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[AV]Pushing the Boundaries of Exploration in East Malaysia: Building on Early Success*

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Abstract

Murphy Oil entered Malaysia in 1999 with a strategy of combining exploration and development of low risk, shelfal sandstone plays together with frontier, high-impact oil exploration targeting Tertiary deep-water sandstones in the undrilled, deep-water region of Sabah. Interest in the Sabah area had been prompted by the presence of several large, anticlinal thrust structures with evidence of a live hydrocarbon system in the form of gas chimneys in the seismic data and sea floor and ocean surface seeps.

Murphy Oil acquired a substantial acreage position in deep-water Sabah, and the first exploration wells were drilled in 2002. After two unsuccessful wells, the third well of the programme discovered the Kikeh Field as a significant oil accumulation in water depths of 1300m, the first deep-water oil discovery in Malaysia (Algar et al., 2007; Masoudi et al., 2013). By 2007, less than 5 years from discovery, Kikeh came on production and 15 further deep water discoveries, including important look-alike oil discoveries such as Gumusut-Kakap, Siakap-North Petai, Jangas, Kikeh Kecil, and Kerisi fields, had been made in the play. Not only was this a remarkable fast track development, but the Kikeh discovery opened up a significant new oil play in an area that until then had been regarded as gas-prone, with little known about the main reservoir objective of Tertiary deep-water sandstones. Detailed regional and field studies have now documented that the reservoirs in the Kikeh Field are deep-water marine turbidite lobes that are interbedded with mass-transport deposits and pass laterally into distal, thin-bedded equivalents of the turbidite sand lobes. Much less sand is recognised as being introduced onto the slope than was originally envisaged, with

most sand input being restricted to a short time period in the late Miocene, well constrained by biostratigraphy (Morley, 2014). Turbidites were derived from a narrow shelf and transported down an unstable slope, where syn-depositional-thrusting-modified slope topography and influenced sand distribution down and along the slope. The structural framework differs remarkably between the northern and the southern parts of the Sabah Basin. Hydrocarbons are considered to be sourced from transported coaly organic matter deposited with the turbidites. Selective gas leakage from the crests of the thrust-related anticlines strongly influences the hydrocarbon phase retained in many of the deep-water Sabah fields.

Murphy also opened a new play in the northern area of deep-water Sabah with the discovery of gas in excellent quality, high net-to-gross Upper Miocene sandstones that accumulated in topographic lows (‘mini-basins’) which formed in response to syn-depositional tectonism. Low-relief, combination structural-stratigraphic traps were developed and charged with a mix of thermogenic and biogenic gas. Of particular note is the Rotan Field discovery in Block H in 2007, some 250km NE of the Kikeh Field, which led to the sanction of the Rotan cluster FLNG project in 2014, one of the world’s first of its type, with gas production scheduled to start in 2018.

To date Murphy has drilled 30 exploration wells in deep-water Sabah, resulting in a gross volume of nearly 1.3 Billion BOE reserves being discovered. The discovery of Kikeh opened a new era of technical research into deep-water depositional systems in Malaysia, initially driven by development considerations, but now extended to other exploration opportunities in the area. The geology of these deep-water fields reveals significant information that is being applied to both field development and exploration in the area. Some of the key areas of technical interest Murphy has focused on are:

- The types of depositional systems developed within an active deep-water fold and thrust belt and their evolution into high net-to-gross sand lobes and laterally equivalent, extensive, thin-bedded deposits containing significant hydrocarbon reserves.
- The significance of the control on deposition exerted by mass-transport deposits (MTDs) and their role in defining reservoir distribution and trapping.
- The nature of top seals across structures and the controls on hydrocarbon column heights.
- The nature, distribution, and maturity of source rocks across the Sabah margin.
- The critical aspects of reservoir quality and sand distribution that are essential to understand during the appraisal phase in order to optimise deep-water development plans.

Understanding these controls on the petroleum system across the Sabah Margin is important, not just in the Kikeh area but throughout NW Borneo, and offers a significant technical advantage in the exploration, development, and evaluation of deep-water areas. Murphy continues to explore in Malaysia and is optimising the knowledge derived from its deep-water Sabah fields and excellent working relationship with PETRONAS and partners to focus its ongoing exploration activities.

Selected References

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Morley R.J, 2012, A review of the Cenozoic palaeoclimate history of Southeast Asia, *in* Biotic Evolution and Environmental Change in SE Asia, D. Gower et al., editors: Systematics Association, Cambridge University Press p. 79-114.

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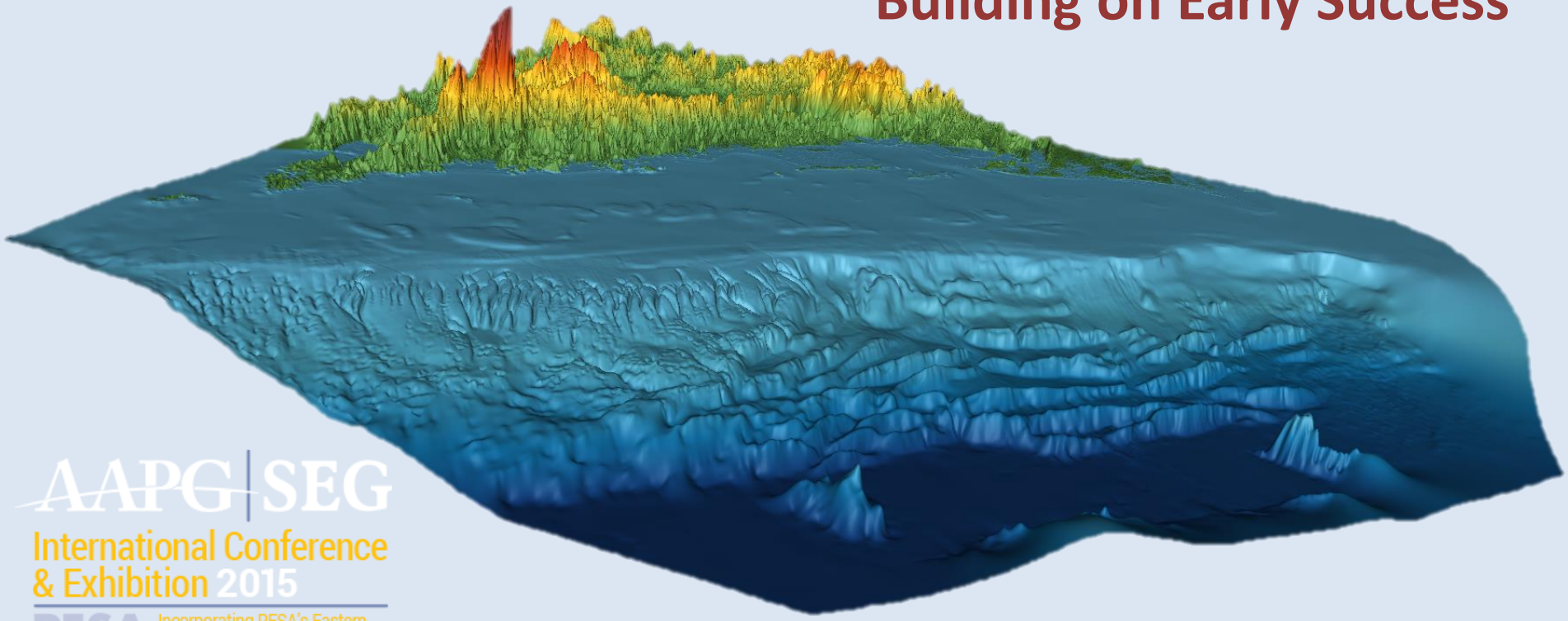
Pushing the Boundaries of Exploration in East Malaysia: Building on Early Success



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Mark Jones, Stuart Burley, Neil Sharp, and Nick Wilson

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MURPHY OIL CORPORATION

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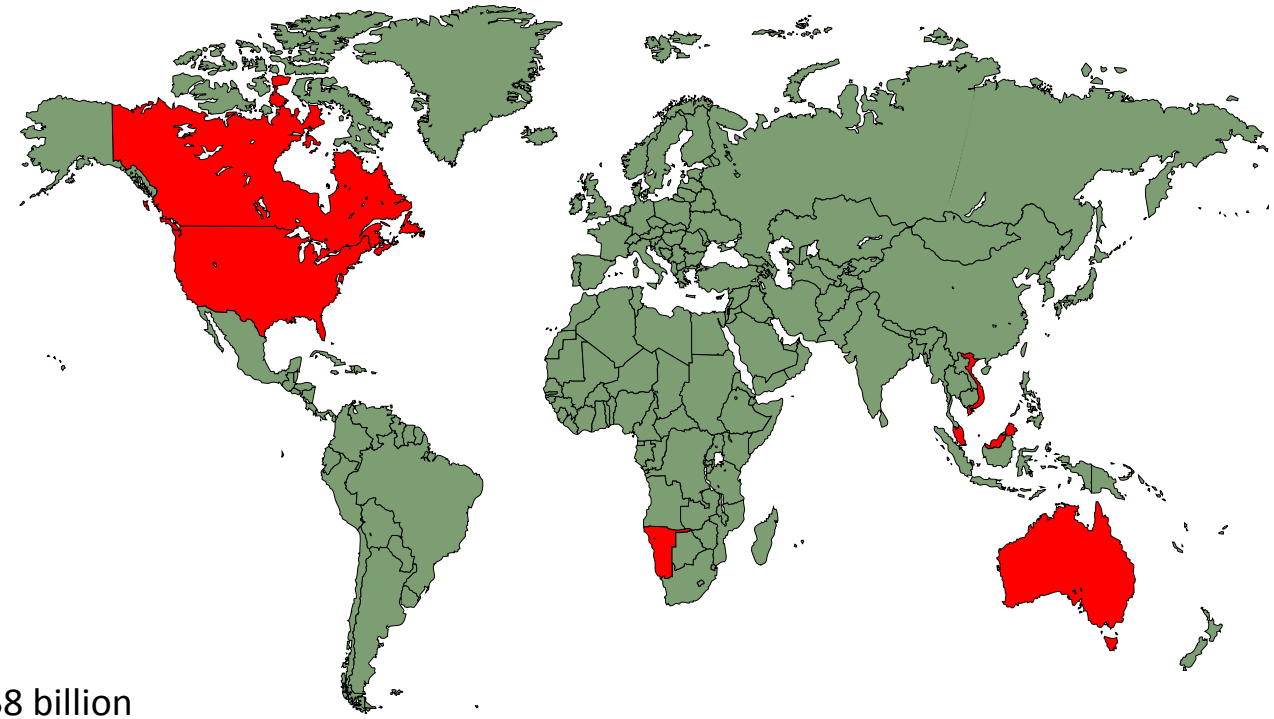
  - Management at Murphy Oil for permission and support for preparing and making this presentation
  - Colleagues in Murphy Malaysia for helpful discussions and inputs

Murphy Oil Corporation Overview

- **Headquartered in the United States with operations in:**
  - Eagle Ford (South Texas)
  - Gulf of Mexico
  - Canada
  - Malaysia
  - Brunei
  - Vietnam
  - Australia
  - Equatorial Guinea
  - Namibia

