# Sequence Stratigraphic, Sedimentologic and Petrographic Insights of the Miocene (Stage IVA) Outcrops of the Klias Peninsula and Labuan Island, Sabah, Malaysia, Borneo*

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## Abstract

The Miocene Stage IV reservoirs are the primary target for present-day exploration in offshore Sabah, Borneo. The Stage IV ranges in thickness from 3 to 5 kms and comprises interstratified sandstones and shales deposited within marginal marine to shoreface environments. Exposed on the Klias Peninsula and Labuan Island, the Stage IV sits on the Middle Miocene Unconformity (MMU), also known as the DRU (Deep Regional Unconformity) and marks the onset of the next major phase of sediment accumulation after the Early Miocene Stage III in NW Sabah.

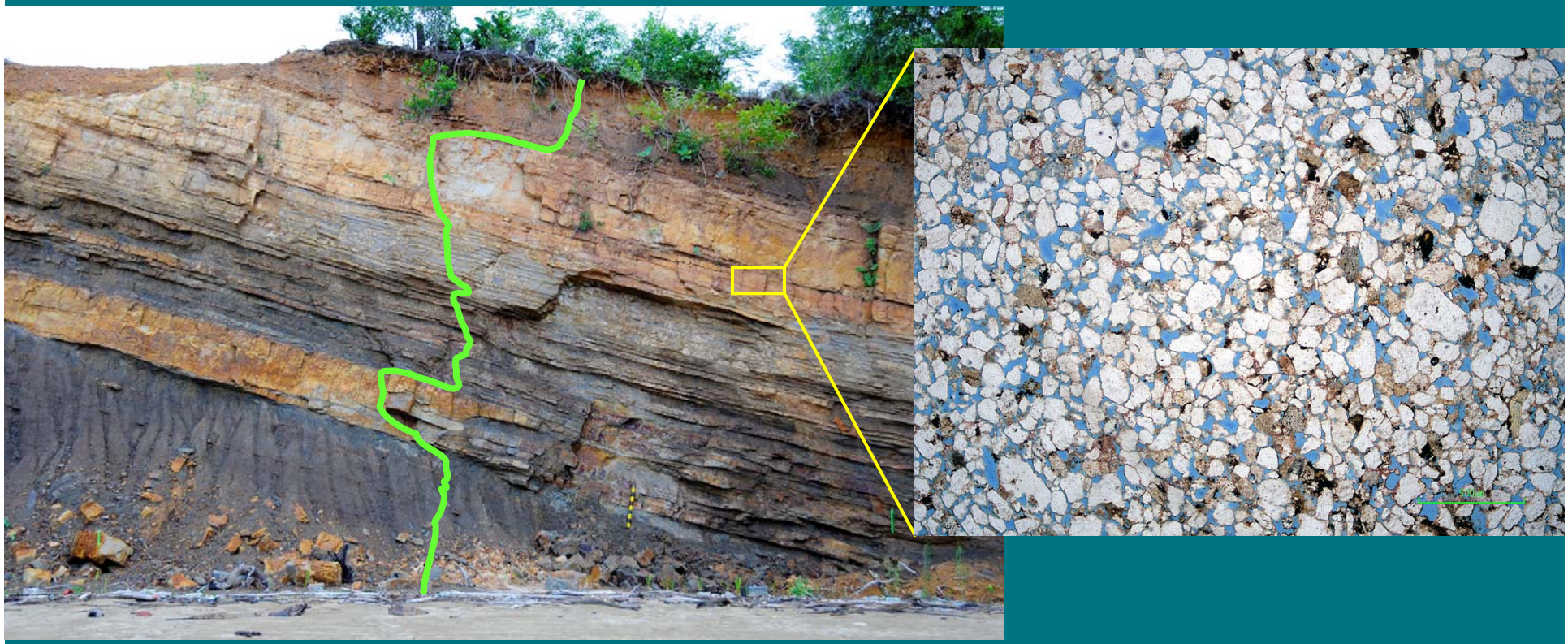
A nearly complete sequence within the Stage IVA is observed in the outcrops at Bethune Head, Ganggarak Quarry and Layang Layangan Beach. The unconformity (sequence boundary) is marked by fluvial deposits of the IVA cutting into the delta front/prodelta and offshore shales of the Miocene Stage III. The lowstand package (LST) comprises fluvial sandstones and conglomerates, which are capped by tidal flats or a highly bioturbated sandstone with burrows extending up to ½ metre into the underlying dark grey shale (Glossifungites), marking the onset of transgression.

The transgressive package (TST) is dominated by wave-dominated delta to shoreface sandstones and shales, which are capped by a thick offshore shale (Bethune Head) to prodelta (Batu Luang) section interpreted as the maximum flooding surface (MFS). This represents the end of transgression and the beginning of the relative sea-level highstand.

The highstand package (HST) is made up of coarsening-upward sandstone packages deposited in a wave-dominated delta system containing tidal flats, distributary channels, delta front sands and prodelta sediments. These sand packages are contained within the clinoforms of the delta as it prograded into the basin during the highstand.

The sandstones in the IVA typically fall into the quartz-dominated, sub-lithic arenite classification and have a pore-system dominated by primary pores with subordinate secondary pores formed by the dissolution of unstable grains (feldspars and unstable lithics). Overall reservoir quality varies with facies type; the fluvial and deltaic sandstones can have similar porosity measurements, but the higher degree of sorting in the deltaic sands is an indicator of better permeability in this facies. Although the lowstand sands have relatively good reservoir quality, the transgressive and highstand shelf sediments have a wider distribution making them more targetable.

# Sequence Stratigraphic, Sedimentologic and Petrographic Insights of the Miocene (Stage IVA) Outcrops of the Klias Peninsula and Labuan Island, Sabah, Malaysia, Borneo



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AAPG ICE 2012
SINGAPORE

# Presentation Flow

1. Introduction
   a. Legacy Work
   b. Study Location

2. Outcrops Descriptions and Interpretations
   a. Depositional Model
   b. Klias Peninsula – Batu Luang Quarry/Road-cut
   c. Labuan Island – Bethune Head Beach

3. Sequence Stratigraphic Model

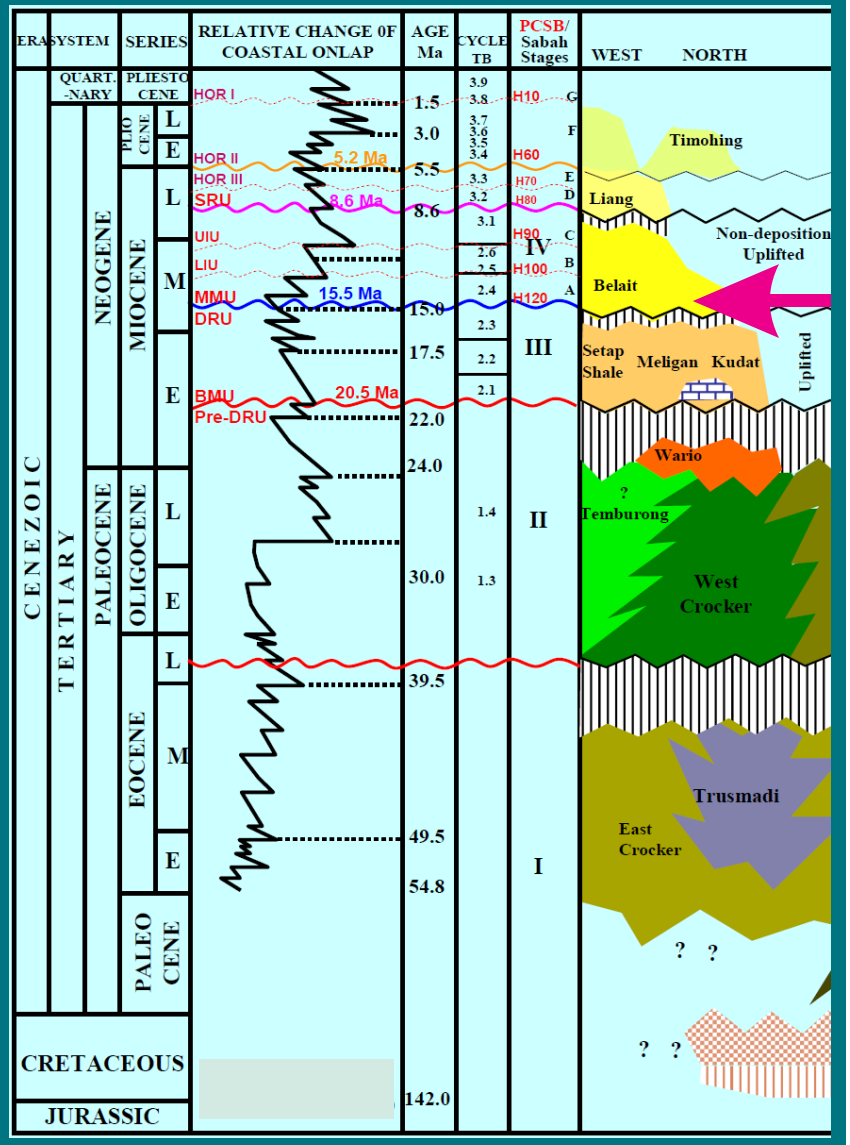
4. Petrographic Review

5. Summary

# Introduction

Talisman Malaysia undertook an outcrop study (2010/2011) of the Miocene Stage IVA section onshore Sabah, Borneo to understand better the depositional setting and potential facies distribution in the middle Miocene Stage IVA-F throughout their exploration acreage on blocks SB309/310.

This study will review the 2 main outcrops, place them into a sequence stratigraphic context and assess reservoir quality of the different facies identified.



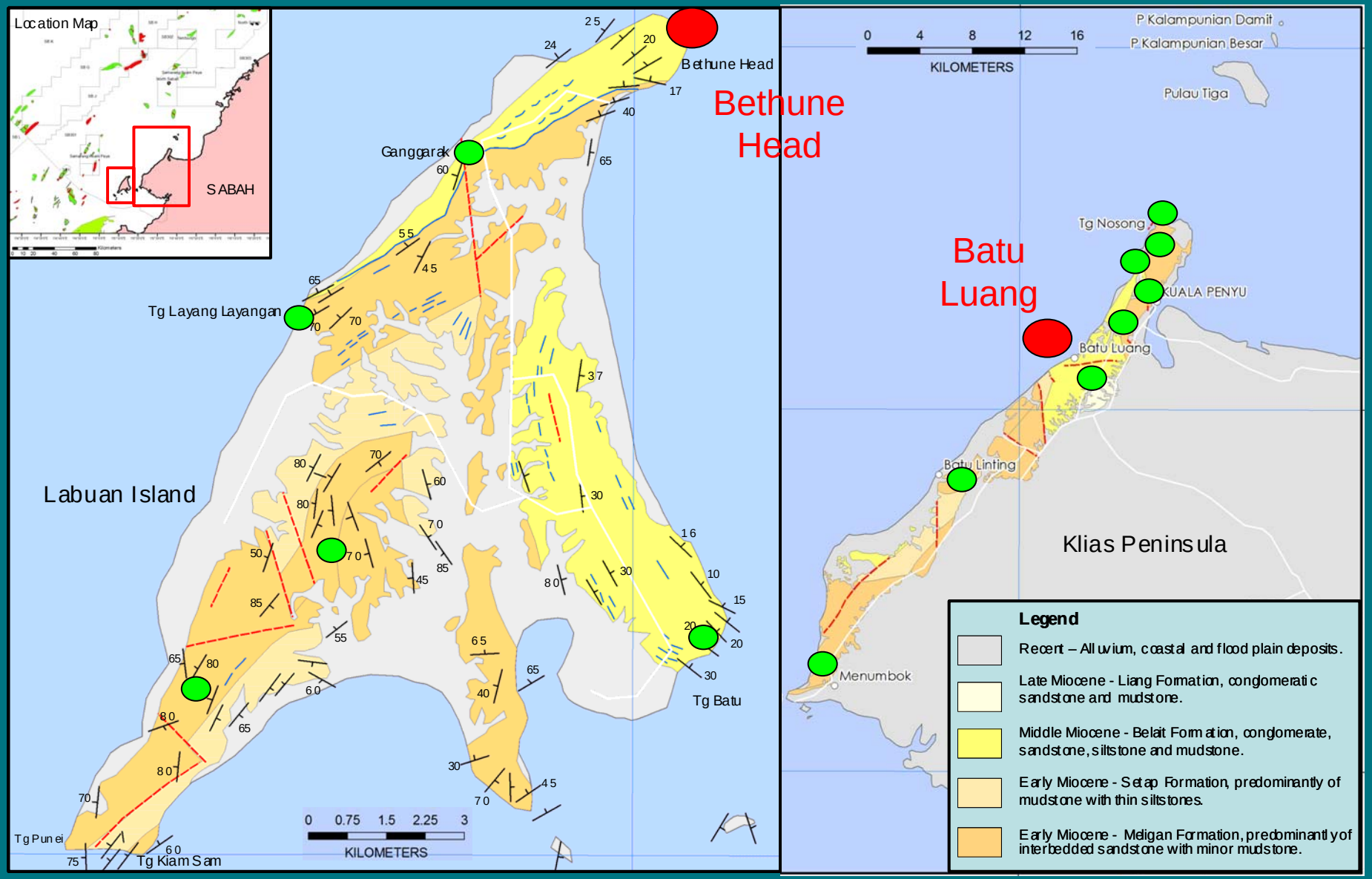
# Legacy Work

- Shell Company of North Borneo Ltd.
- R.A.M. Wilson *et al*., 1964 Geological Survey, Borneo Division
- Hutchison – Geology of NW Borneo
- Lambiase - Miocene sections in Sarawak/Brunei
- Madon (PETRONAS)

