Impact of the Surrounding Subduction Zones on the Tectonic Evolution of the South China Sea

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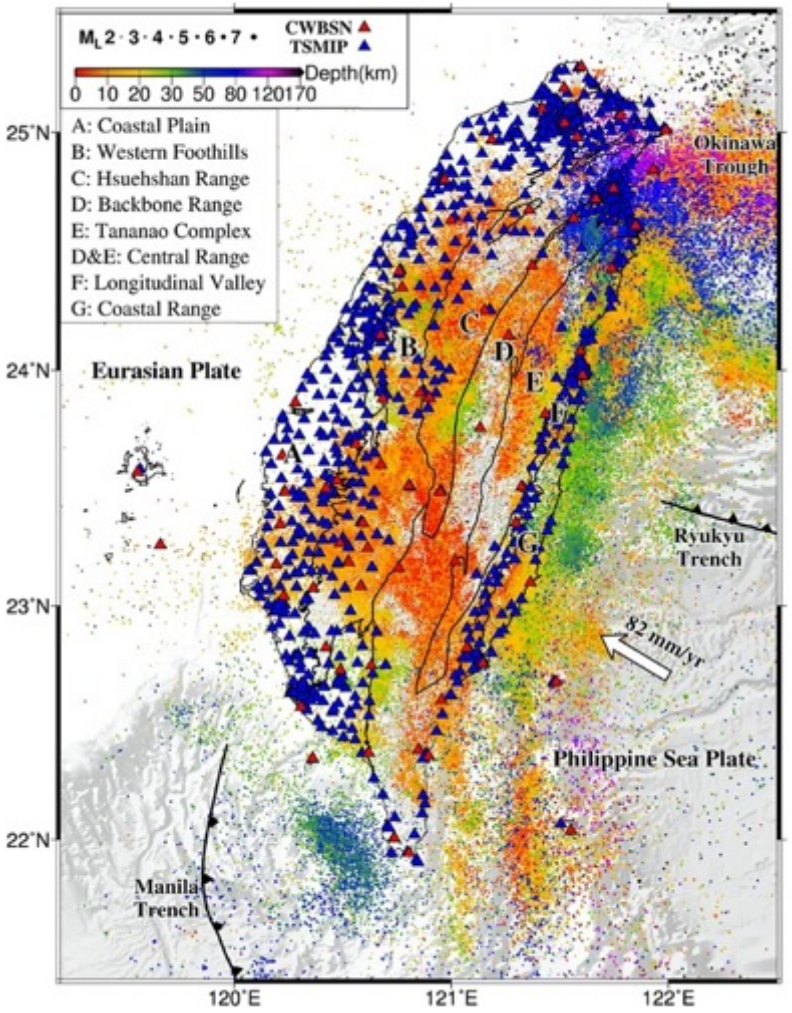
Manuel Pubellier, Matthias Delescluse

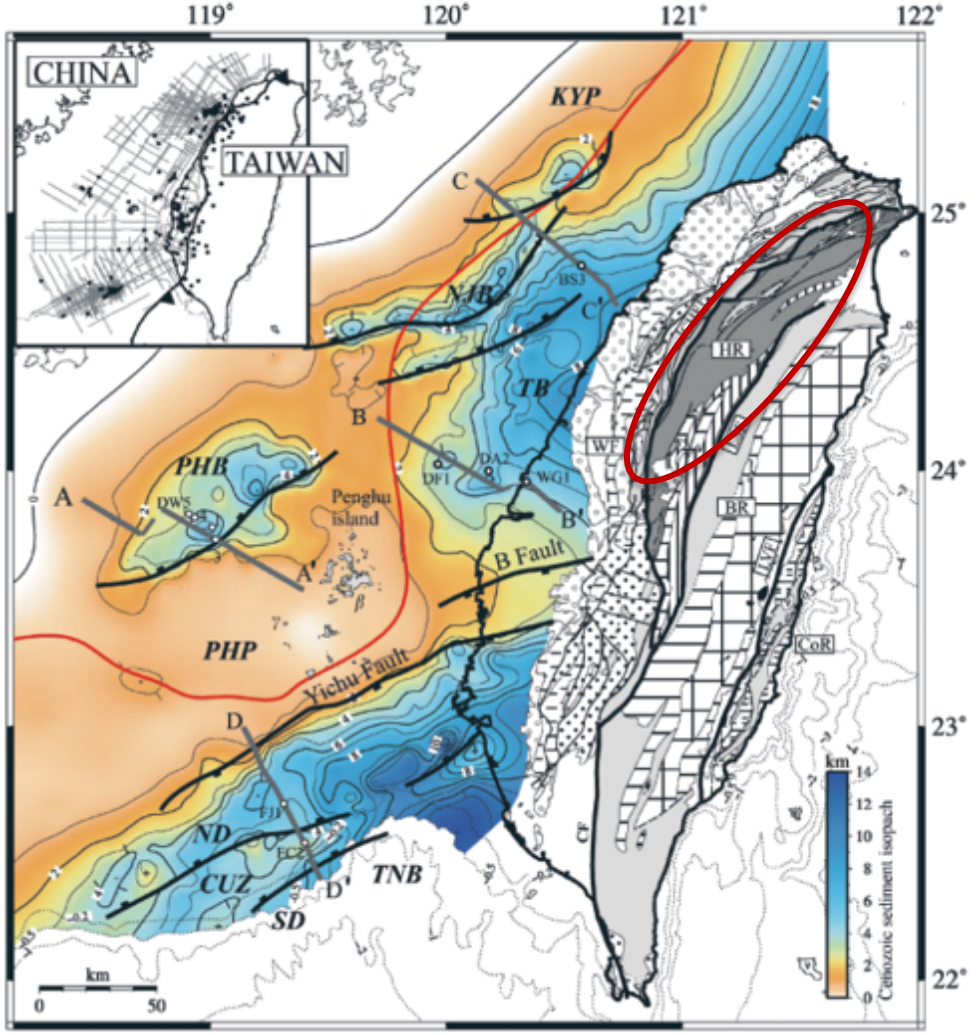
The Natural Laboratory: Taiwan Orogeny

Active subduction-collision zone



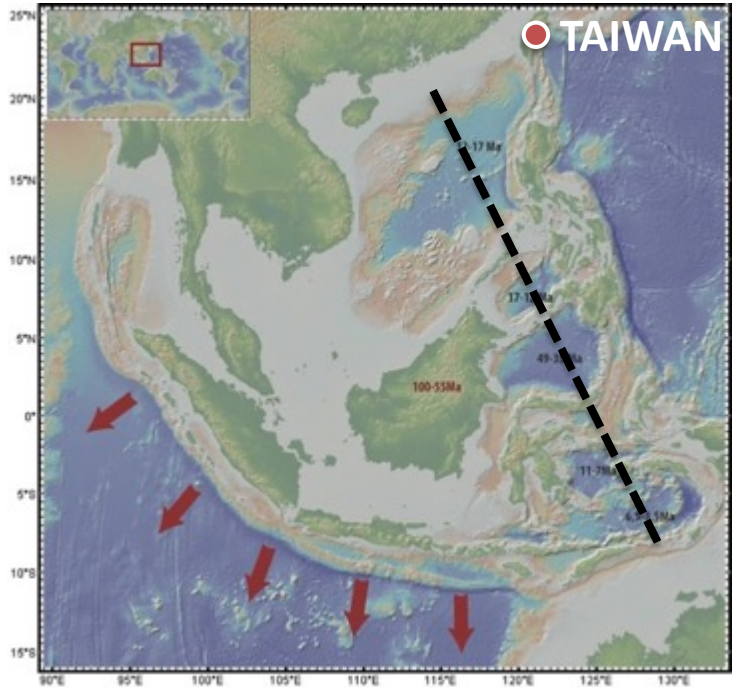
Wu et al. (2018)

Pre-orogeny configuration

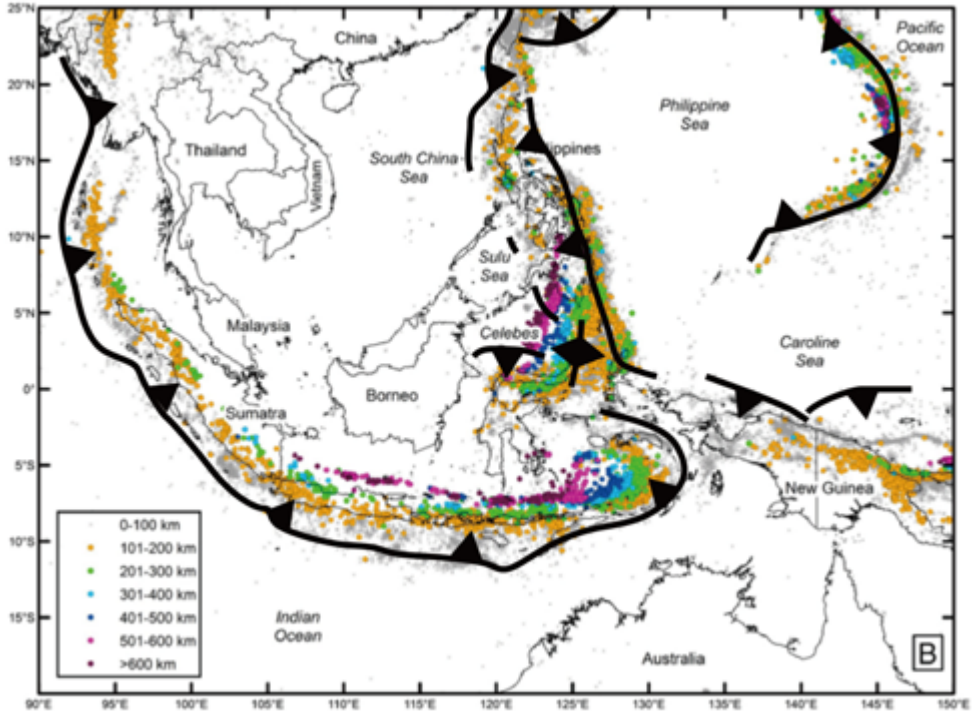


Lin et al. (2003)

Active Tectonic in SE Asia: Example in the SCS

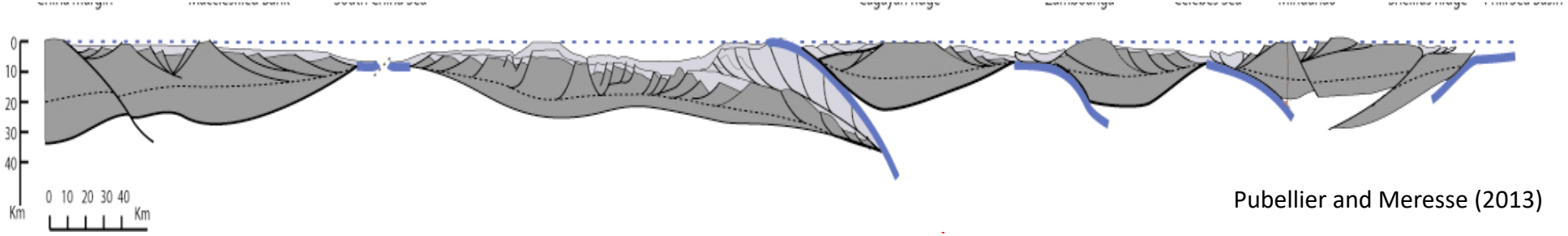


Pubellier and Meresse (2013)



