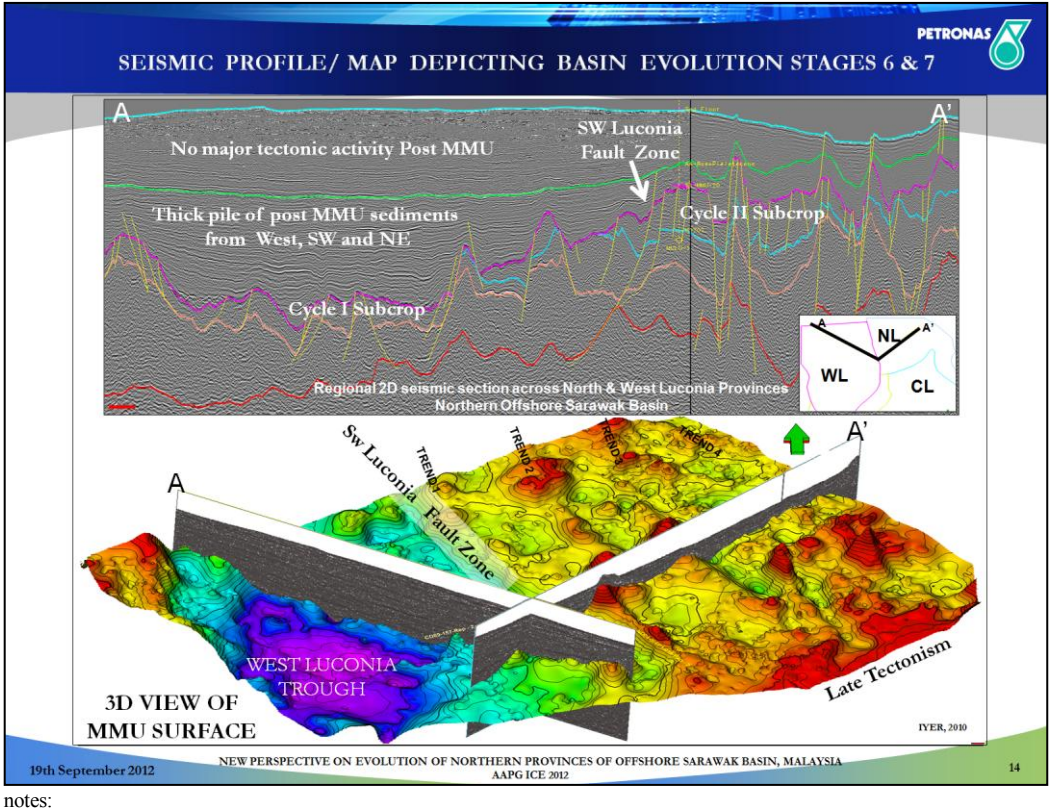
Presenter's notes:

- Representative seismic profiles across the study area demonstrate the highly diachronous nature of the regional unconformity (MMU).
- Regional unconformity (MMU) is more pronounced in the northern & western parts of the study area.
- Time gap (missing section) based on dating from existing wells varies from 2 Ma to 8.5 Ma (S to N) in North Luconia. More well penetrations are essential to constrain the MMU time gap.
- Unconformity duration has implication on HC maturation history and expulsion timing.
- Timing of deposition of post-MMU regional top seal sequence with respect to HC migration timing is very critical in exploration.



Presenter's notes:

- Stage 6 represents further easterly tilt and down-to-the-basin faulting along East Natuna Hinge zone to the west and a major transtension (?) along SW Luconia Fault Zone to the east, resulting in the formation of West Luconia Trough (WLT).
- Possible uplift of hinterland to the south and increased slope into the WLT triggered the progradation of West Luconia Delta in the western part of the study area.
- The WLT was filled with outer neritic to upper bathyal sediments during late Miocene to early Pleistocene, sourced from south, west, and also from east of SW Luconia Fault Zone.
- Stage 7 depicts further NE sag of the basin during Pleistocene to Recent resulting in a deep-water setting in the study area characterized by mass transport deposits (MTD) and hemipelagics.
- Evidences of late-stage transpression are observed towards the eastern part, but it needs confirmation through additional studies.



Presenter's notes:

- Representative seismic profile shows the thick pile of post-MMU sediments in the WLT.
- 3D view of the MMU surface shows the WLT separated from North Luconia by the SW Luconia fault zone.
- High trends observed in North Luconia are possibly related to late stage tectonism.

CONCLUSIONS

- Present study clearly depicts the seven stages in the evolution of Northern part of Offshore Sarawak Basin .
- Two phases of extension are envisaged for the pre MMU section followed by a third associated with the passive margin phase for the post MMU section.
- Unequivocal evidences for the presence of an early rift section represented by Sequence–A, which can constitute a new hydrocarbon play, have been demonstrated.
- New models based on evidences from new seismic and wells have been envisaged to revise the existing paleogeographic models and gross depositional environments.
- New insights increase the probability of source and reservoir in the study area and can change the petroleum prospectivity outlook.

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