

# **Evidence of Currents in Outcrops of Pliocene Ayeyarwaddy River Implication for Sands Distribution in Deep Waters West of the Myanmar Coast\***

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## **Abstract**

Recently announced gas discoveries in the Plio-Pleistocene of the southwestern offshore of Myanmar between 2012, when MPRL E&P's Pyi Thar-1 discovery opened a new gas play, and 2015-2017 when three more wells discovered gas in deep waters, showed significant sands development. These relatively abundant sands, definitely not from the Bengal Fan, prompt the question of their provenance, timing, and mode of deposition.

Publicly available data, announcements and literature, as well as extensive field work by MPRL E&P, indicate intermittent detachment episodes of the semi-rigid Myanmar Platelet from the India Plate during its continuous translational subduction below the Sunda Plate. These episodes are marked by catastrophic regional slumps exceeding 1,500 km<sup>2</sup> in area and several hundred meters in thickness in two distinct periods, Lower Pliocene and Upper Pleistocene.

The absence of mega-slumps during Middle to Late Pliocene and Early Pleistocene suggests that the Myanmar Platelet was locked to the India Plate during these times, which were therefore favorable to connect the terrestrial fluvial system of the Ayeyarwaddy River with deep water deposition through the Watthe slump scar area. Paleo-current data from onshore, Southern Central Myanmar basin Plio-Pleistocene formation indicates a W or SSW directed trend, consistent with a paleo-Ayeyarwaddy fluvial system reaching the sea in the Chaungtha-Ngwe Saung area. The Watthe Lower Pliocene mega-slump opened a breach through which the paleo-Ayeyarwaddy River (paleo-Pathein River), brought massive sands into the Bengal Bay during the Pliocene and Lower Pleistocene, filling a section of the trench between the India Plate and the Myanmar Platelet. This area was therefore part of the submarine Ayeyarwaddy Delta during the Plio-Pleistocene, and distinct from the Rakhine Offshore Basin fed by the Ganges-Brahmaputra River system.

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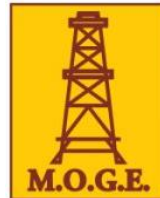
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# EVIDENCE OF CURRENTS IN OUTCROPS OF PLIOCENE AYEYARWADY RIVER

## IMPLICATION FOR SANDS DISTRIBUTION IN DEEP WATERS WEST OF THE MYANMAR COAST

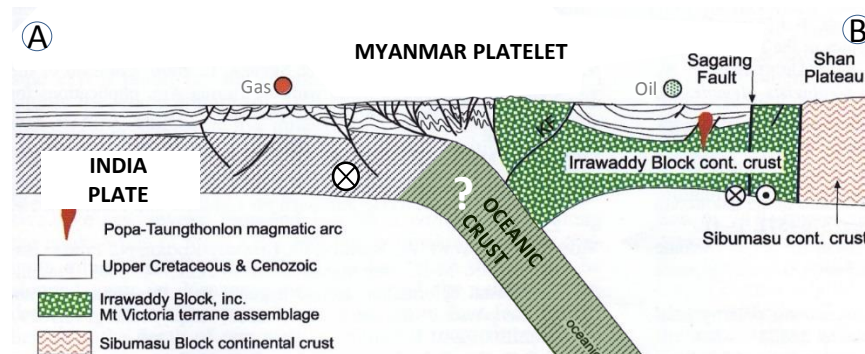
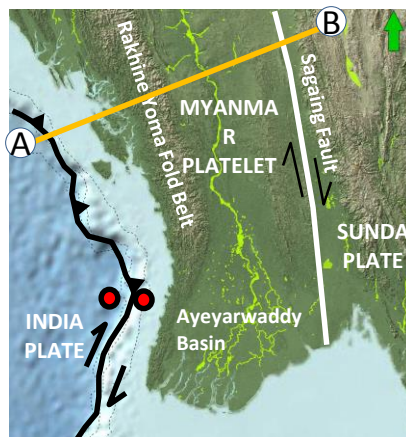


By U Kyaw Zin Oo and MPRL E&P's Exploration and G&G Team

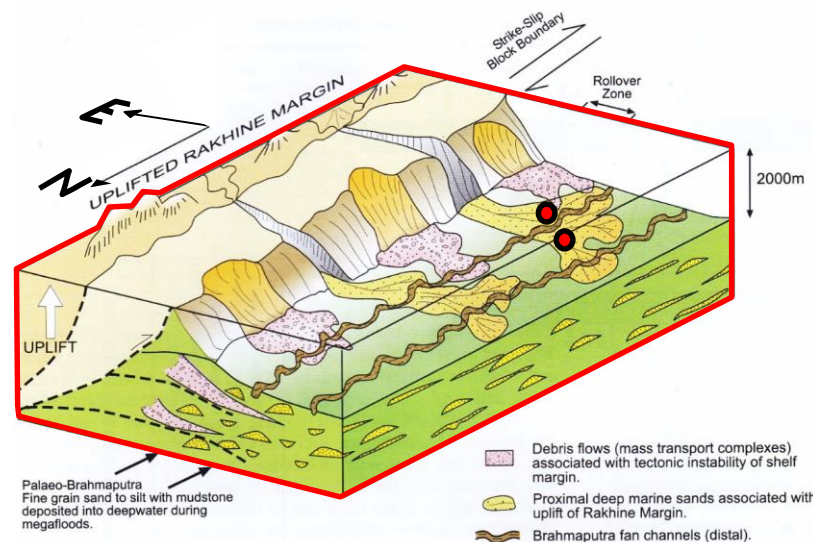
## INTRODUCTION

### How are western shores of Myanmar related to the Ayeyarwady Basin?

- The western shore of the Ayeyarwady Division is geologically located in a complex convergent zone resulting from the continuous translational movement of India beneath Myanmar platelets
- Most Pliocene was eroded from or not deposited on the Rakhine Fold Belt during the Pleistocene uplift
- In March 2012, MPRL E&P pioneered the discovery of gas-bearing sandstones in Pyi Thar-1ST-1 in Block A6
- MPRL E&P and JV partners Woodside & Total announced more gas-bearing sands in deep-water wells drilled in 2016-2018, some with appraised commercial potential
- Is there any relation between these sands and Pliocene sands outcrops in the Ayeyarwady Delta?**