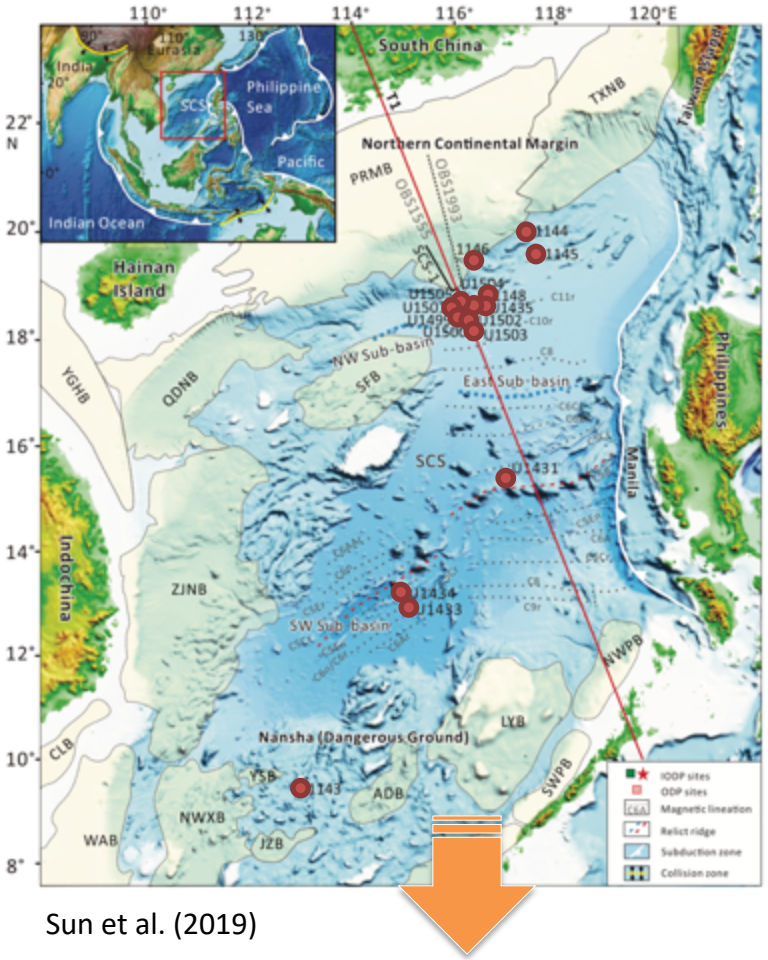
Hall and Spakman (2015)

NW South China Sea (SCS) ← → Proto-SCS (PSCS) → ← SE



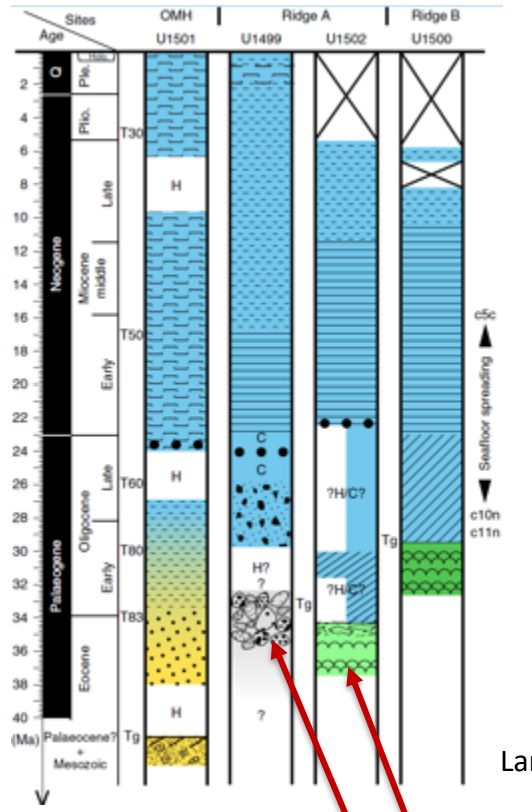
Pubellier and Meresse (2013)

Coeval of Subduction and Rifting in the South China Sea Margin

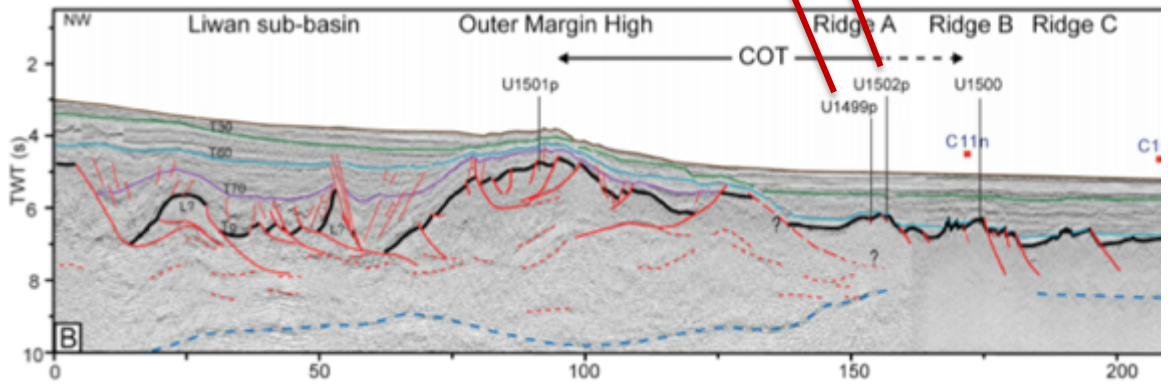


Sun et al. (2019)

6 ODP wells
11 IODP wells

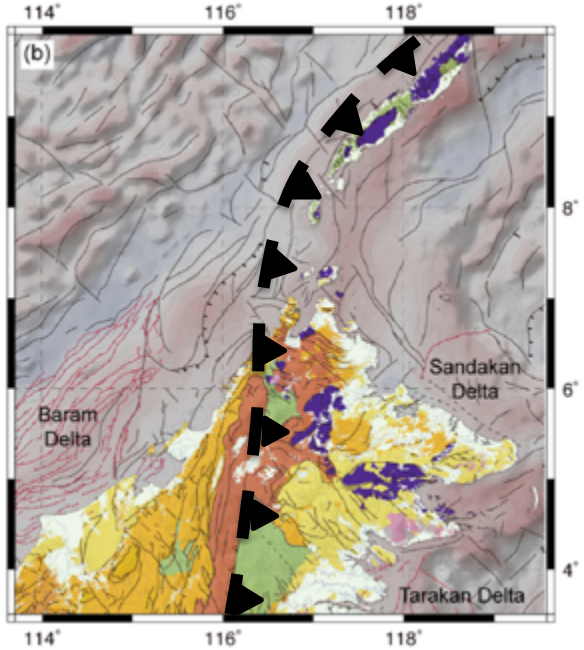


Larsen et al. (2018)



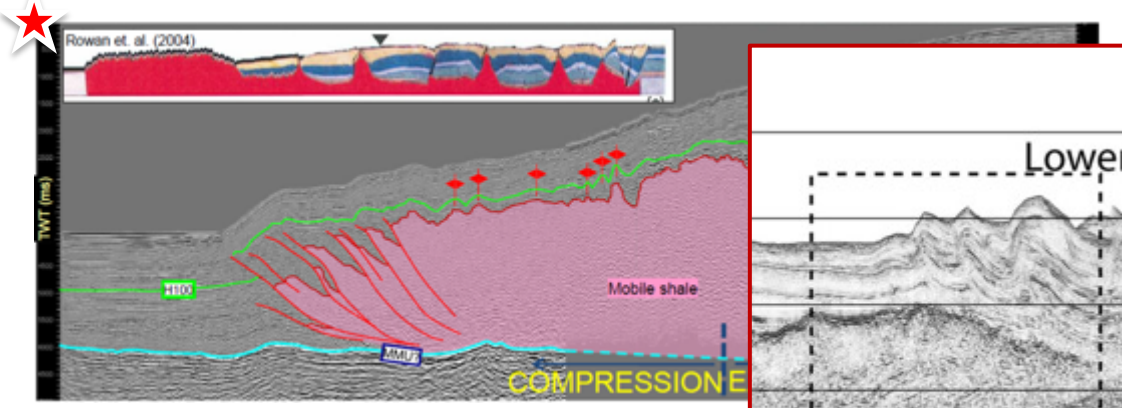
Nirrengarten et al. (2020)