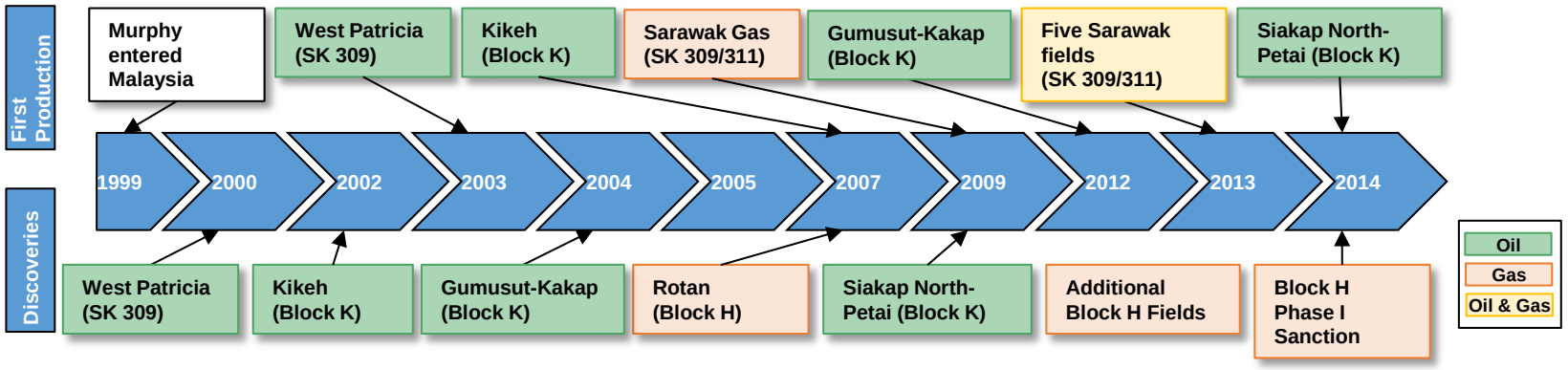


- **Key Statistics:**
  - Market Capitalization: ~$8 billion
  - Employees: ~1,500
  - Net Proved Reserves: ~750 MMBOE
  - 2014 Net Production: ~225,000 boe/d

MURPHY OIL CORPORATION

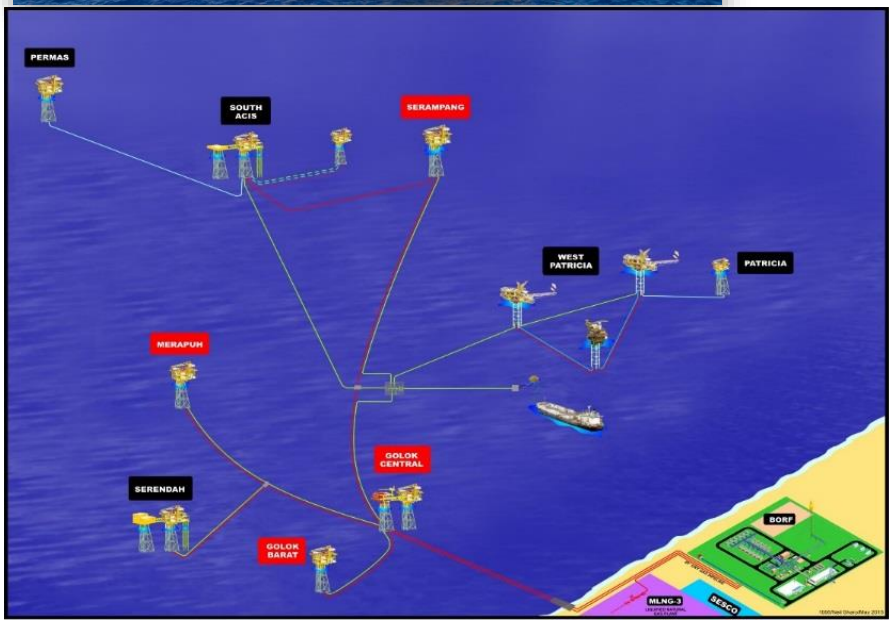
Murphy in Malaysia - *16 Years of Commercializing Malaysia Discoveries*

- **A strong 16 year relationship with PETRONAS**
- **Track record of successful exploration, efficient development, and reliable operations**
- **Murphy has participated in nearly half of all Malaysia deep-water discoveries, totaling 3.2 Bboe gross recoverable [(1)]**
- **Prolific diverse asset base across shallow and deep water**
  - Shallow Water: SK 309/311/314A
  - Deep Water: Block K/Block H/ SK2C



(1) source: PFC Energy

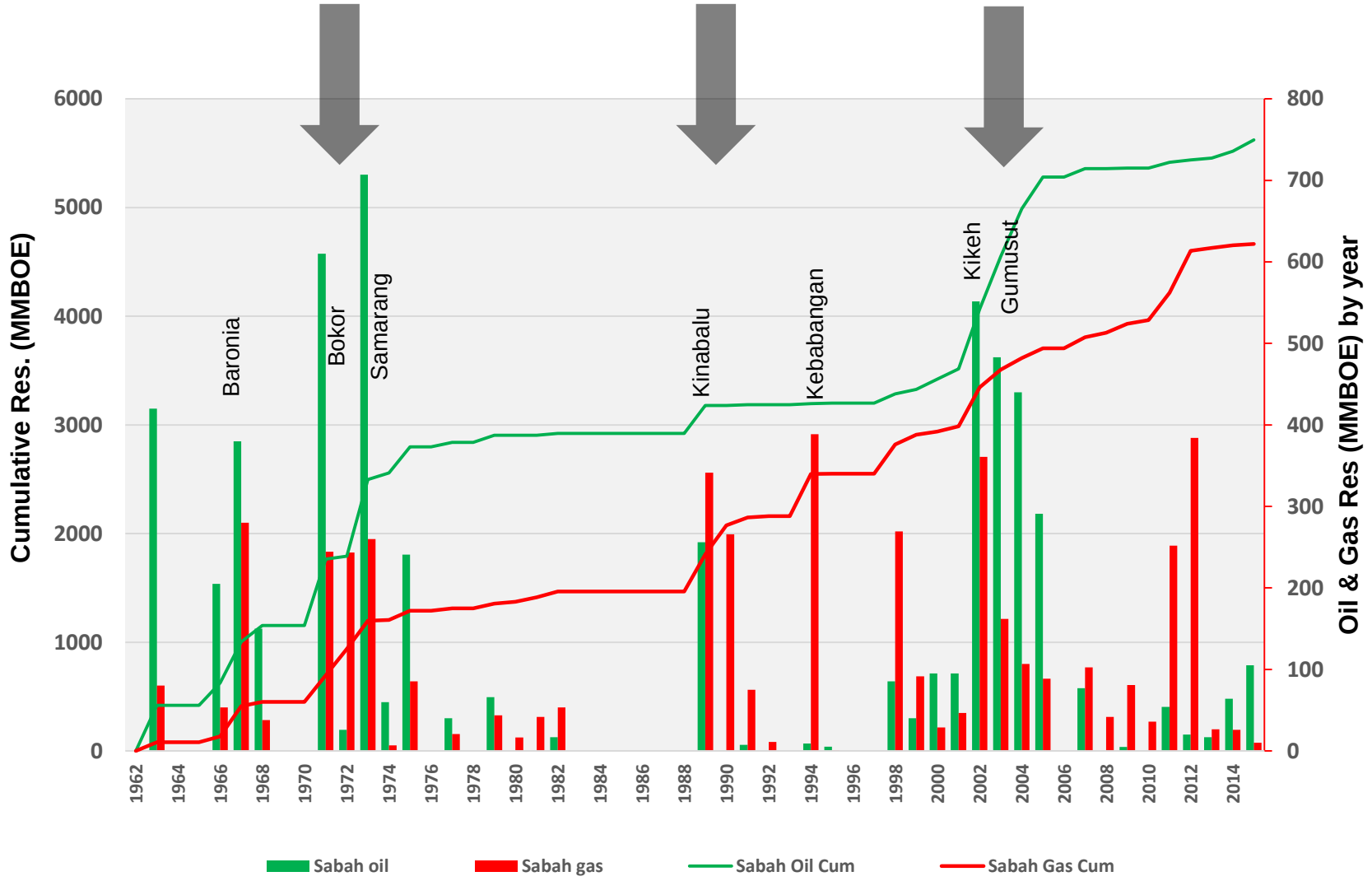
Types of Development in Sarawak and Sabah



Creative solutions to Development

Sabah Exploration History

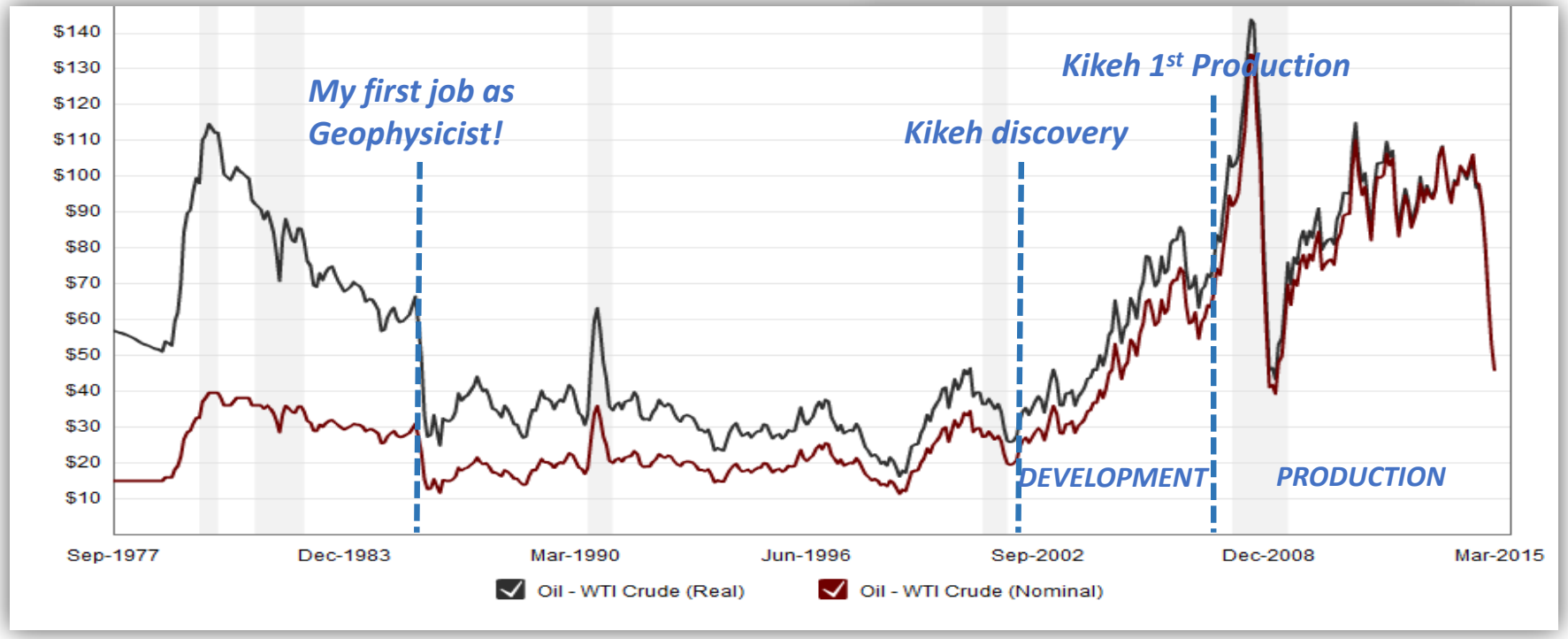
Rejuvenation more than once, time for another?