# Study Location


Satellite maps care of Google Earth

# Geology Map of Labuan and Klias

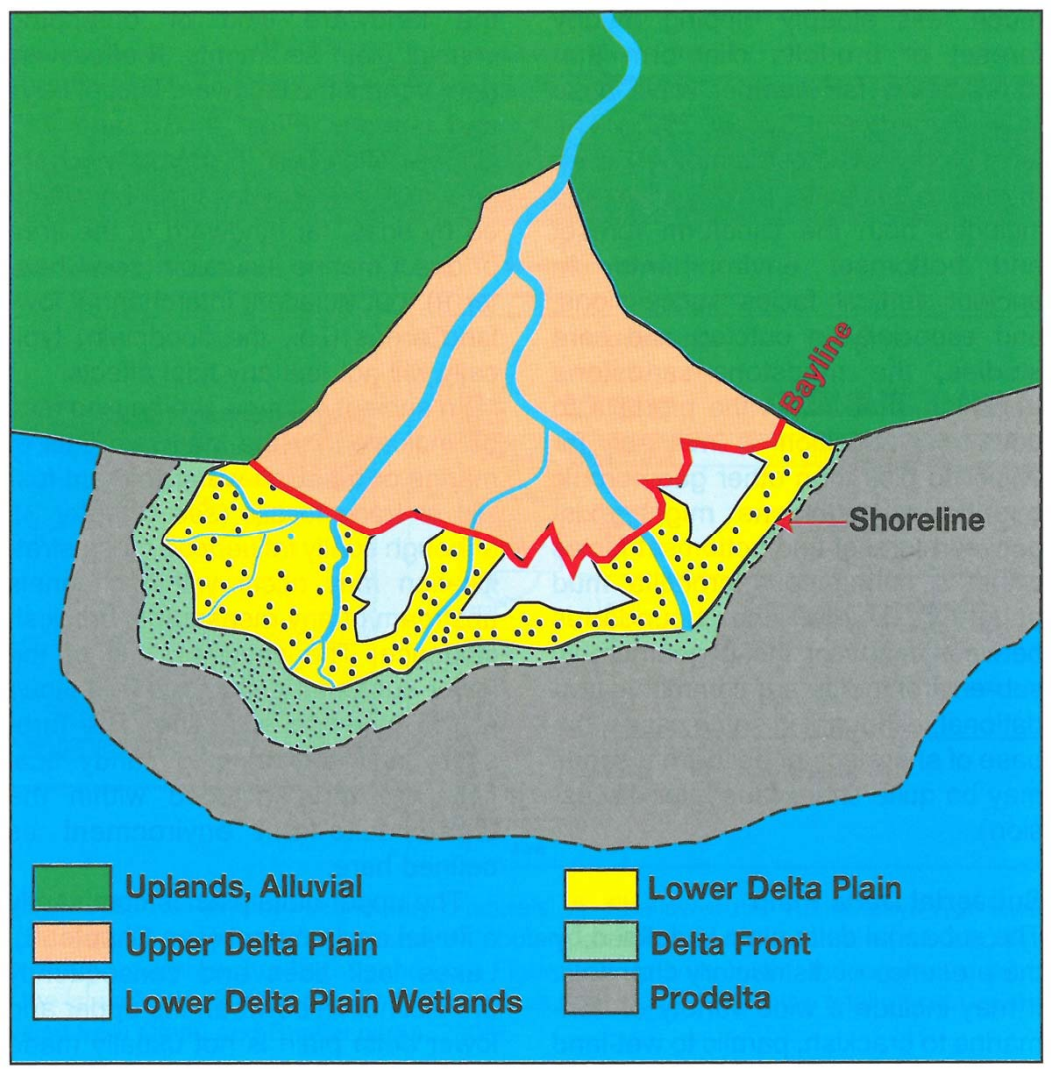



Geology Map after R.A.M. Wilson (1964), Geological Survey, Borneo Region

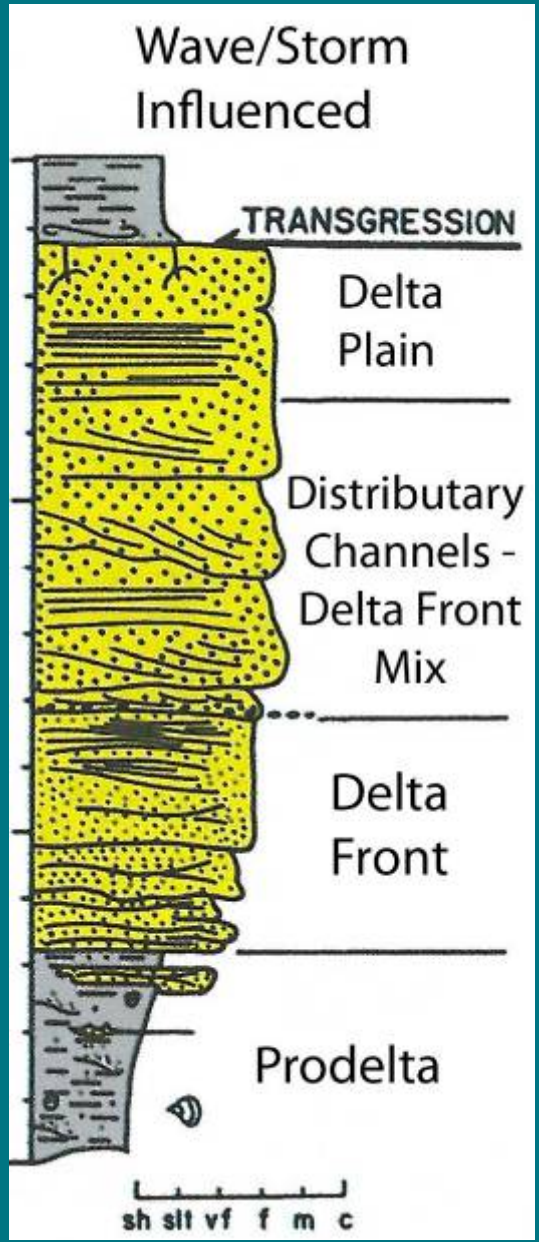
# Outcrops & Depositional Model

# Depositional Model

- Wave/Storm-influenced Delta System




Bhattacharya, 2011




After Bhattacharya, 2011

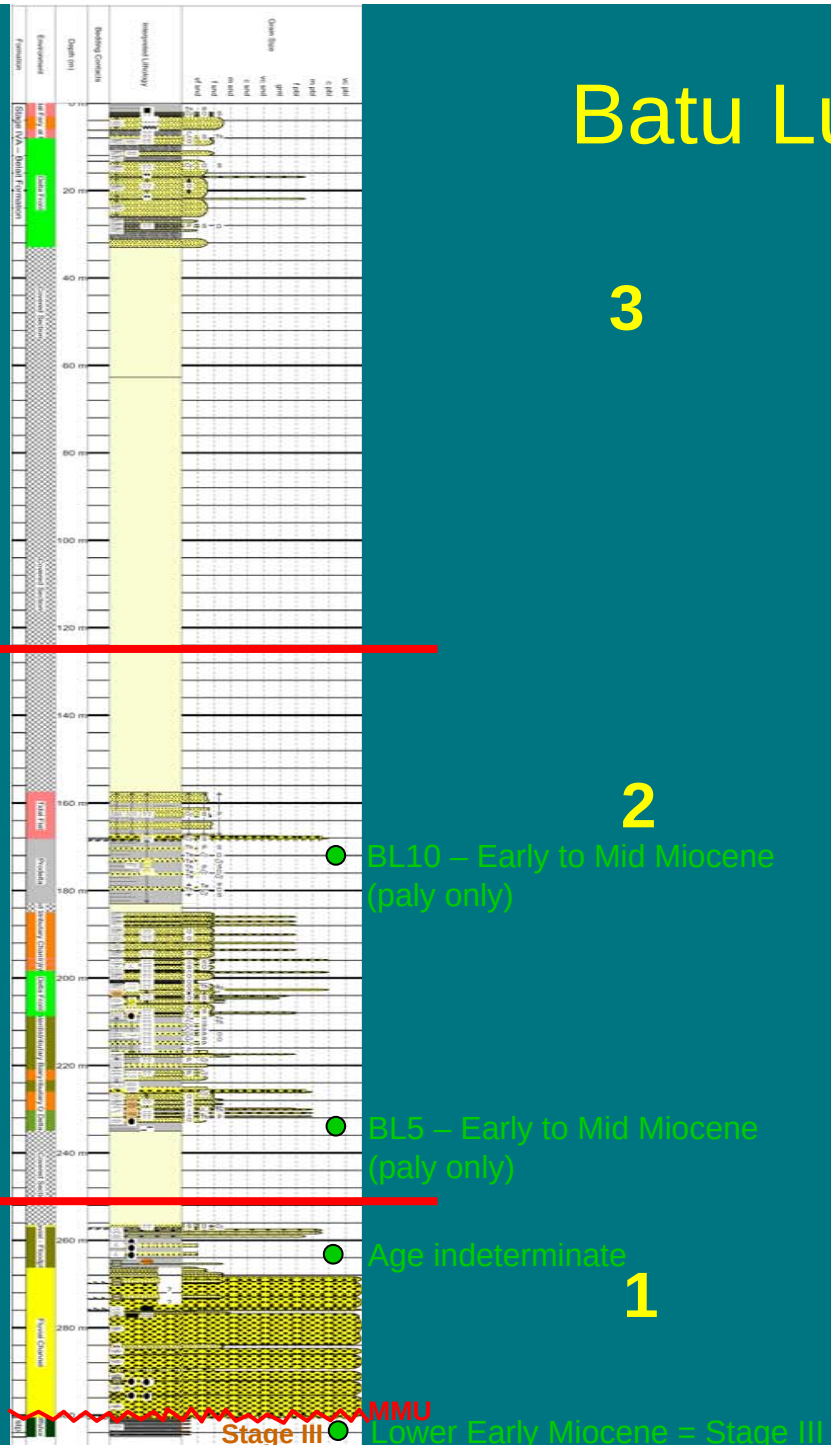
# Batu Luang
# Klias

3

2

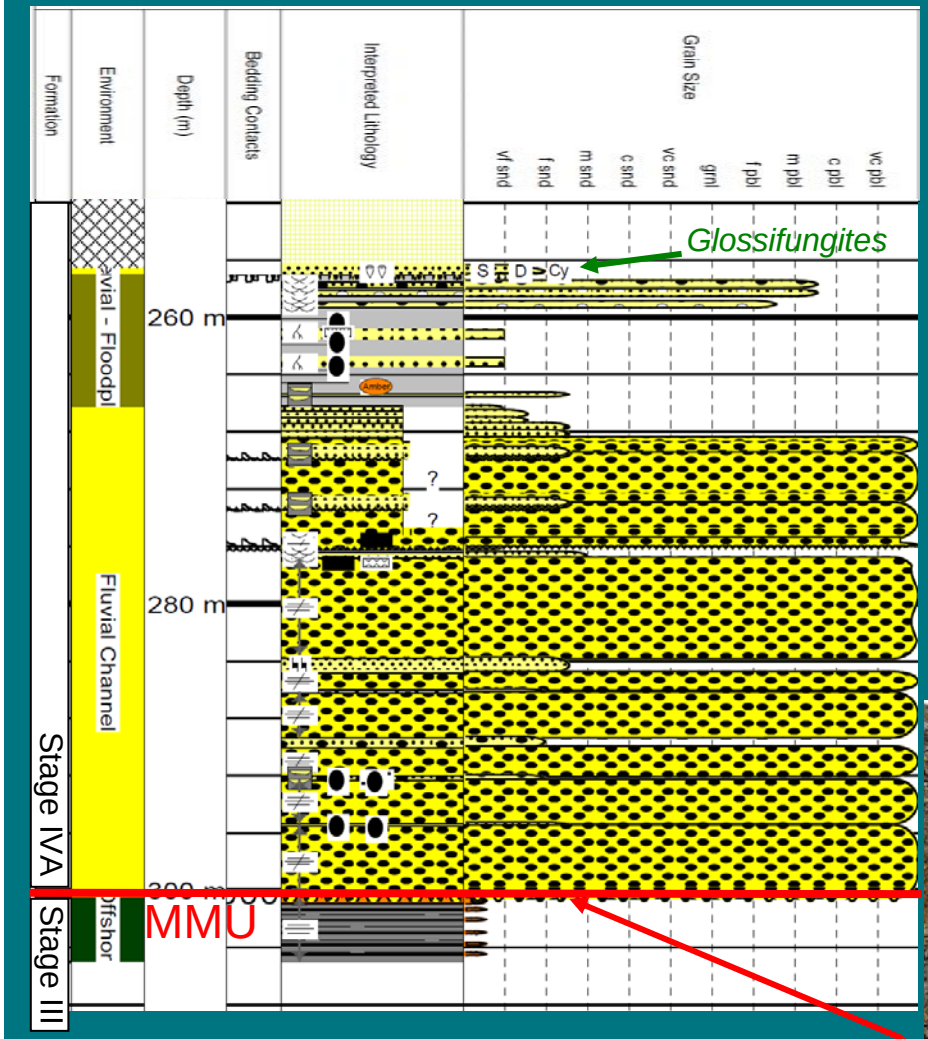
1

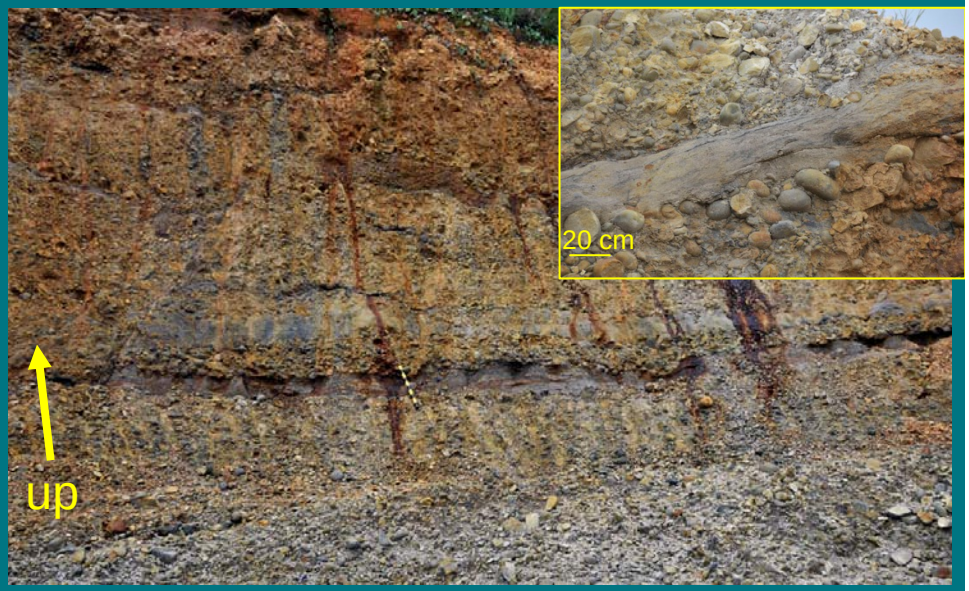
# Batu Luang – Klias




- Approximately 305m of section (including visible and covered intervals)
- Biostrat data collected indicates an age of early to middle Miocene (Stage IVA) above Lower Early Miocene (Stage III)
- Subdivided the outcrop into 3 sections

# Batu Luang - 1



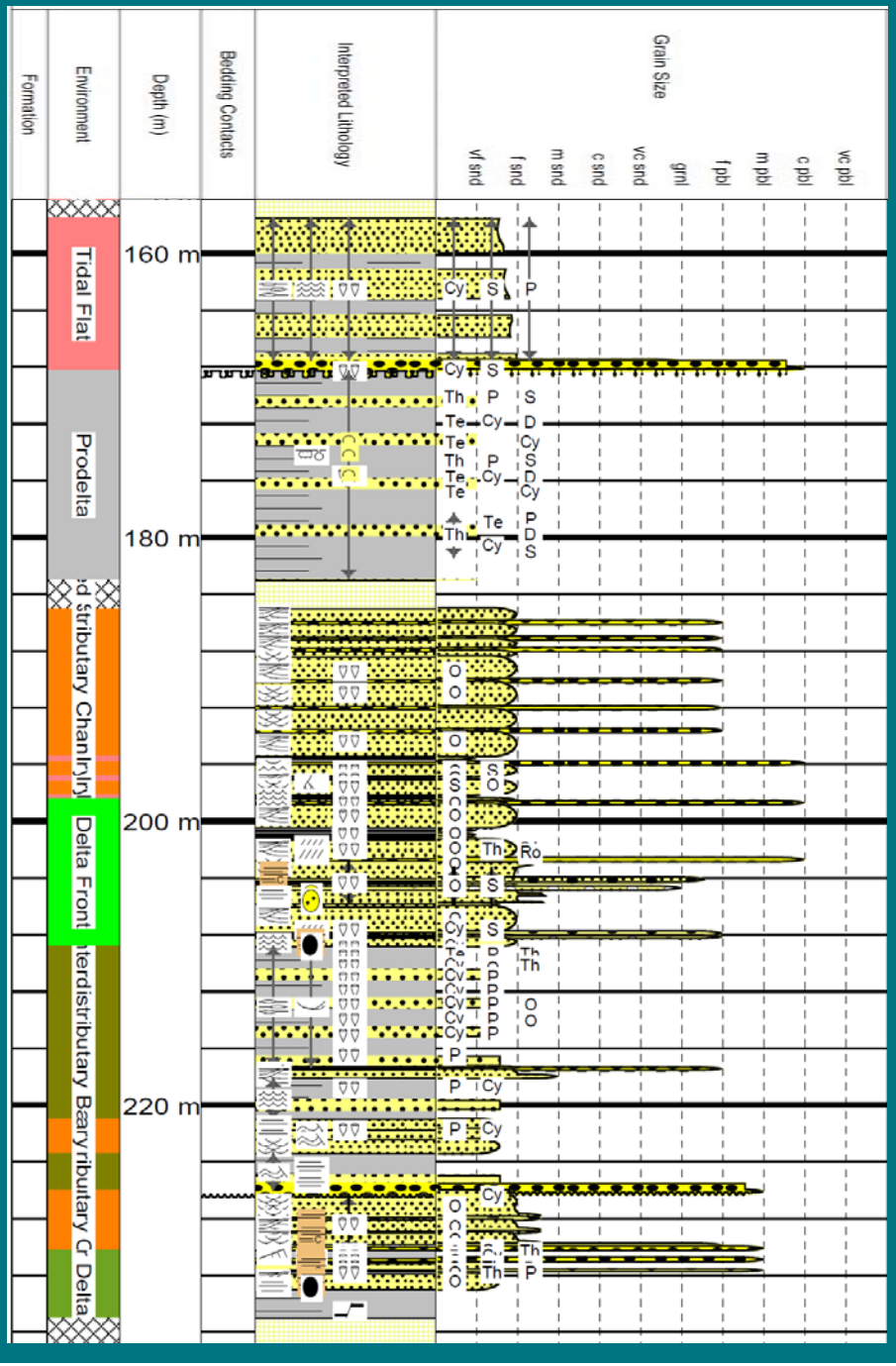


- Angular unconformity cutting into the Stage III – Setap shale
- Thick-bedded, matrix- to clast-supported conglomerates with thin ss beds and coalified logs