Active Fold-and-thrust Belt Performed on the Seismic Profiles

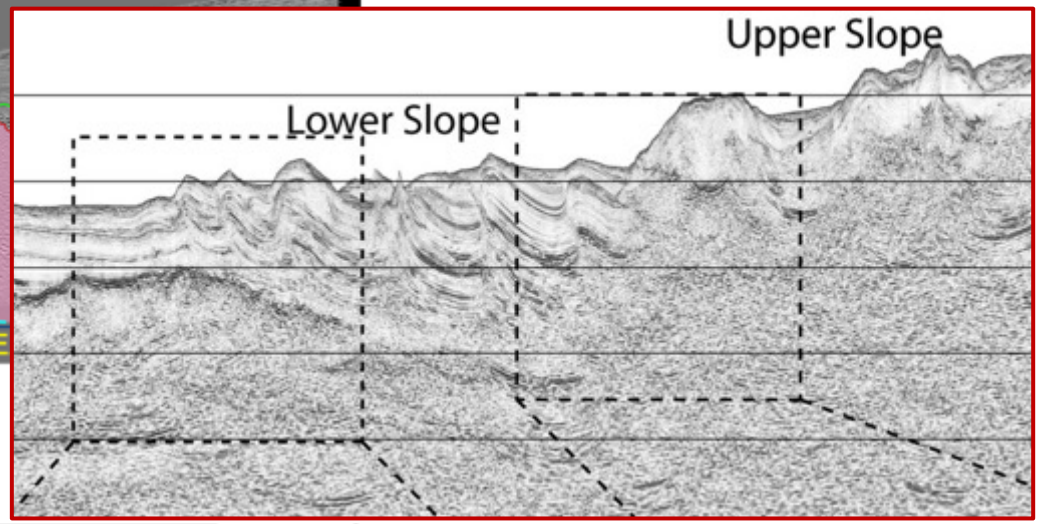


NW

SE

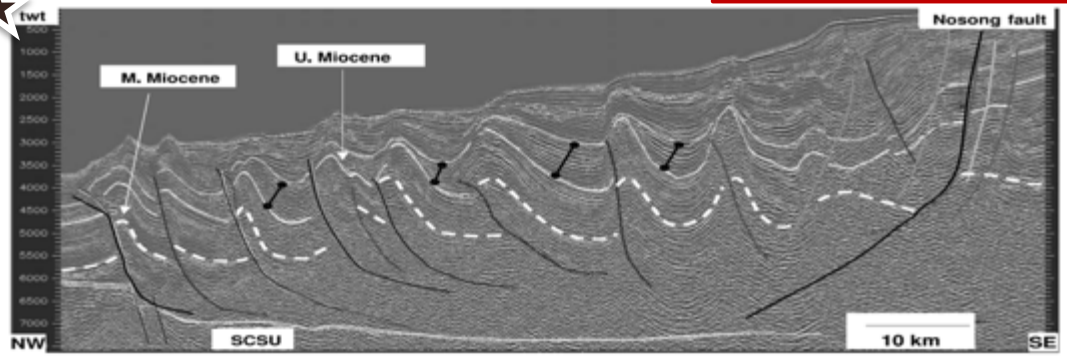


Offshore Taiwan



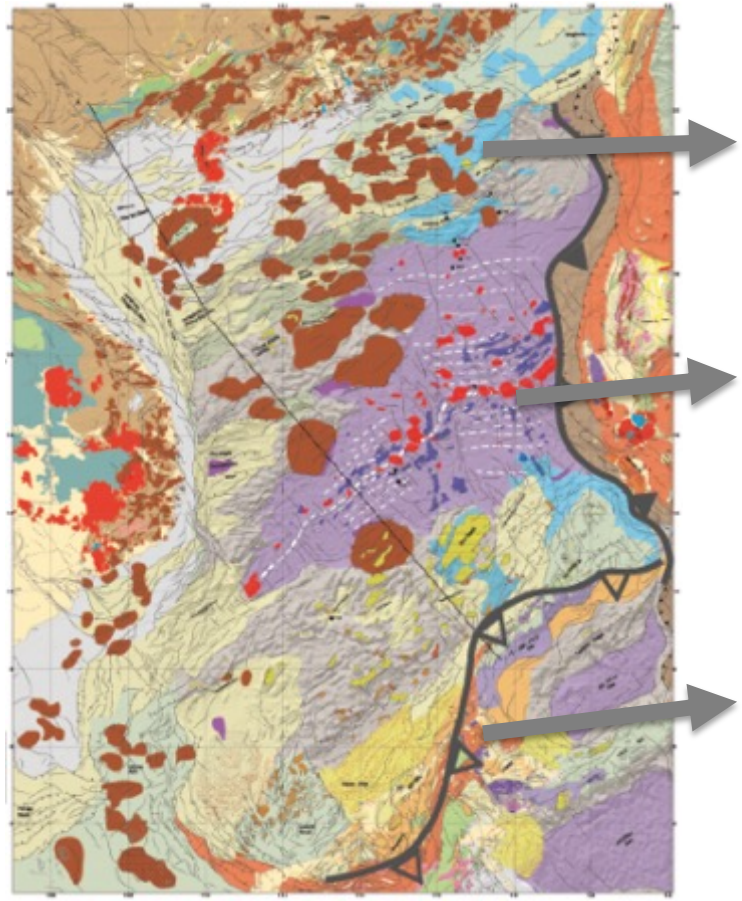
Lester et al. (2013)

NW



Cullen et al. (2010)

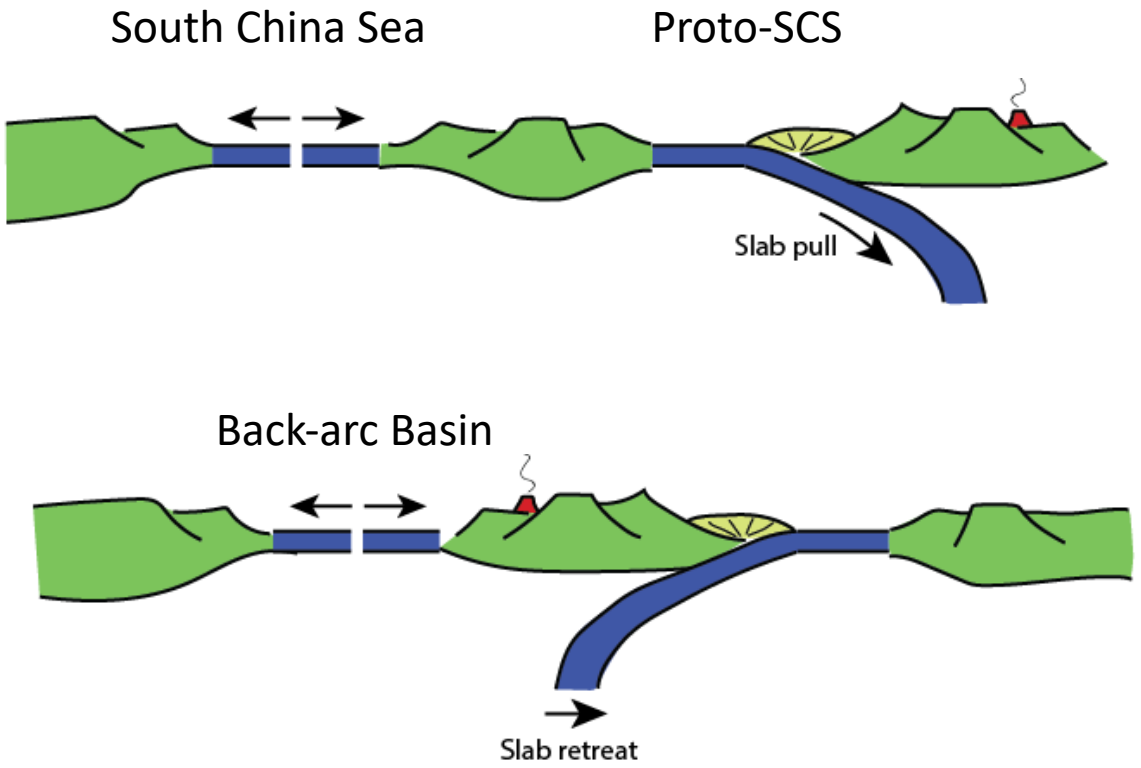
Coeval of Subduction and Rifting in the South China Sea Margin



Rifting:
Eocene

Seafloor Spreading:
32-16 Ma

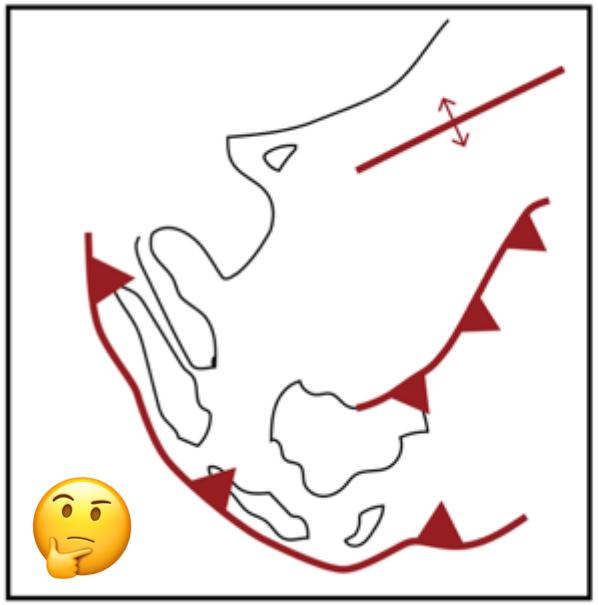
Sarawak Orogeny:
37Ma



Modified from Pubellier et al. (2016)

Geodynamic Settings

PSCS southward subduction



Hall and Spakman (2015); Pubellier et al. (2003)

PSCS northward subduction

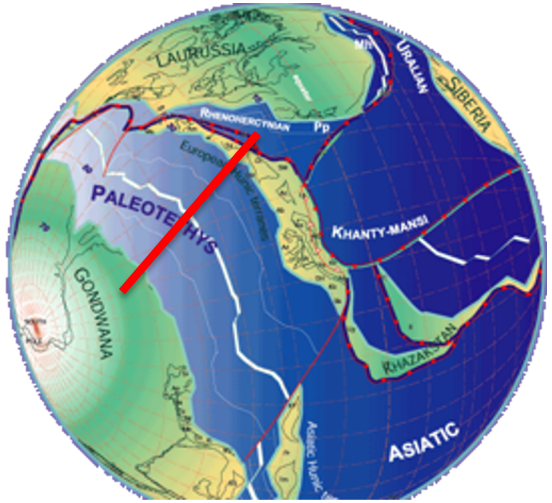
Wu et al. (2016); Li et al. (2020)

Indochina Extrusion

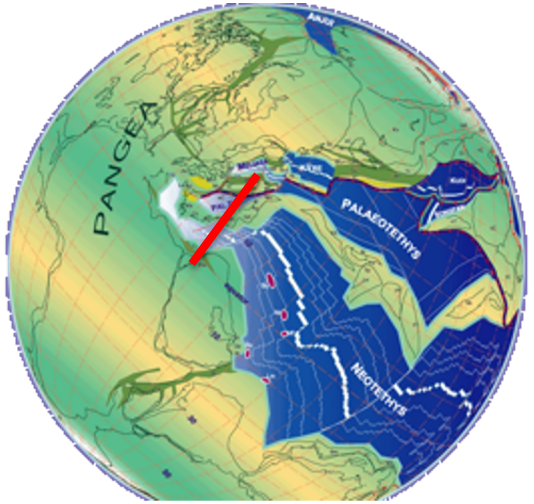
Tapponnier et al. (1982); Briais et al. (1993); Schellart et al. (2019)

Two Types of Basin Opening in Earth History

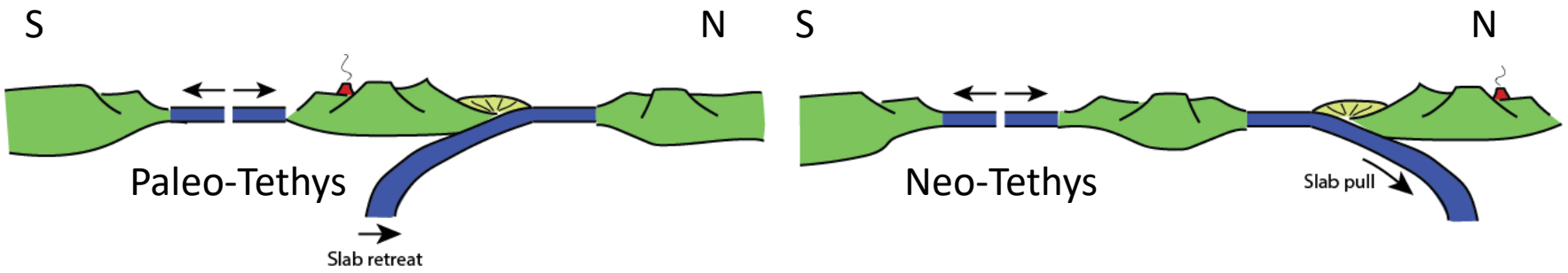
380 Ma (Middle Devonian)