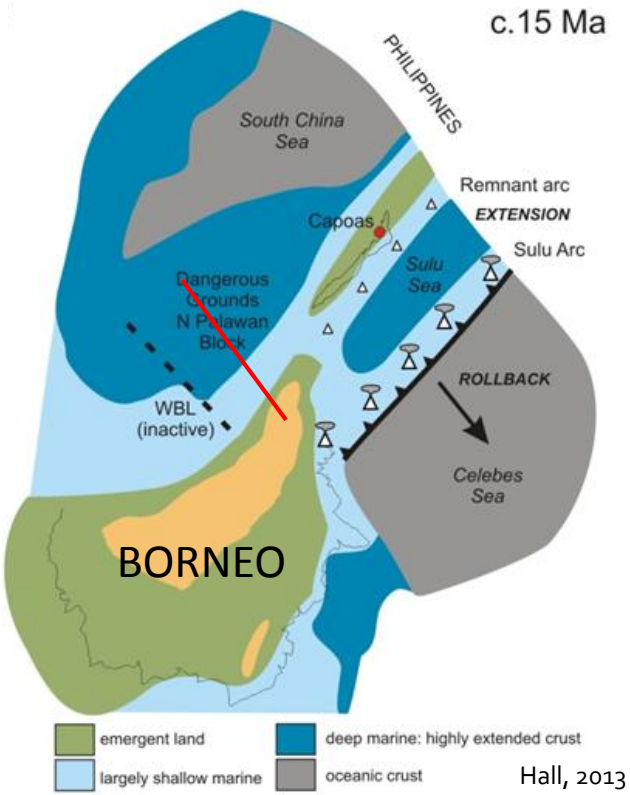
Under-explored!

Source: IHS Energy Database 2015

A bit of luck on timing can help……

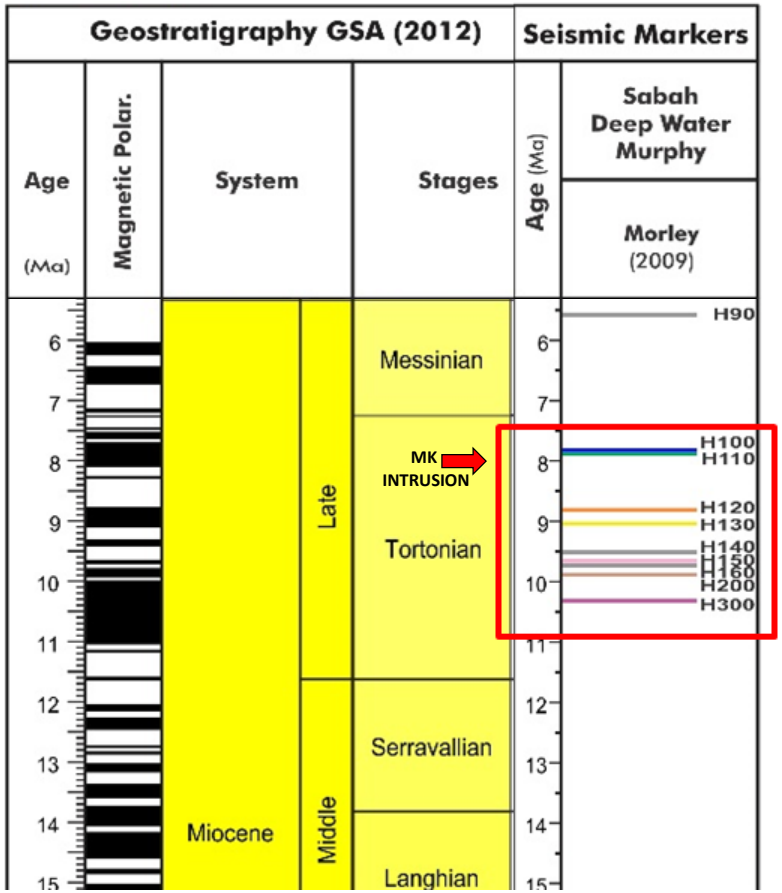


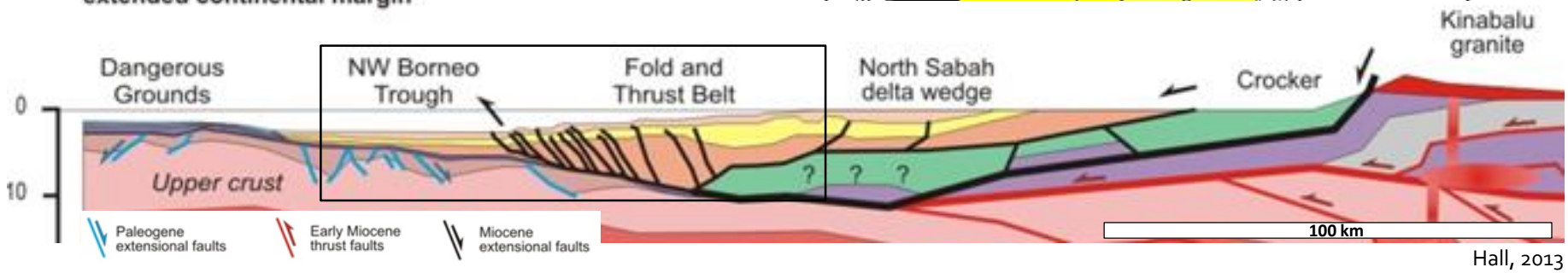
Regional Tectonics and Stratigraphy



Hall, 2013

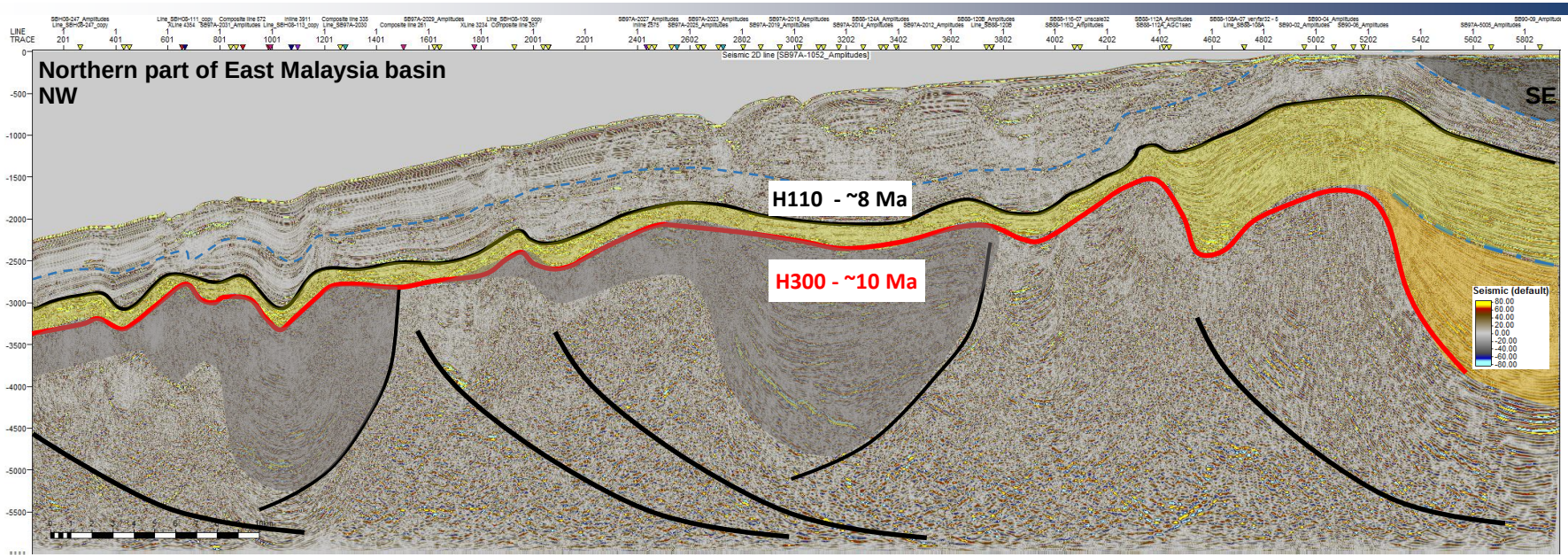
South China Sea extended continental margin