Racey et al., 2015



## REGIONAL GEOLOGIC SETTING

### Tertiary of Western Shore consistently deeper marine than in Ayeyarwady Delta

Deep ← → Shallow

#### Western Shore of Myanmar

#### Onshore Ayeyarwady Delta

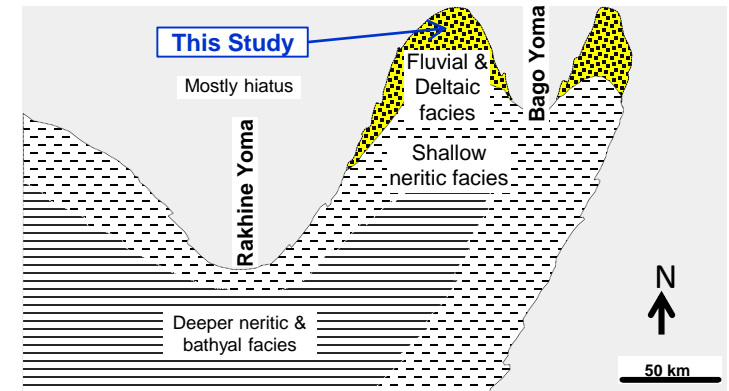
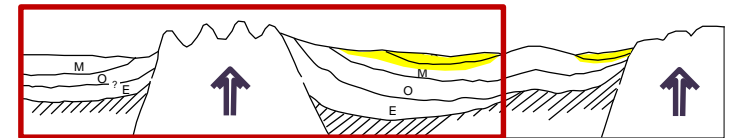
AGE (ma)	STRAT. SCALE	REGIONAL EVENTS	FORMATION NAME & Thickness in ft	ENVIRONMENT OF DEPOSITION	LITHOLOGY	FORMATION NAME & Thickness in ft	ENVIRONMENT OF DEPOSITION	LITHOLOGY
5.2	PLIO-PLEIST.	Rakhine Yoma and Central Myanmar Basins major deformation phase	<i>Erosion</i>		Raised beach	<i>Irrawaddy</i> 100'	Fluvialite grading Southwards and upwards to shallow marine	sand, gravel, clay, sandstone, lignite, fossil wood
	MIOCENE	Translational subduction of India plate below Rakhine, Chin and Naga hill ranges	<i>Hnget Taung</i> 500-2,700'	Grading upwards to shallow sea & beach deposits	Black, micaceous and bentonitic silt, Pack/Wack, Larger Forams (Banner Reef)	<i>Kathabaung</i> 1,600 - 2,000'	Estuarine to shallow marine	Alternation of sandstones and shale, massive calcareous sandstone and shale
		Rakhine Yoma and Bago Hills fold formation	<i>Ngasaw</i> 5,500-6,500'	Medium deep water fans, channels with overbank deposits	Quartz-arenite, Feldspathic Litharenite, Subarkose, Lithic arkose	<i>Kwingyaung</i> 2,300 - 2,700'	Shallow marine	fossiliferous marls and Miogastropal limestones
23.8		Gradual subduction of India below SE Asia starts from Naga Hills and progresses S'ward as clockwise rotation of SE Asia plate continues						
	OLIGOCENE	Rakhine Yoma emerges again becoming a source for mass flow deposits	<i>Erosion or non-deposition</i>			<i>Tumyaung</i> 4,800 - 5,200'	Shallow to neritic	claystones with tuff beds, sandstone, transgressive bioherms? "v" = volcanics
		Subduction of India below SE Asia causes clockwise rotation of SE Asia plate						
33.7								
	Eocene	Ocean between India and Asia closes. Frontal subduction below Tibet starts.	<i>Taunggaile</i> 900'	Basin floor fans	Shale, very hard, Arkose, Lithic arkose, Shale, carbonaceous and silty, Lithic arkose, Feldspathic lithic arenite	<i>Taunggaile</i> 3,000 - 3,500'	Shallow to neritic	fine grained and laminated silty sandstones and claystones
			<i>Mawdin</i> 8,000-9,000'	Mass flow deposits	Lithic arkose, reworked sediment, Lithic arkose with volcanic fragments 18%, Shale highly carbonaceous, "v" = volcanica, Lithic arkose with volcanic fragments, (Faulted)	<i>Kanbala</i> ca 4,000'	Shallow to occ. coastal	Nummulitic limestones
			<i>Zigyang</i> 3,500'-4,000'			<i>Mawdin</i> ca 8,000'	Mass flow deposits in deep sea	truncated and skewed flysch sequences with exotic blocks
54.8			<i>Kwingu</i> 3,500'-4,500'		Feldspathic litharenite with volcanic fragments, many exodids, Lithic arkose with volcanic fragments, Shale, very hard and calcareous			
	PALEOCENE	Rakhine Yoma emerges as a chain of islands before submerging again						
60.0			<i>Shwedindu</i> ca 1,000'		Lithic arkose v. fine to silty carbonaceous with pyrite			
	MESZOZOIC	Rakhine Yoma is under open marine pelagic conditions	<i>Thanbaya</i> a.k.a. Hainggyi 250-600'					

Onshore Bay of Bengal from MPRL E&P geological field trips 2007-2009, Ayeyarwady Basin from Bannert 1977, Best 1984, Nöllnert 1984, Gross 1985 and U Kyaw Zin Oo 2017

#### Western Shore of Myanmar

#### Onshore Ayeyarwady Delta

#### Shan Plateau



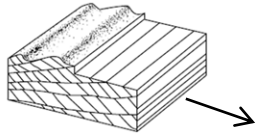
Pliocene Area of deposition & non-deposition in southern CMB (from Maung Thein 1973)

- Focus area is in the western shore of Myanmar and Ayeyarwady Delta
- Indo-Burman Ranges (Rakhine Yoma Fold Belt) uplifted / folded after deposition of Pliocene Sands (Irrawaddy Formation) as well as probably during Miocene
- Irrawaddy Formation deposited in fluvial & deltaic environment together with the southward progradation of Ayeyarwady Delta



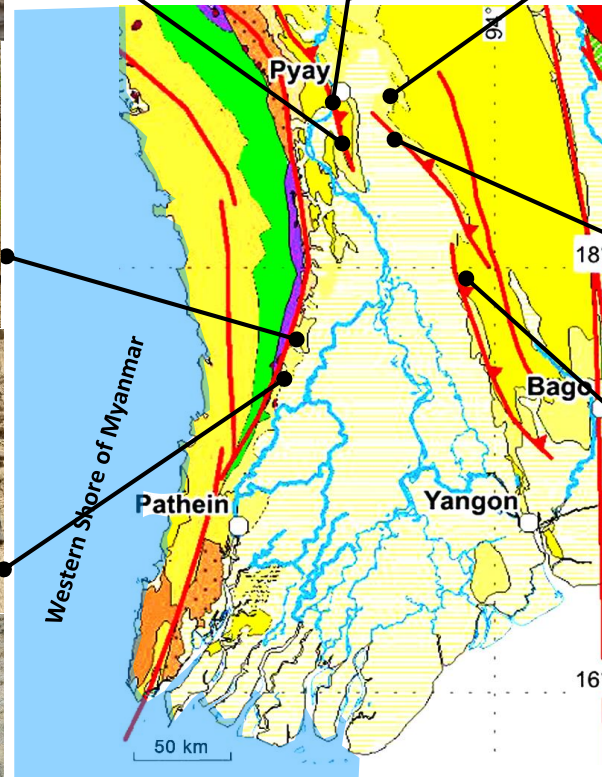
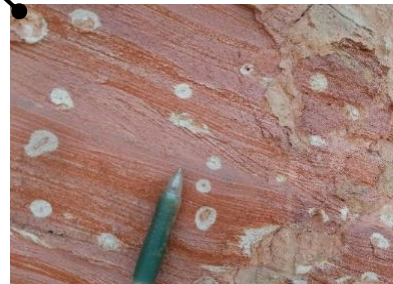
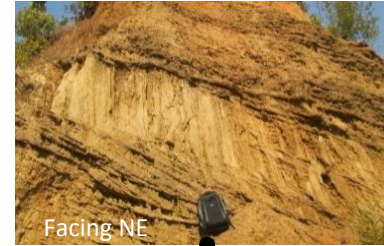
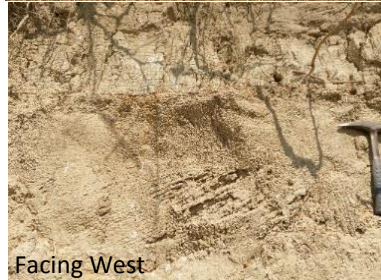
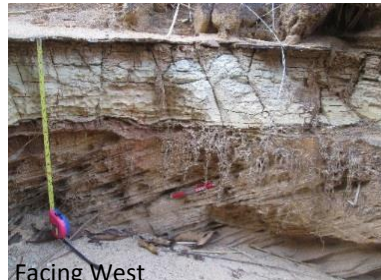
## ONSHORE PLIOCENE PALEO-CURRENT