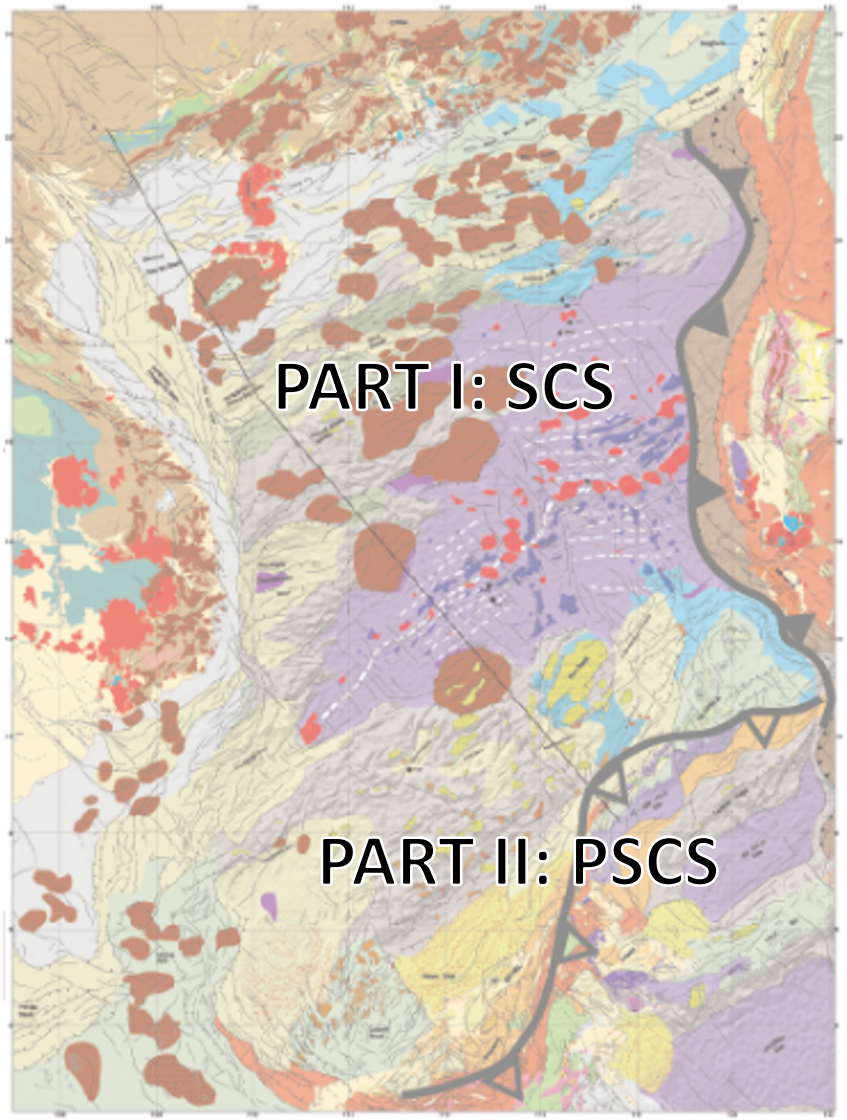
230 Ma (Middle Triassic)



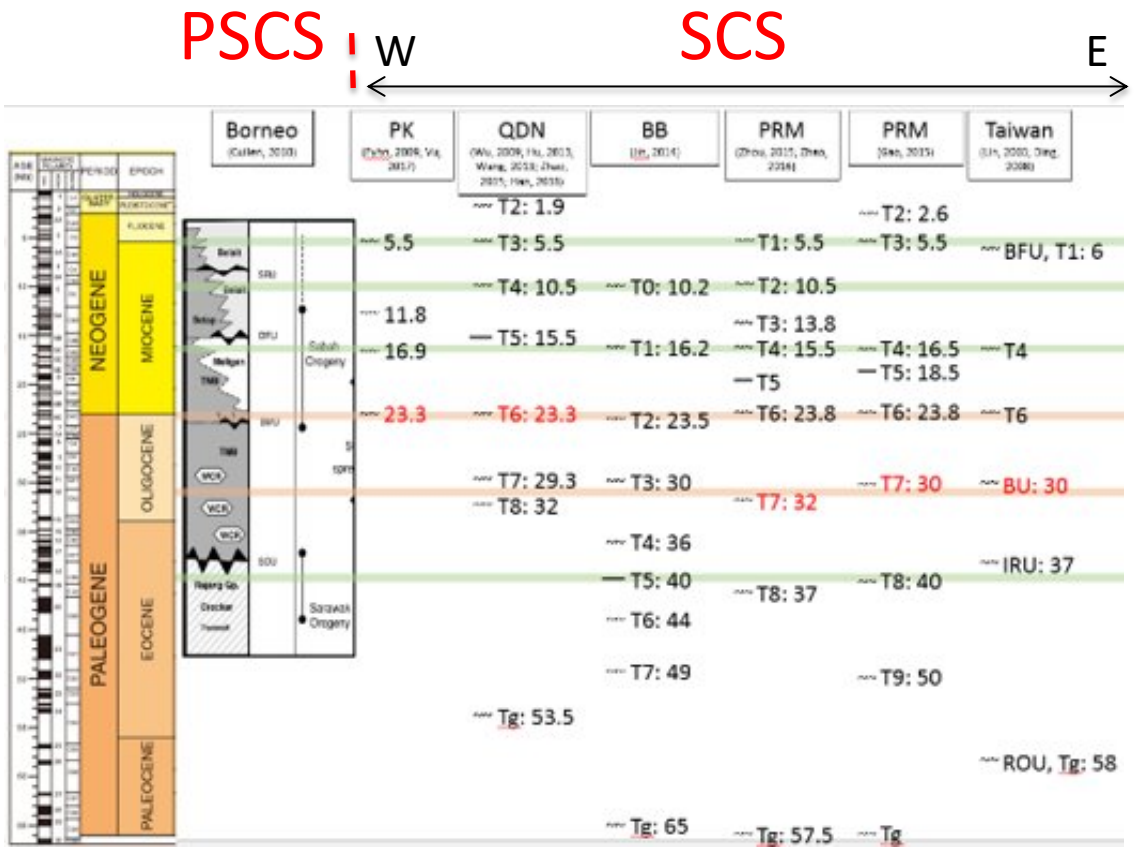
Stampfli and Borel (2002)



Objectives: Stratigraphic Correlation



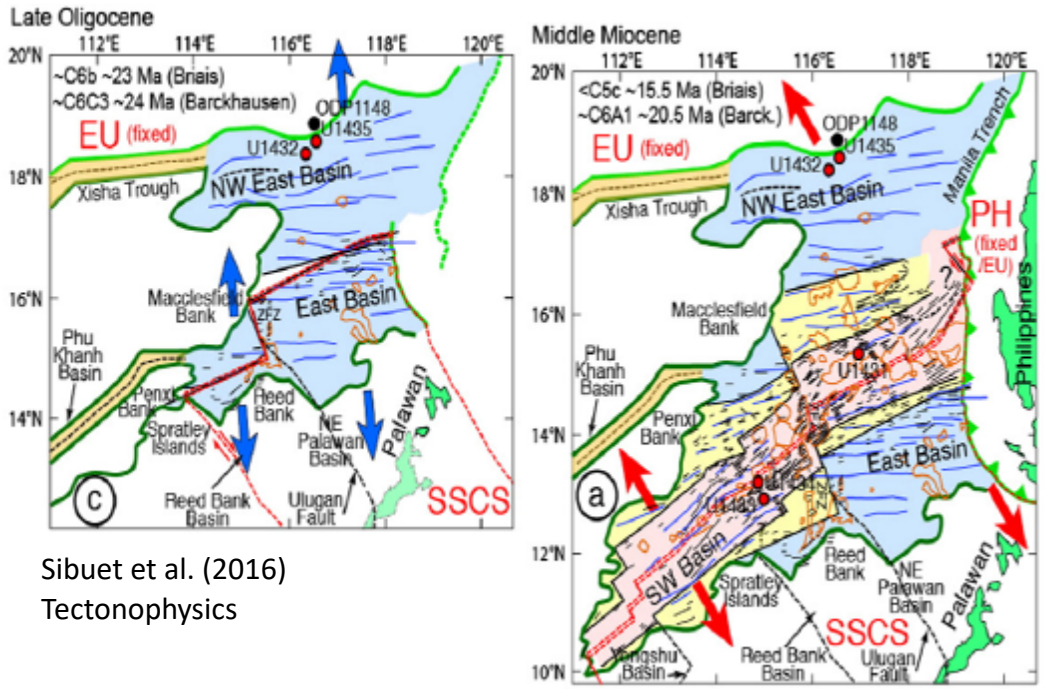
Modified from Pubellier et al. (2016)