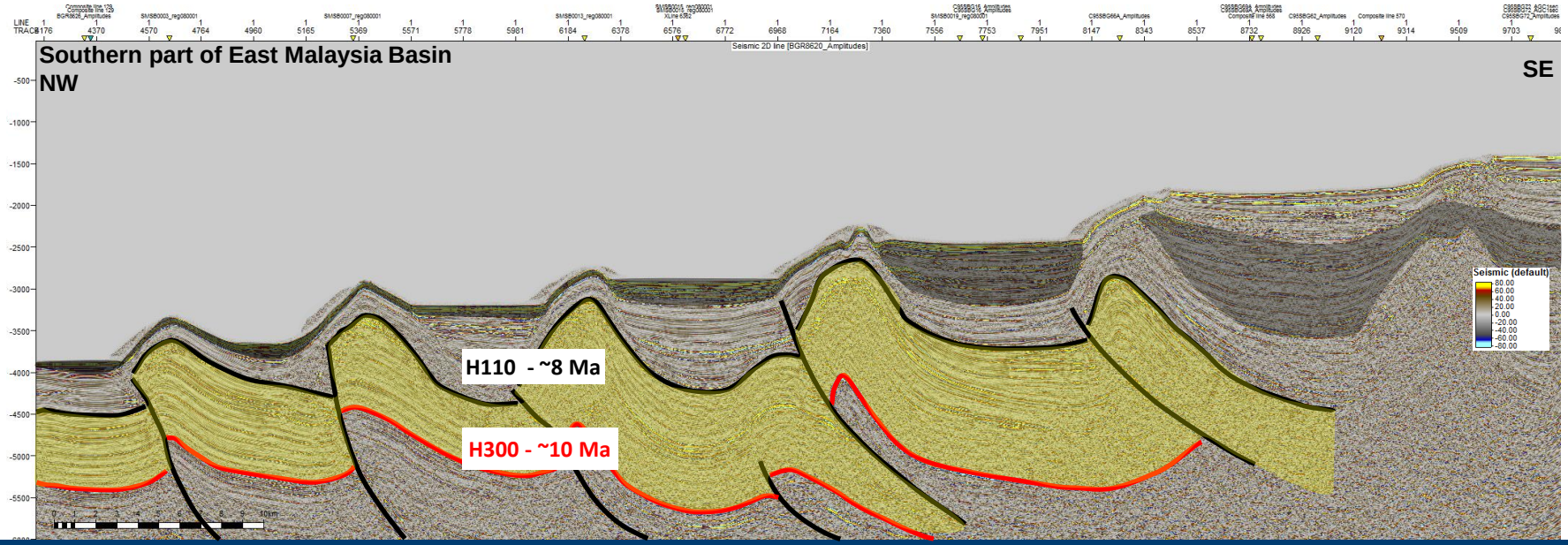




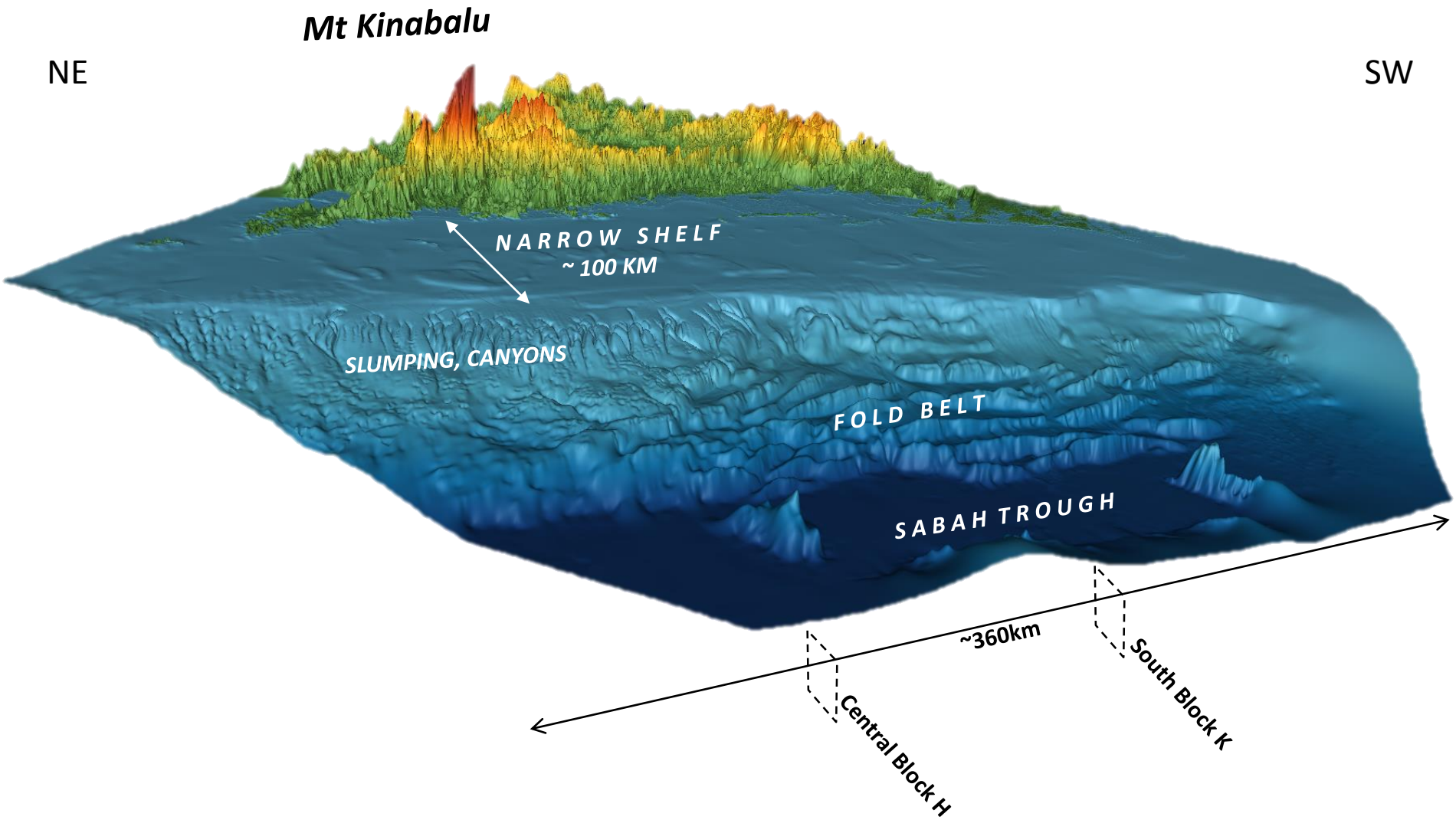
Hall, 2013

Variation in Systems across East Malaysia offshore

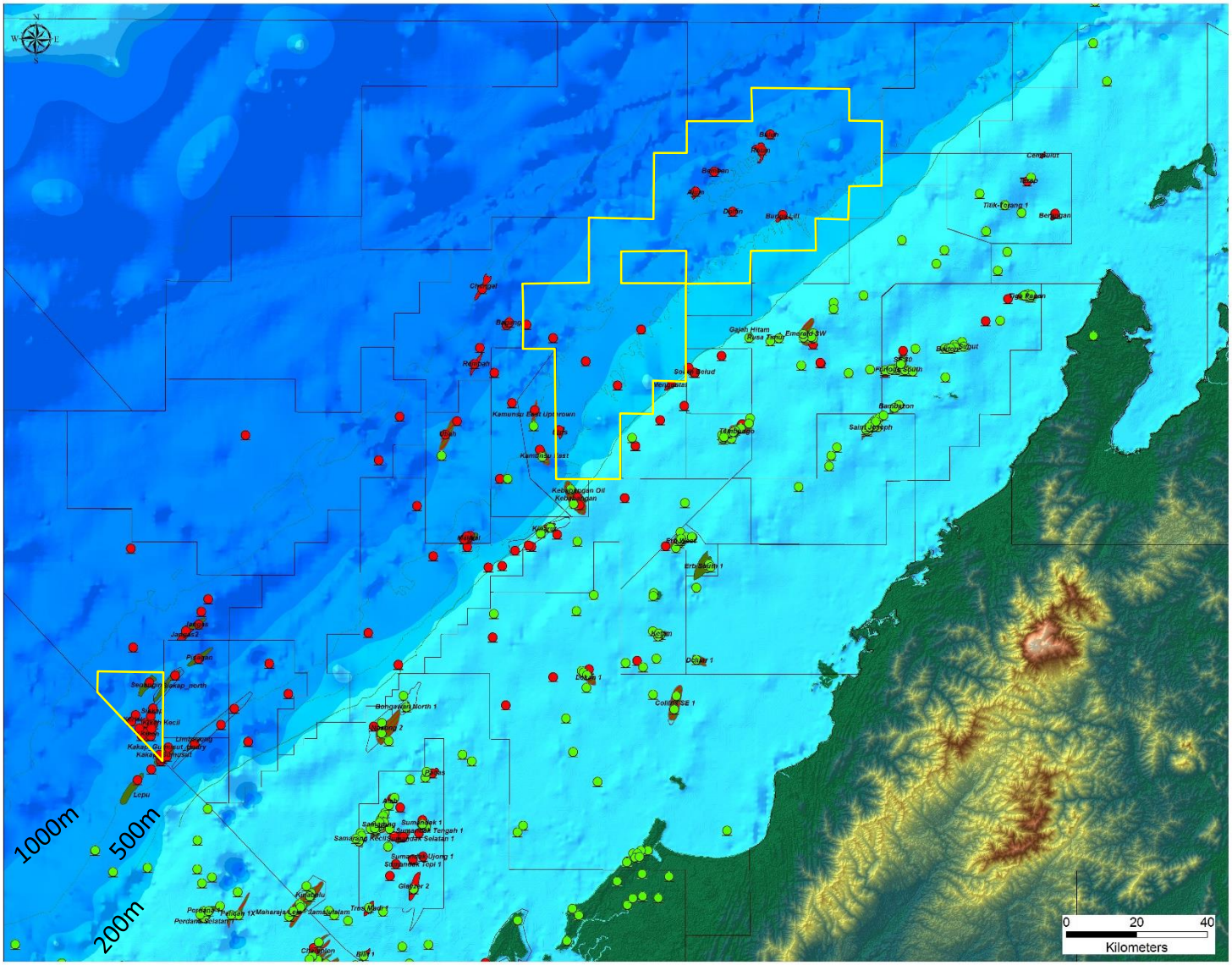




Present day topography – view towards South East



Sabah Exploration Wells 2015 and Fields



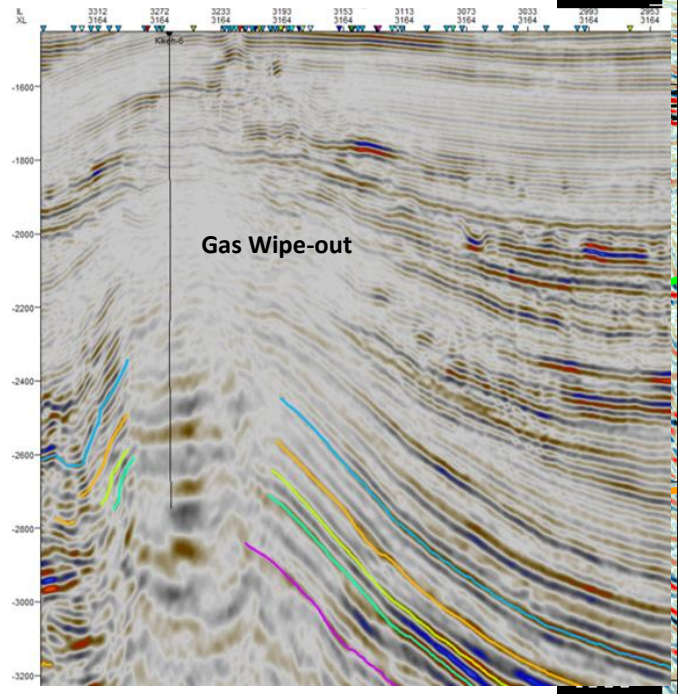
Expl wells post-2002

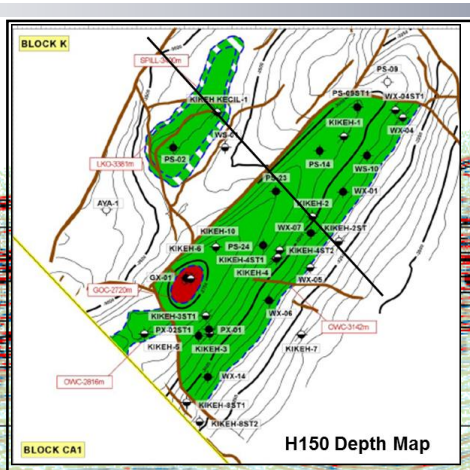
Expl wells pre-2002

Murphy acreage

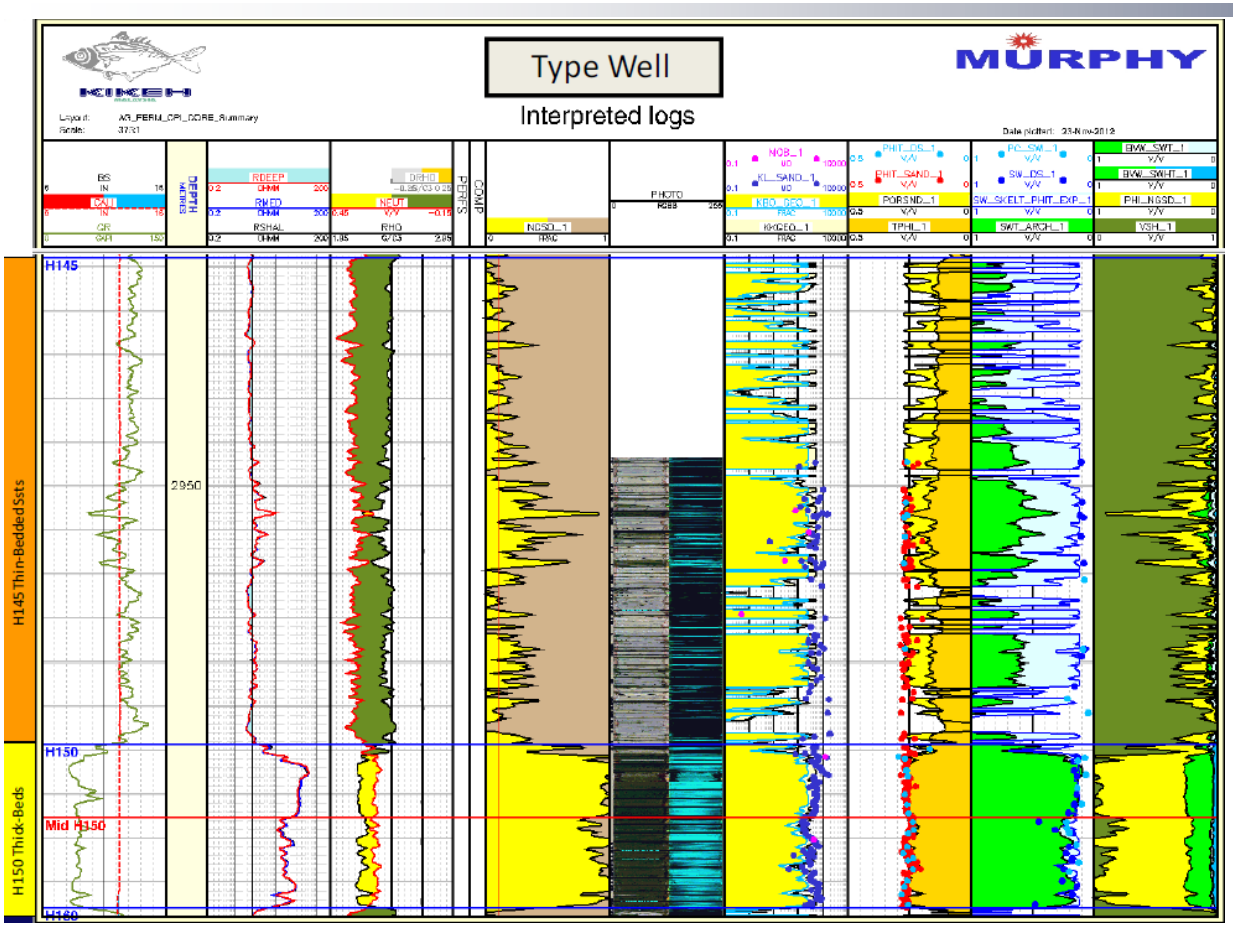
K Field – discovery made in 2002

- Thrusted anticline; 4-way dip closures; Gas wipe-out on crest
- Late Miocene turbidites, massiv thin-bed sandstones; High poro-
- High quality light oil, minor gas
- Sealed by Mass Transport Depos up to 100s of metres HC column