### Cross-bedding predominant in Pliocene Irrawaddy Fm of the Ayeyarwady Delta



Current (Tucker 1982)

- Recent tectonic and sedimentological fieldwork has focused on the outcrops of Pliocene Irrawaddy formation around the delta
- Total 25 outcrops with paleo-currents data measured in Pyay & Irrawaddy sub-basins
- Measured from cross-bedding compensated for structural deformation
- Noted decreasing scale of cross-beddings in the South (i.e. cross-bedding to cross-stratification)

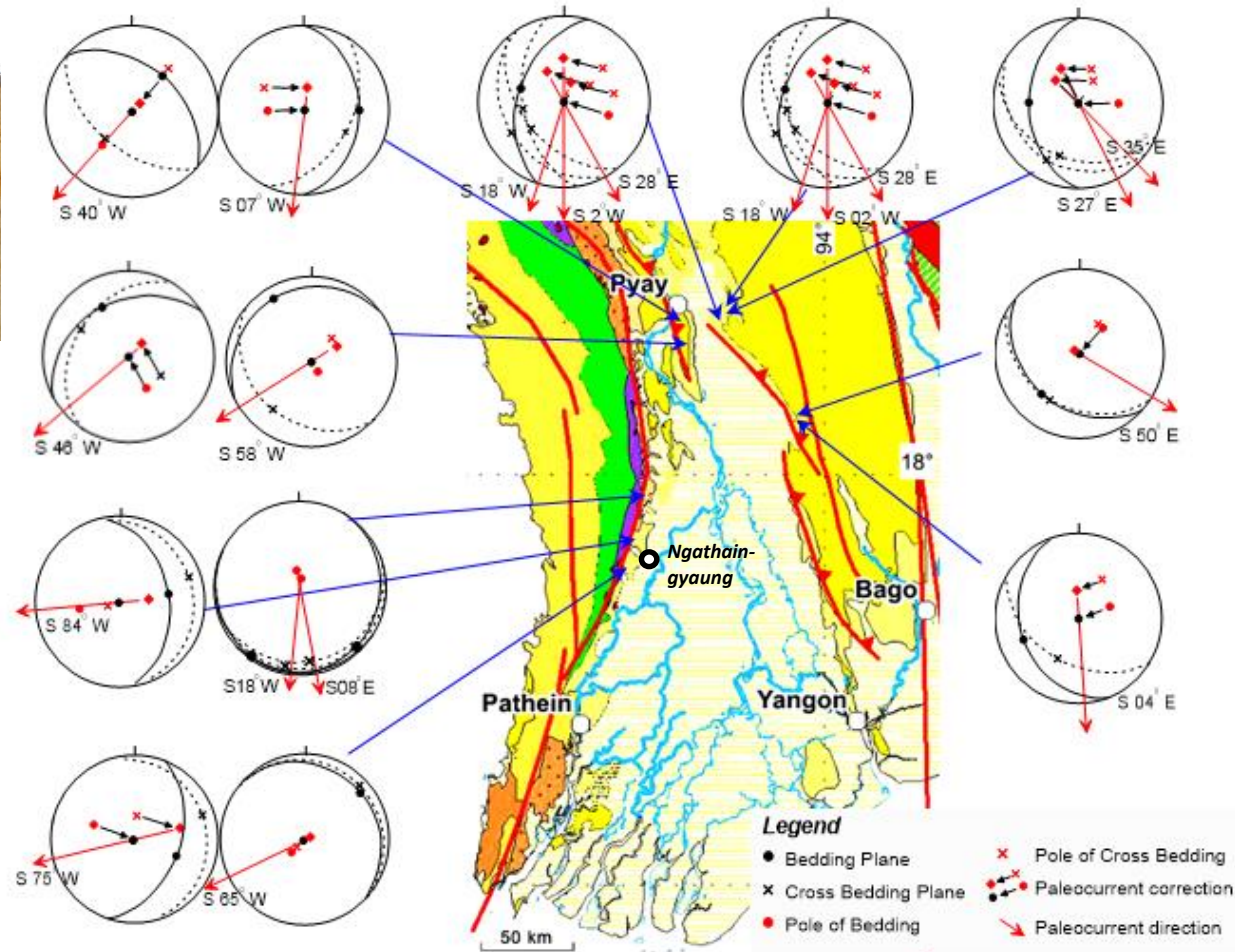
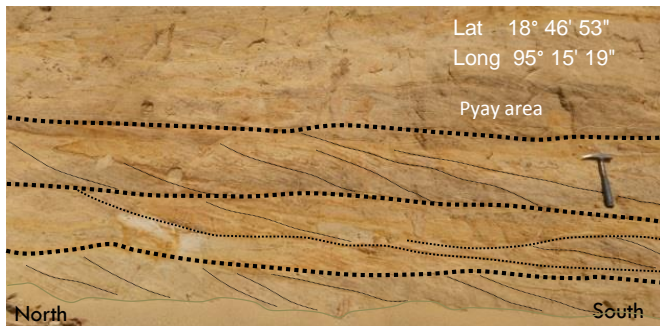
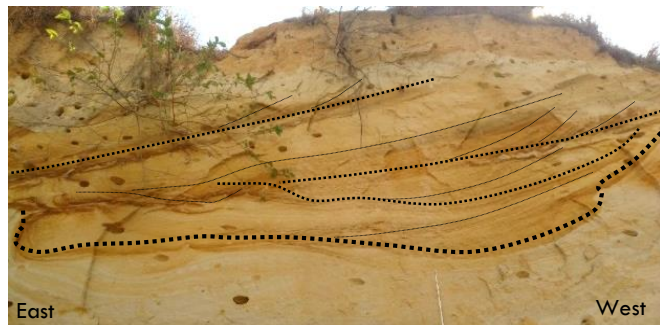


Geological Map of Myanmar (MGS 2014)



