

# **Coeval Oligocene- Miocene Extension in East Andaman Basin / North Sumatra Region and in the South China Sea: Geodynamic Consequences and Implications for Hydrocarbon Research\***

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## **Abstract**

The South China Sea (SCS) and the East Andaman Sea (EAS) basins are part of a large extensional zone affecting the continental crust around the Sunda block. Formation of these basins is tectonically dependent on the collisions of exotic terrains during the Late Cenozoic, the Philippine Mobile Belt (PMB) from the West, the India sub-continent from the East and Australia from the South.

Understanding the complex geodynamic evolution of this plate junction is the key to building a tectonic and sedimentary model for the basins surrounding Sunda and, particularly in this context, the SCS. A good knowledge of the onshore geology surrounding these marginal basins needs also to be integrated into offshore data. Both EAS and SCS basins show coeval thinned continental crust with presence of oceanic crust in the Eastern SCS only.

In the EAS, Sunda continental crust was stretched mostly during a late Eocene-early Miocene dextral N-S transtensive episode (Mergui and North Sumatra basins pinned northward in the Myanmar Martaban Basin). A regional 20Ma disconformity can be traced all along the EAS with maximum extension into the West. From the early mid -Miocene to the present, this West Sunda continental margin was the site of hyper-oblique India/Sunda transpressive wrenching, leading to progressive docking and accretion of India Oceanic Ridges sliver terrains now observed in the West Andaman Sea. This tectonic transfer did not affect significantly the EAS 20 Ma seal, offering good opportunities for hydrocarbon exploration in this area.

Along the West side of the Sunda block, in the SCS, continental extension was active during the same period of time (late Eocene to early Miocene) along the N-S-trending dextral East Vietnam Fault. Spreading was also present eastward where E-W-trending magnetic anomalies are clearly identified and were recently drilled (from 33 Ma to 20.5 Ma). This main SCS spreading direction suddenly stopped at the same time as the extension in the EAB.

A second SCS spreading or post-spreading extension episode, trending NE-SW, is suspected (and still in discussion among the scientific community) due to the invasion of Neogene seamount volcanism. This kind of fast change in marginal-basin-spreading direction is classically observed in other dying spreading centers, such as the Shikoku Basin in Japan. This could be the result of new segmentation of the recently opened SCS by oblique PMB vs Sunda convergence as dated onshore. This new NE-SW extensional trend in the SCS is also parallel to the Neogene Proto South China Sea (PSCS) subduction zone present southeastward in the Sulu Sea and ending with the Palawan collision 15 Ma. We think the youngest SCS extension event (20 Ma to 15 Ma) was the result of the last PSCS subduction episode dragged by oblique PMB/Sunda motion.

In this scenario both West and East Sunda block margins were affected from the late Eocene to the early Miocene by continental crust thinning just before PMB and Indian Ridges impingement occurred during the early Neogene. This main extension was controlled by subduction retreat along the Sumatra Java trench and its eastern extension in central Sulawesi.

The challenge is to find preserved hydrocarbon plays sealed by the 20Ma unconformity in both basins. This is relatively simple in the EAB but rather difficult in the SCS, where post-early Miocene deformation still persists up to present time.

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Coeval Oligocene-Miocene Extension in  
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# The South China Sea geodynamics

1: Paleogene large back-arc extension was active all around the Sunda Plate. Trench roll back along the Sumatra-Java-Sulawesi subduction zone was the source for this regional Sunda continental crust thinning.

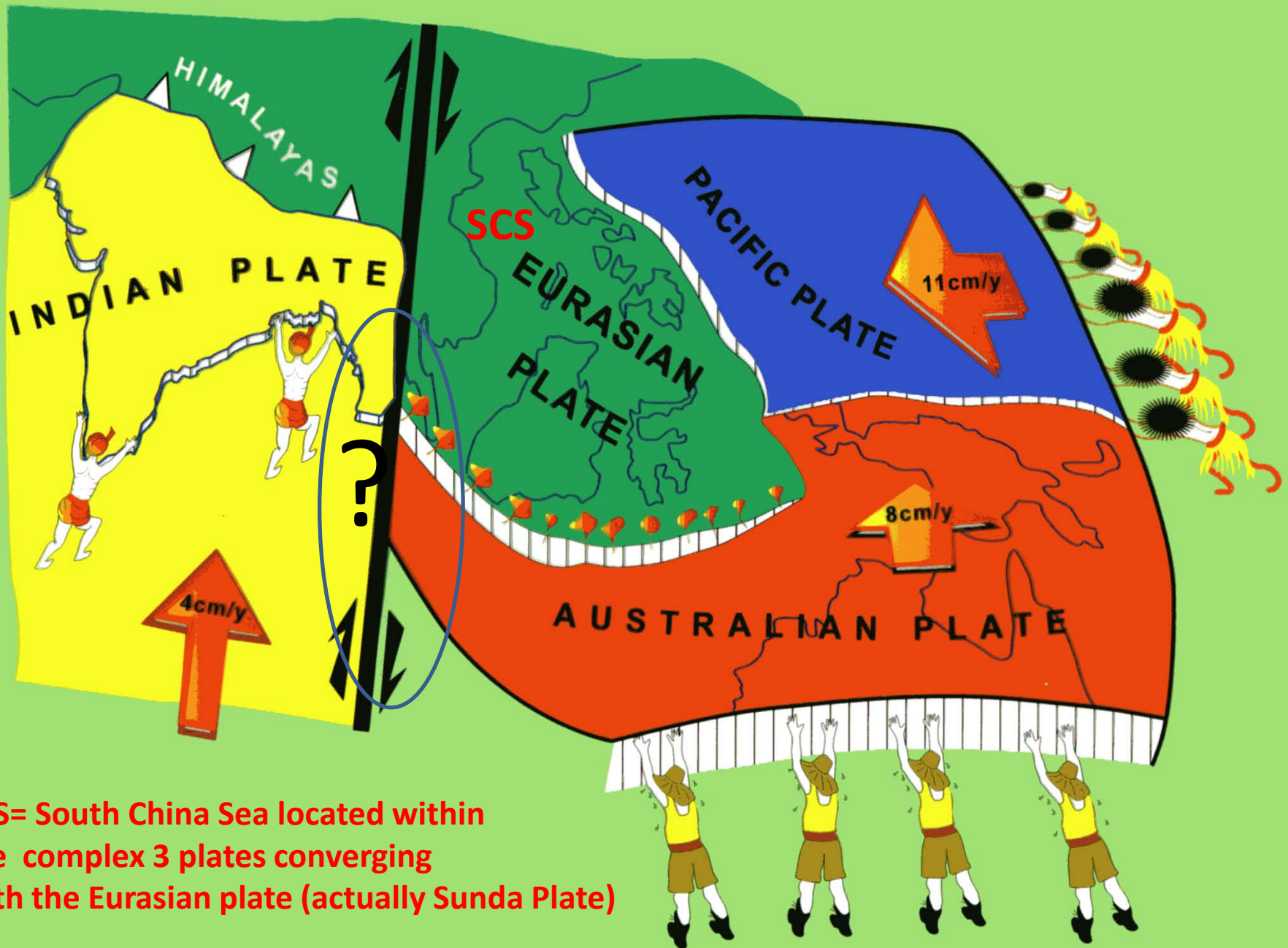
2: During the Neogene this active subduction margin was colliding with three exotic plates: the India plate into the West, the Philippine Sea plate into the East and the Australian plate into the South.

The present study integrates old and recent data acquired in the South China sea and the West Andaman Sea to test this Paleogene crustal extension, and Neogene tectonic inversion as well as related regional unconformities.

Difficulty is to locate in this complex geodynamic setting the hydrocarbon plays located in the sealed sedimentary sequences below the 20 Ma disconformity