- Capped by a surface containing a *Glossifungites* Ichnofacies

# *Glossifungites* Surface


- Burrows extend down (up to 1 metre) from the sand:shale contact
- Burrows are filled with the same sand comprising the overlying sand package
- Burrow types include *Diplocraterion, Skolithos* and *Cylindrichnus*
- *Glossifungites* ichnofacies are indicative of different types of discontinuities including transgressive surfaces, amalgamated sequence boundaries, and flooding surfaces (MacEachern *et al*., 2007).

# Batu Luang - 2



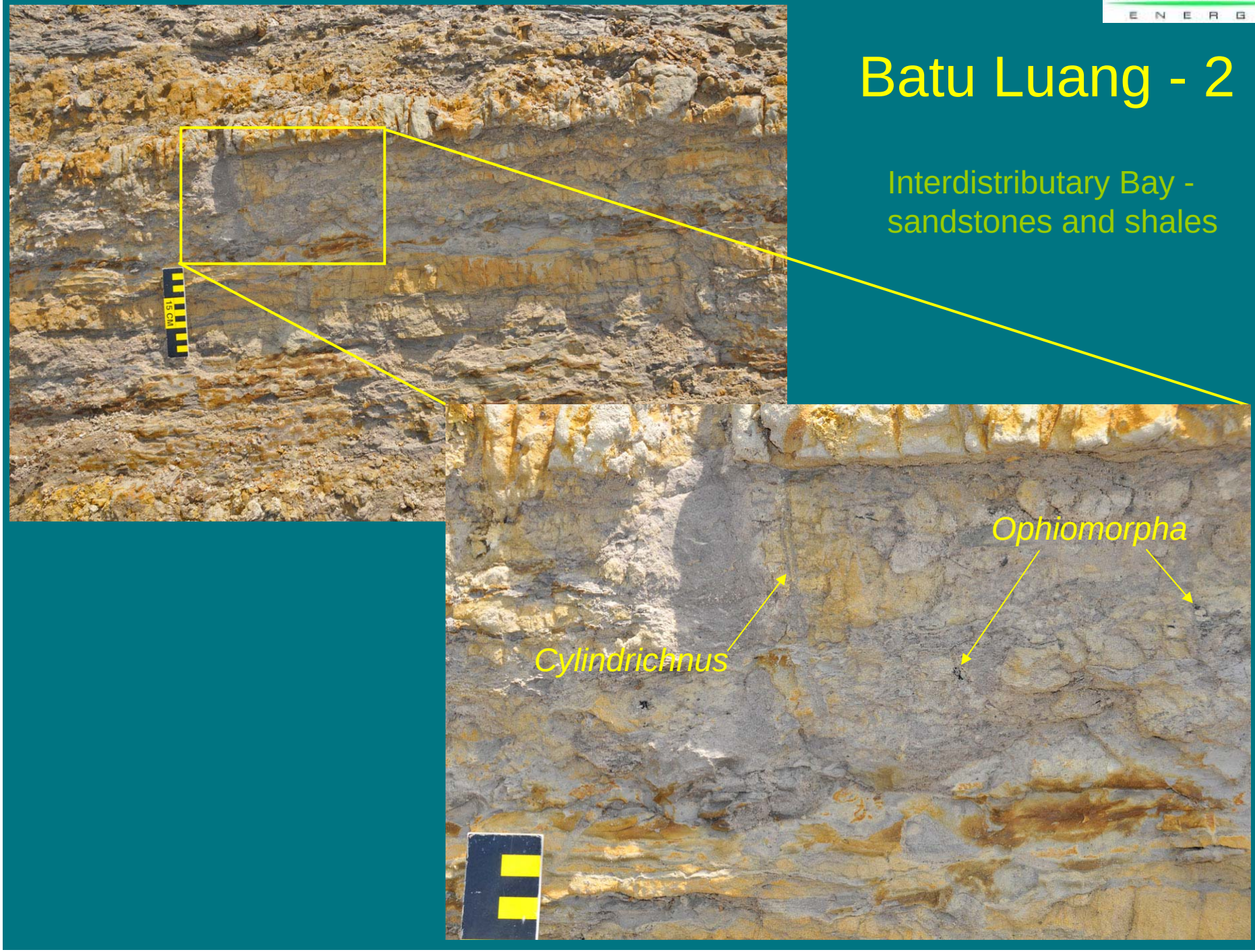


- Deposits composed of inter-stratified distributary channels, tidal flats, interdistributary bay and delta front and prodelta deposits
- The distributary channels are dominated by trough-cross-bedded, upper fine to lower medium sandstones sitting on a conglomeratic lag; *Ophiomorpha* burrows are also observed.
  - these deposits also contain some wave-modification in the form of swaley-cross stratification