## ONSHORE PLIOCENE PALEO-CURRENT

### Cross-bedding in Pliocene Irrawaddy Fm shows a very consistent dual trend

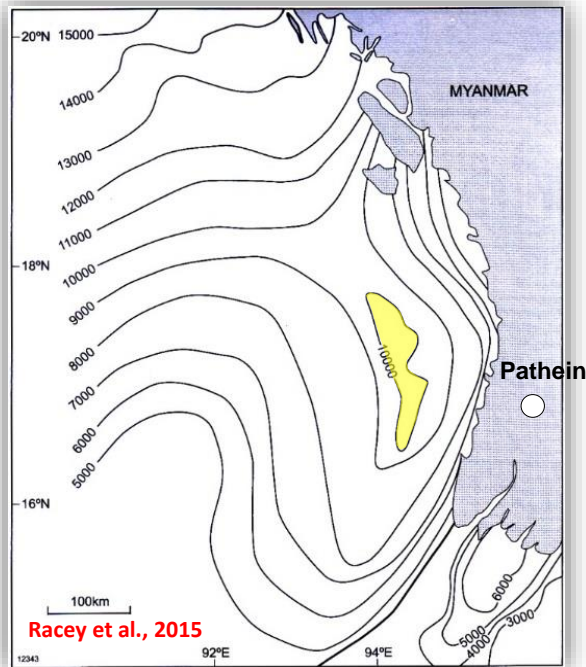


- East of the study area: Southwards to SE'wards paleo-flow direction
- West of the study area: SW'wards to W'wards; increasingly westwards to the South

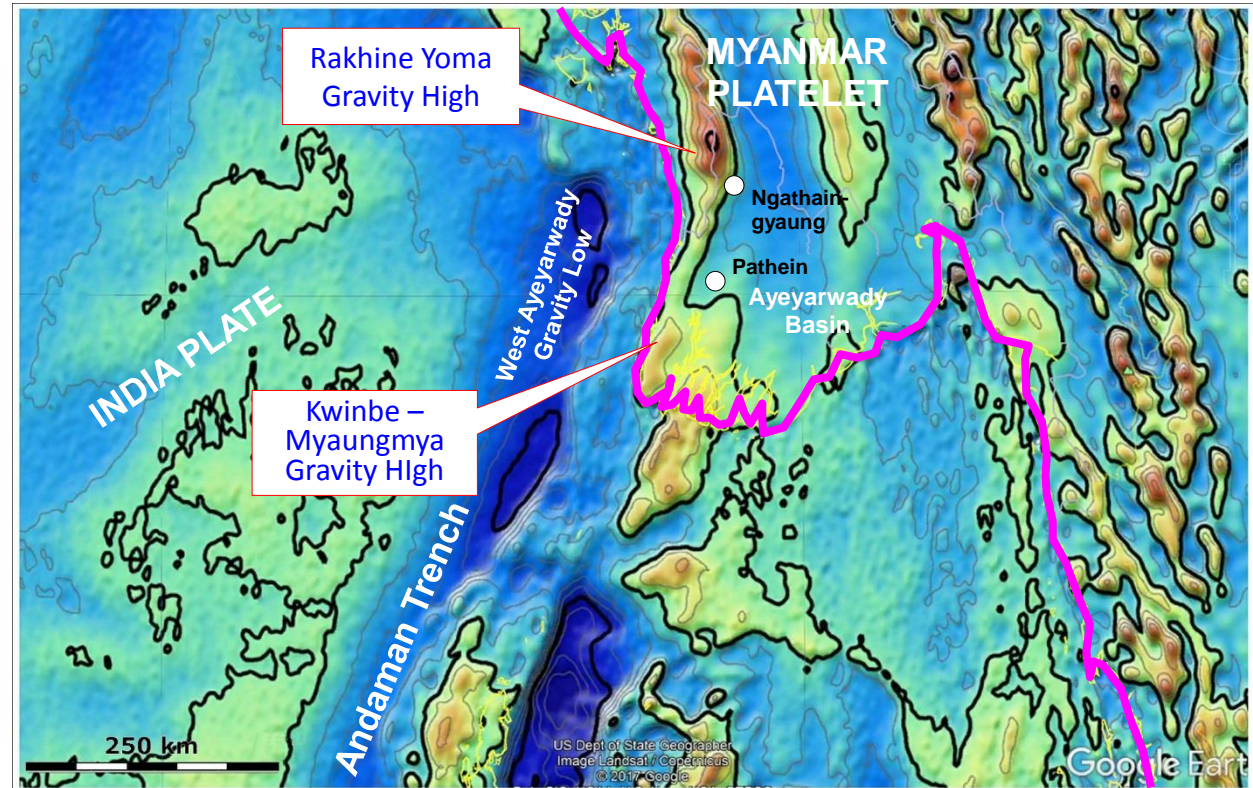


## GRAVIMETRY AND BASIN BOUNDARIES

### Back to Big Picture: What Lies to the West of the Ayeyarwady Basin



Isopach map of the west coast of Myanmar (in meter)



Free-air Gravity map (20 mGal contour)

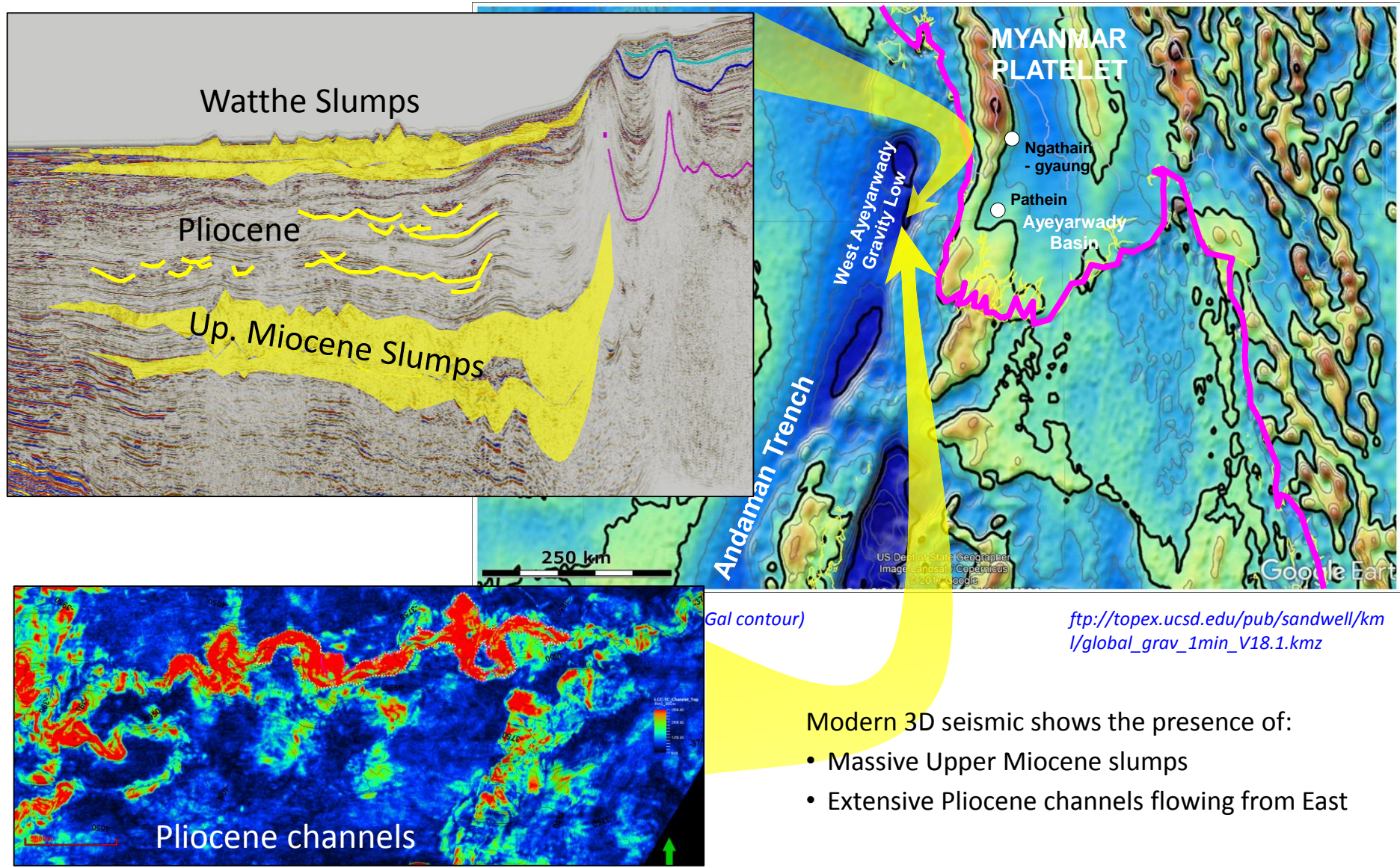
[ftp://topex.ucsd.edu/pub/sandwell/kml/global\\_grav\\_1min\\_V18.1.kmz](ftp://topex.ucsd.edu/pub/sandwell/kml/global_grav_1min_V18.1.kmz)