***Some slides were removed from the original presentation due to confidentiality.***

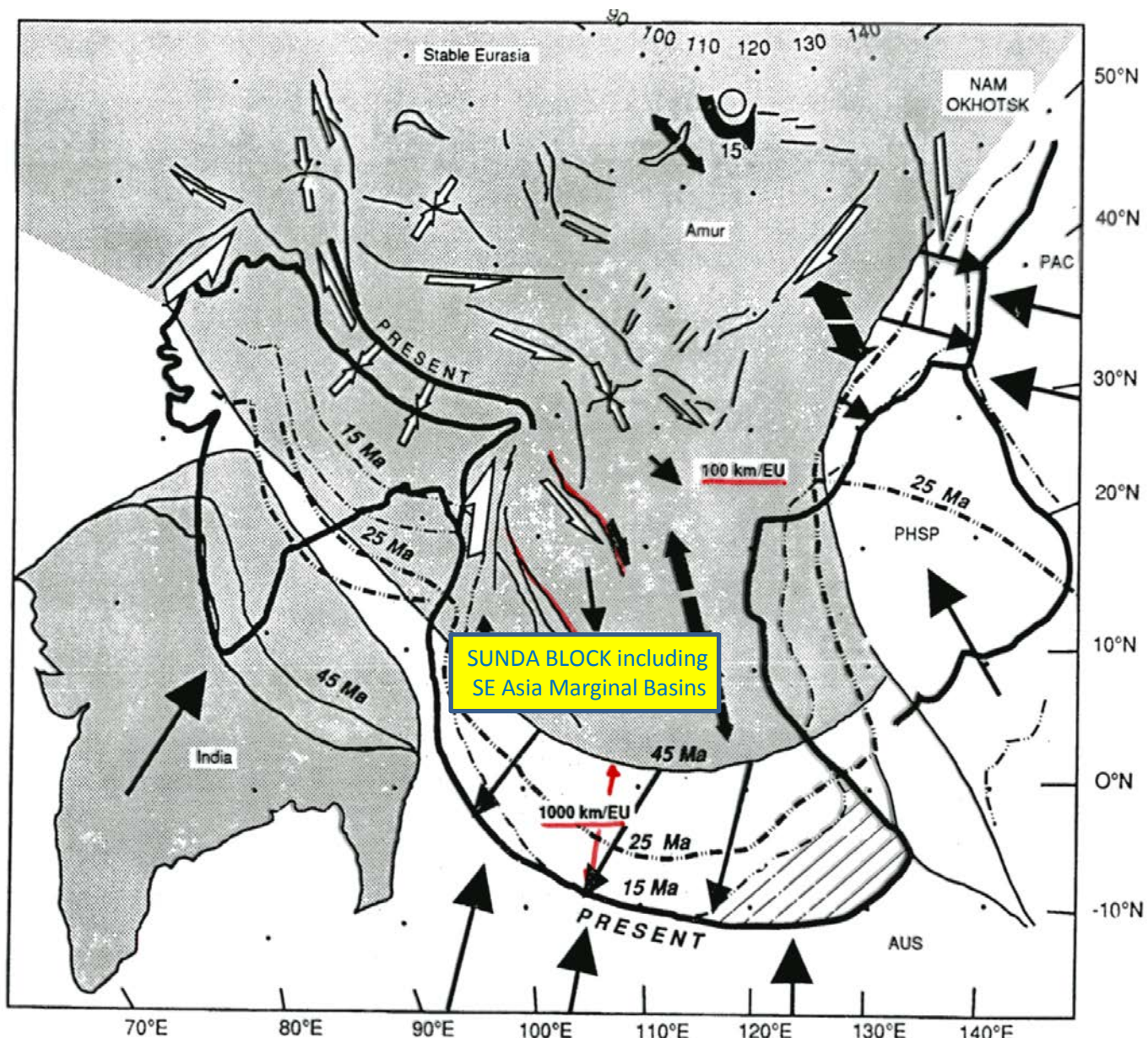
# SE ASIA: 4 Plates JUNCTION



SCS= South China Sea located within the complex 3 plates converging with the Eurasian plate (actually Sunda Plate)

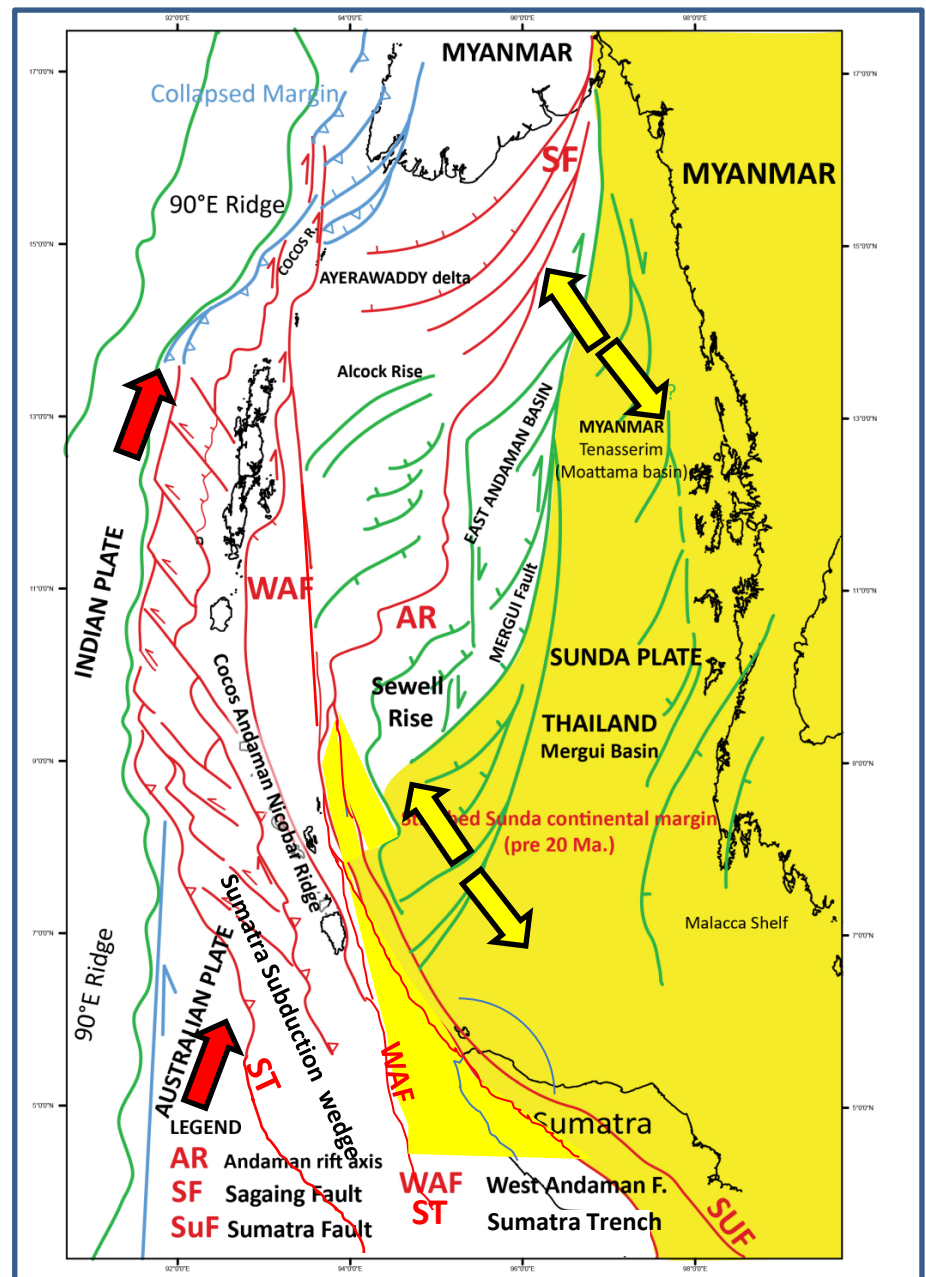
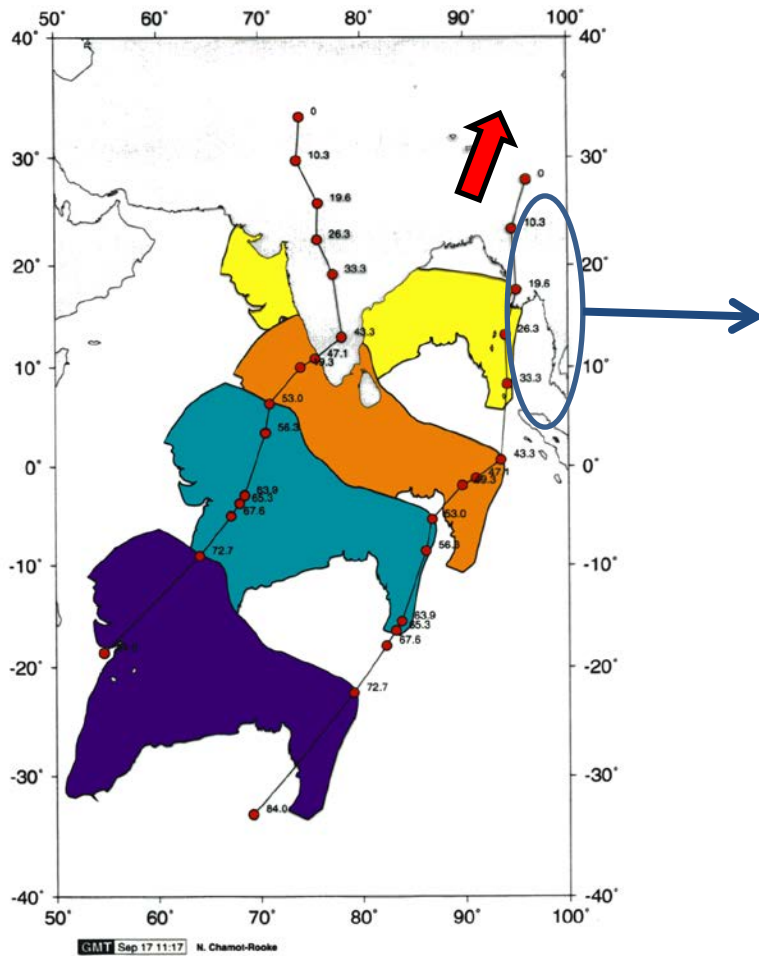


Sunda block is jammed between India and the Philippine Sea Plate (PHSP). Along the southern Sunda plate free boundary, the Sumatra Java (Sulawesi) subduction induced a trench pull effect and main back-arc extension in the Sunda Block.