TALISMAN ENERGY

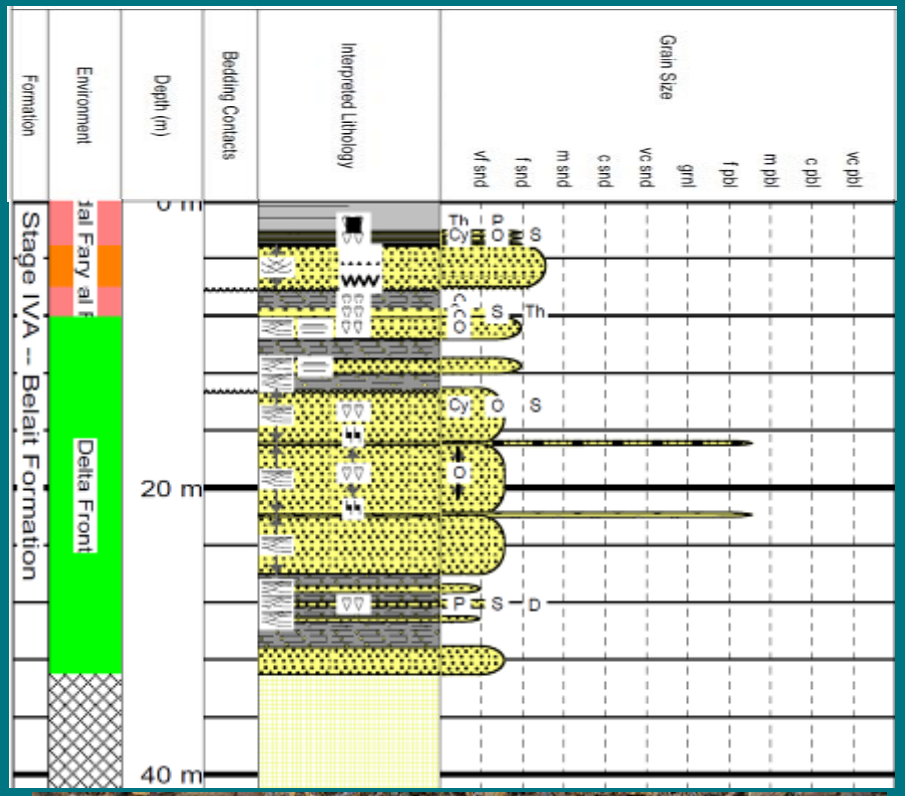
# Batu Luang - 2

Interdistributary Bay - sandstones and shales



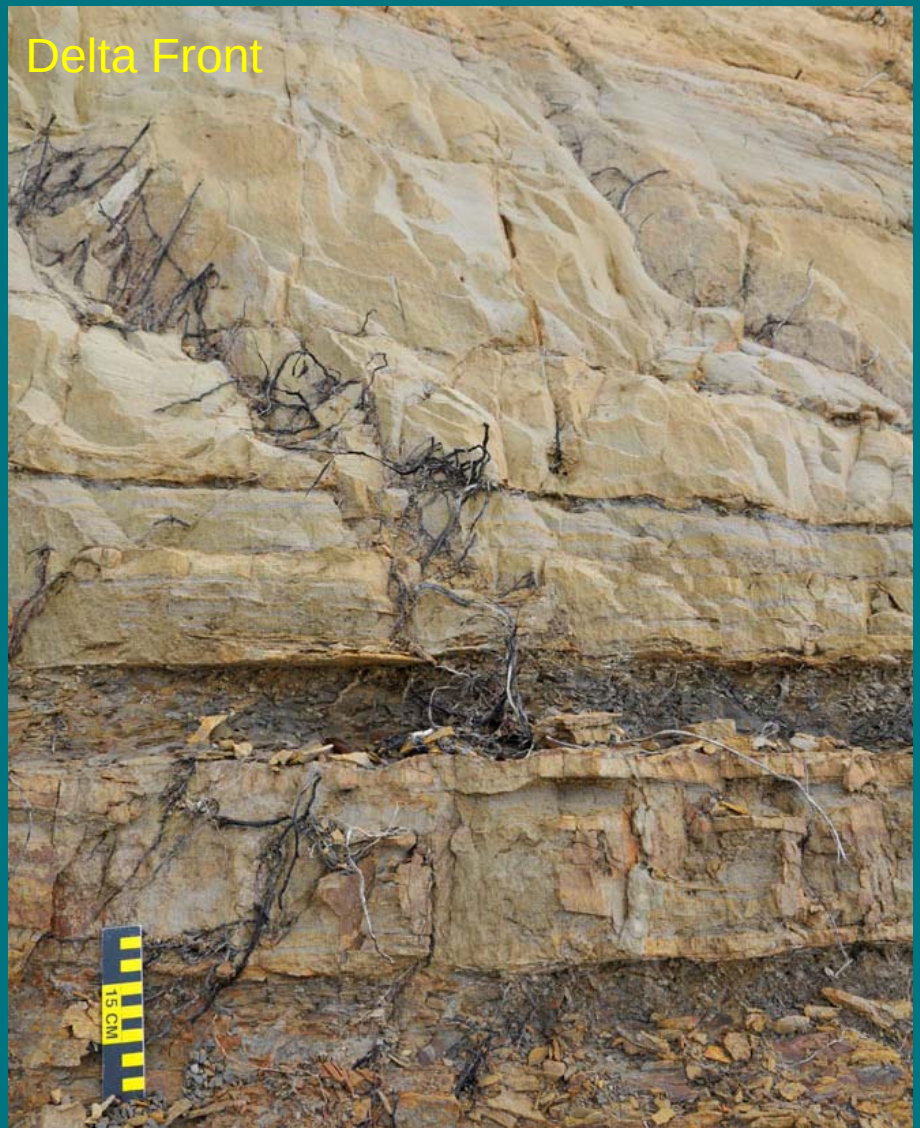
# Batu Luang - 3

- This thin interval is dominated by swaley cross-stratified, delta front sandstones capped by tidal flat and distributary channel sandstones





Swaley Cross Stratification

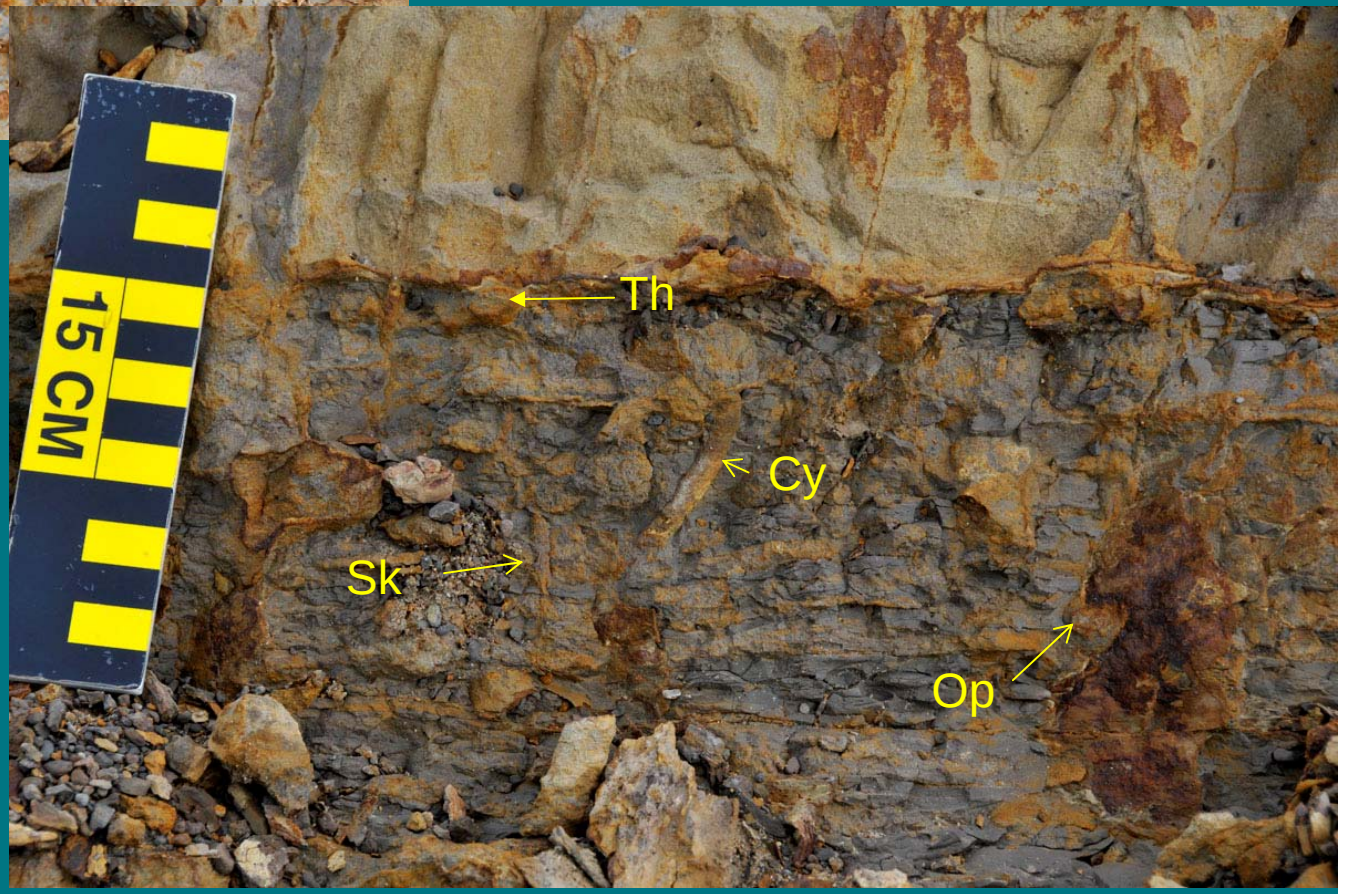


# Distributary Channels

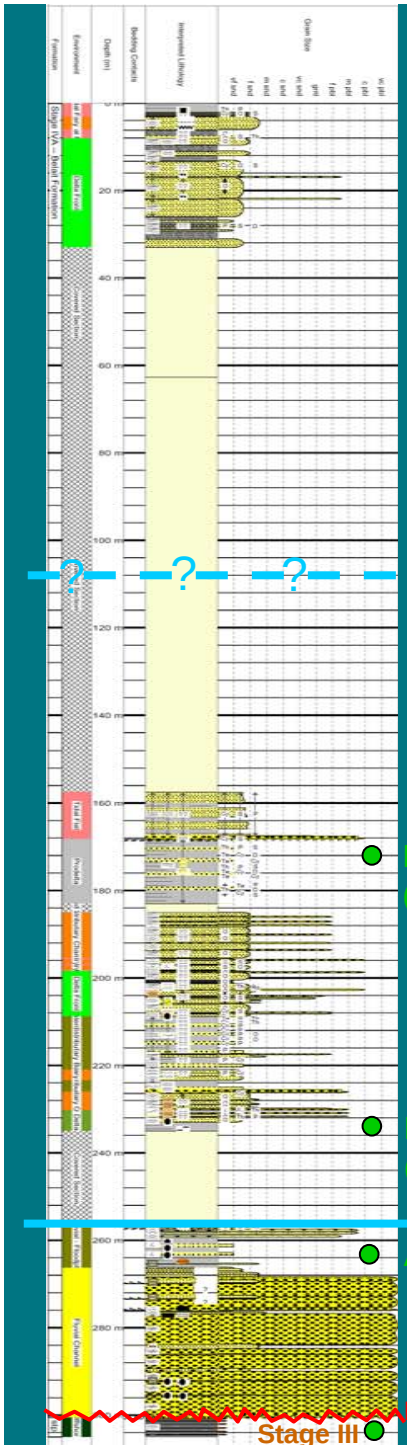
Trough cross-bedded sandstones sitting on an erosive base.