- Gravimetry map indicates that the northern extension of the Andaman Trench stops just West of the Ayeyarwady Basin in the West Ayeyarwady Gravity Low
- Trench is filled with about 10 km sediment



## SEISMIC AND BASIN BOUNDARIES

### Back to Big Picture: What Lies to the West of the Ayeyarwady Basin



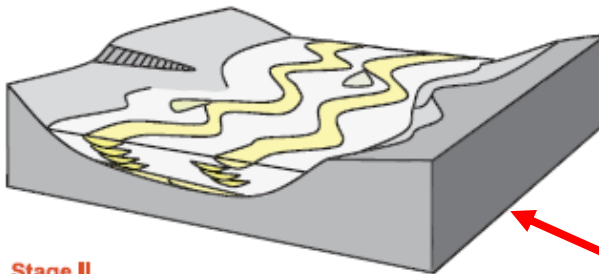


## ANALOGY

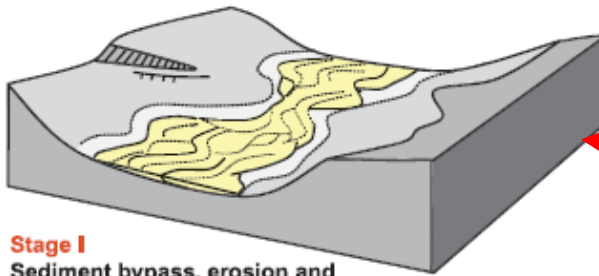
### Role of Mass Transport Complex in Deepwater Channels Evolution

#### Depositional Evolution of Sequoia Deep-water Channel System, West Nile Delta

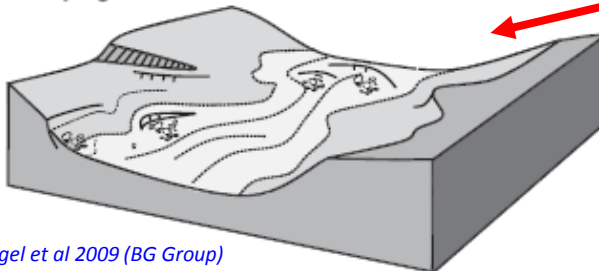
##### Stage III Aggradational sinuous channels



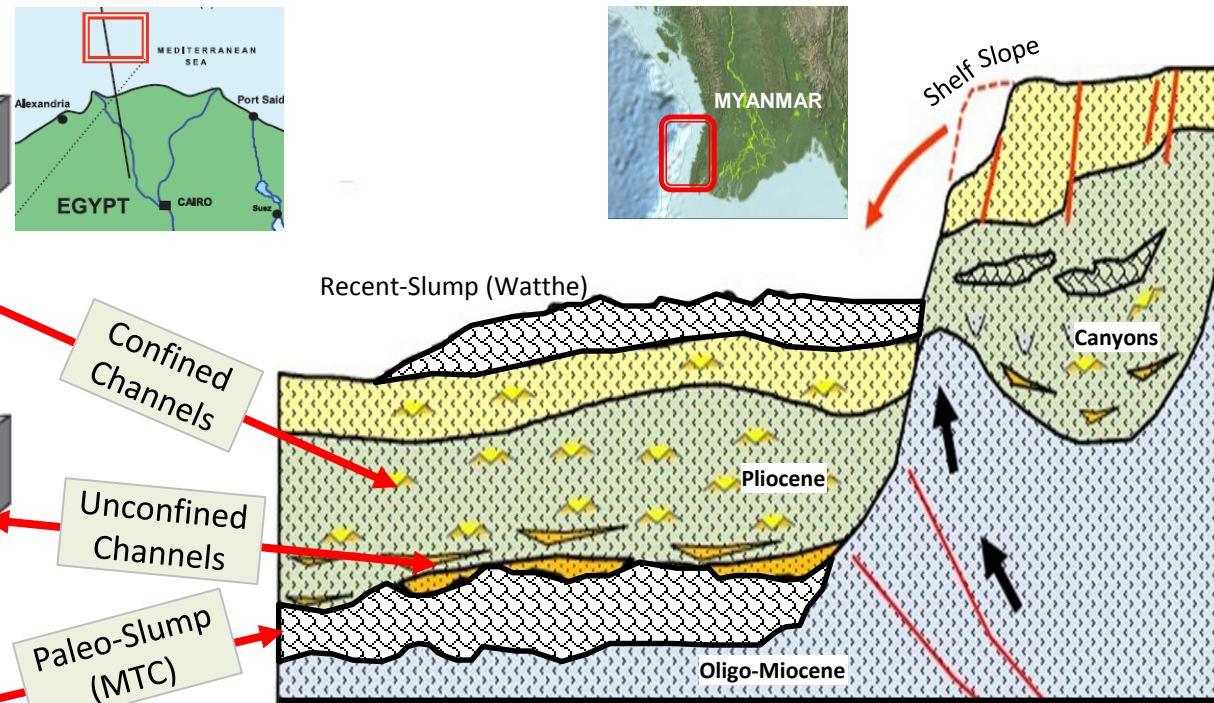
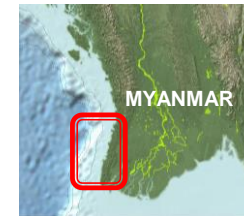
##### Stage II Laterally amalgamated channels