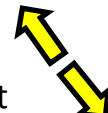


# Continental extension and dextral wrenching along the West Sunda margin

## The East Andaman Sea



Active plates  
relative motion  
Extract from PGS report



Oligocene to early  
Miocene extension



Eurasian  
plate

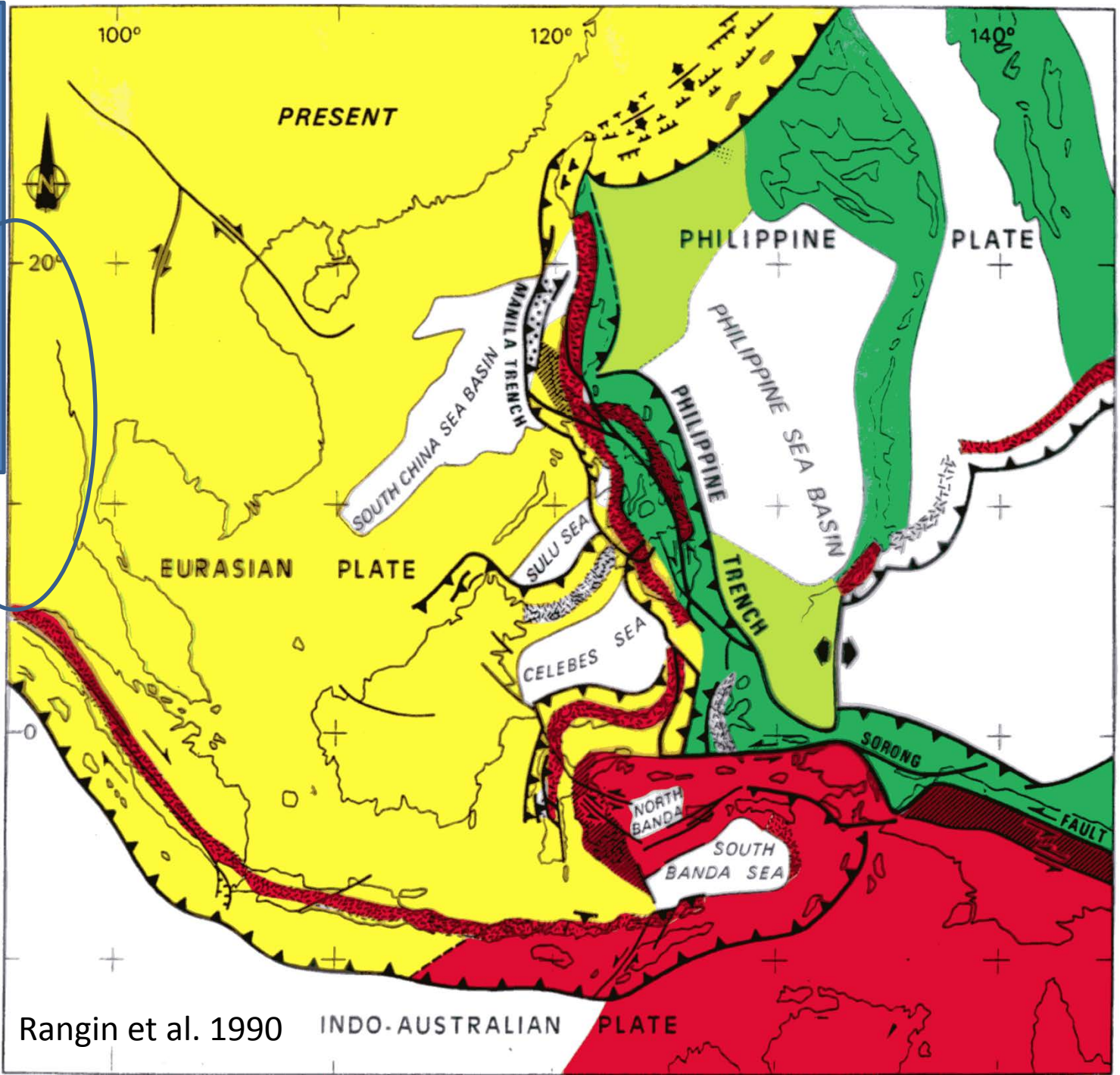
Philippines  
Sea plate

Australian  
plate

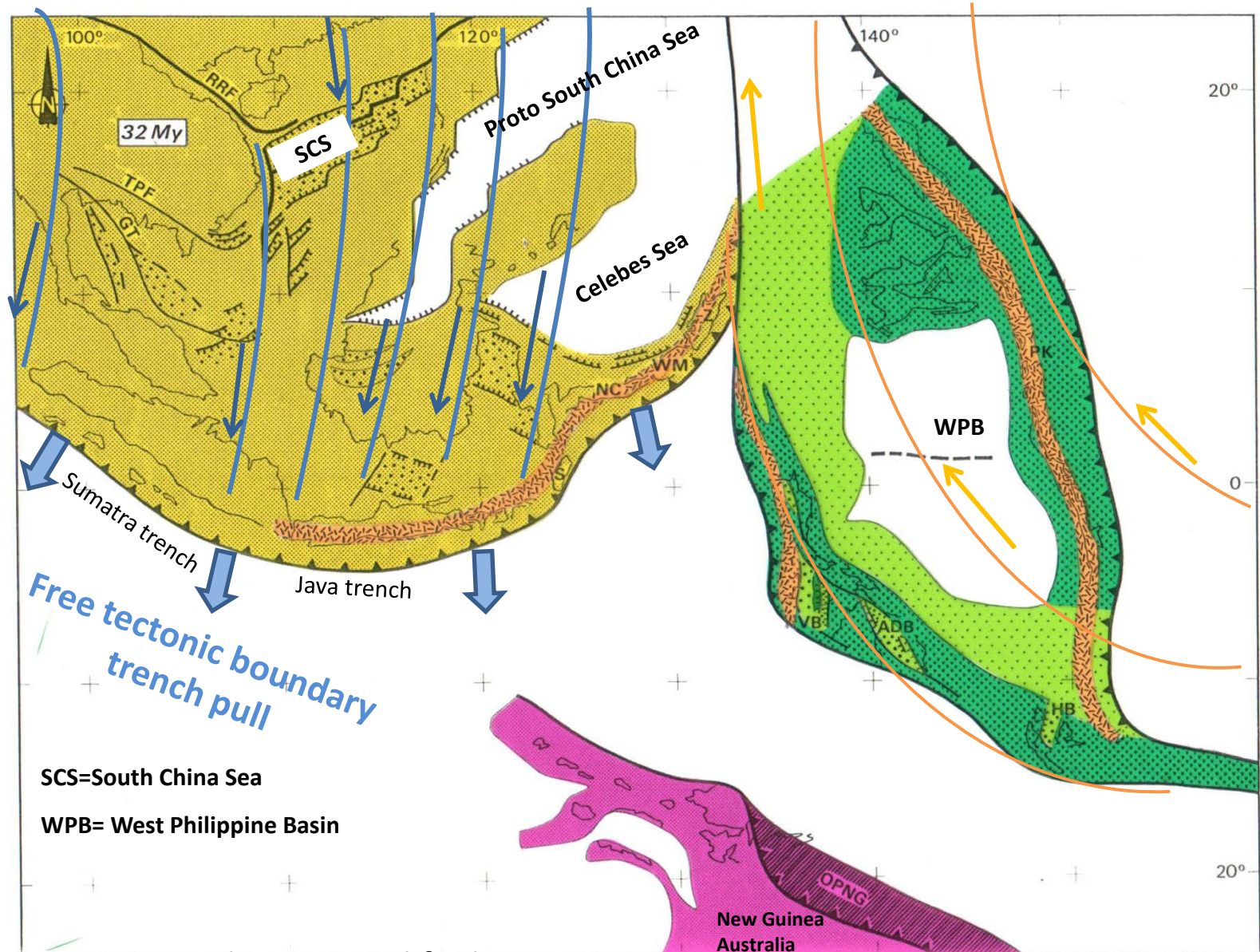
India/Eurasia  
Plate boundary

What do we  
know exactly?