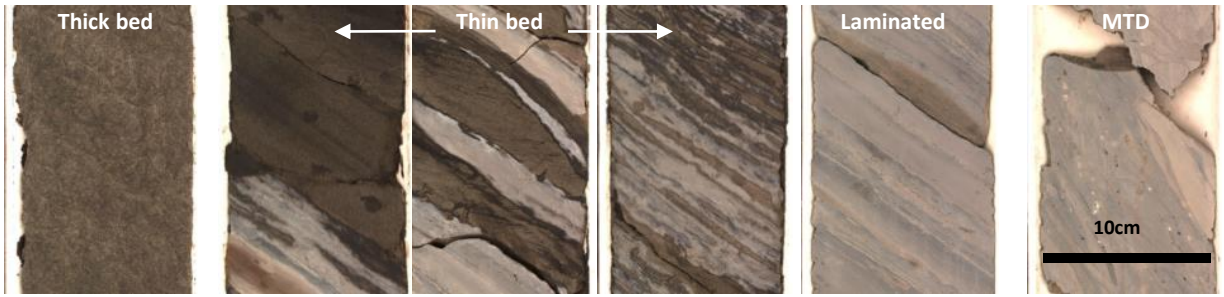




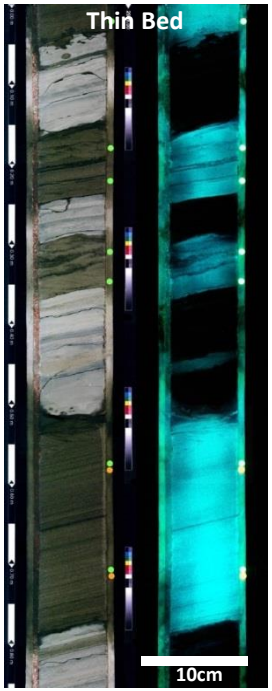
K Typical Reservoir – Thick Bed vs Thin Bed



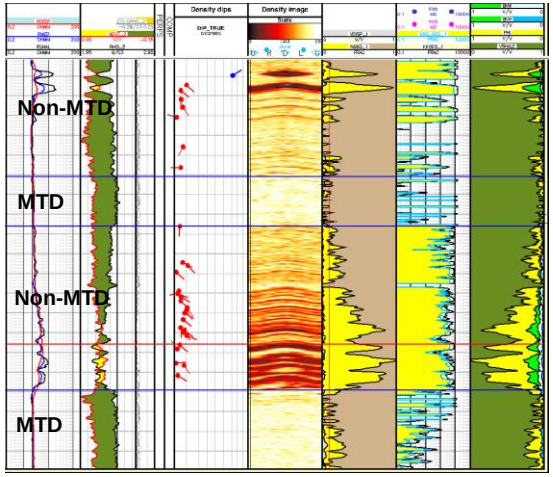
- Submarine fan facies
- Reservoir zones separated by non-reservoir Mass Transport Deposits (MTDs)
- Reservoir zones – high quality, poroperms 28-32%, ~1,000mD
- Thicker beds often at base
- Thin bed (cm thickness)
- Mudrock interbeds

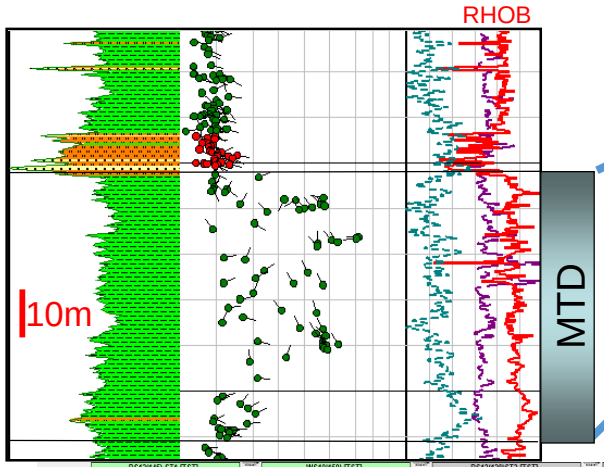


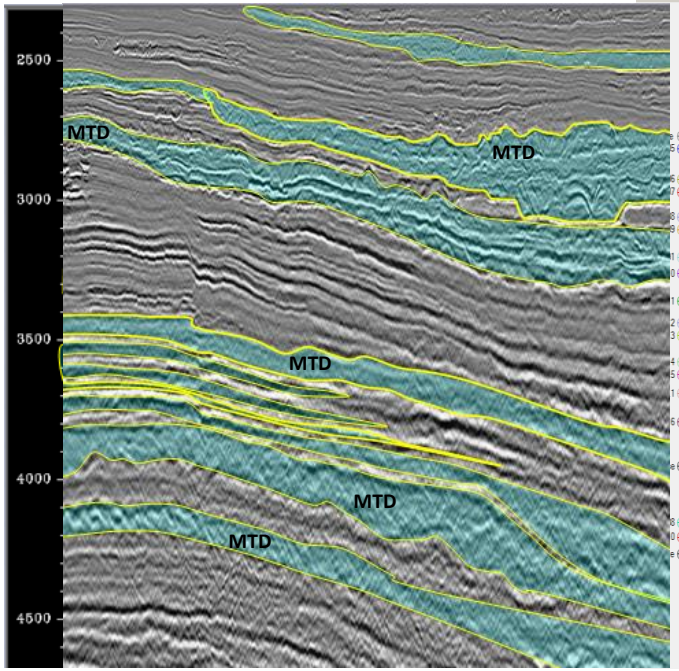
- Very fine - fine grained well sorted sands
- Parallel & ripple lamination
- Individual beds fine upwards
- Sharp bed bases & tops
- Carbonaceous material

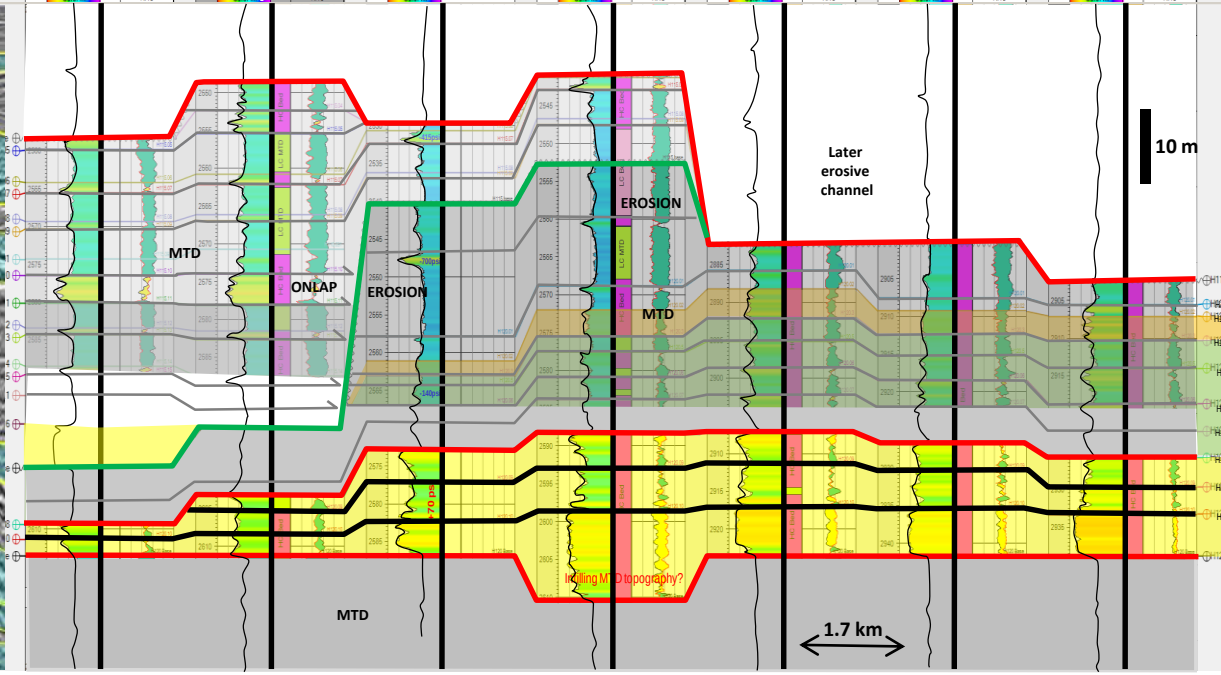


Reservoir Sandstones and Mass Transport Deposits (MTDs)