##### Stage I Sediment bypass, erosion and slumping – Channel initiation



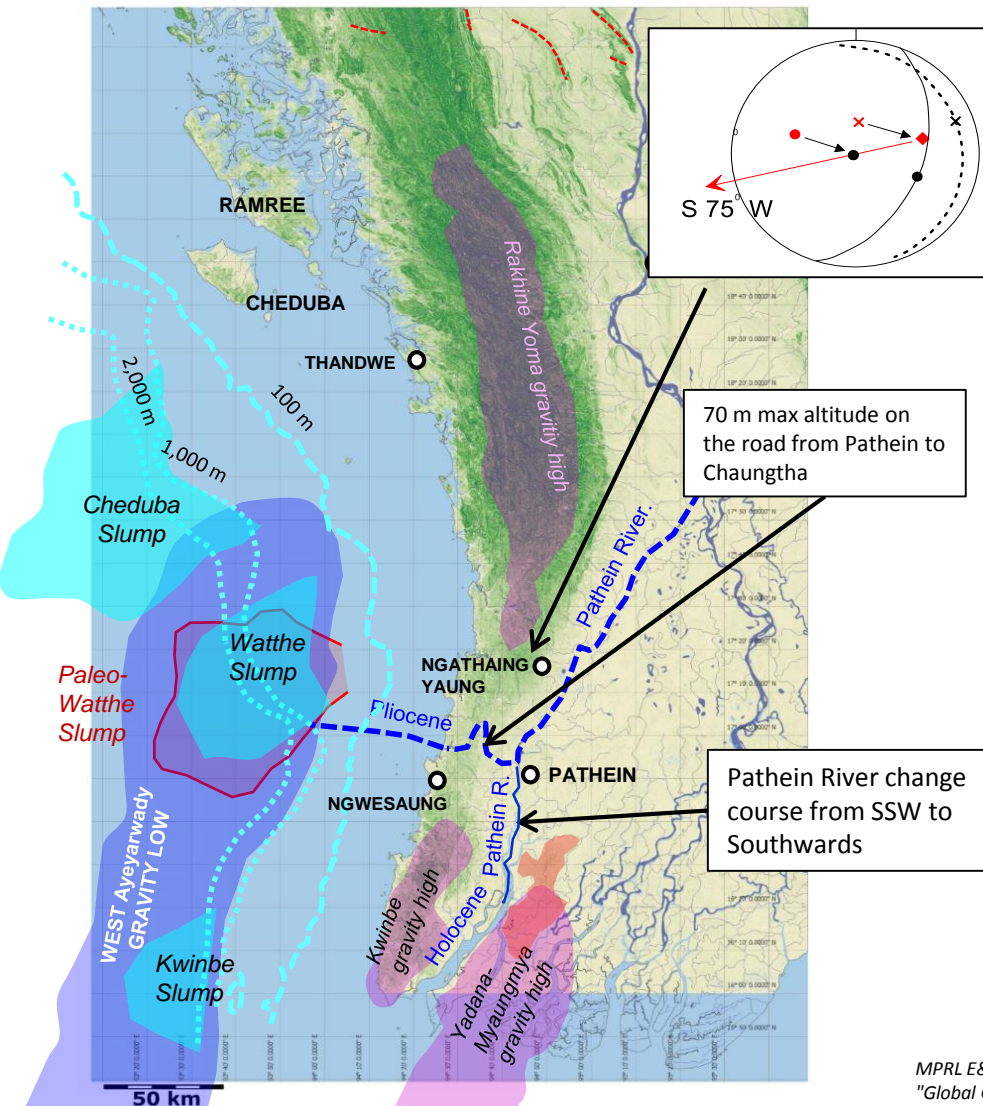
#### Schematic Section for the Southern west Coast of Myanmar Deep-water