SCS, Sulu and  
Celebes seas  
were opened  
within the  
Sunda plate



## SE Asia reconstruction 32 Ma



Rangin et al. 1990 modified



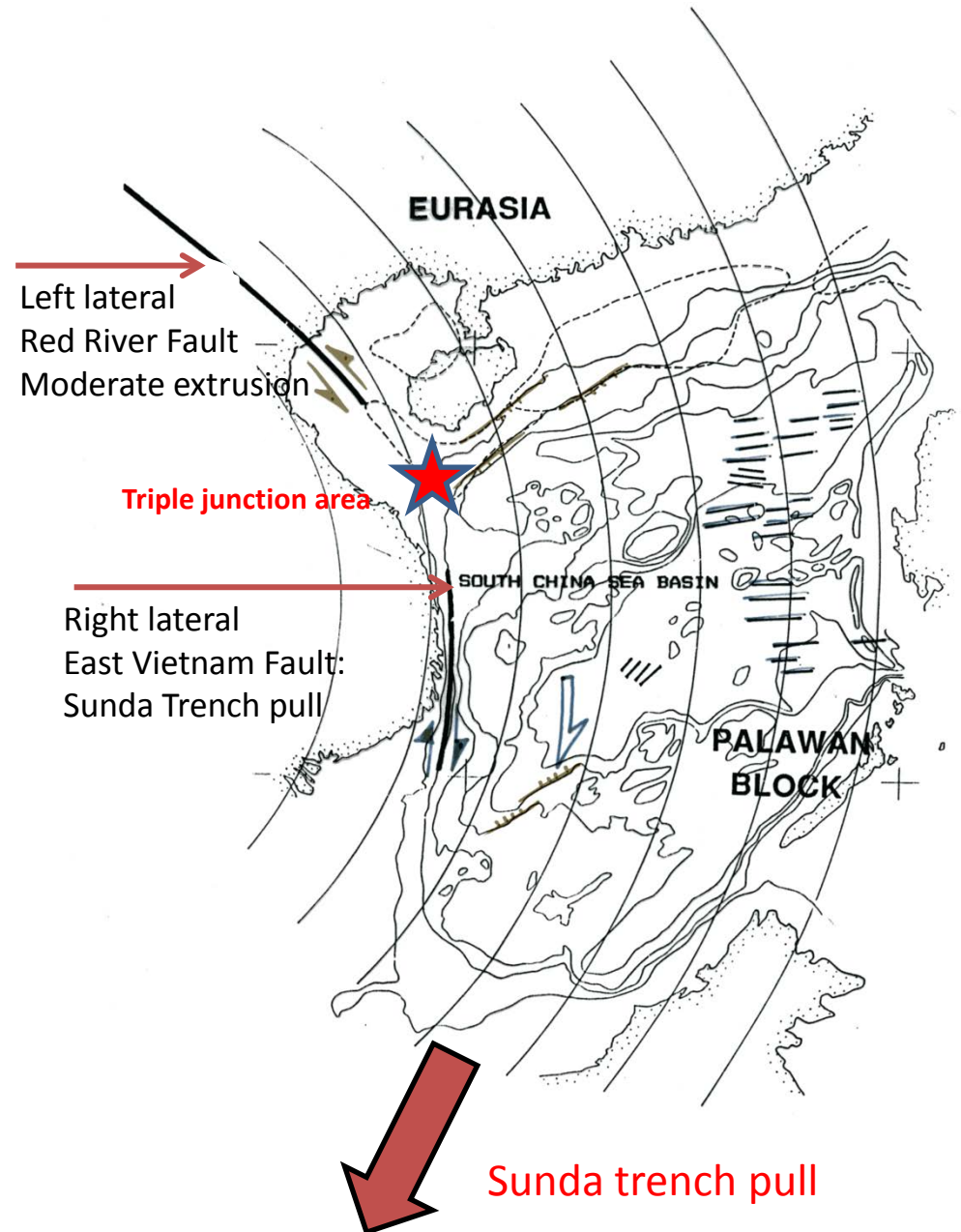
## The South China Sea tectonics from 32 to 20 Ma.

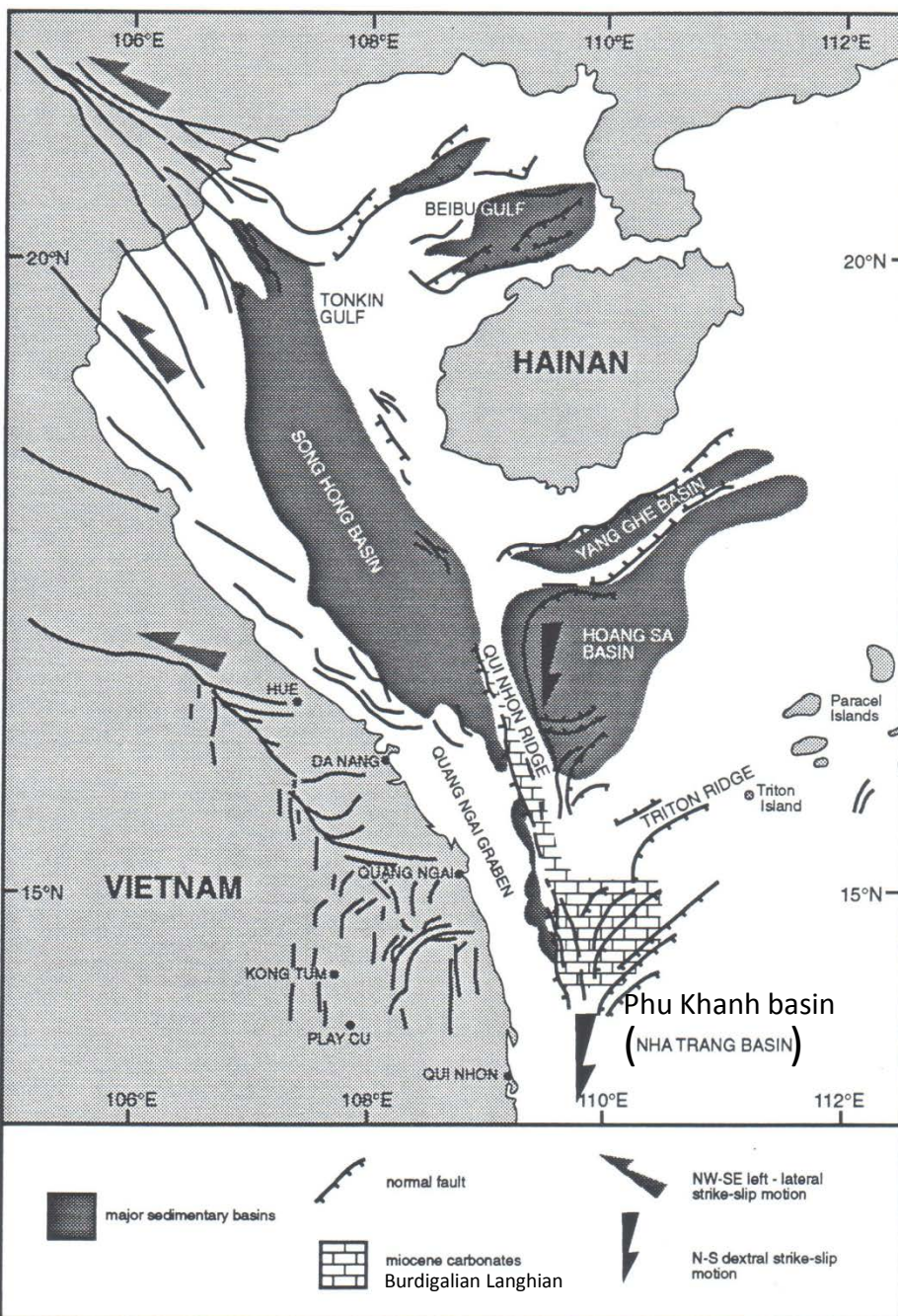
Before 20 Ma tectonics of the South China Sea was controlled by moderate extrusion of Sunda in response to India-Asia collision, but also by strong trench pull along The Sunda Trench.

The left lateral Red River fault accommodated the extrusion, and the dextral East Vietnam fault, the trench pull.

Both faults are aligned along the same circle and connect in the Song Hong Basin, interpreted as a triple junction area.

Spreading of the South China Sea is controlled by transform faults that fit the same circle.





## Coeval sinistral and dextral strike slip motion along the Vietnam Eastern margin:

**Dominant dextral motion** along the Da Nang-Qui Nhon Vietnam N-S continental margin during the Oligocene - early Miocene (extension of the Hoang Sa and Phu Khanh basins). Qui Nhon ridge and Quang Ngai graben are part of the dextral N-S **East Vietnam Shear Zone** reactivating a wider Hercynian shear zone observed on land along the upper continental margin.