TALISMAN ENERGY

# Tidal Flat



# Batu Luang – Klias



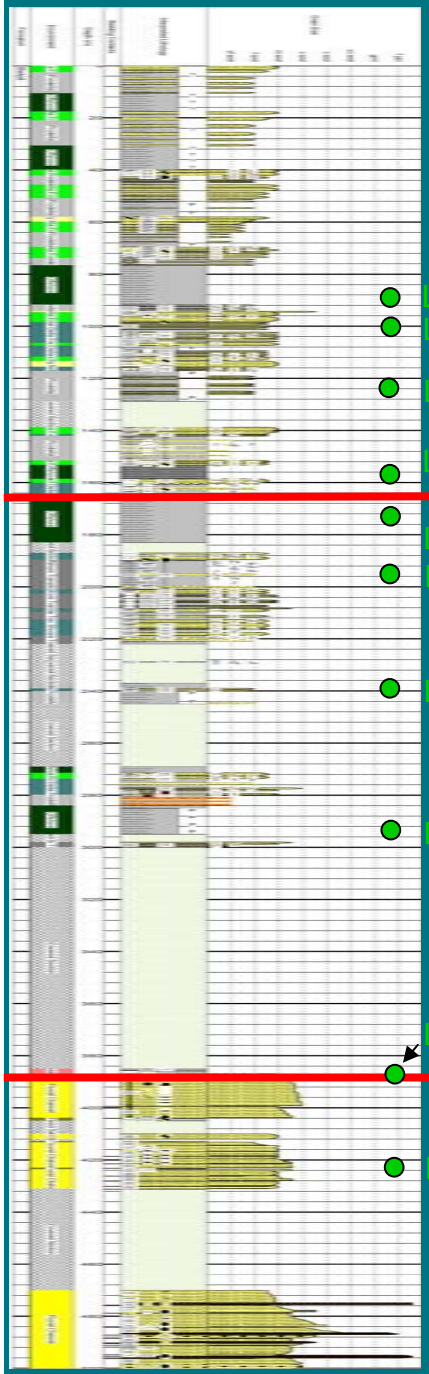

Interpretation:

- LST – conglomerate with medium sandstone matrix, channel-form sandstone lenses and local coalified logs (braided fluvial)
- TST – stacked tidal flats, interdistributary bay deposits, distributary channels, delta front and prodelta deposits (deltaic sediments)
- HST – stacked tidal flat, distributary channel and delta front deposits (deltaic sediments)

# Bethune Head

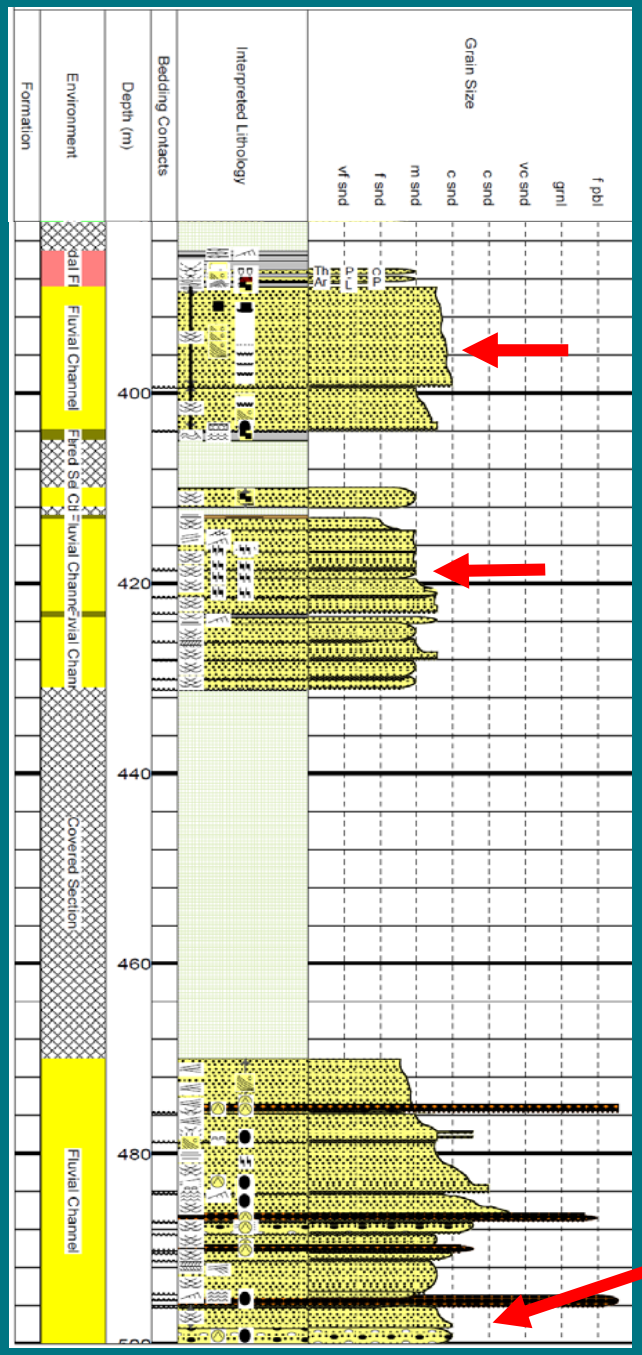


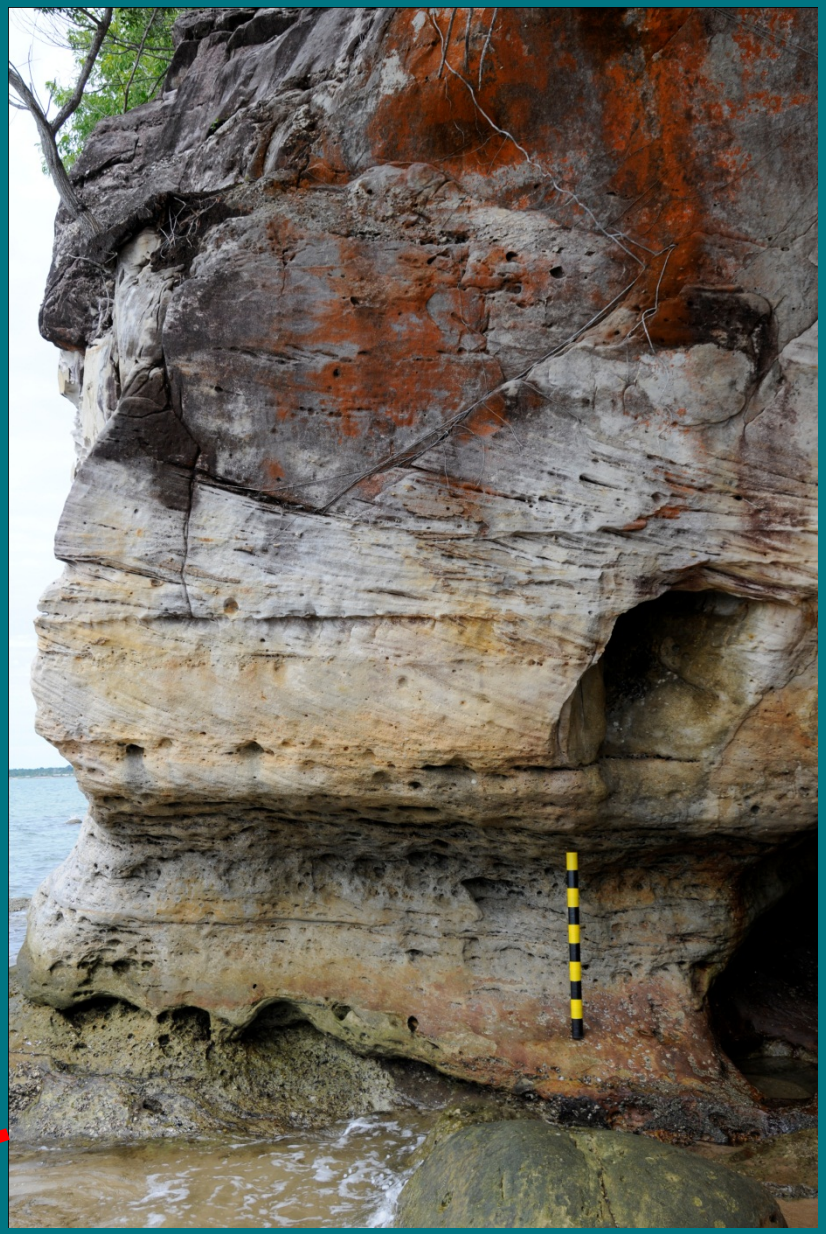

# Bethune Head – Labuan Island




- Approximately 500m of section (including visible and covered intervals)
- Biostrat data collected indicates ages ranging from Middle Miocene near the bottom to Late Middle Miocene near top (all Stage IVA)
- Subdivided the outcrop into 3 sections

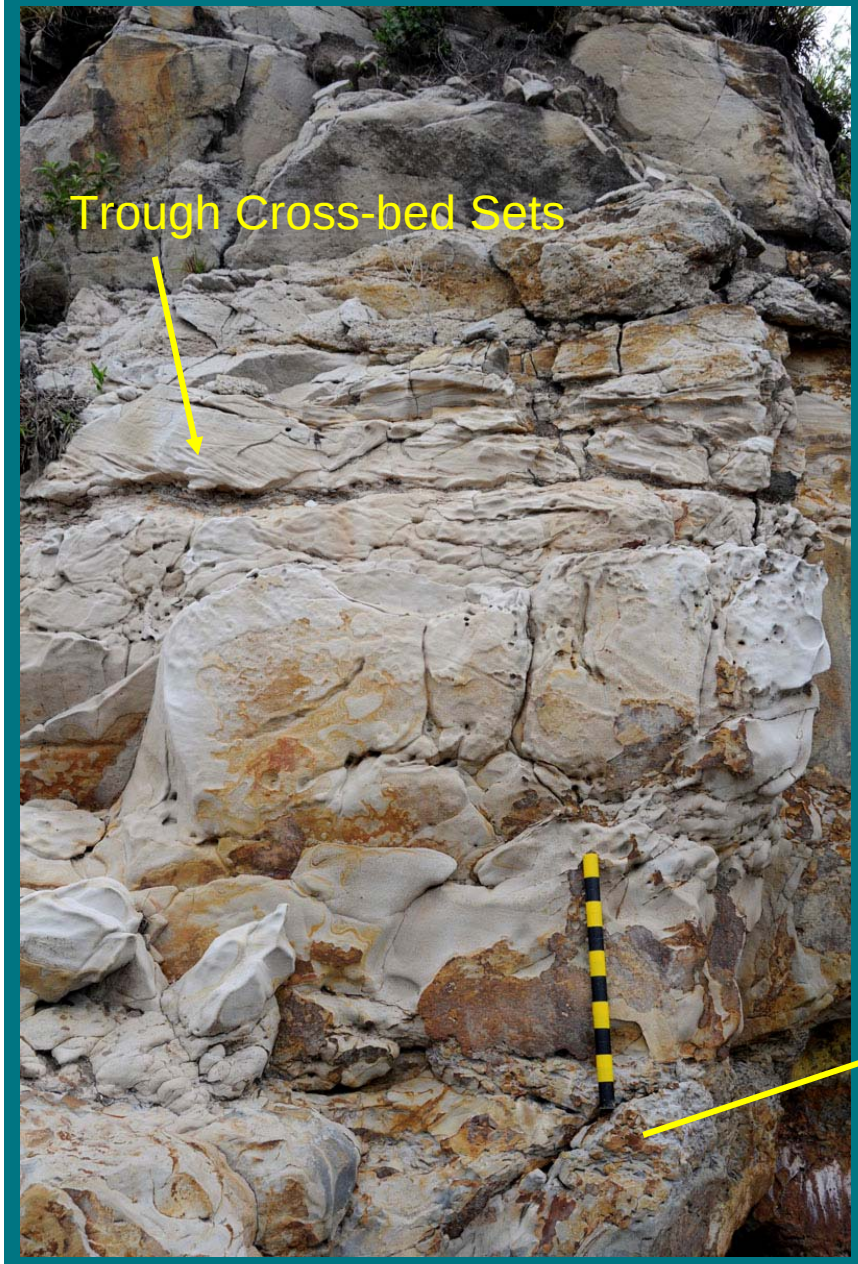
# Bethune Head - 1



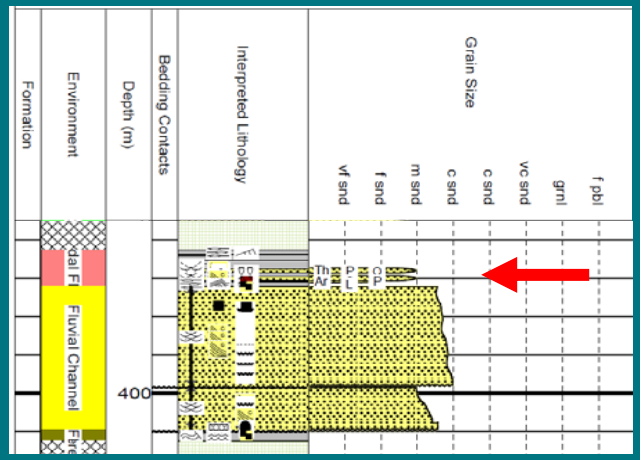
Stacked trough cross-bedded sandstones and pebbly sandstones