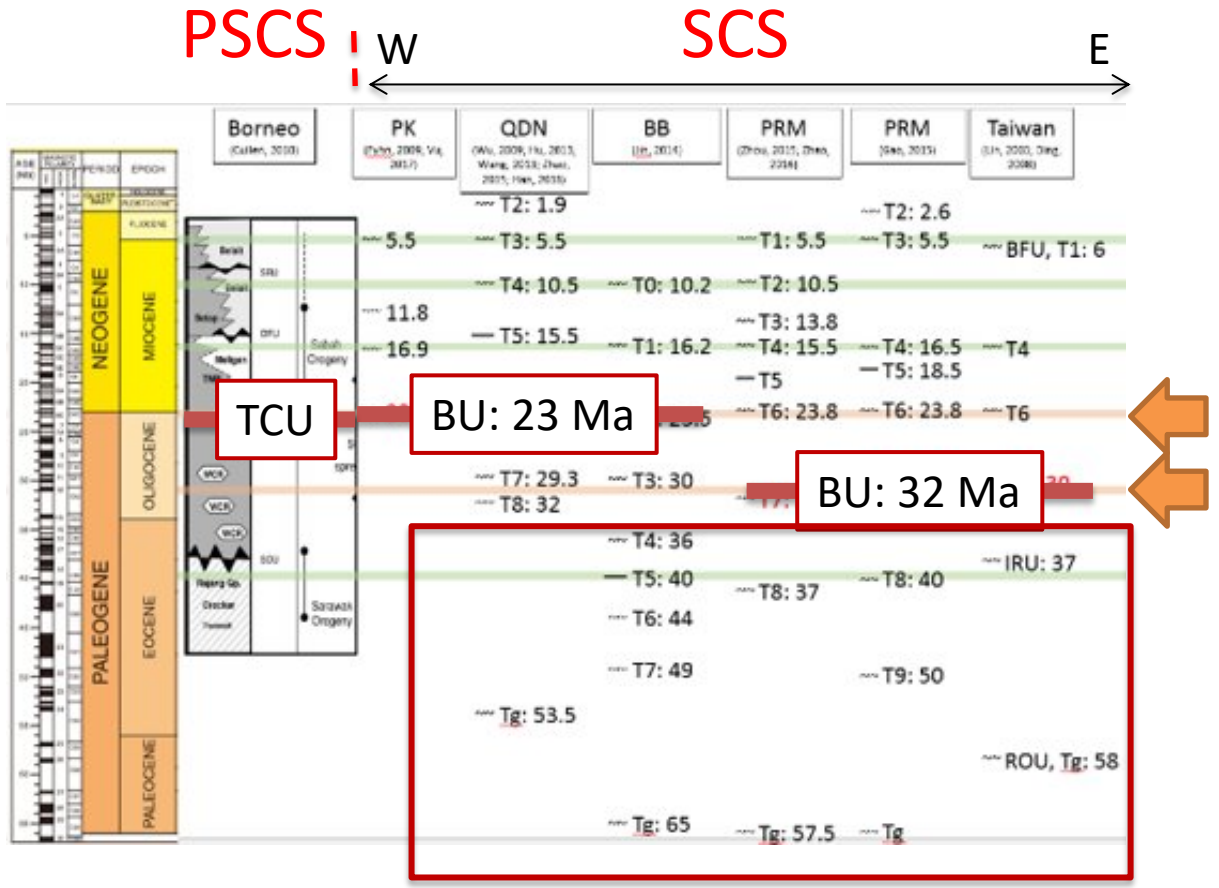
Correlation of structures and time (stratigraphy)

- Part I: Rifting, Breakup, & End of Spreading
- Part II: Subduction & Collision

Tectono-stratigraphy through the Rifting and the Seafloor Spreading



Sibuet et al. (2016)
Tectonophysics

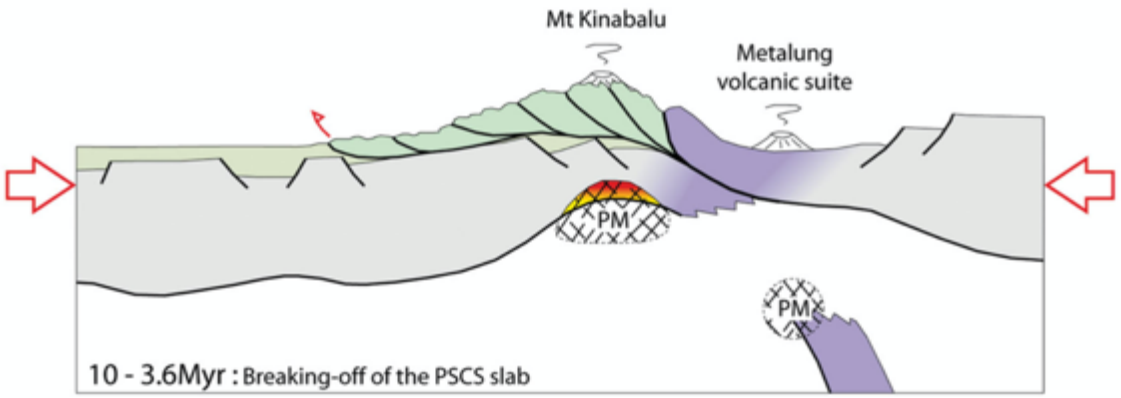


Breakup process?

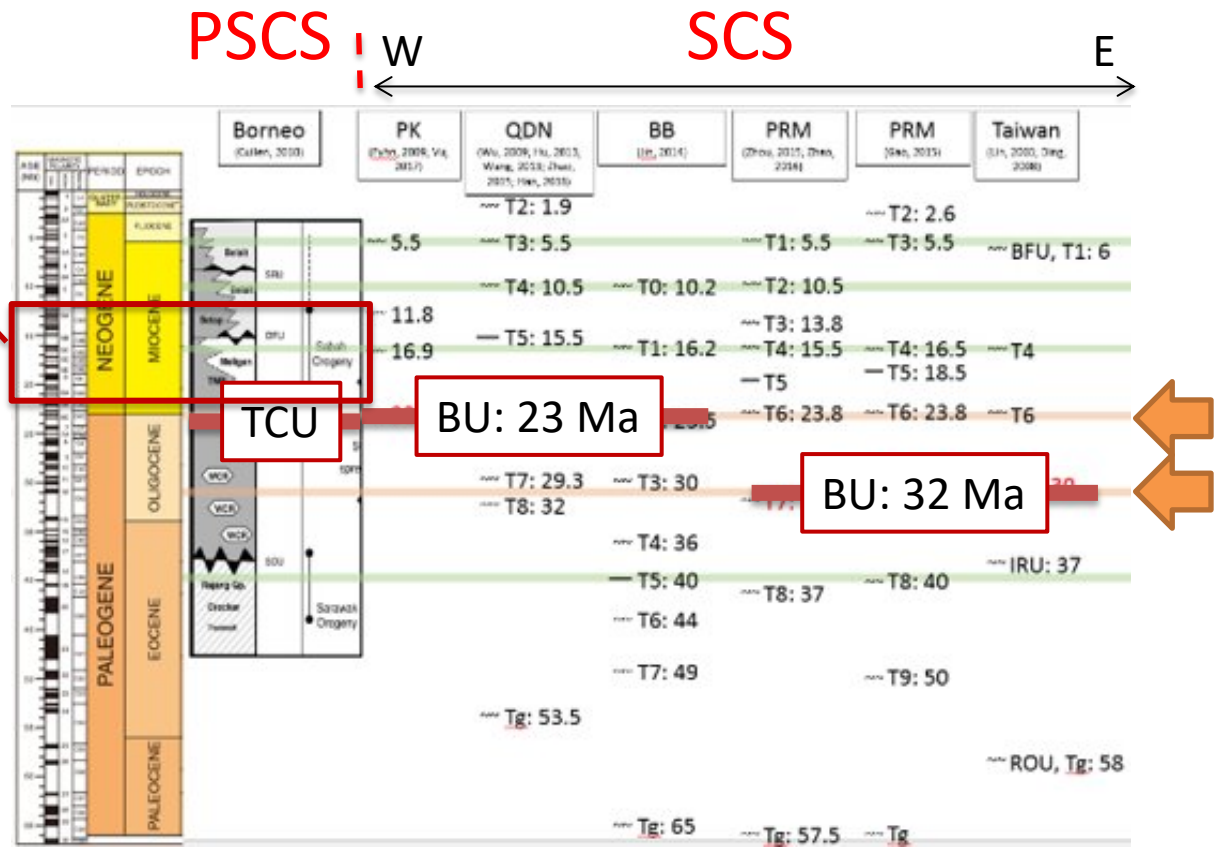
Rifting process?

Tectono-stratigraphy on the Coeval Convergent Zone

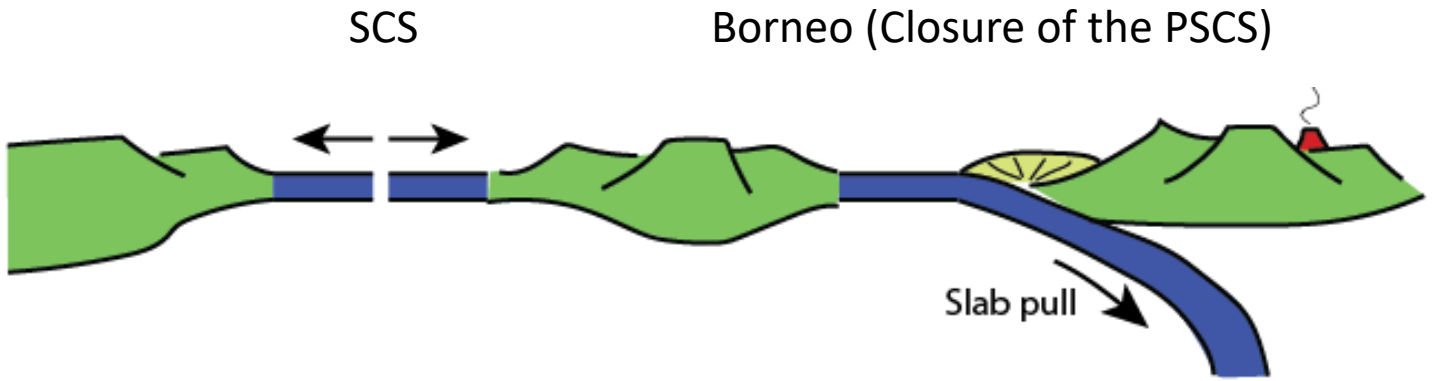
When is the termination of Sabah Orogeny?



Sapin et al. (2013)



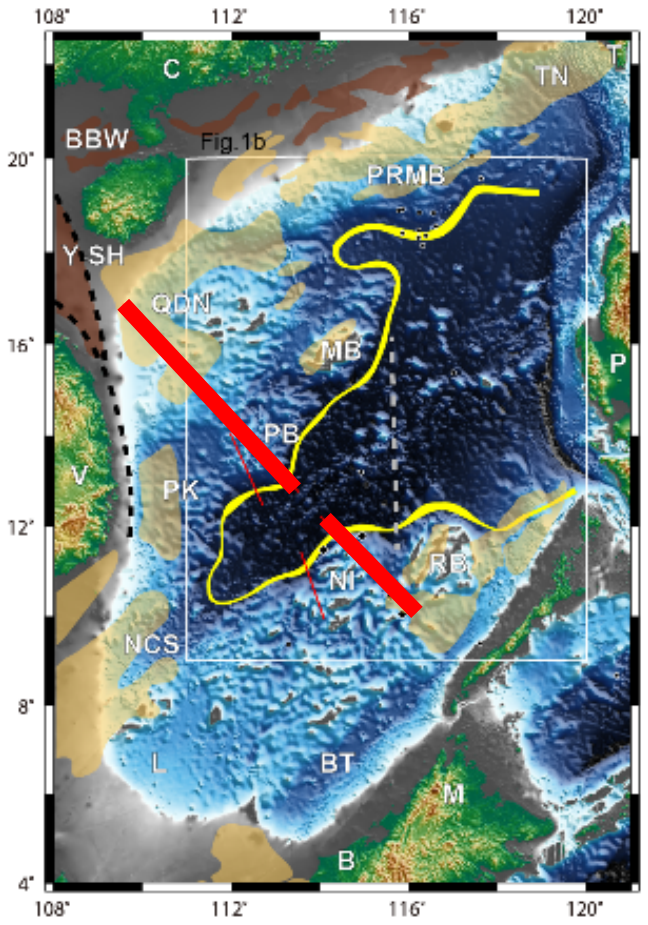
Is There a Genetic Link between the Subduction of the PSCS and the Opening of the SCS?