Reference to GIAC 1999 Regional 2D lines

# INTEGRATION OF GEOMORPHOLOGY, GRAVIMETRY, SEISMIC AND PALEO-CURRENT FLOW

## Integration strongly suggests a Paleo-Pathein River flowing West during Pliocene

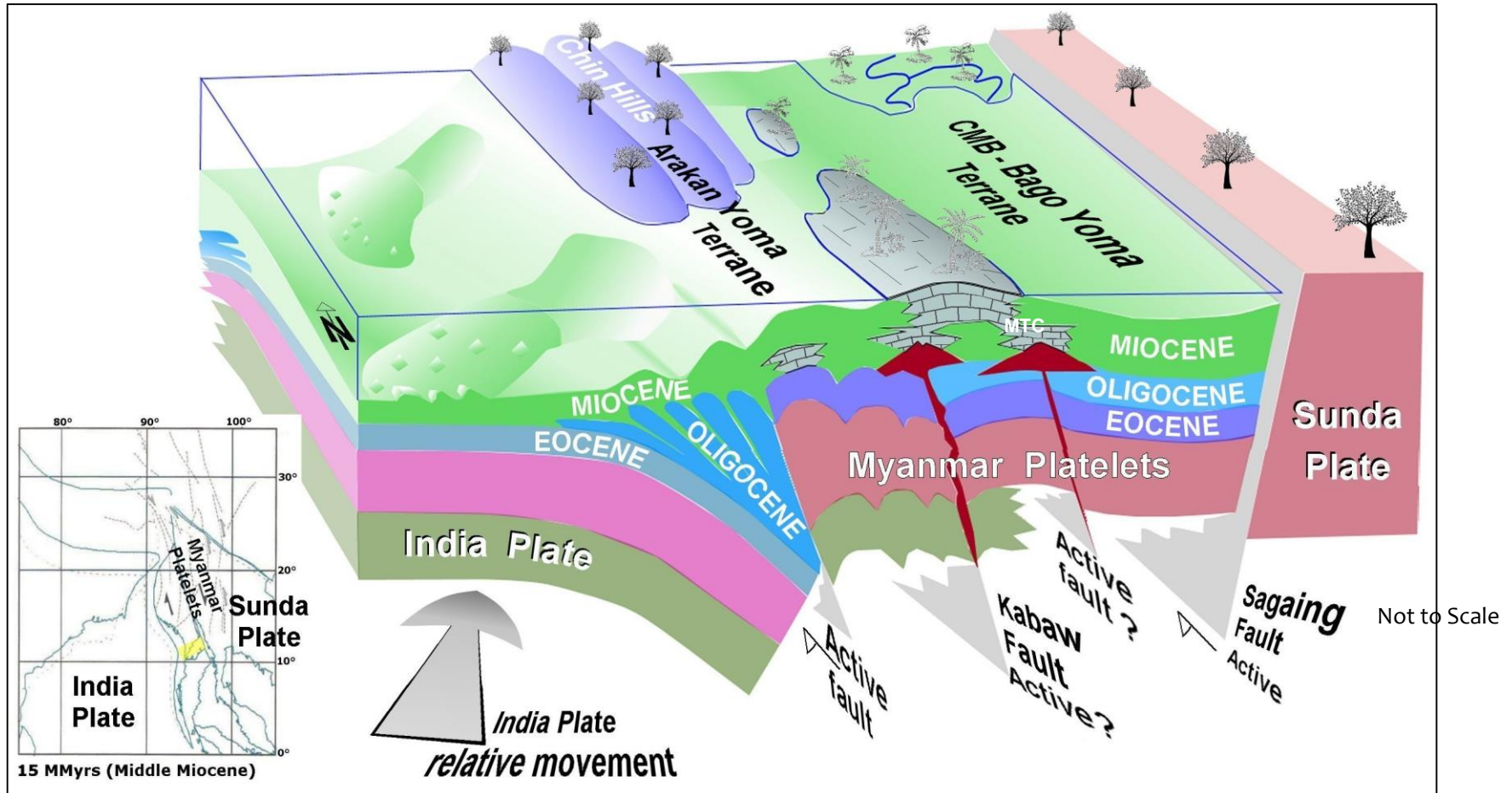


- **Pleistocene uplift:** the most important deformation phase of the Myanmar Platelet has modelled the topography of the country
- **Topography:** Rakhine Yoma range gradually decreases in altitude Southwards to reach only 70 m NW of Patheine at its lowest point
- **Hydrography:** Patheine River, an arm of Ayeyarwady River, distinctly changes course W of Patheine, exactly at the lowest point of the Rakhine Yoma Range
- **Gravimetry:** Distinct gravity low on Rakhine Yoma range corresponding to Patheine River course change as well as to the Rakhine Yoma range
- **Paleo-current onshore:** Indicate to the W or SW near Ngathaingyaung area
- **Deepwater exploration** West of Myanmar confirms the existence of westwards flowing significant channels systems
- **Integration** of topography, hydrography, gravimetry, paleo-current and deepwater exploration show that the Patheine River flowed during the Pliocene W to SW'wards through the scar left on the shelf break by an Upper Miocene giant slump



## CONCEPTUAL MODEL – LATE MIOCENE

### Stage 1 - India Plate detached from Myanmar Platelet before Pliocene

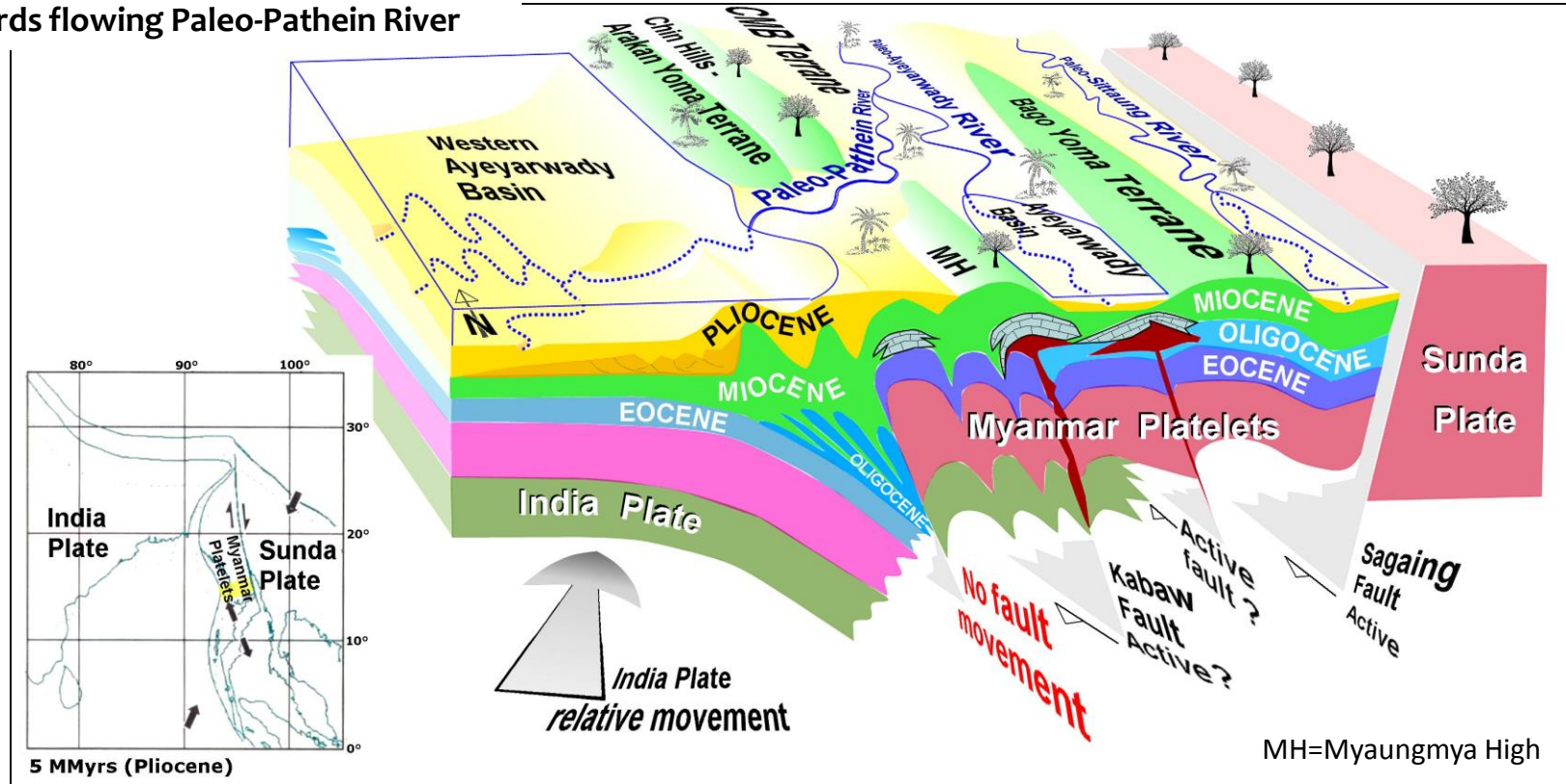


- Translational Subduction of India Plate beneath the Myanmar Platelet; main tectonic event indicated by massive Mass Transport Complex (MTC)
- Mass Transport Complex (MTC) creates scar = accommodation space in shelf area favorable the sedimentation pathway from shelf to deep-water