# Bethune Head - 1

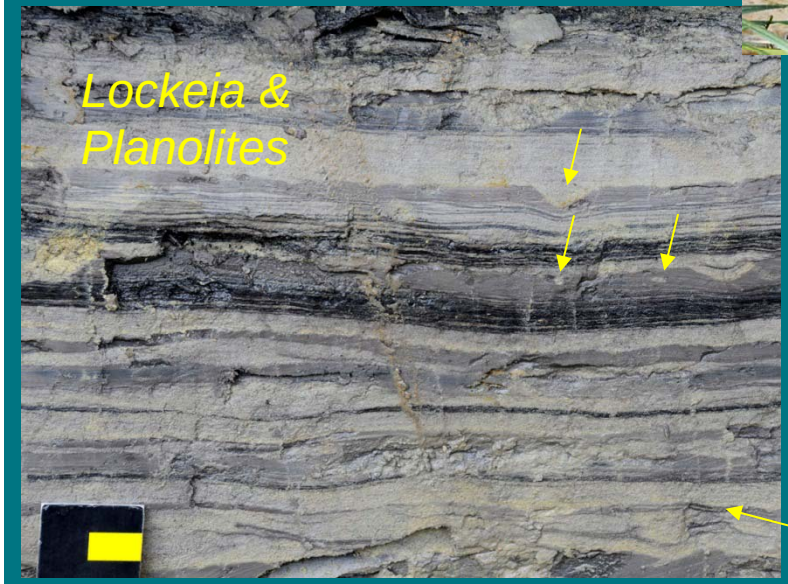


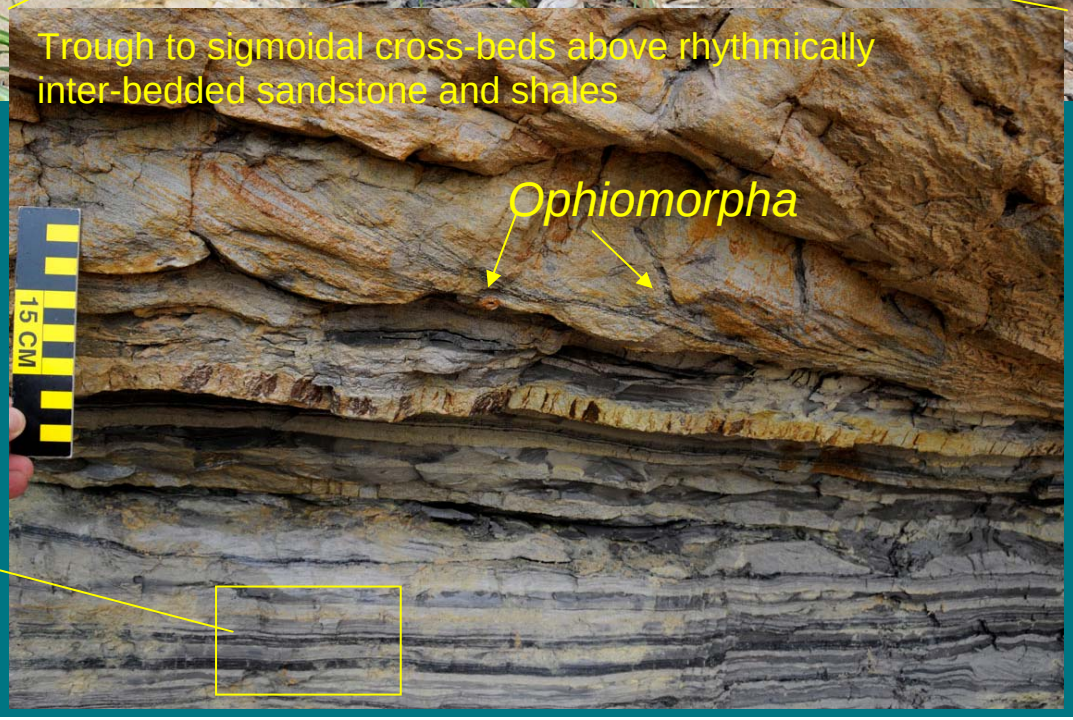


# Bethune Head - 1

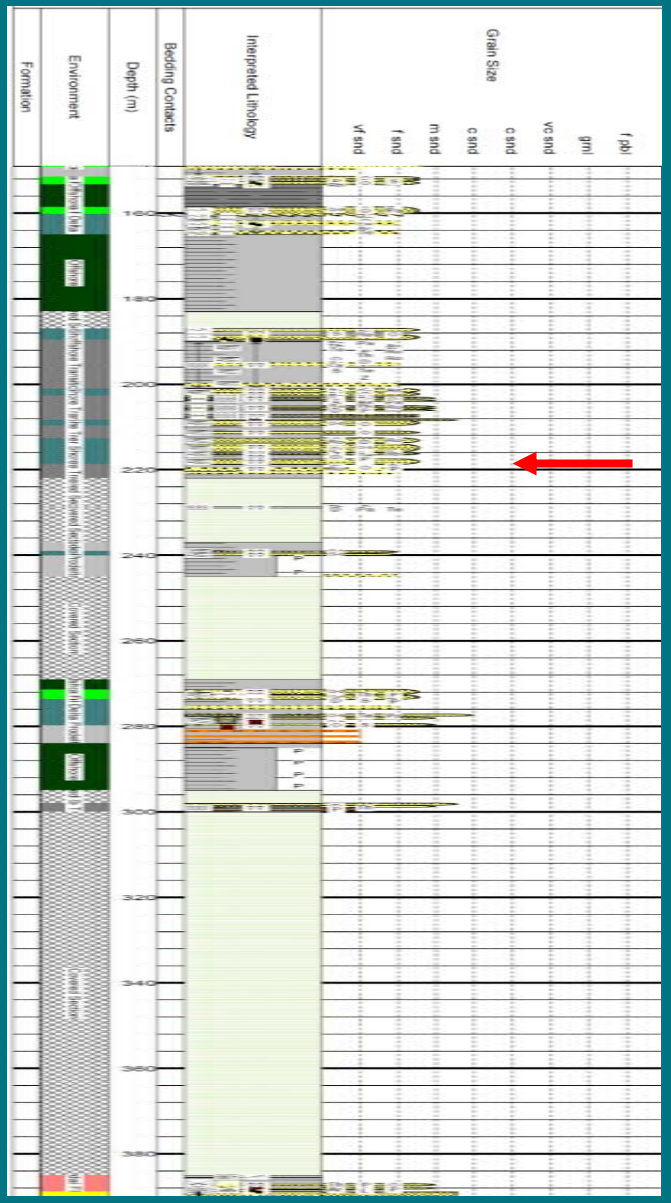



Trough to sigmoidal cross-beds above rhythmically inter-bedded sandstone and shales