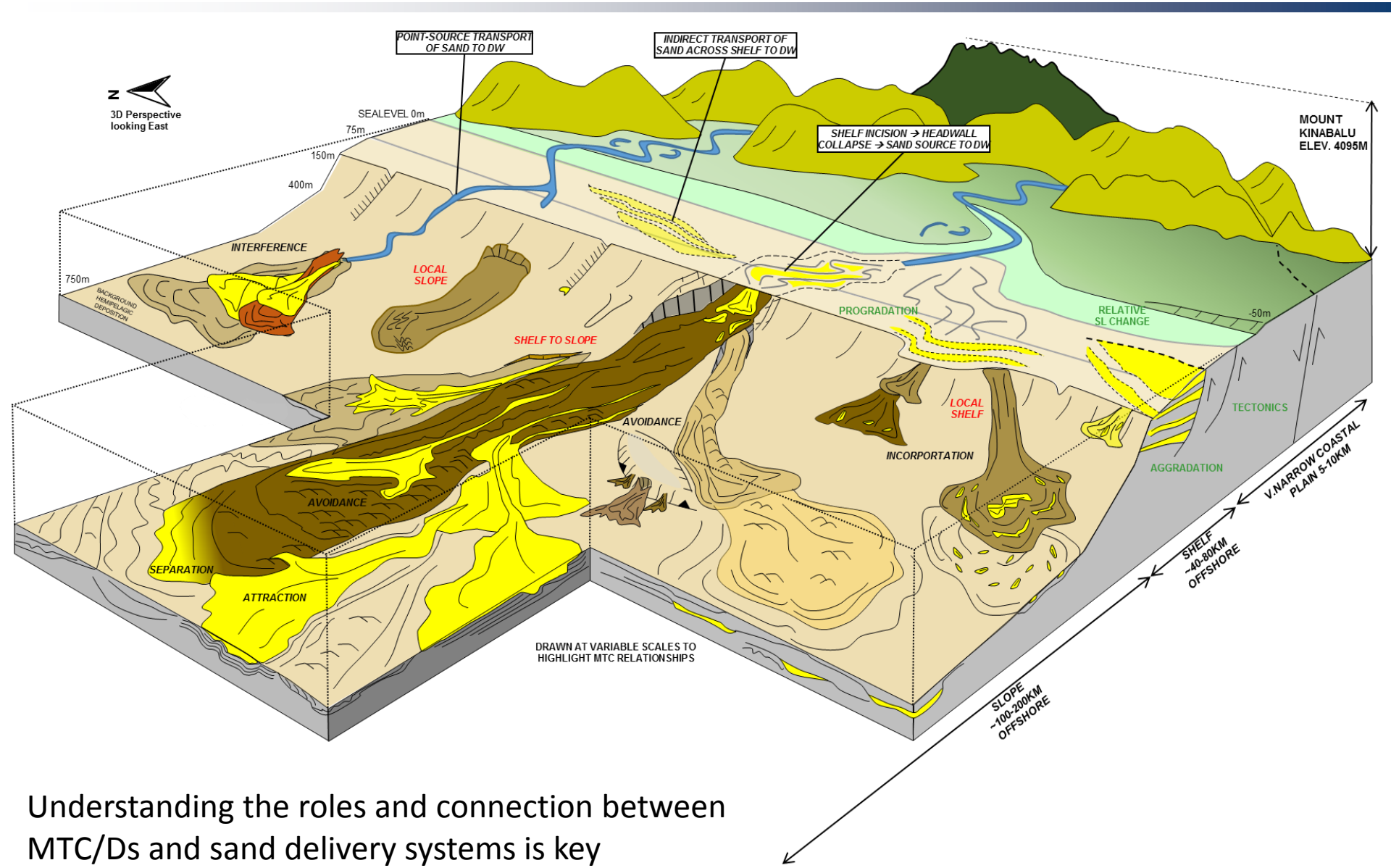






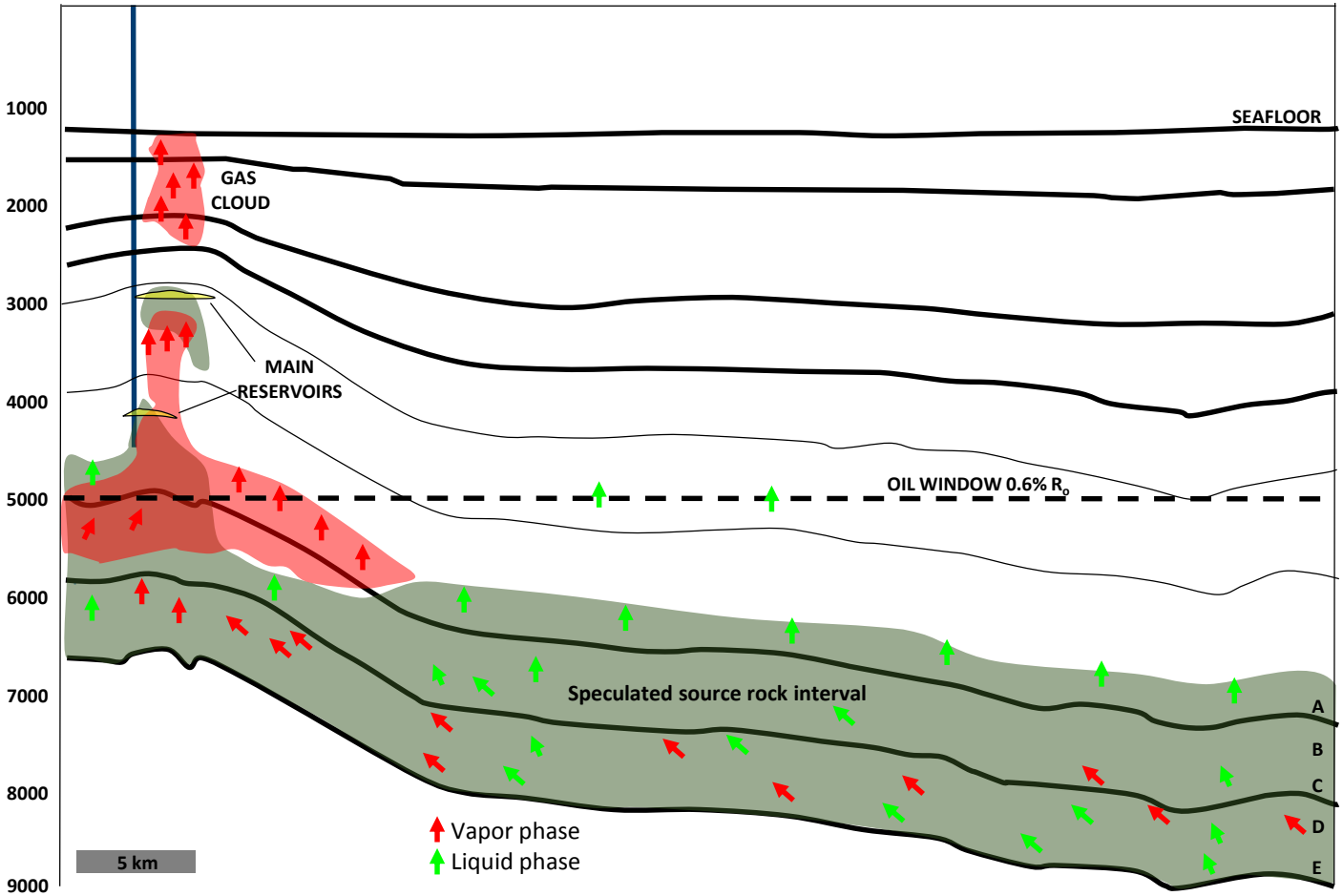


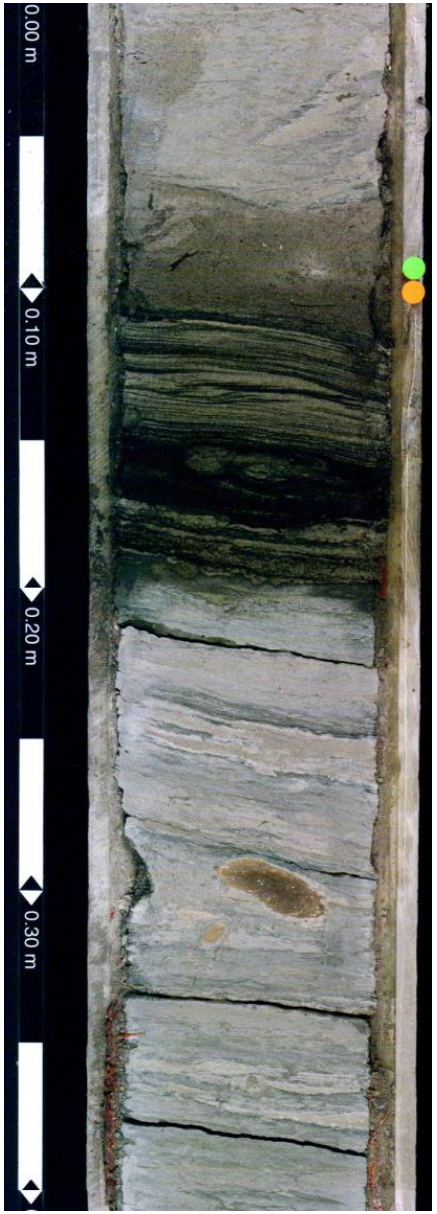
Mass Transport Complexes/Deposits



Understanding the roles and connection between MTC/Ds and sand delivery systems is key