## CONCEPTUAL MODEL - PLIOCENE

### Stage 2 - India Plate attached to Myanmar Platelet during Pliocene

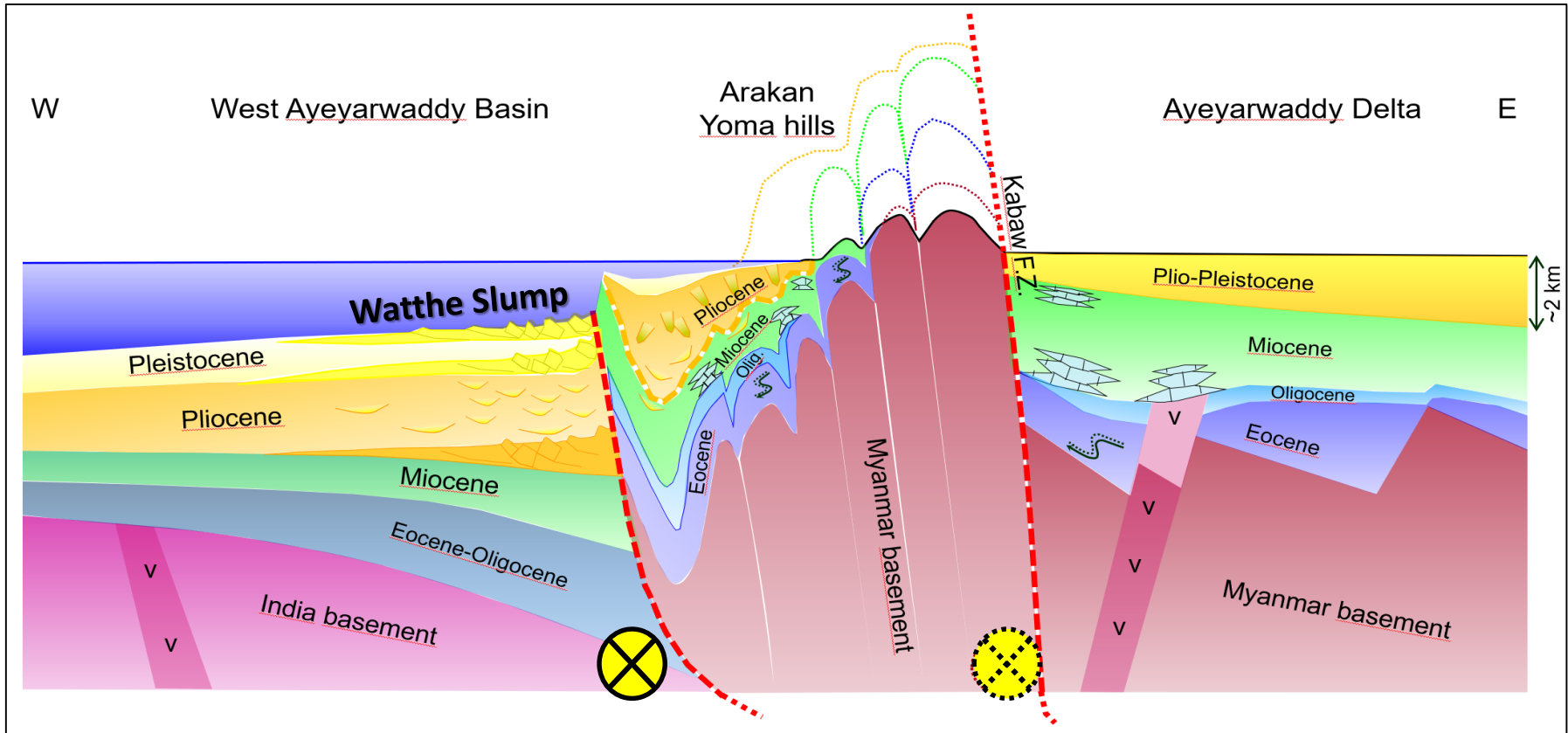
Westwards flowing Paleo-Pathein River



- No relative movement of India Plate vs Myanmar Platelet W of Ayeyarwady area
- Translational Subduction of India Plate beneath the Myanmar Platelet transferred more to the East, such as along the Kabaw fault and/or the Sagaing fault
- MTC scar area now avenue for sedimentation path way from shelf to deep-water
- Onset of Fluvial (Proto-Ayeyarwady) & Deep-waters depositional system developed in the west coast of Myanmar

## CONCEPTUAL MODEL - PLEISTOCENE

### Stage 3 - India Plate detached again from Myanmar Platelet after Pliocene



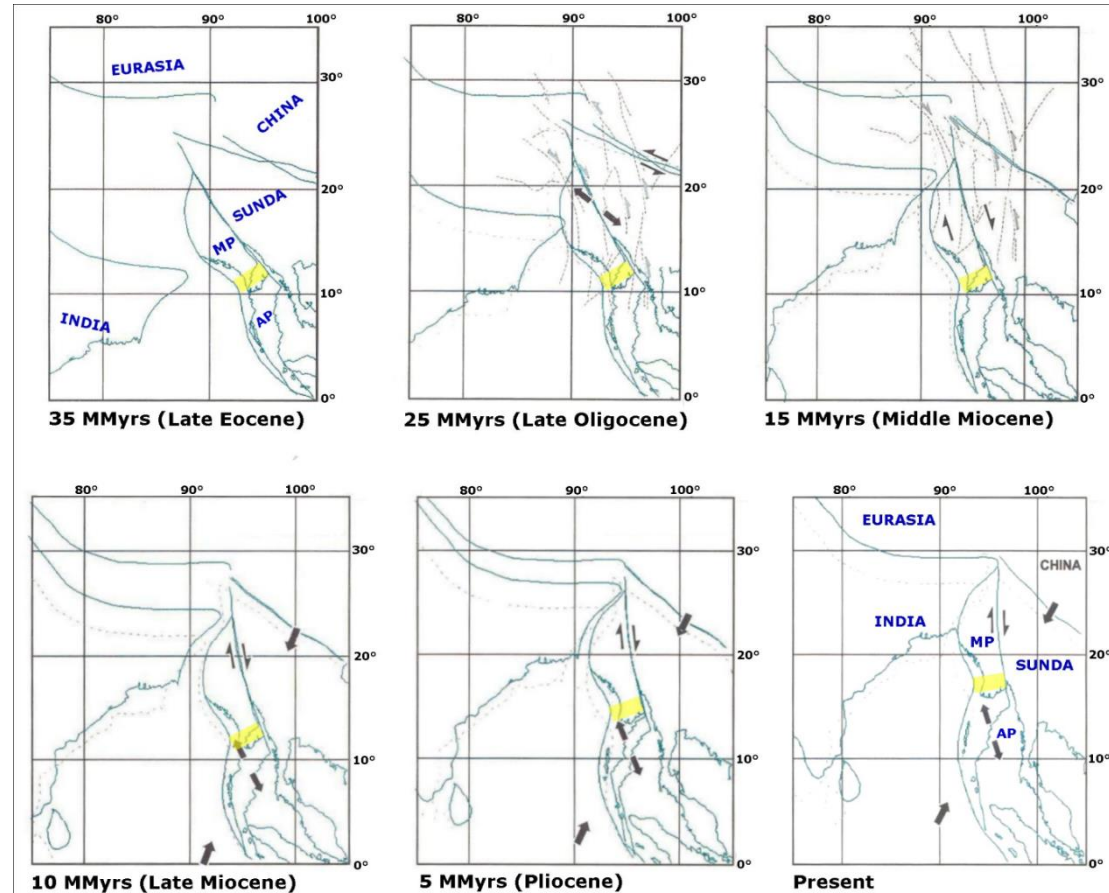
- Slumping resumes (Watthe Slump)
- Paleo-Ayeyarwady River flow back to Bay of Mottama
- This detachment of India Plate from Myanmar Platelet also causing
- This is one of the events of the Pleistocene still ongoing major deformation phase affecting onshore Myanmar



## CONCLUSION

### Never lose sight of continental plates

- The Mid-Tertiary to Pleistocene geology of West and Central Myanmar is controlled by the intermittent attachment/detachment of the Myanmar Platelets to each other and to the India Plate
- The Patheingyi River, a western branch of the Ayeyarwady River, most likely crossed a low area of Rakhine Yoma fold belt during Pliocene to pour sediments that made up the reservoirs of the recent gas discoveries in Block A-6
- Pleistocene uplift of the Rakhine Yoma has cut off the Ayeyarwady delta from the western shores of Myanmar, causing mega-slumps of the shelf break and diverting the Patheingyi River back southwards to the Gulf of Moattama
- The A-6 gas discoveries have revealed the existence of a separate sedimentary basin in the Bay of Bengal, essentially fed by the clastics of the Pliocene Patheingyi River: the **WEST AYEYARWADY BASIN**



GIAC, 1999

Q & A

Thank You.