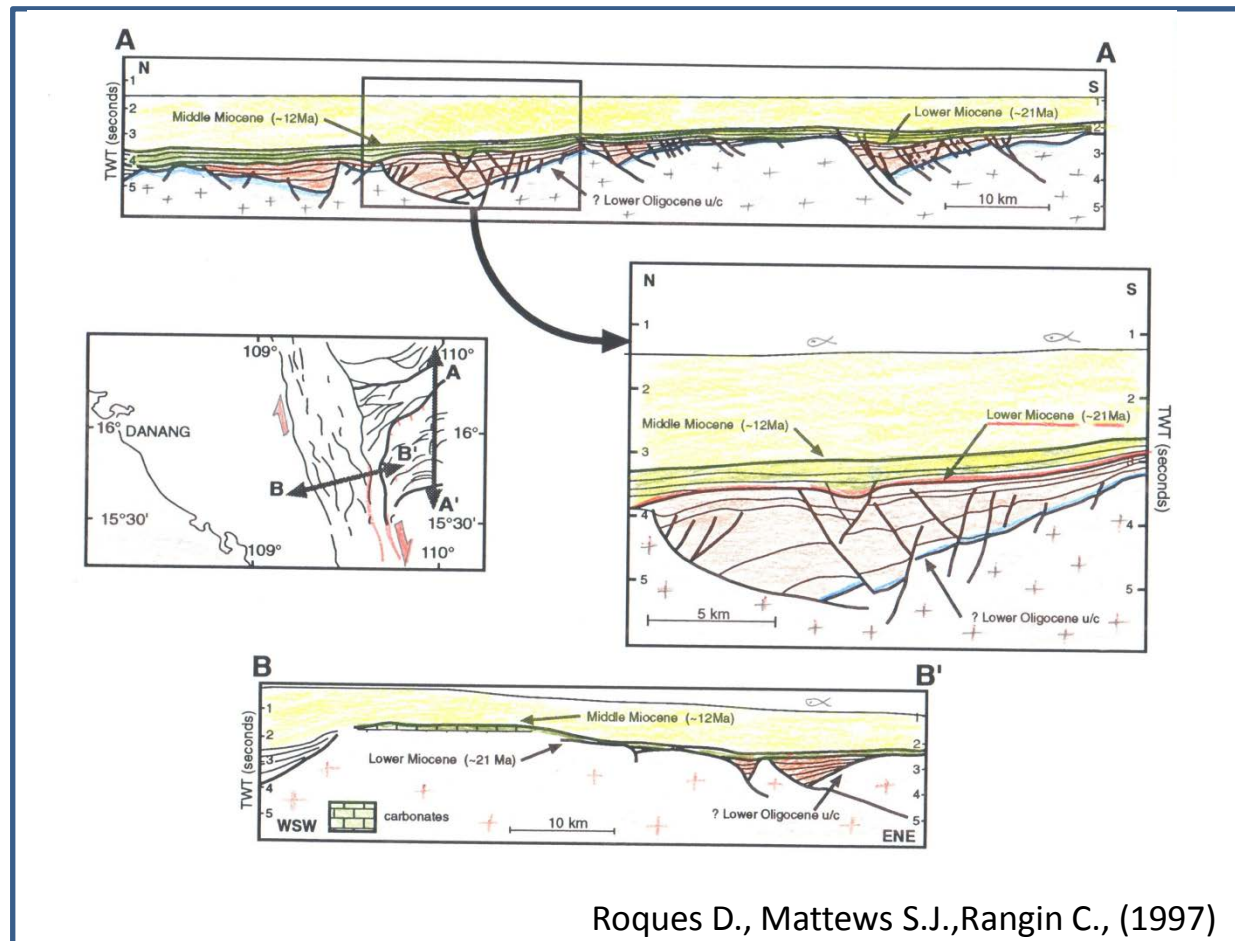
**Minor sinistral motion** observed in the Tonkin Gulf and Song Hong Basin from Oligocene to middle Miocene (Rangin et al., 1992) on Total seismic lines calibrated by drilling. On land coeval reactivation of older sinistral NW-SE-trending strike slip faults (Red River F and Song Ma fault system). Tonkin Gulf faulting was active up to late Miocene.

Roques D., Matthews S.J., Rangin C., (1997)

*Constraints on strike slip motion from seismic and gravity data along the Vietnam margin...*

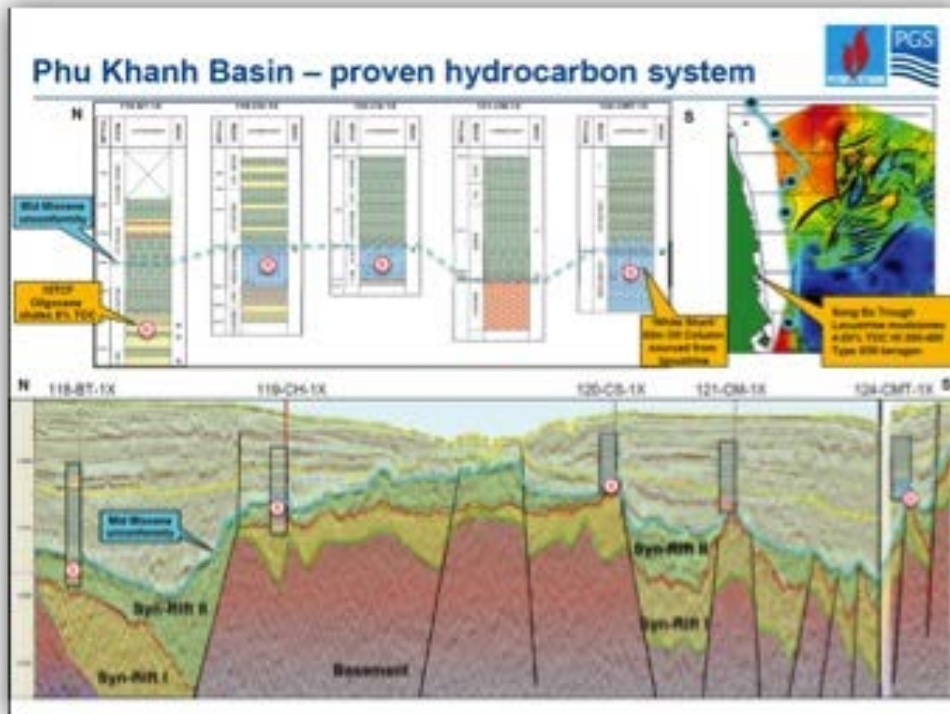
## Synthetic seismic line drawings of the Vietnam margin offshore Da Nang and Qui Non.

Two main extensional events: 1: Oligocene-Early Miocene, 2: Middle Miocene 20-12 Ma.