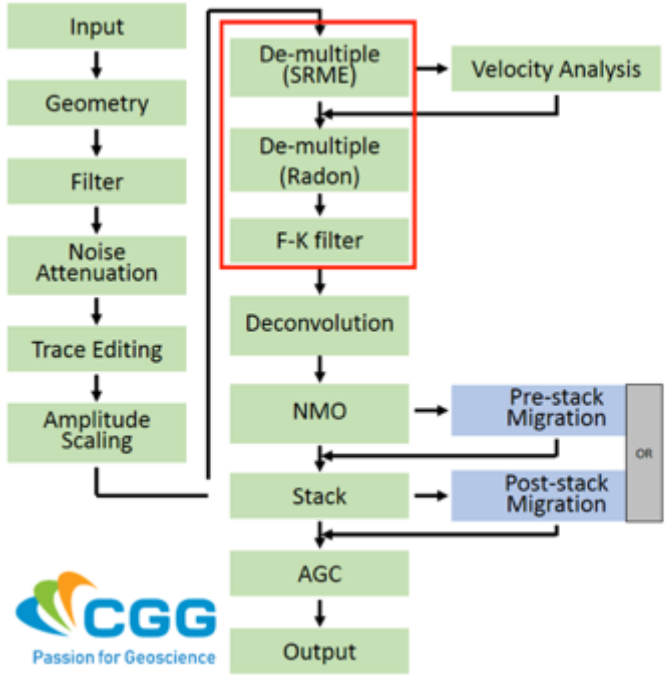
- Rifting,
- Breakup
- End of spreading

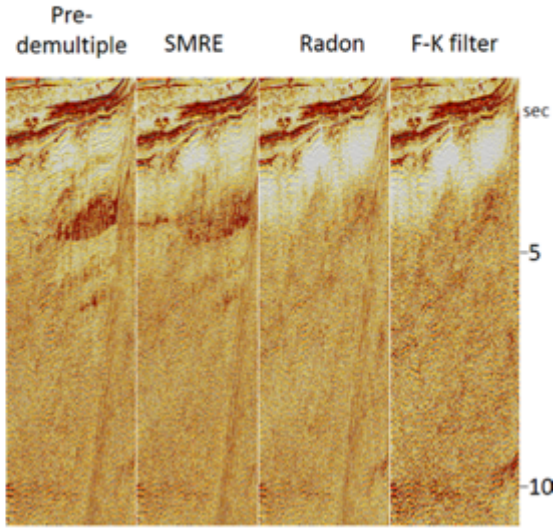
- Subduction
- Collision
- Slab detachment