Source Rock and Petroleum Systems model

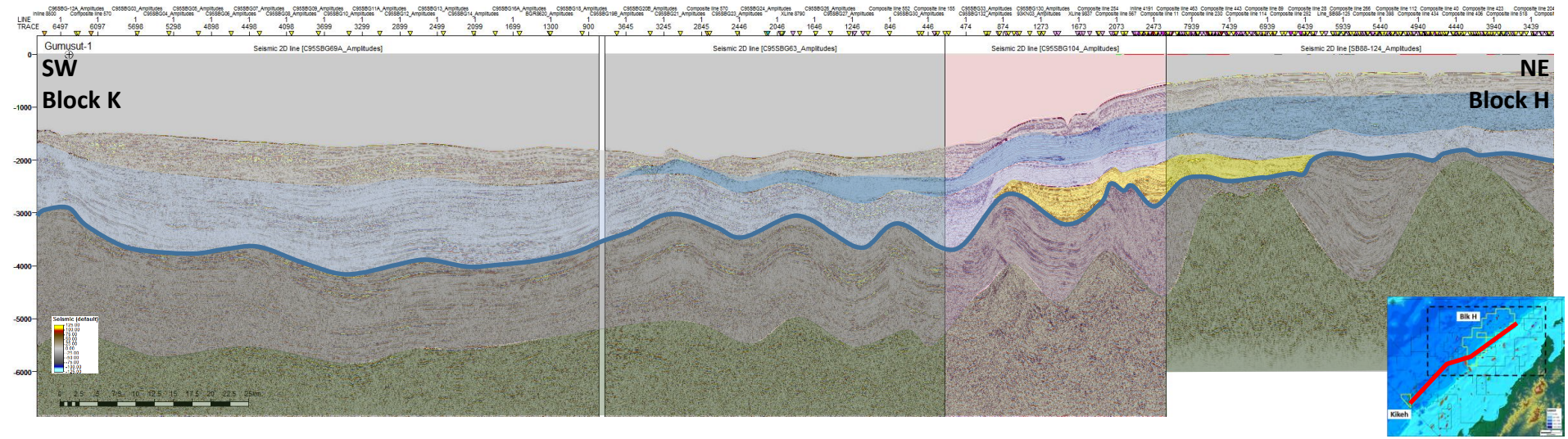




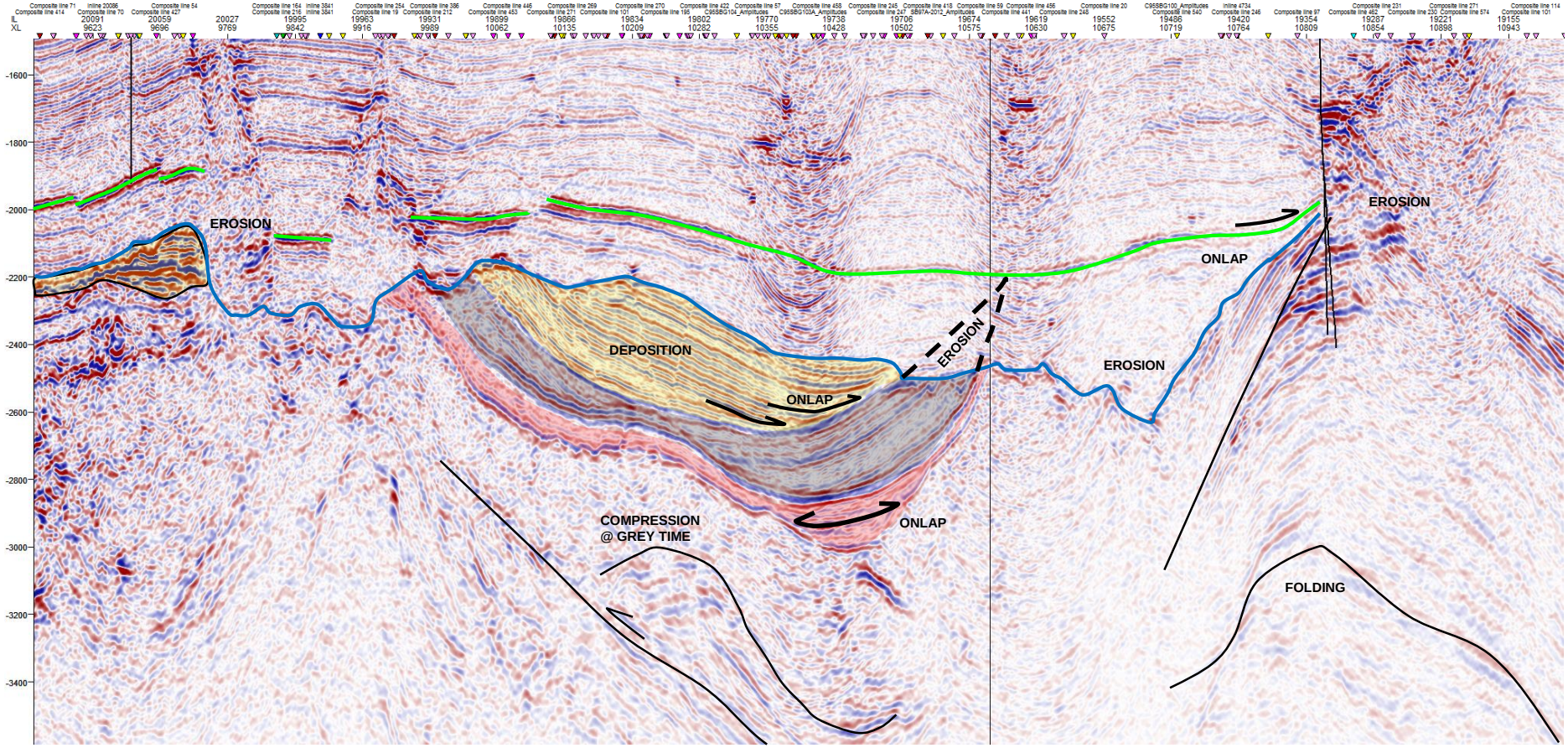
- Organic Matter accumulated in a deltaic peat environment → Re-deposited onto the shelf → transported to Deep water associated with sands
- Low TOC (<2%) and Low HI (<200HI) Terrestrial Source rock

Block H Exploration Success

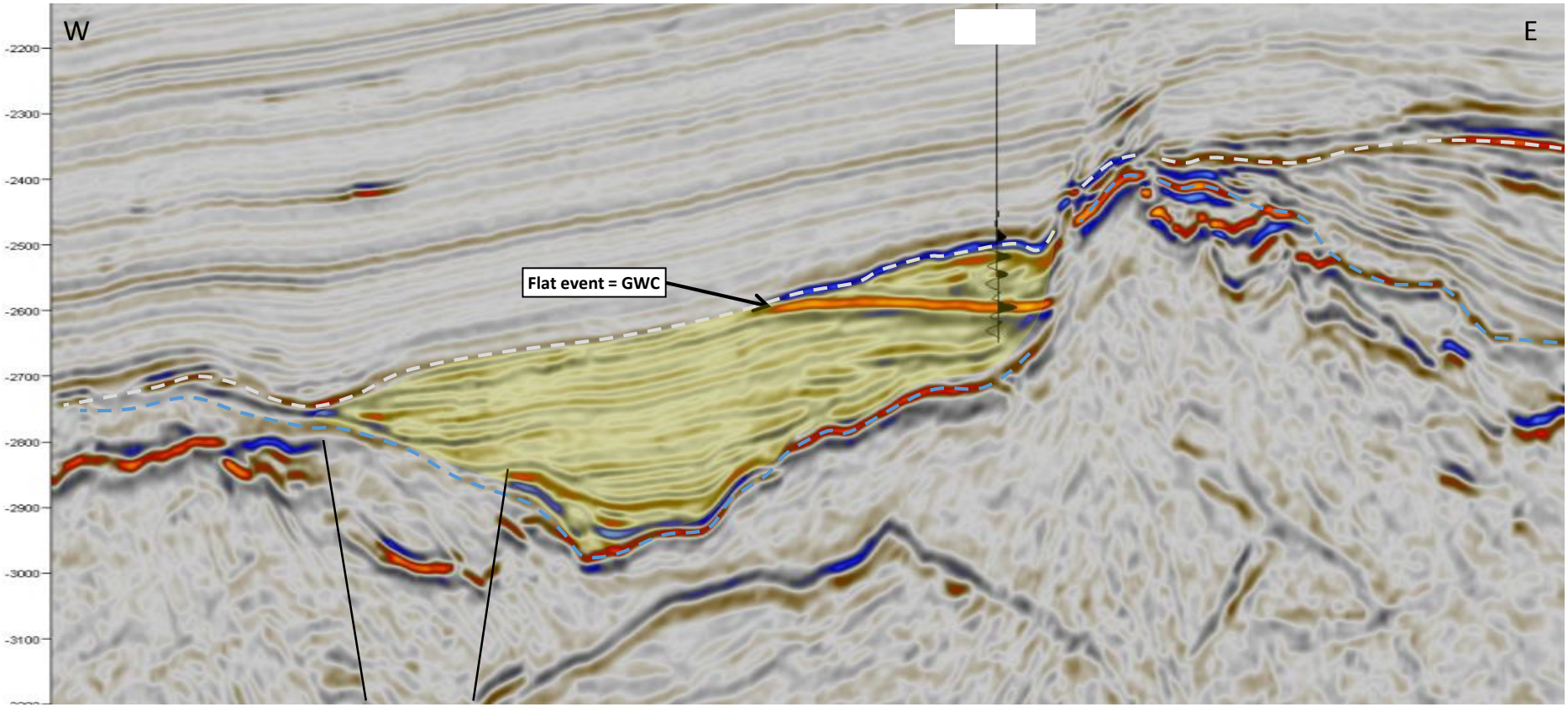
- **Rotan discovery in 2007**
- **Cluster of 8 dry gas discoveries**
- **Murphy to provide feedstock gas to PETRONAS FLNG Project**



Complex Relationship between Deposition, Tectonics and Erosion

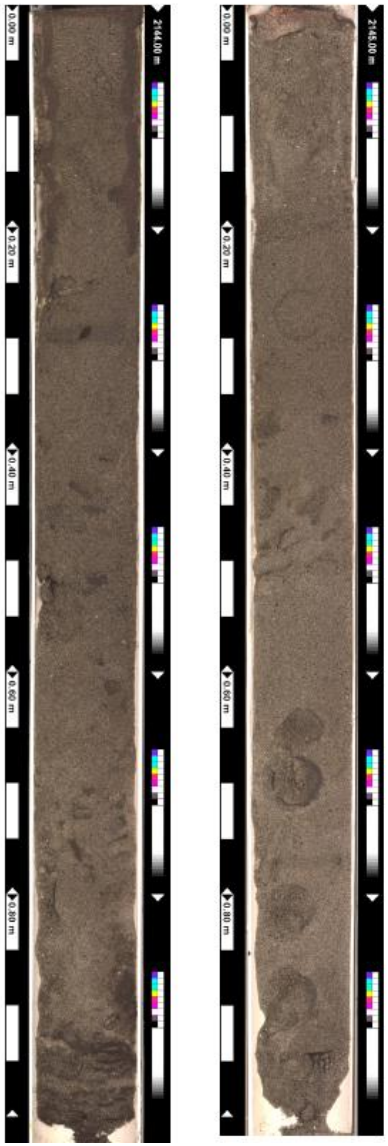


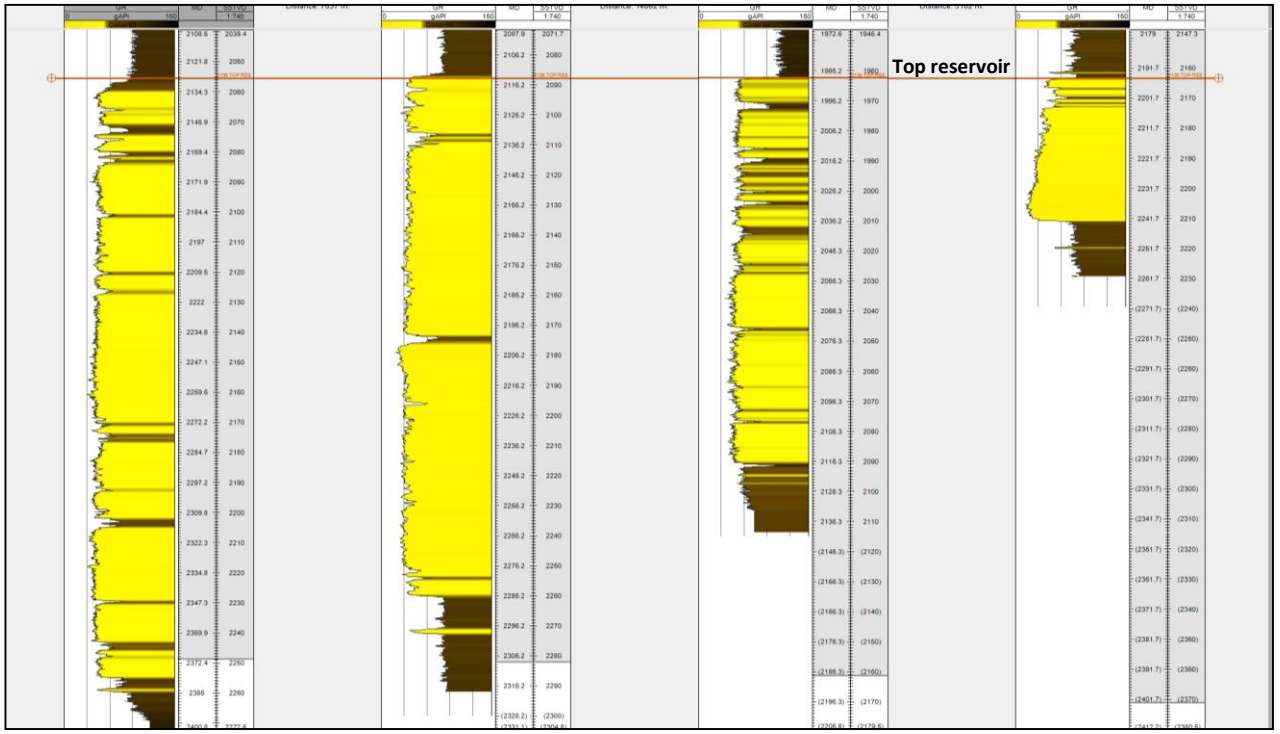
Rotan Seismic



- Rotan reservoir sands deposited in one of a series of mini-basins that developed beyond the shelf-edge break
- Sands accumulated in series of structurally-controlled mini-basins