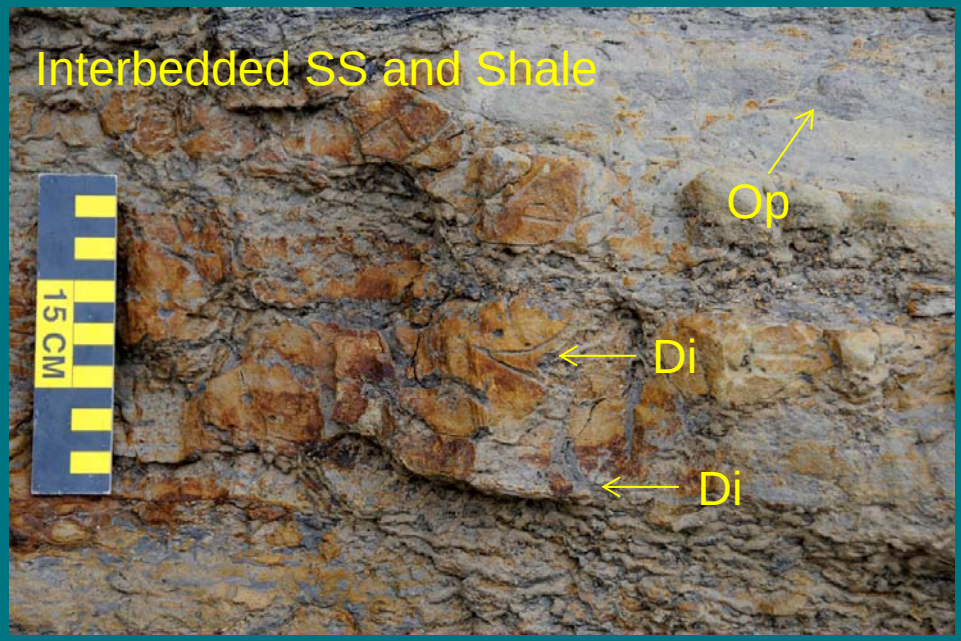


# Bethune Head - 2

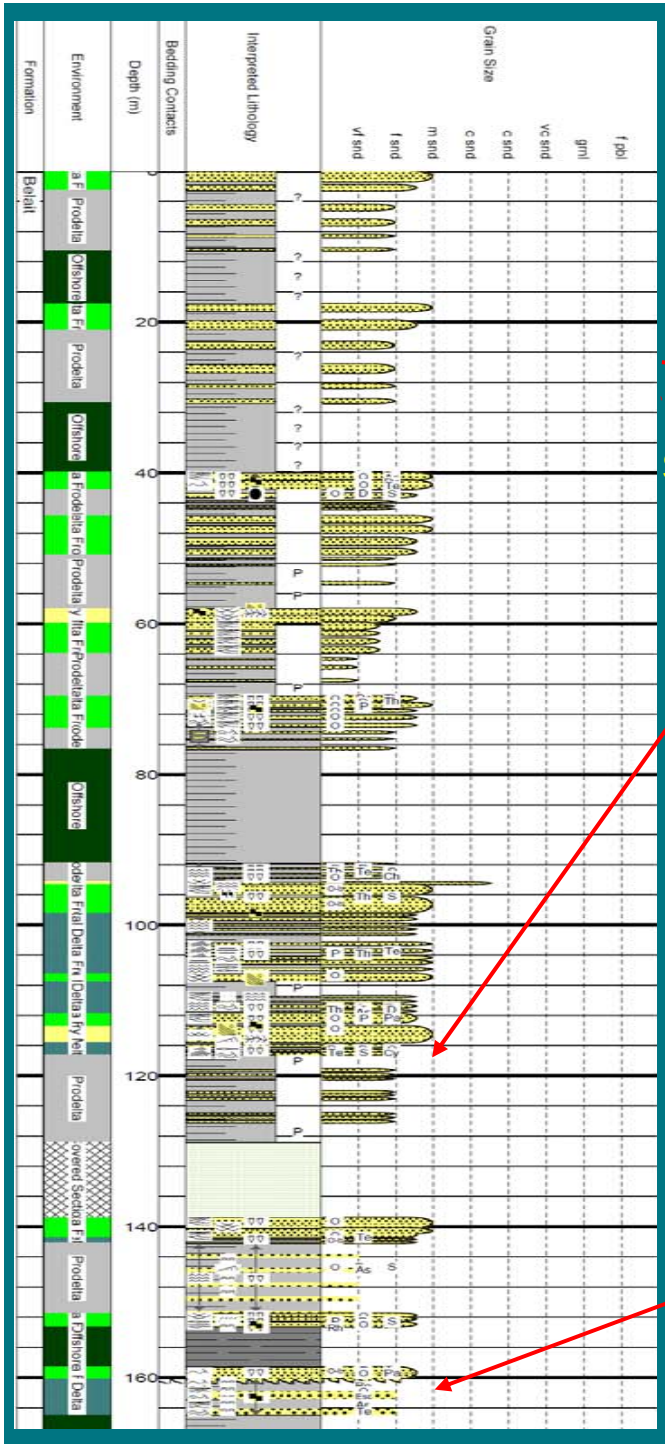


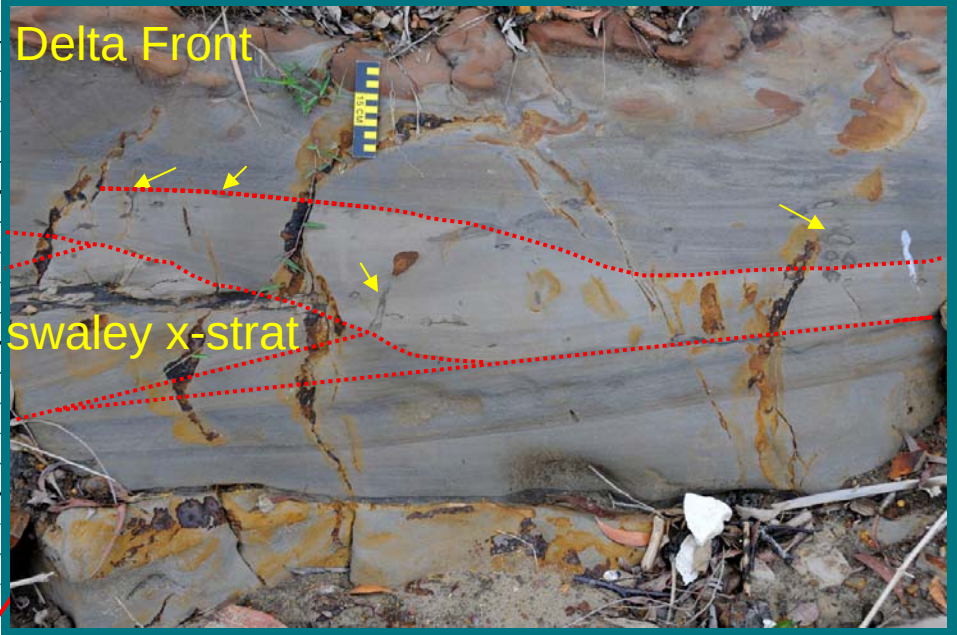




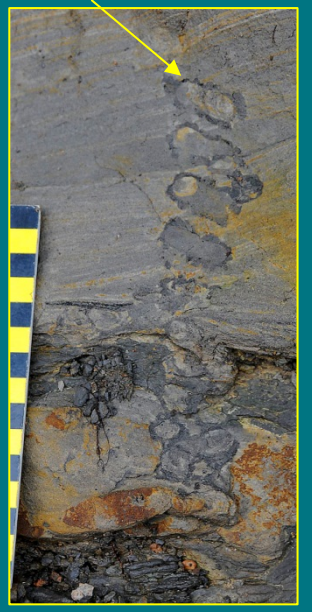
# Bethune Head - 3

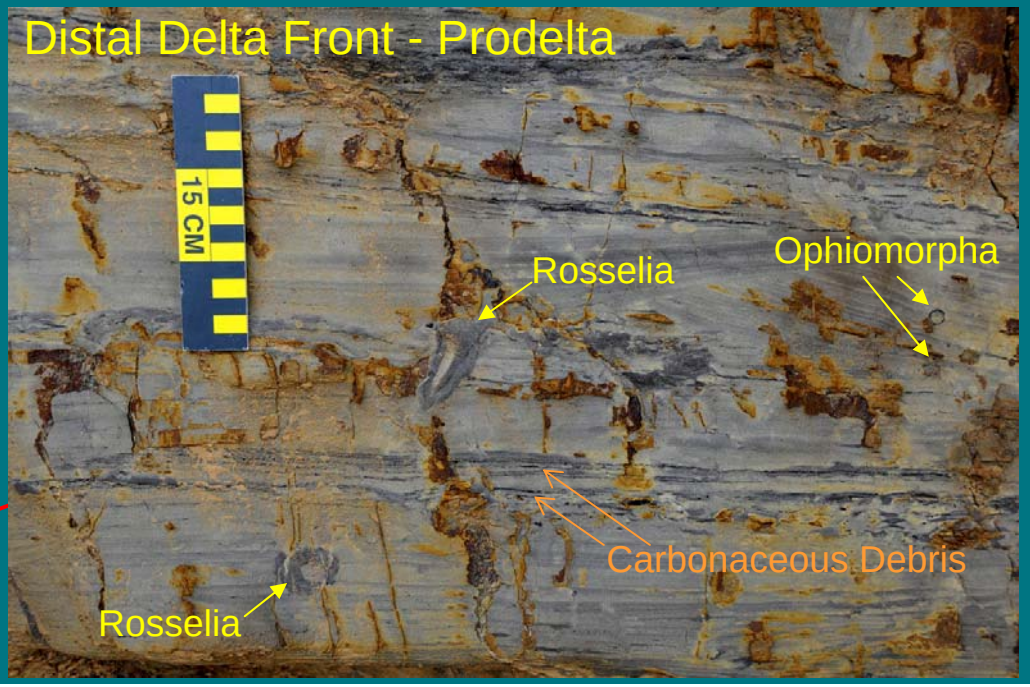
TALISMAN ENERGY



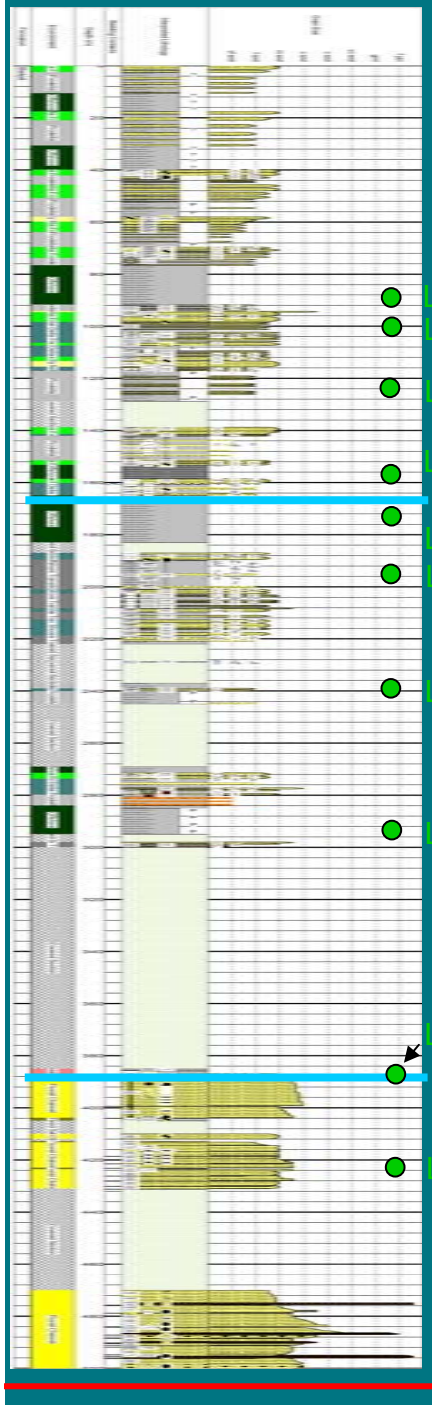

*Ophiomorpha Borneensis*





# Bethune Head - 3

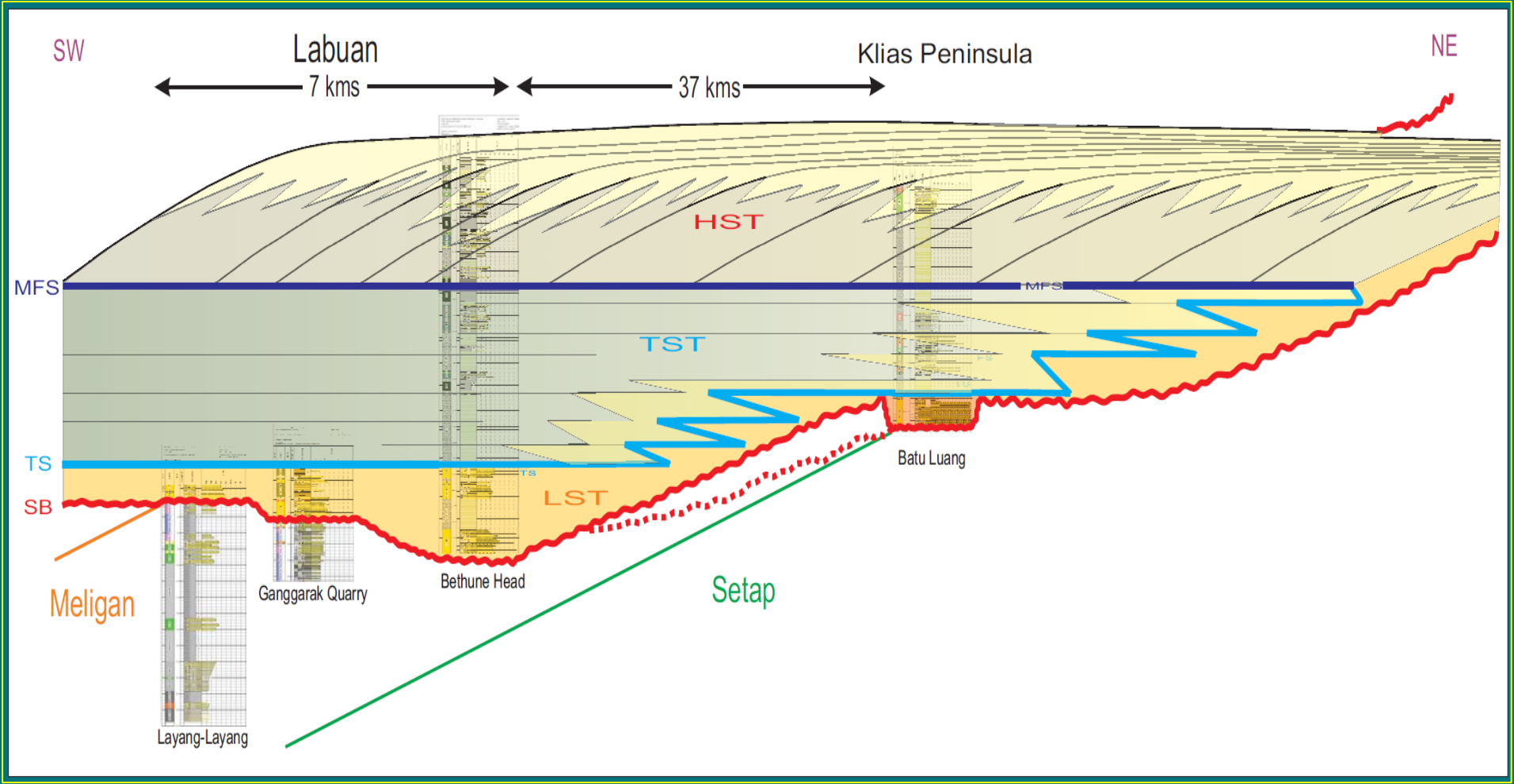
# Bethune Head – Labuan Island




Interpretation:

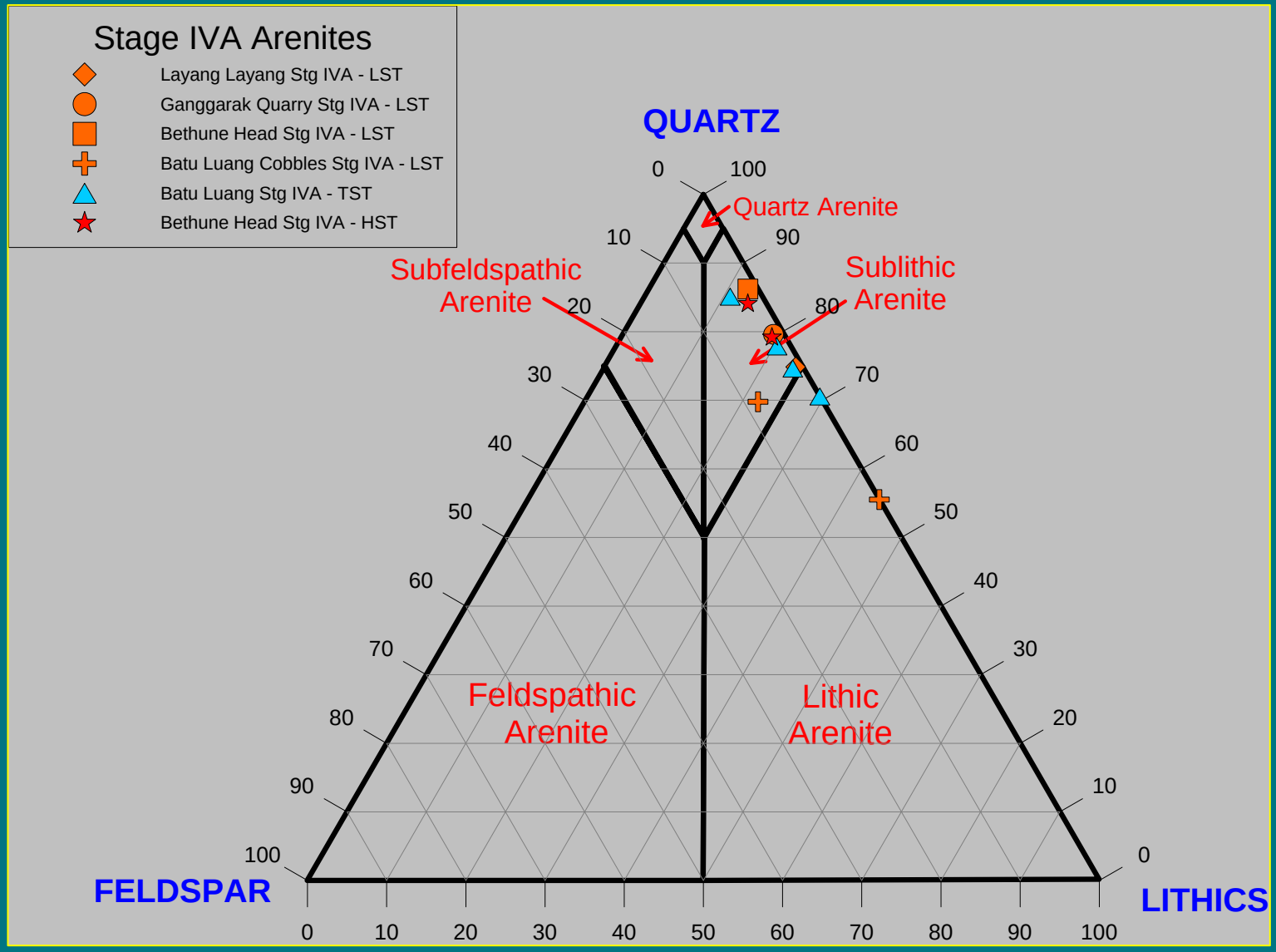
- LST – pebbly sandstones with trough cross-beds and current ripples; local coalified logs; the MMU is not exposed at this location but is observed at 2 other locations on Labuan Island
- TST – interstratified deltaic/ shoreface to shelf sediments
- HST – progradational, stacked distributary channel, delta front, prodelta and shelf shales