PART 1 – South China Sea: Seismic Data

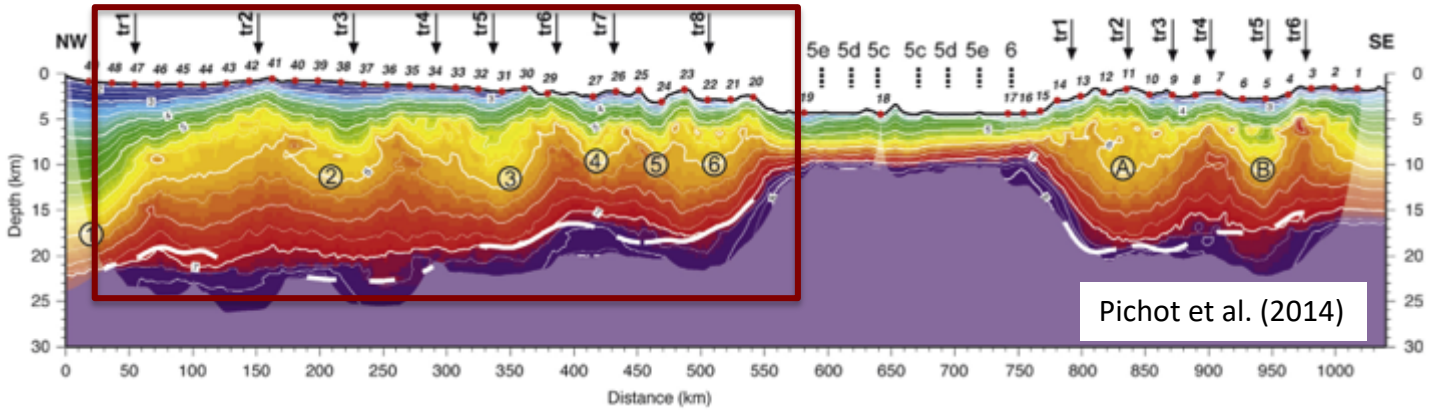


MCS processing

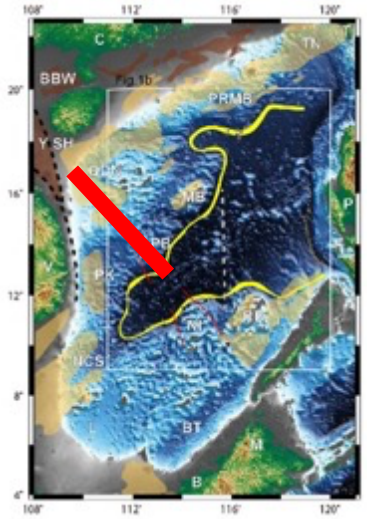




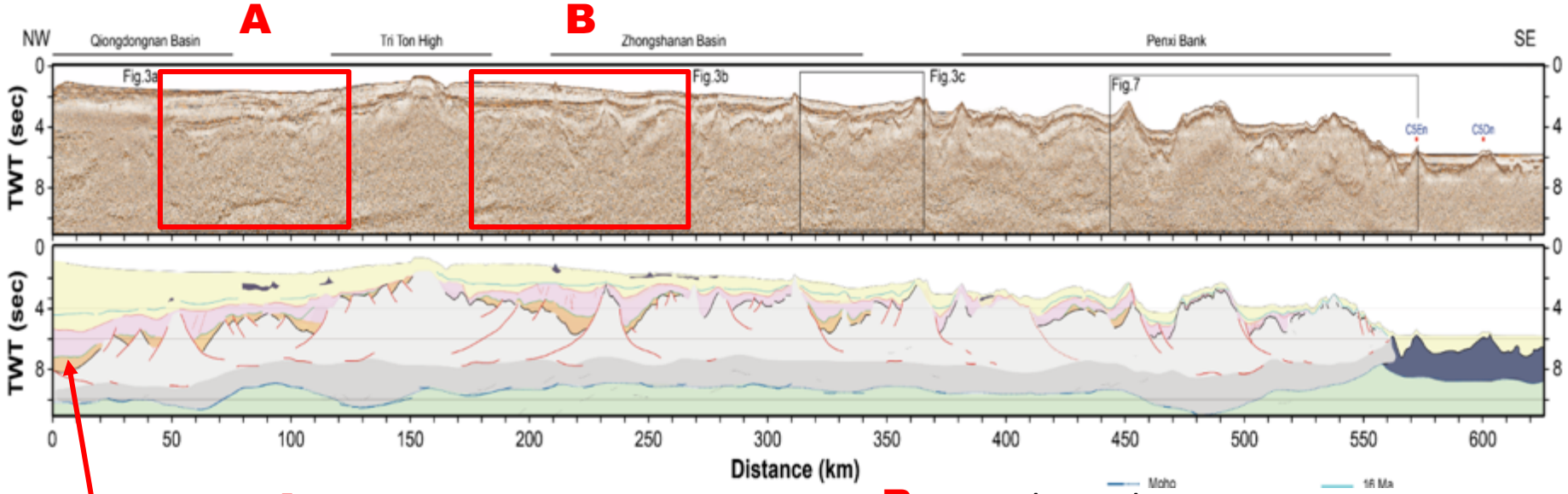
OBS velocity structure

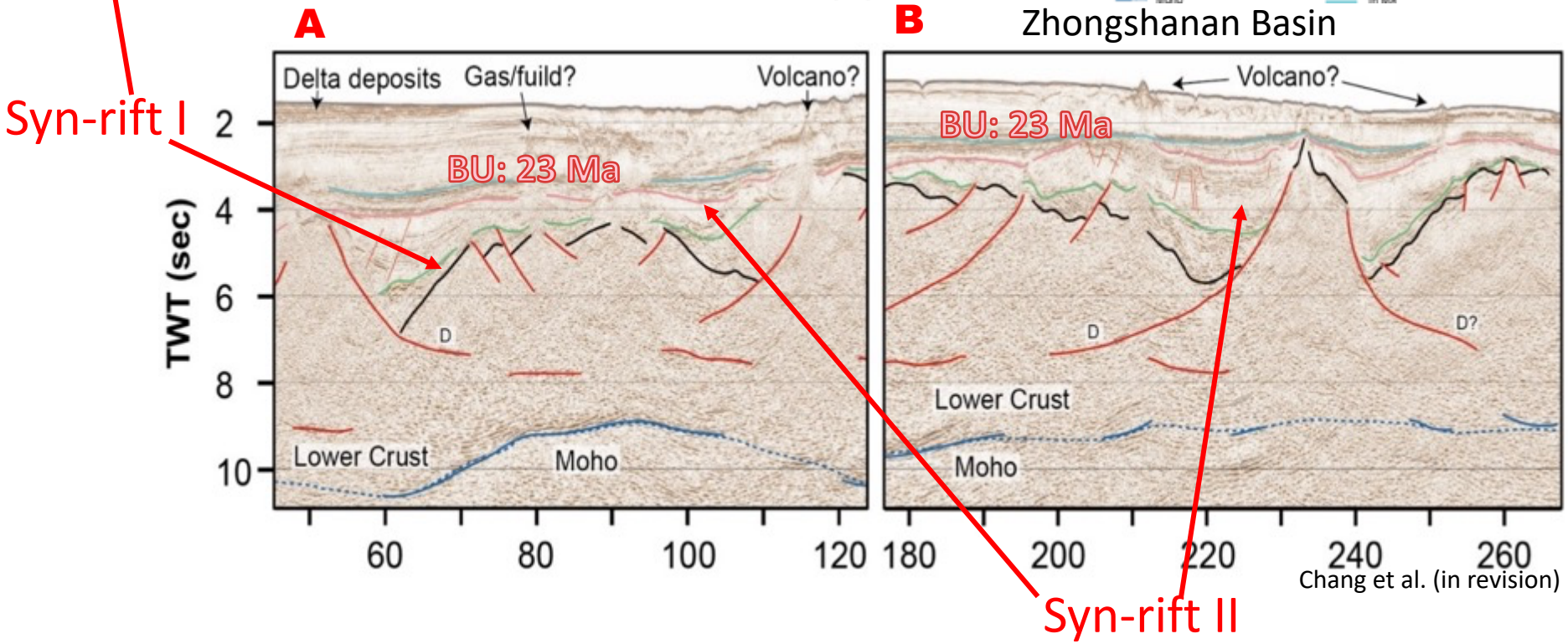


East Vietnam Margin in the South China Sea



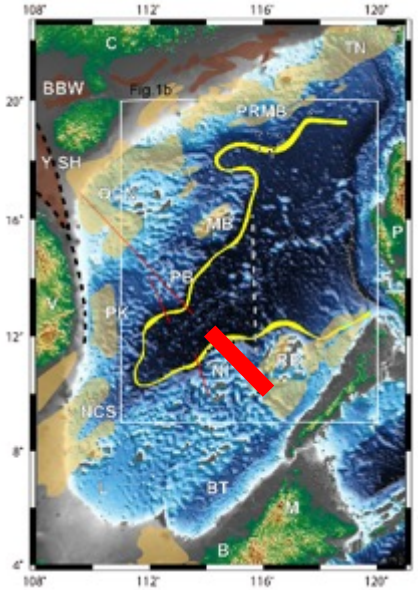
3 steps

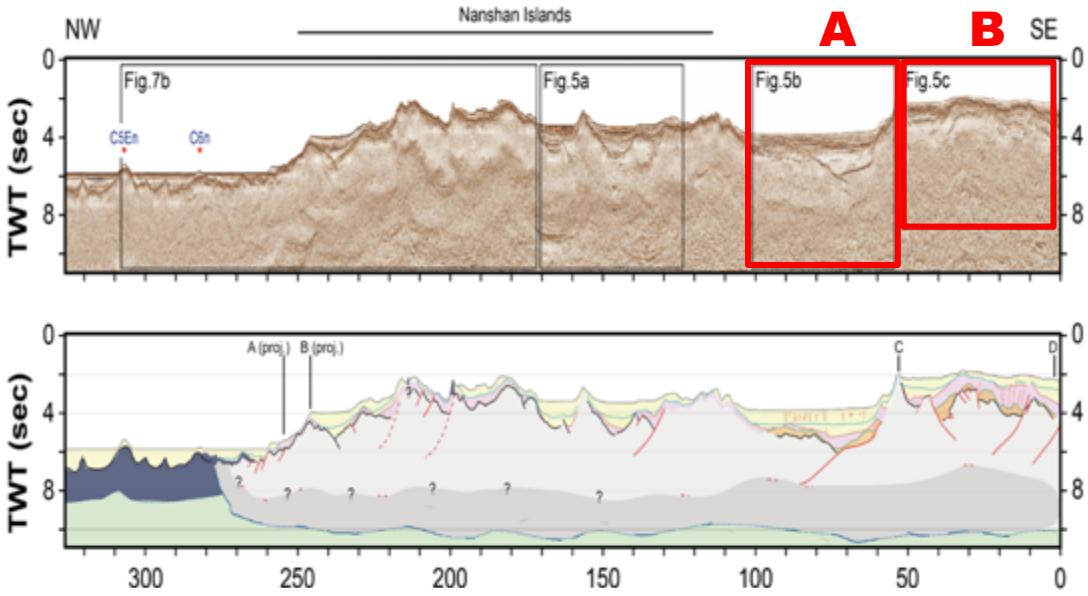


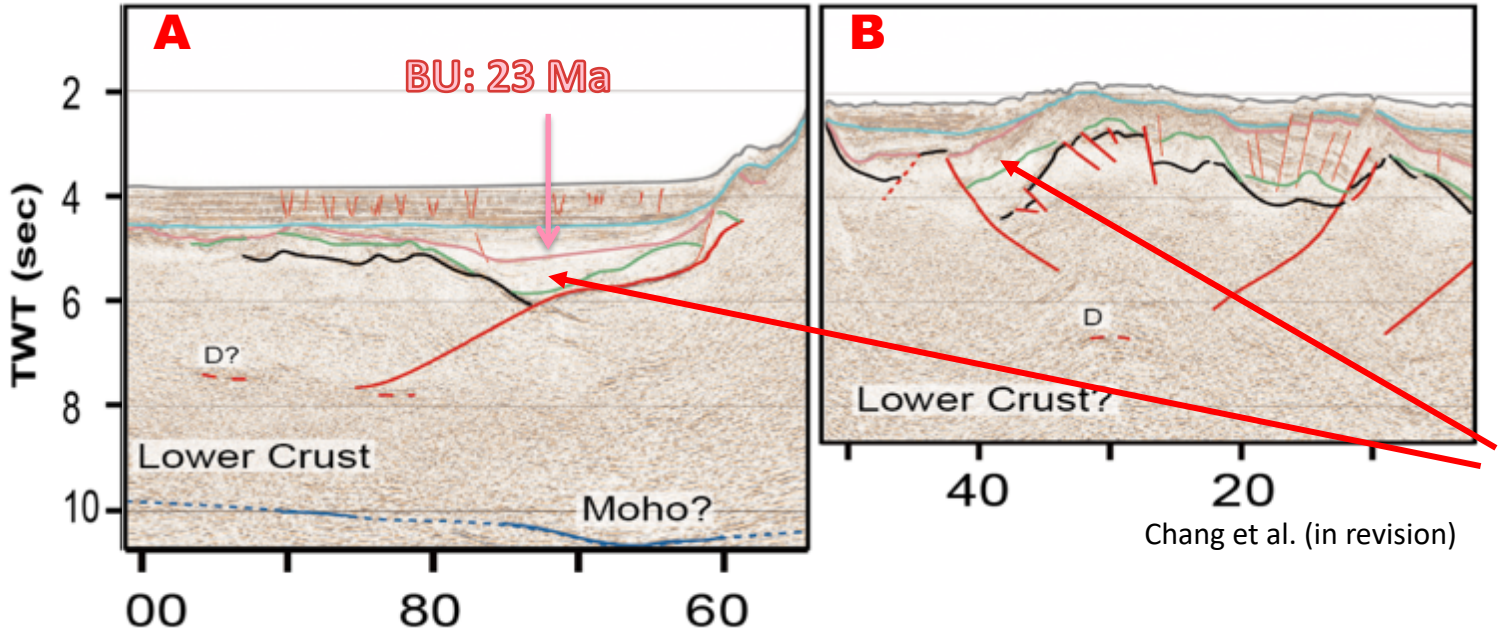


Chang et al. (in revision)

NW Borneo Margin in the South China Sea

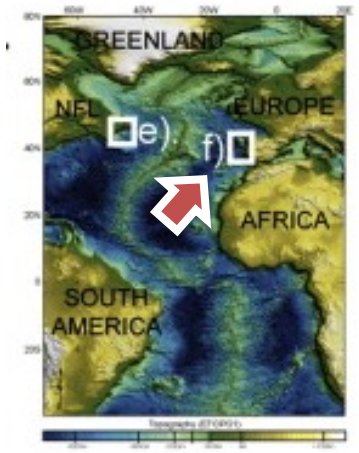


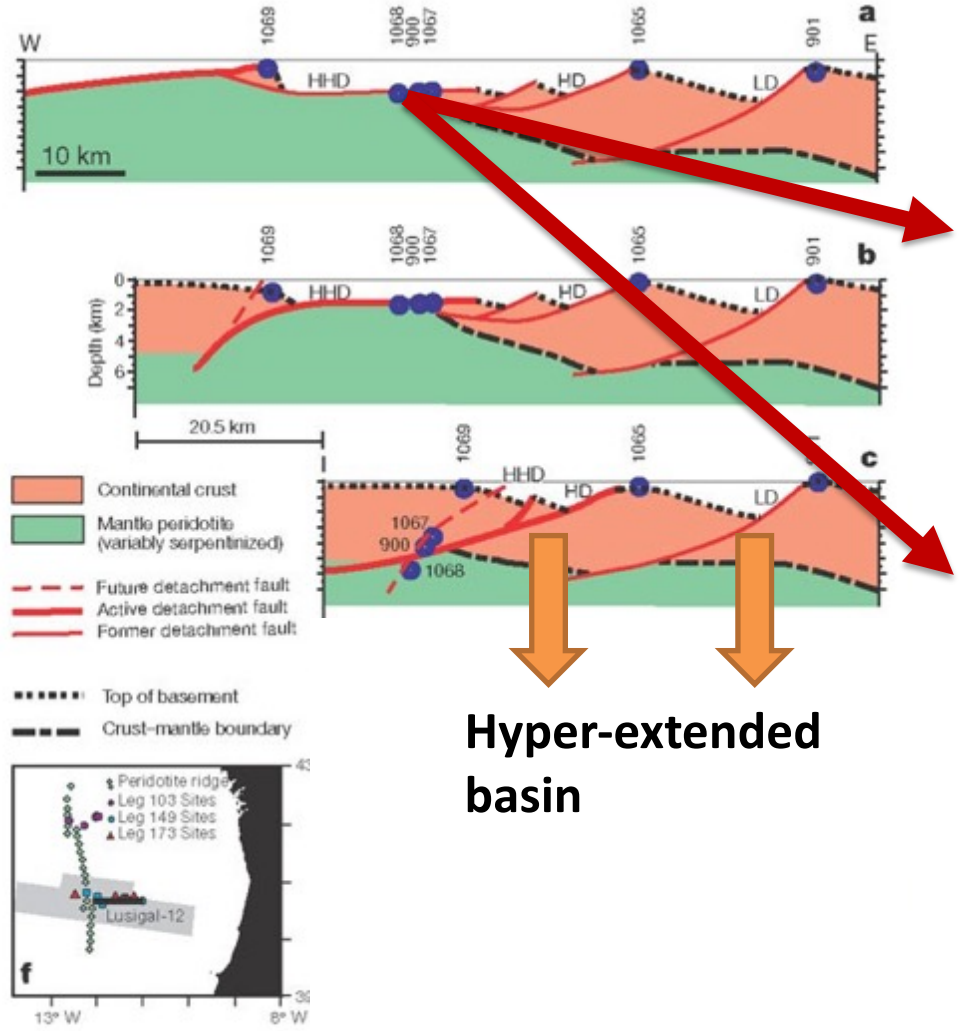




Chang et al. (in revision)

Detachment Fault Found in the Iberia Margin

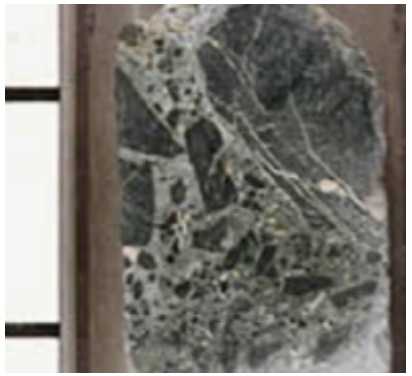




Hyper-extended basin

Whitmarsh et al. (2001)