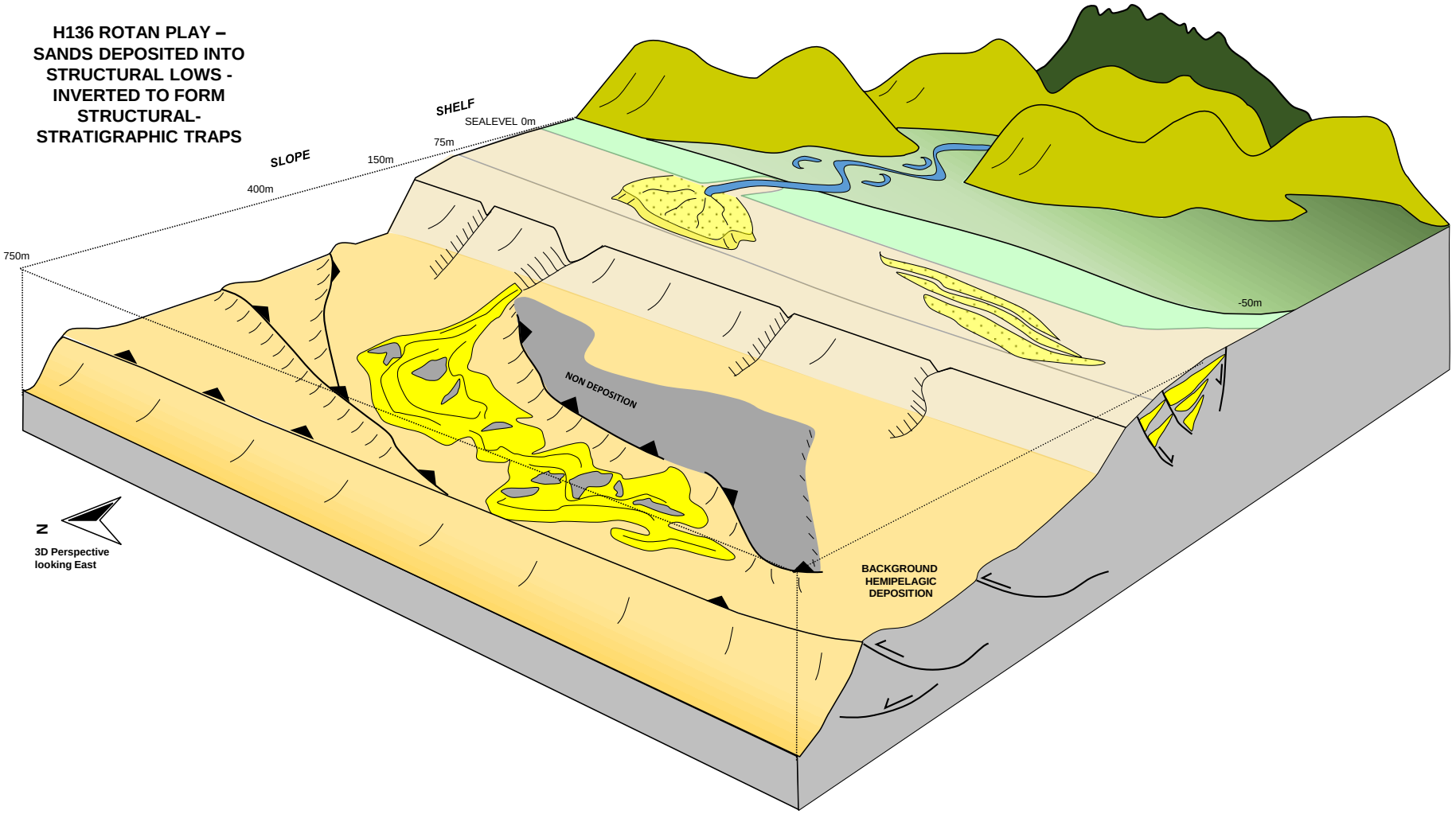
R Play - Logs and Core



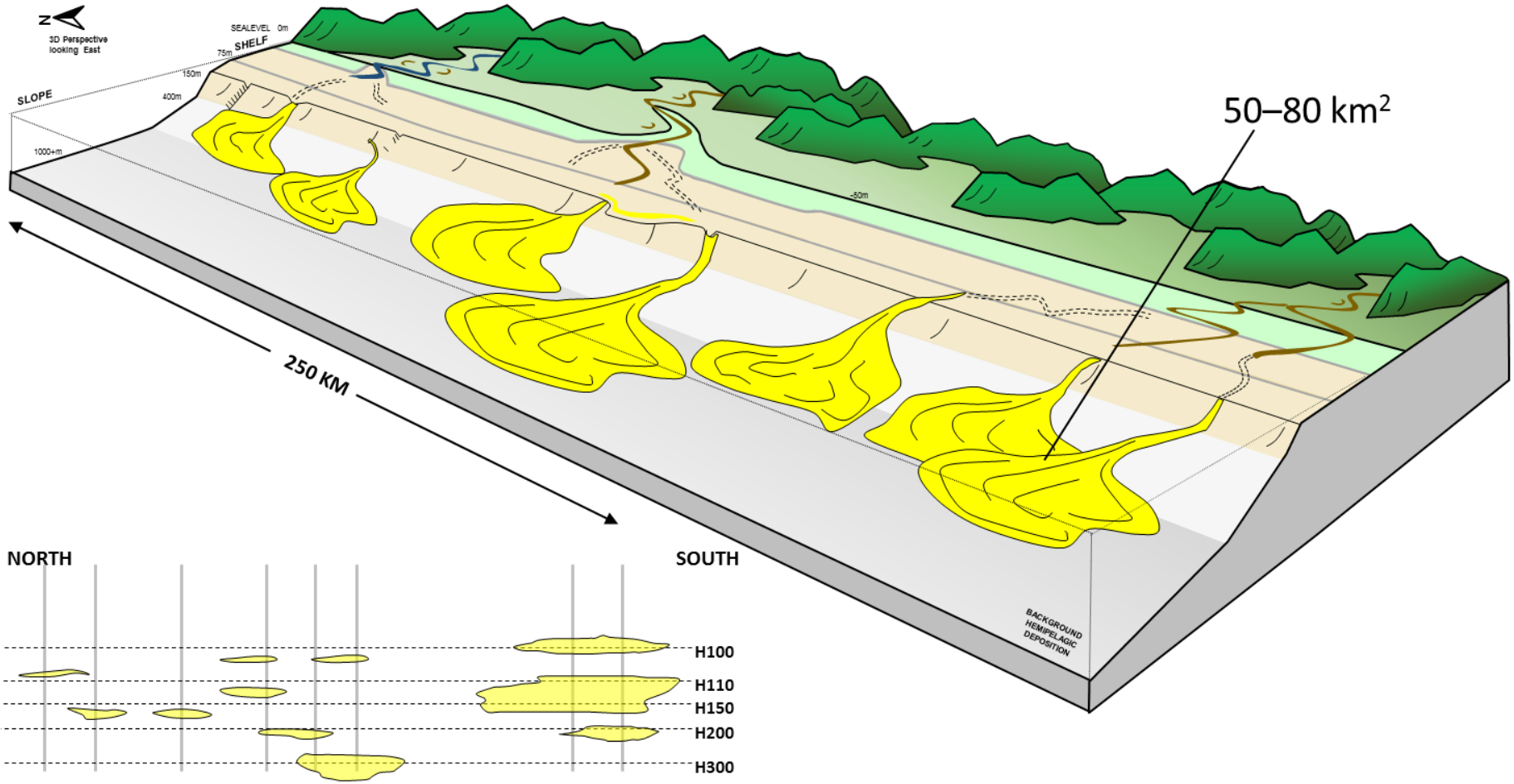


- Up to 200m gross thickness, massively bedded, unconsolidated, high quality reservoirs
- PHI_T 28-37% with high S_g and low V_{sh}
- One reservoir & one contact per structure

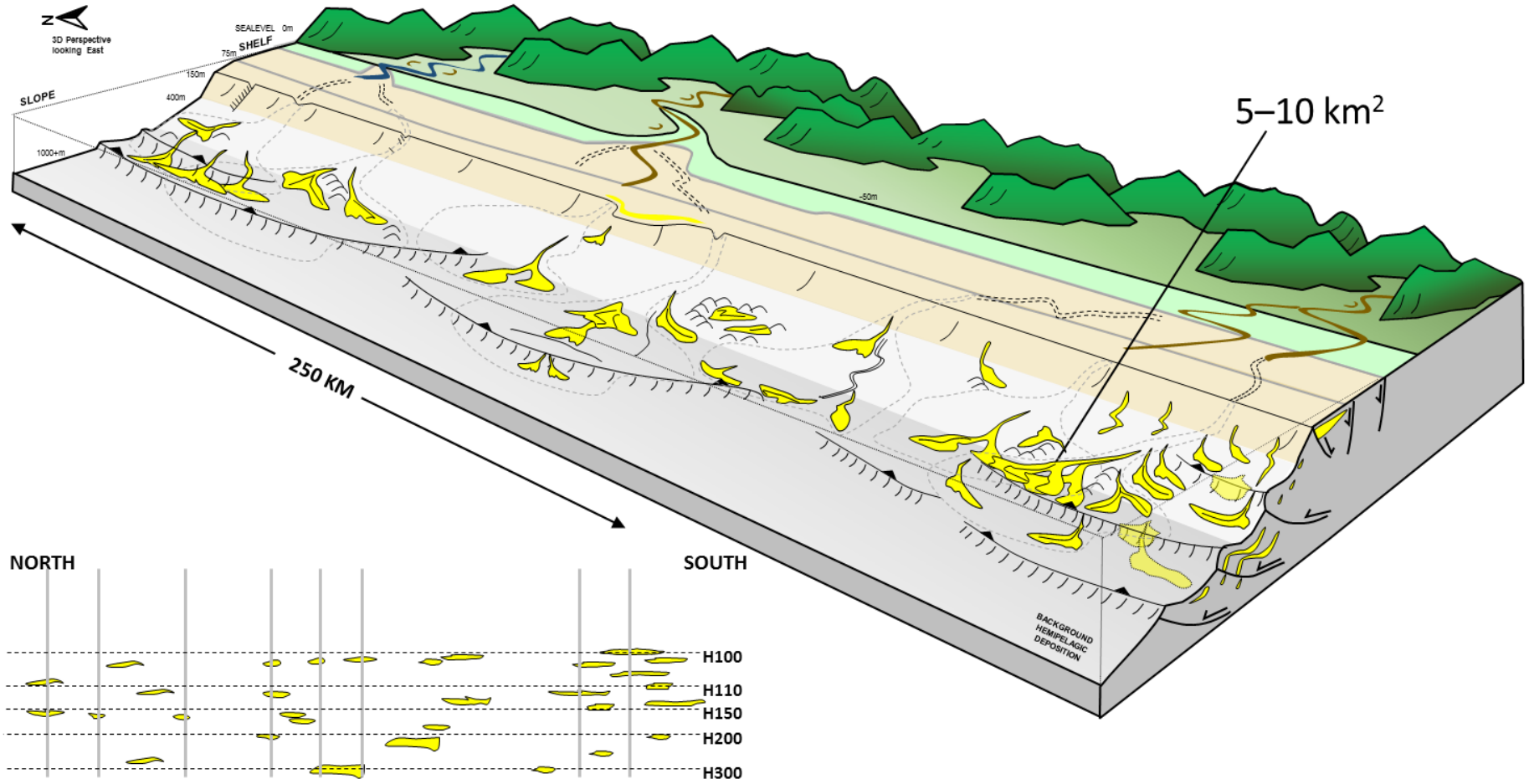
Rotan Play


H136 ROTAN PLAY – SANDS DEPOSITED INTO STRUCTURAL LOWS - INVERTED TO FORM STRUCTURAL-STRATIGRAPHIC TRAPS
SHELF
SEALEVEL 0m
75m
SLOPE
150m
400m
750m
-50m
NON DEPOSITION
BACKGROUND HEMIPELAGIC DEPOSITION
N
3D Perspective looking East

Exploration Model – Initial expectations



Exploration Model – Current reality!



Concluding Remarks

- **Deep-water East Malaysia remains an under-explored but proliferous basin**
- **Major sand input along margin over a short period ~3 Ma**
- **Same age but variable depositional patterns along the same margin**
- **Complex interaction between deposition and structural history**
  - Understanding this relationship is the key to unlocking Exploration potential
  - Essential work – PSDM, structural reconstruction
- **Apply creative thinking to Development options. A close working relationship with the regulator is crucial**
- **New ideas – don't be afraid to challenge existing dogma and be creative!**

THANKS!

PETRONAS

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