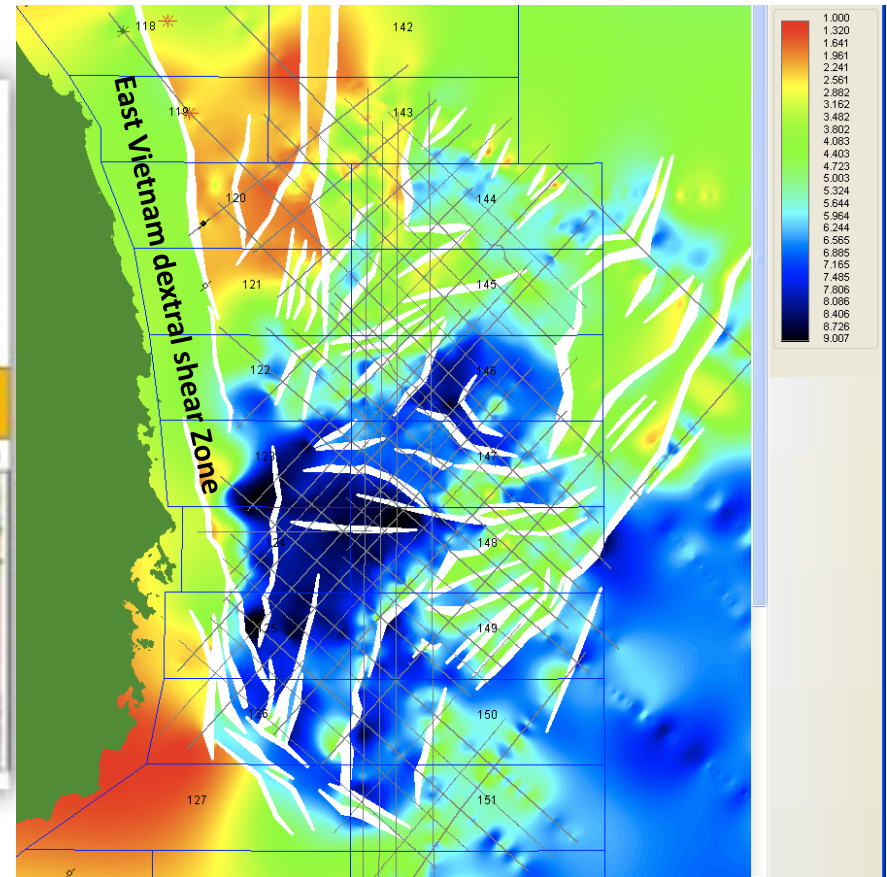




## The same extensional episodes are observable in the Phu Khanh Basin

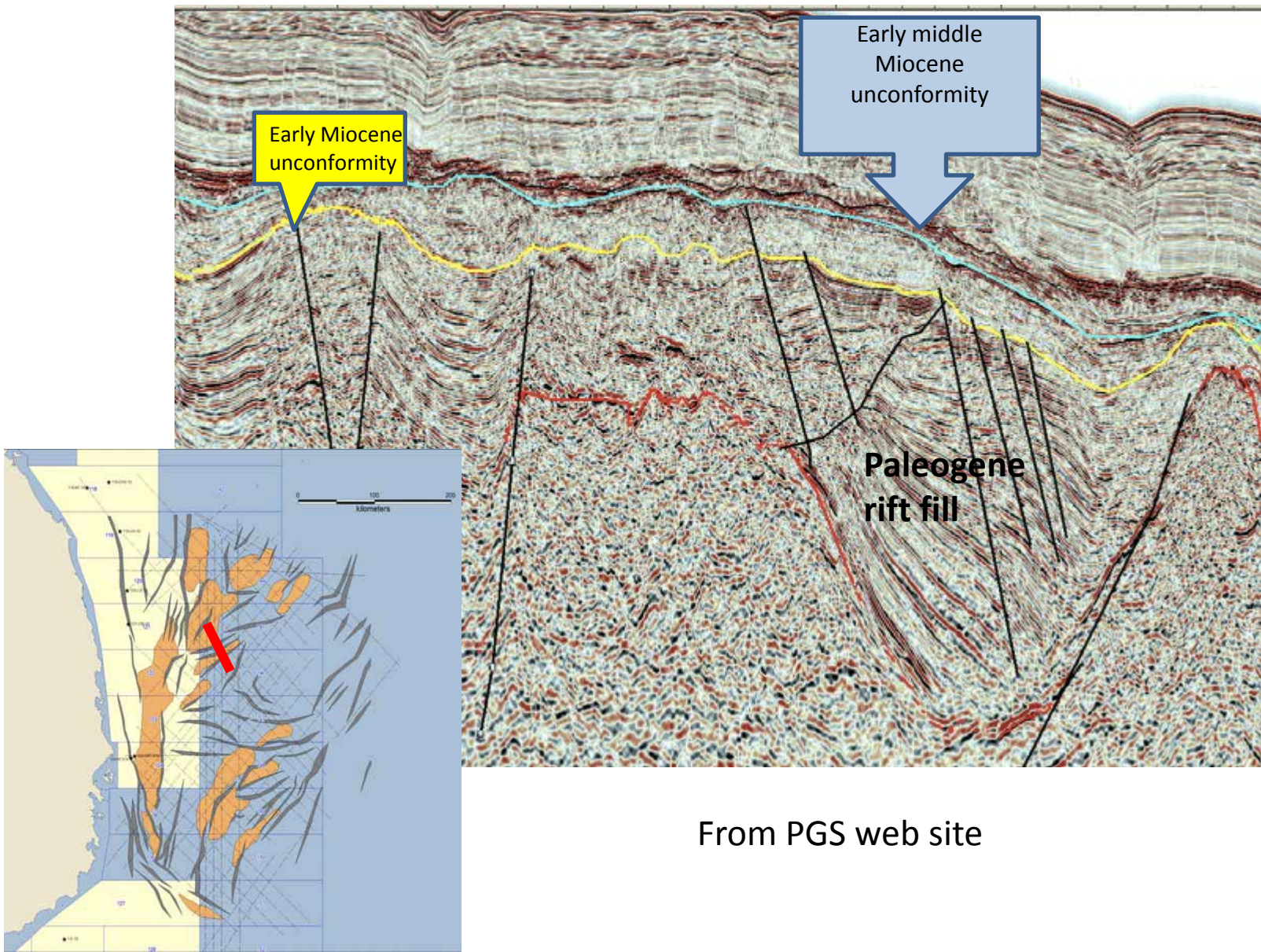


Tad Choi and Jo McArdle, 2015



From PGS web site

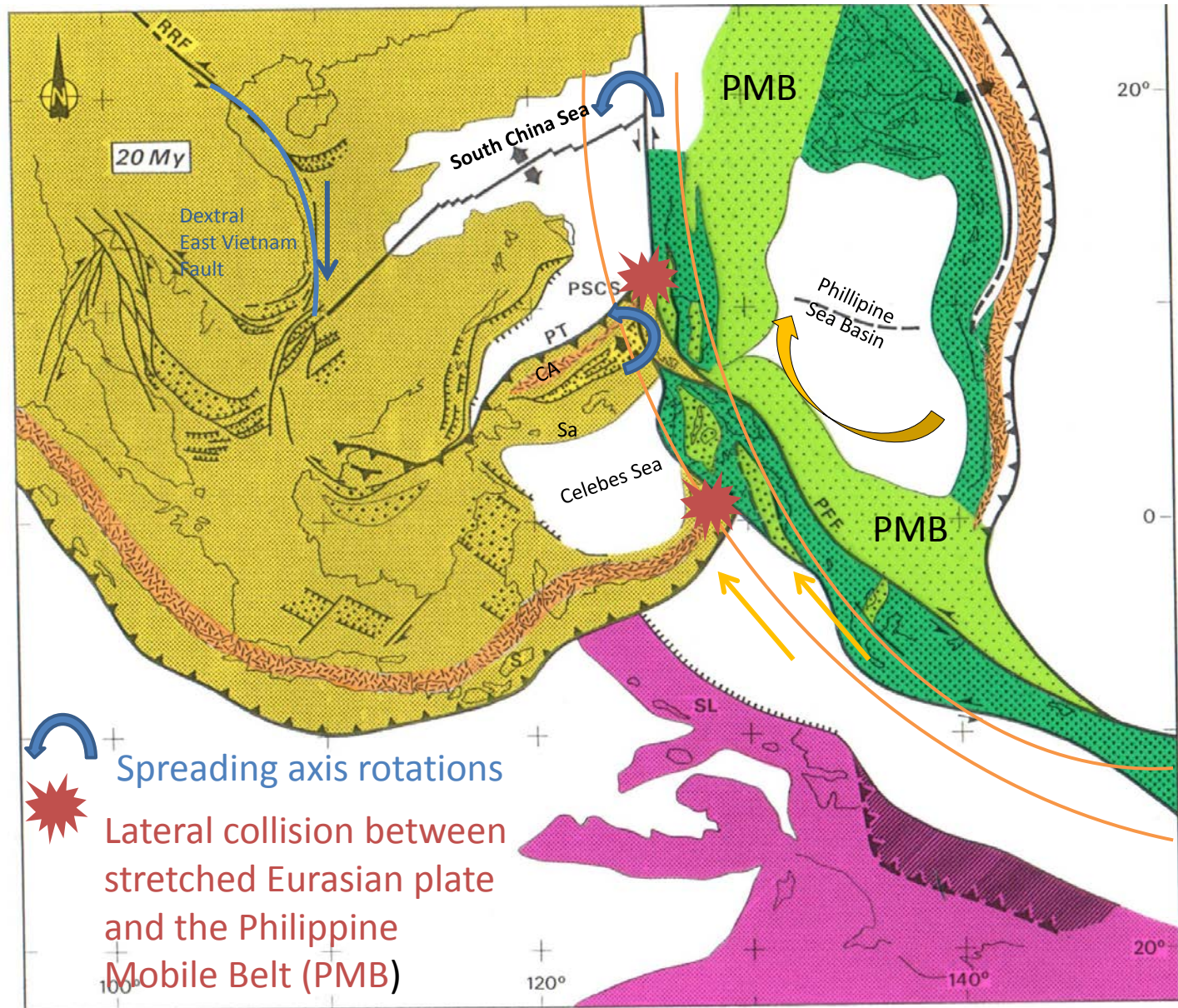
Paleogene-earliest Miocene rifting in Phu Khanh basin during 32-20Ma extension, linked with dextral motion along the N-S East Vietnam shear zone, is the main extension episode.