# Stratigraphic Correlation



# Petrographic Analysis

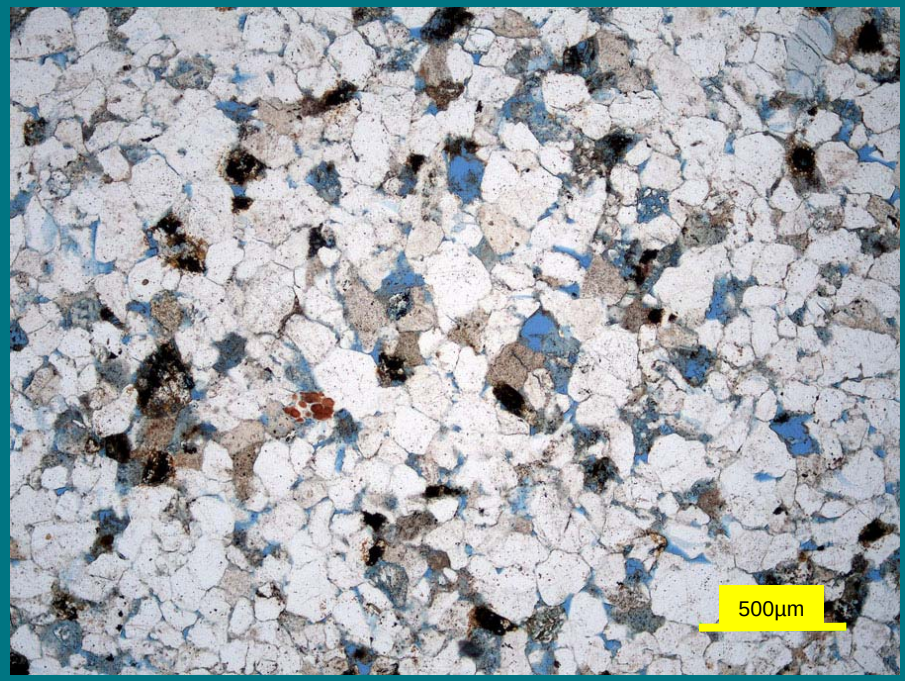
- Ternary plot of the sandstone types in the outcrops broken out by systems tract



# Fluvial Sandstones (LST)


Bethune Head

| | |
|---|---|
| Quartz | 69% |
| Lithics | 10% |
| Feldspars | 1% |
| Quartz Cem. | 4% |
| TS Porosity | 16% |



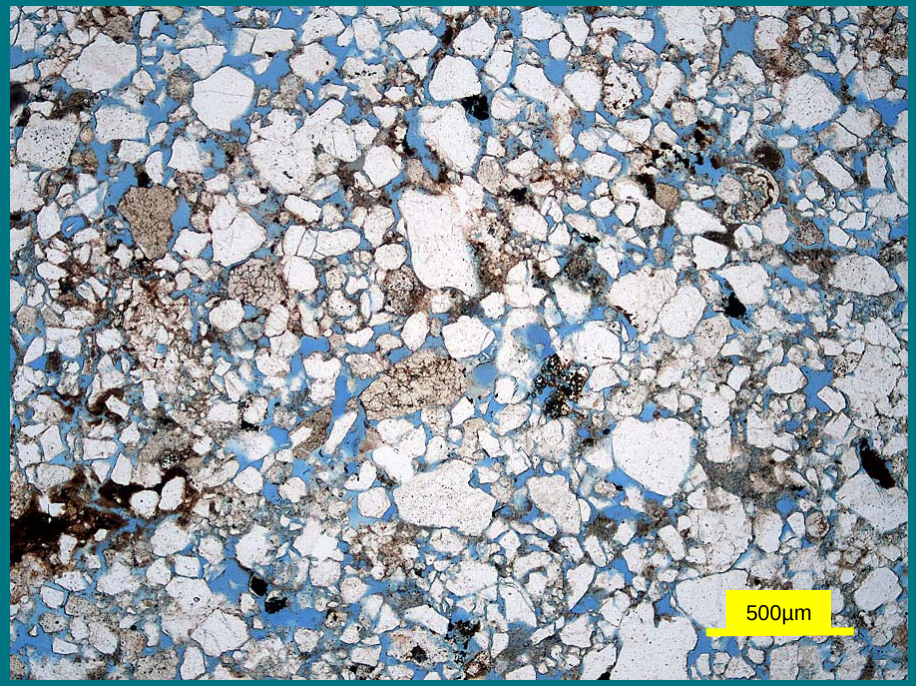

Batu Luang

* Cobble sampled so not a fair comparison

| | |
|---|---|
| Quartz | 54% |
| Lithics | 17% |
| Feldspars | 6.5% |
| Quartz Cem. | 17% |
| TS Porosity | 5.5% |

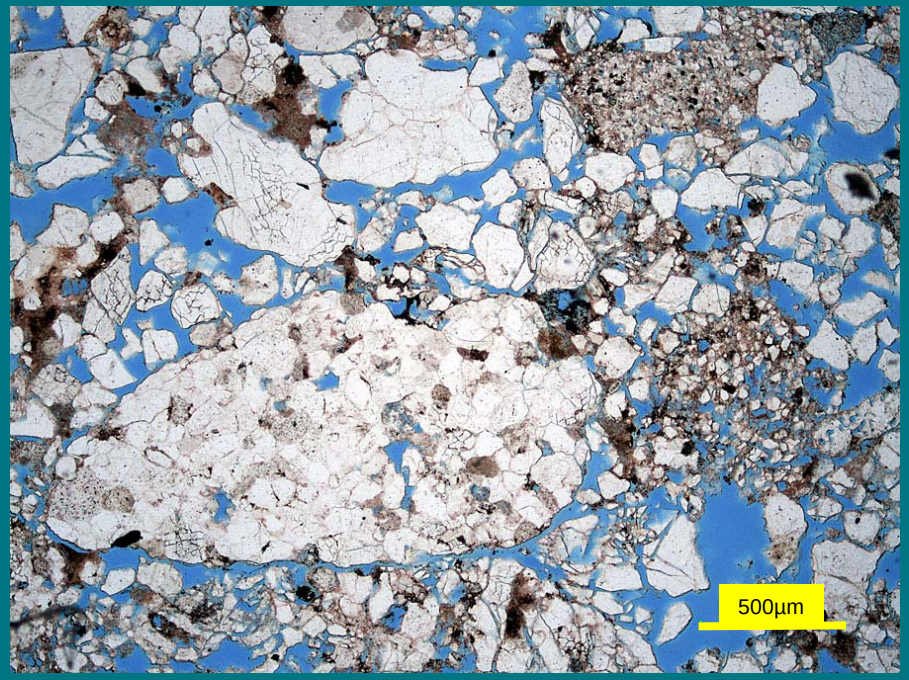
Fluvial Cobble likely sourced from Stage III

# Distributary Channel Sandstones (TST)




Batu Luang

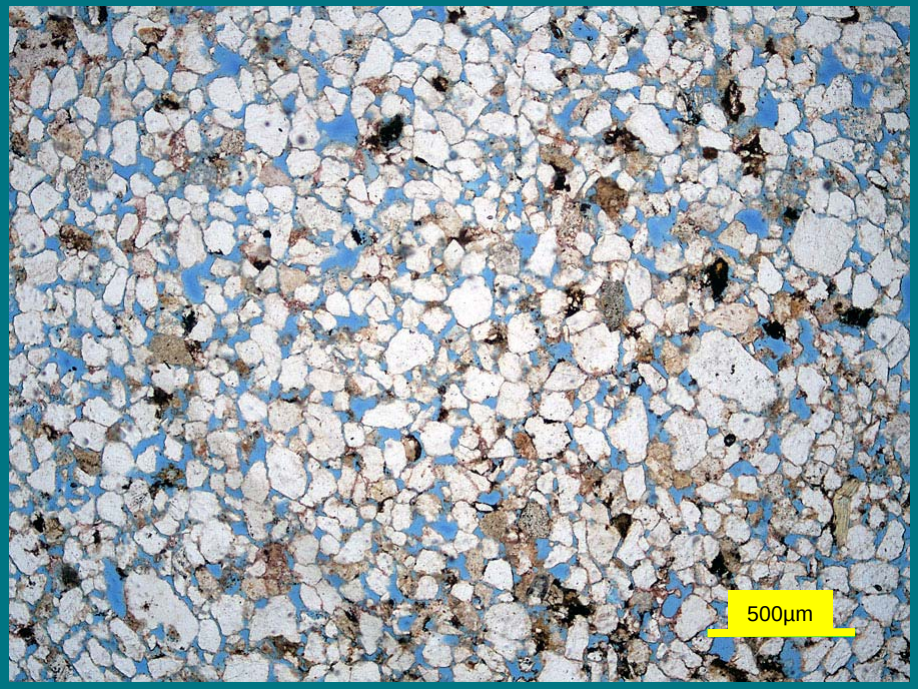
| | |
|---|---|
| Quartz | 54% |
| Lithics | 17.5% |
| Feldspars | 1% |
| Illite | 6.5% |
| Organics | 4.5% |
| Quartz Cem. | 3.0% |
| TS Porosity | 13.5% |




Batu Luang

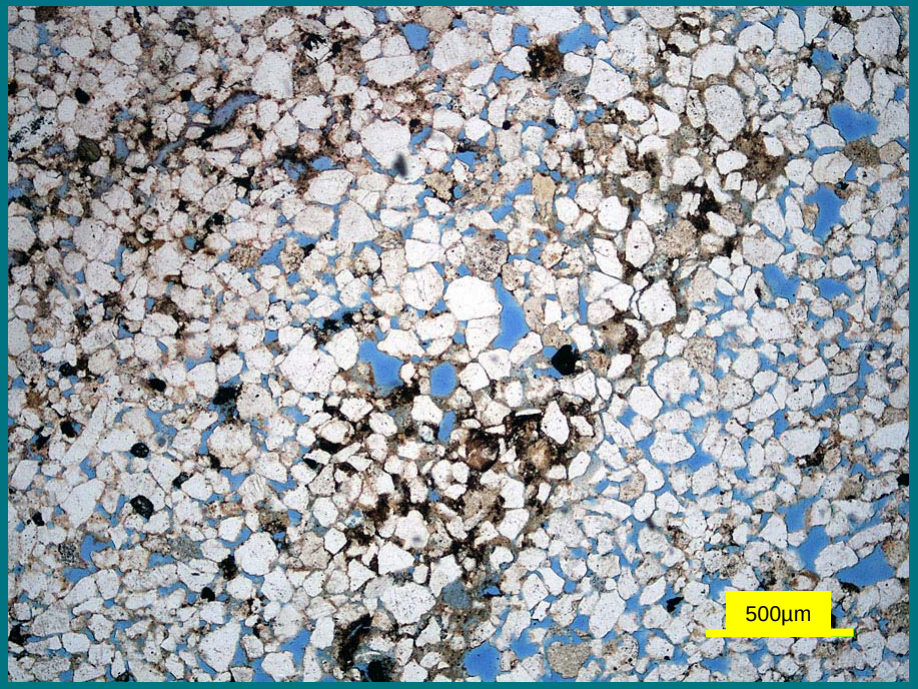
| | |
|---|---|
| Quartz | 56% |
| Lithics | 23% |
| Feldspars | 0% |
| Illite | 6.5% |
| Quartz Cem. | 1.5% |
| TS Porosity | 13% |

# Delta Front Sandstones (HST)




Bethune Head

| | |
|---|---|
| Quartz | 60% |
| Lithics | 10% |
| Feldspars | 2% |
| Glauconite | trace |
| Illite | 6% |
| Quartz Cem. | 5.5% |
| TS Porosity | 16.5% |




Bethune Head

| | |
|---|---|
| Quartz | 61% |
| Lithics | 15% |
| Feldspars | 1.5% |
| Glauconite | 2% |
| Illite | 4% |
| Quartz Cem. | 10% |
| TS Porosity | 6.5% |

# Summary

- The Stage IVA can be subdivided into
  - **Lowstand** (fluvial) – matrix- to clast-supported conglomerate (Klias) and stacked channel pebbly sandstones (Labuan)
  - **Transgressive** (wave-influenced deltaic to shoreface) – prodelta, delta front, distributary channel and tidal flats (Klias) and shelf, prodelta and delta front deposits (Labuan)
  - **Highstand** (wave-influenced deltaic) – delta front, distributary channels, and tidal flats (Klias) and prodelta, delta front and distributary channels (Labuan).

- Reservoir quality rocks were observed is all systems tracts, but the Highstand deposits are the most widespread
  - All systems tracts are mineralogically similar indicating no major change in source during the life of the sequence

# Acknowledgements

Talisman Malaysia Ltd.

PETRONAS

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