From PGS web site

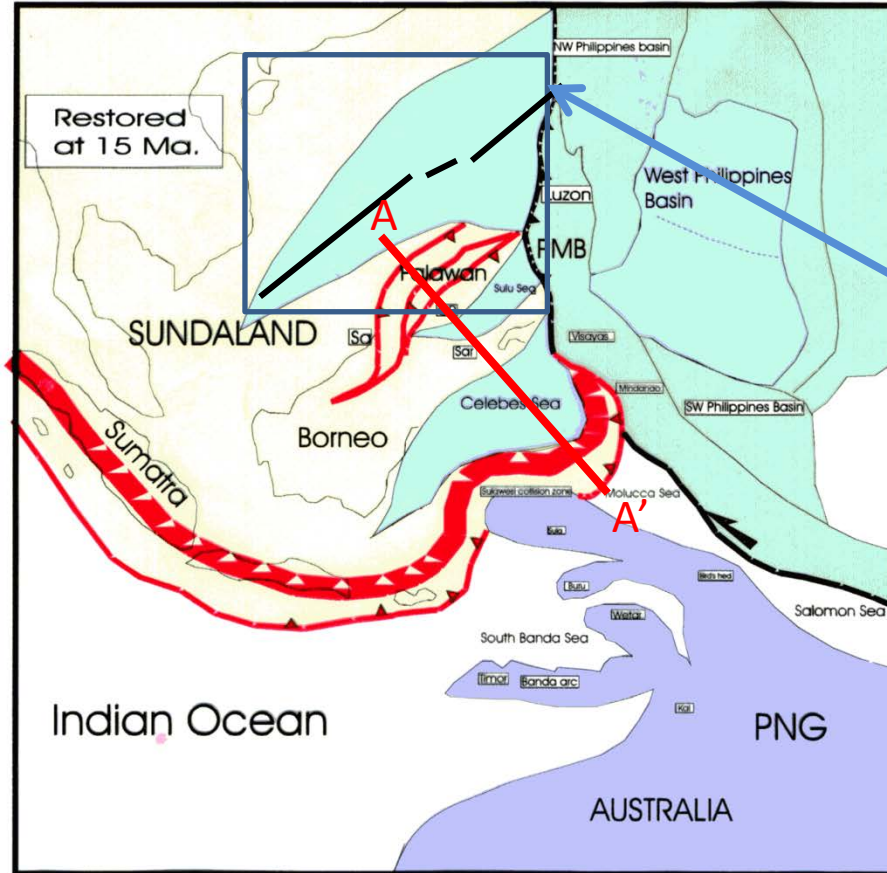


# SE Asia reconstruction 20 Ma, modified from Rangin et al. 1990

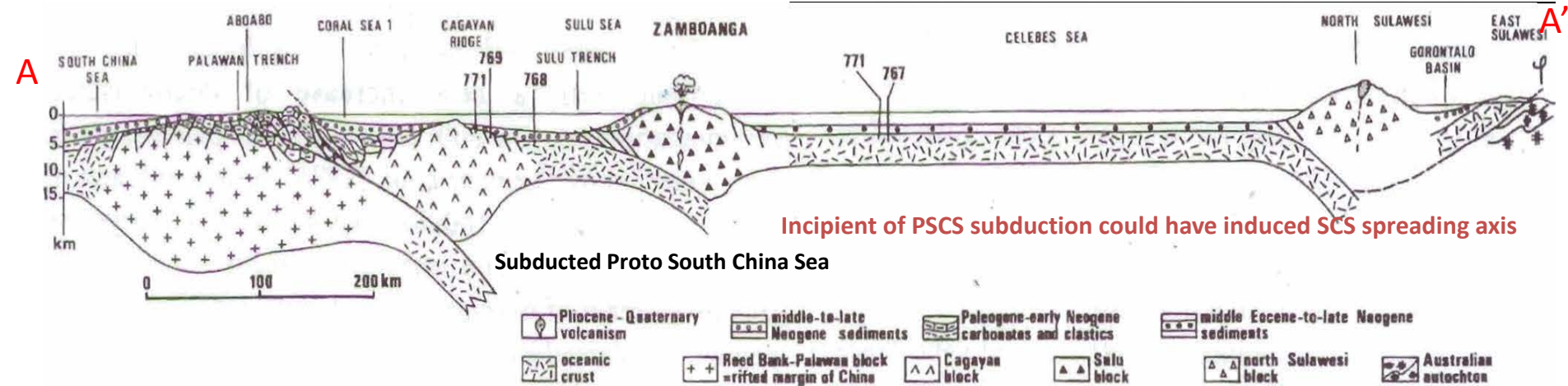
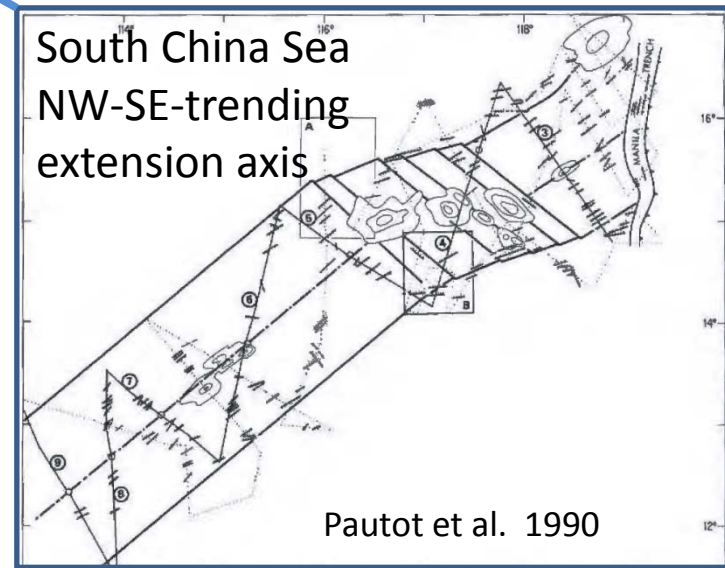


PSCS: Proto South China Sea PT: Palawan Trench, CA Cagayan volcanic Arc, Sa Sulu arc, Sul Sulawesi collision



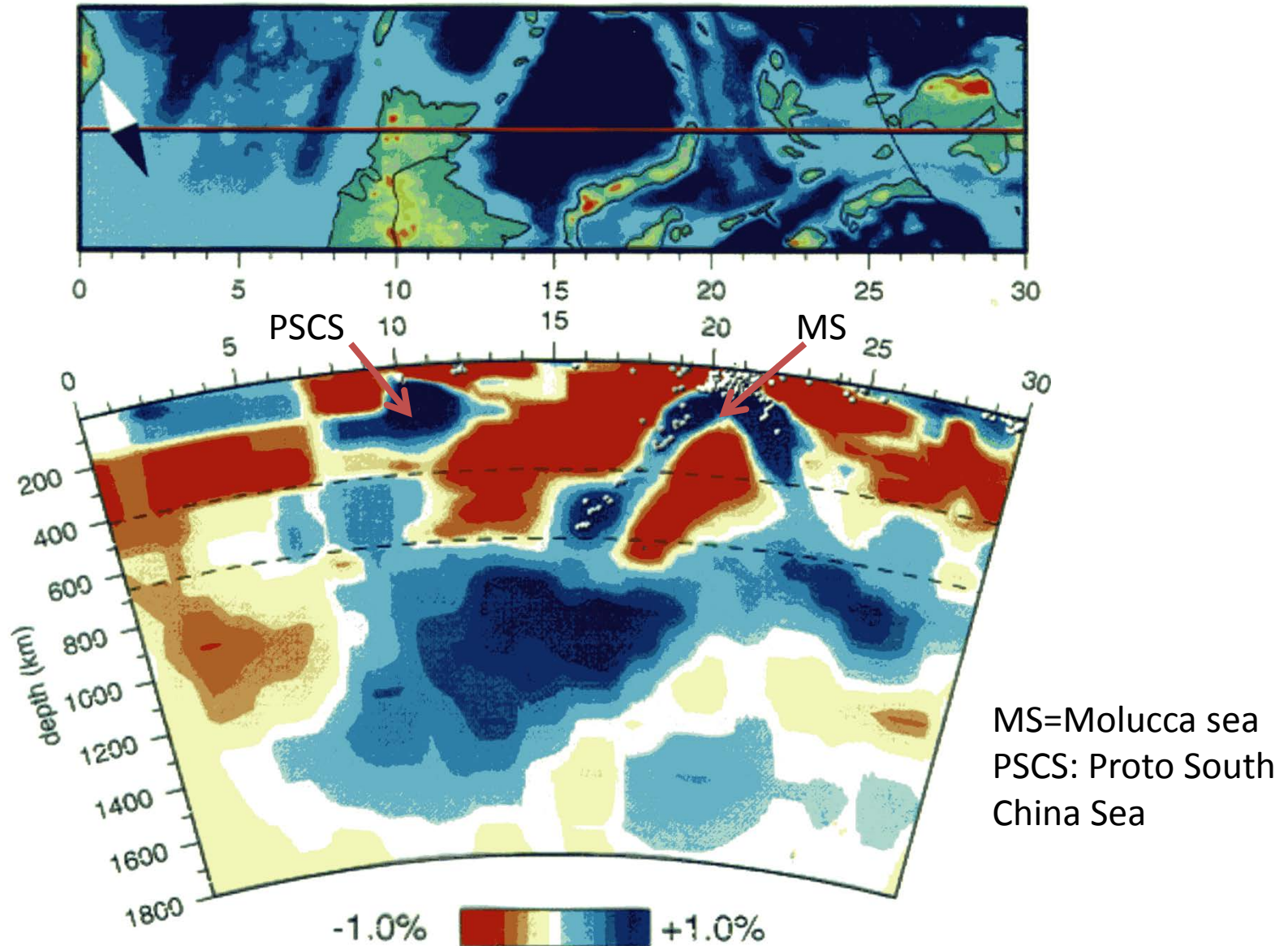


THE SCS 20-15 Ma extension is coeval and parallel to the Proto South China Sea subduction zone in the Sulu Sea



modified from Rangin et al., 1990

The Proto South China Sea = A **narrow** oceanic basin completely subducted



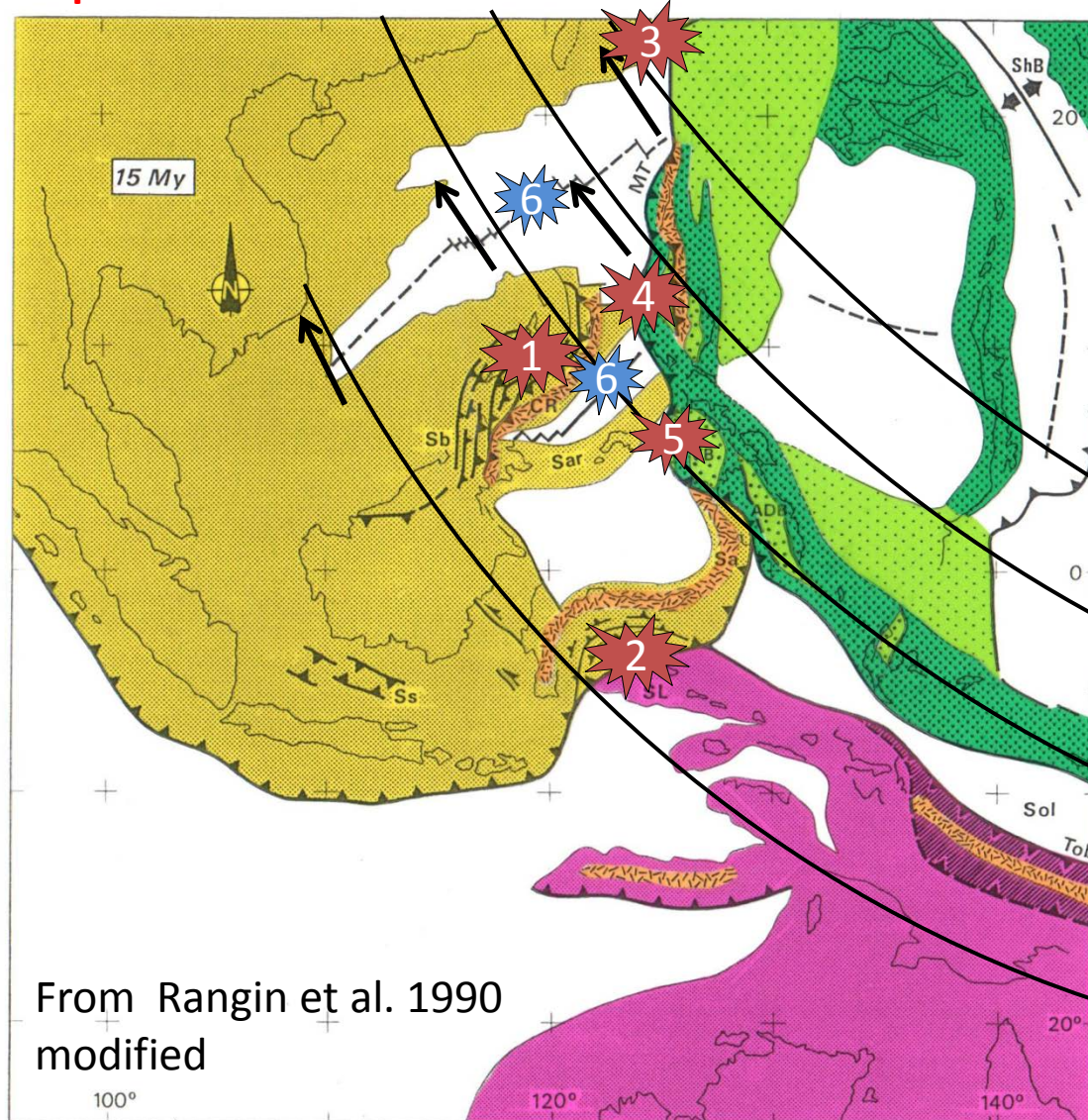
From Rangin et al. 1999



# Early Middle Miocene (15 Ma) reconstruction

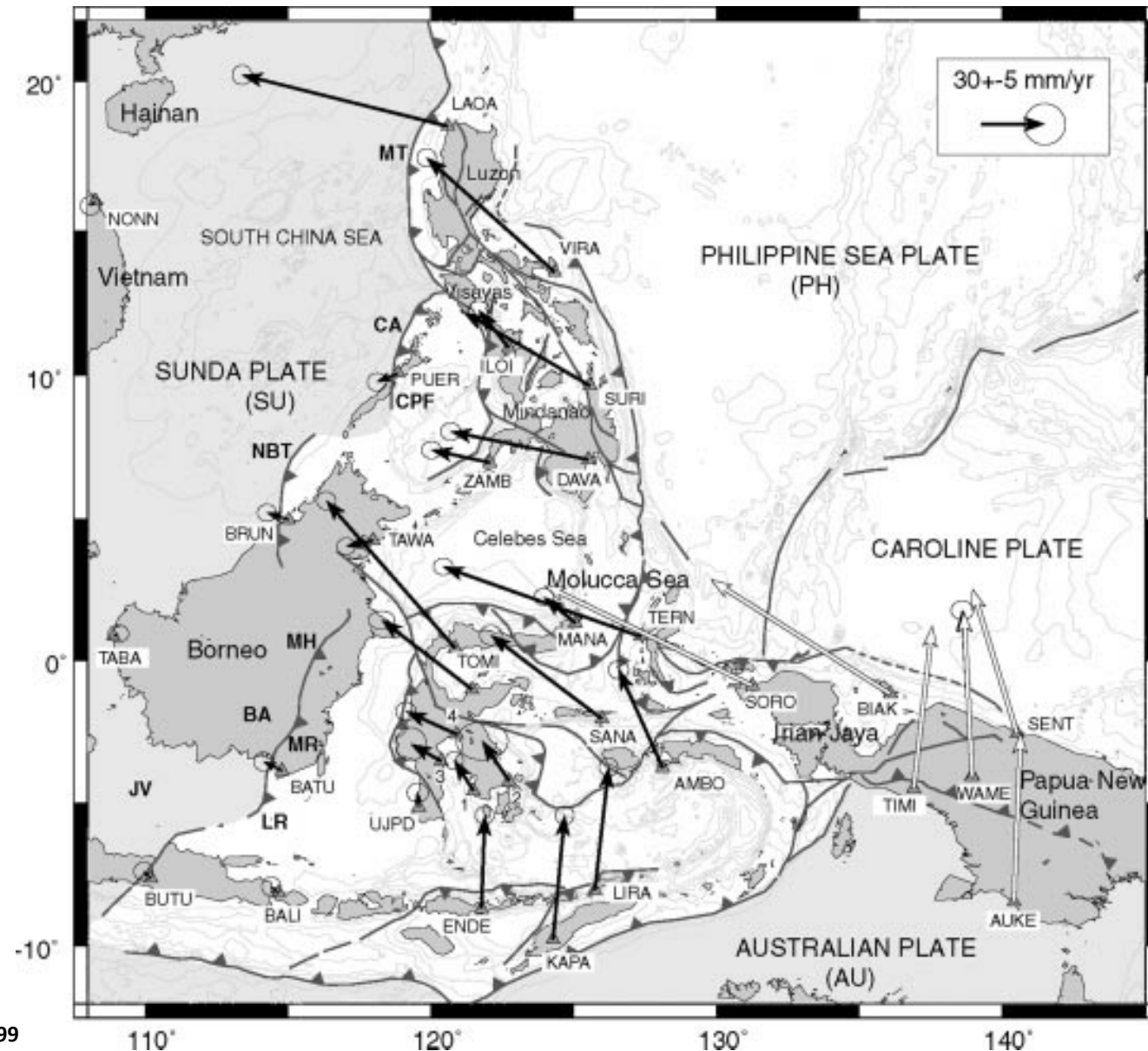
A period of multiple collision around the SCS:  
Collision of the Philippine Mobile Belt (in green) and  
Complete closure of the PSCS.

Main tectonic events at 15Ma  
sealed by the regional Middle Miocene  
Unconformity: a major seal in SE Asia.



- 1 Proto South China Sea final closure: Palawan collision
- 2 Sulawesi micro continent/ Sunda stretched margin collision
- 3 Luzon volcanic arc/ Eurasian collision in Taiwan
- 4 Philippine Mobile Belt/ Palawan microcontinent collision in Mindoro Panay islands
- 5 Philippine Mobile Belt/ Zamboanga microcontinent collision in Mindanao Island
- 6 End of spreading in Sulu Sea and South China Sea

**Active plate convergence measured by GPS across the Sundaland/Philippine Sea plate and Australian plate: The 20-15 Ma tectonic scenario is still active as shown by GPS Geodysea Project.**



# CONCLUSIONS

Similar basin-opening timing (early Oligocene-earliest Miocene) has been documented on both sides of the Sunda microcontinent: The East Andaman Sea into the West and the Western South China Sea.

**Sea floor spreading probably ceased also around 20 Ma (An 06) just before the major shift of seafloor spreading axis in the South China Sea.**

Subduction of a narrow Proto South China Sea and the Palawan collision zone (20Ma to 15 Ma) were probably responsible for this extension axis tectonic swing. Question remains if oceanic crust was produced after 20 Ma in the SCS, as shown by Barckhausen et al. (2014) or just post-spreading volcanism.

During the Neogene up to present time, wrenching and oblique subduction brushes the extended Sunda continental crust both Westward and Eastward: (dextral motion in the Andaman Sea and sinistral motion along the Philippine Mobile Belt).

**Paleogene extension around the Sunda plate was under-estimated.**

**Impacts of Philippine Sea plate and Indian plate on Sunda Plate are the key to understanding the tectonic evolution of the South China Sea.**