900A-81R-2

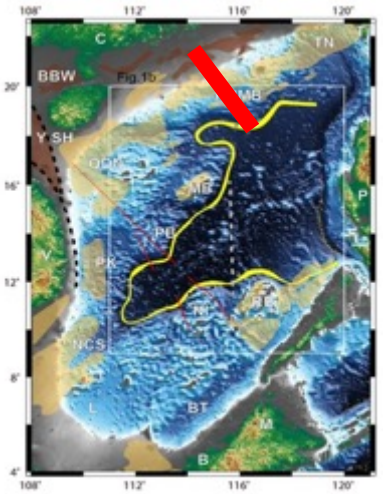


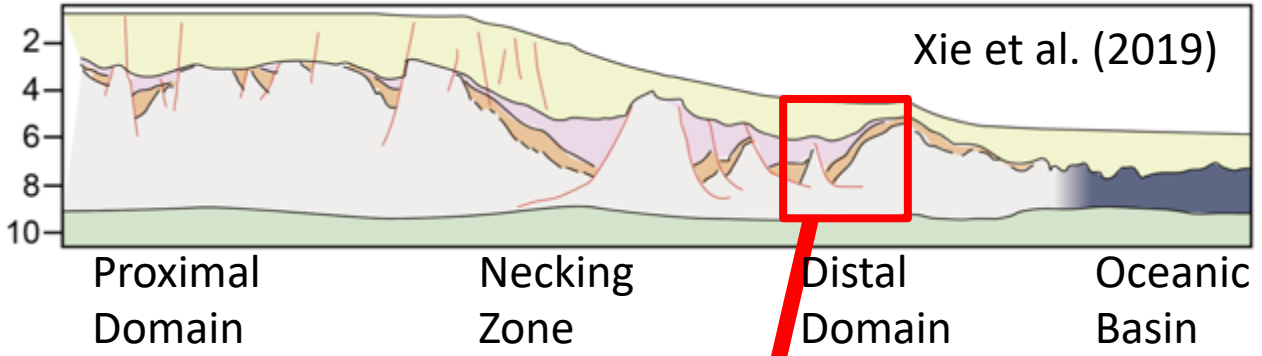
Brecciated zone with fine-grained, angular, mafic clasts.

900A-82R-5

Coarse-grained flasered gabbro. Dark areas represent strained pyroxene that has been replaced by amphibole.

The Northern Section (SE China Margin) in the SCS





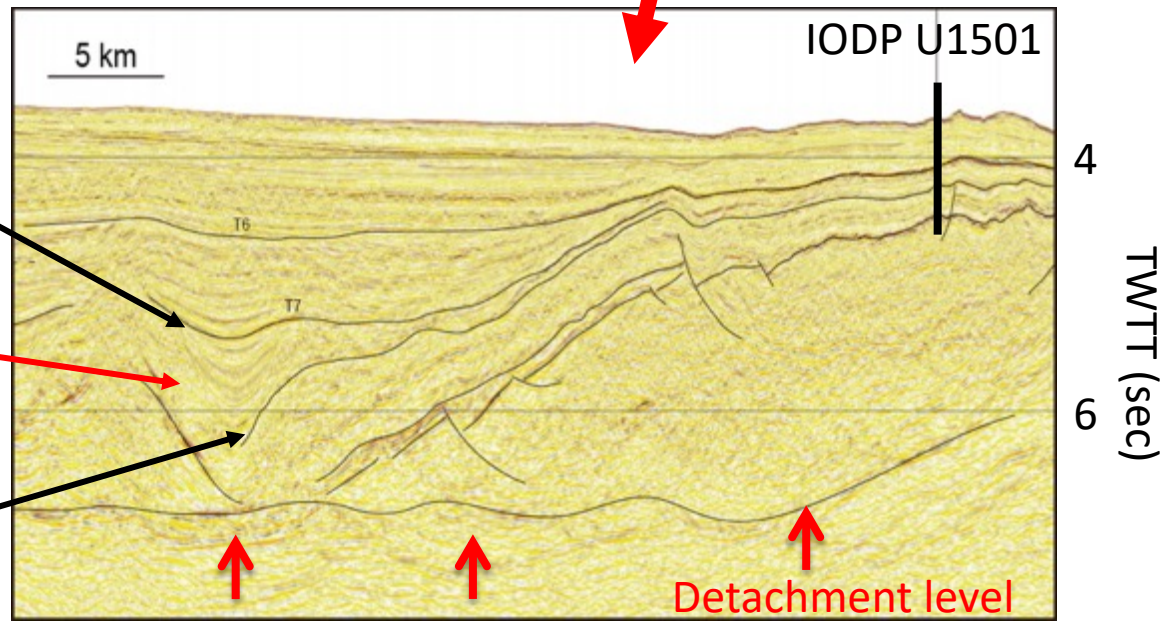
3 steps

Breakup U.: 32 Ma

Upper Syn-rift: Syn-rift II

Intra-Rift U.: 36Ma

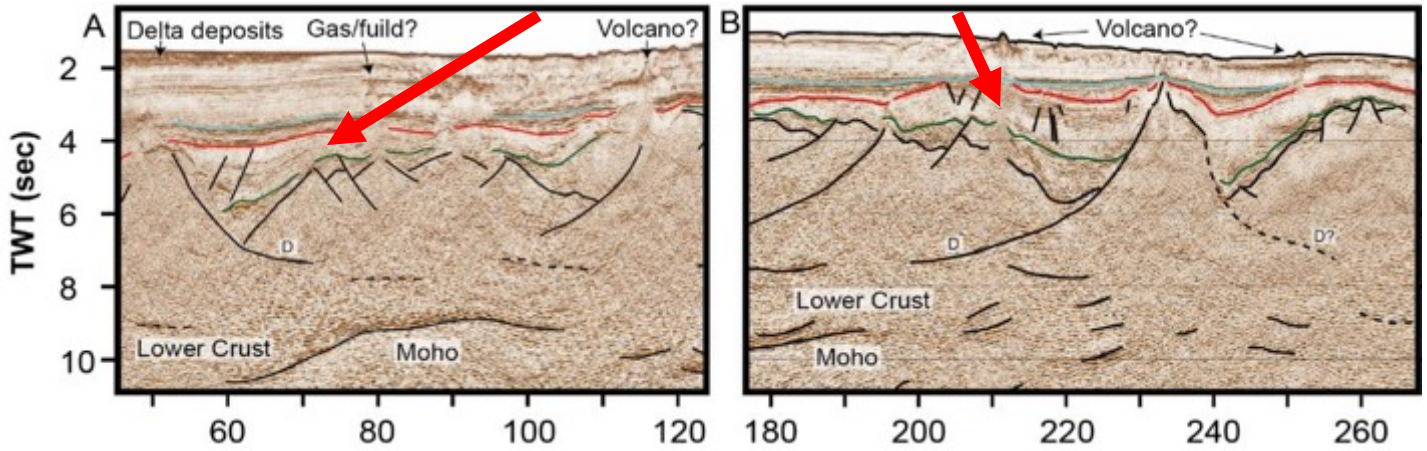
(Xie et al., 2019)



Modified from Nirrengarten et al. (2020)

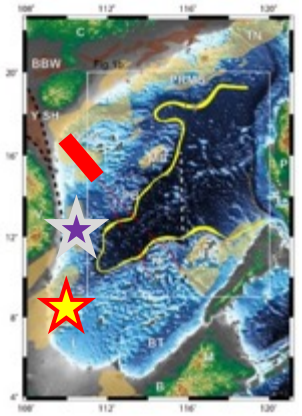
Crust Thinning at the Tip of Propagator but also Elsewhere

Syn-rift II (Late Oligocene)

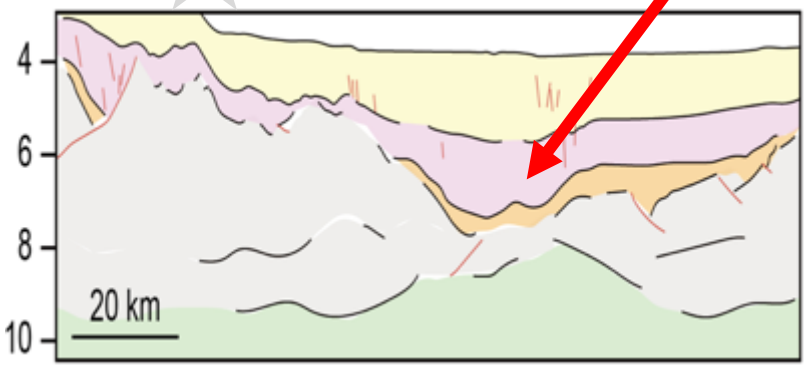


Chang et al. (in revision)

Syn-rift II
(Early Miocene)

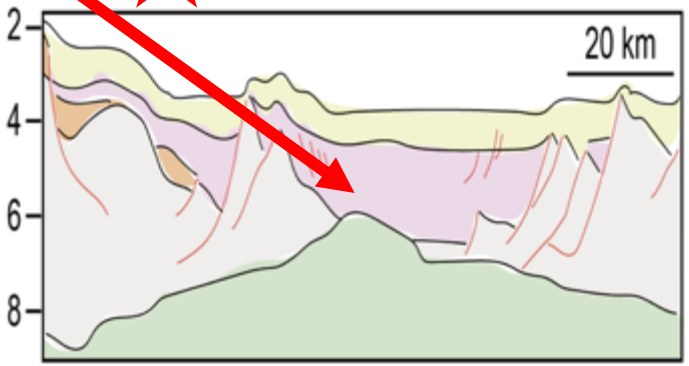


PK Basin



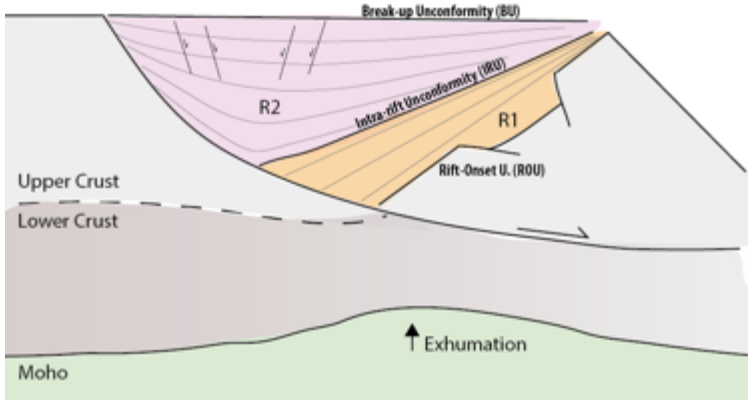
Savva et al. (2013)

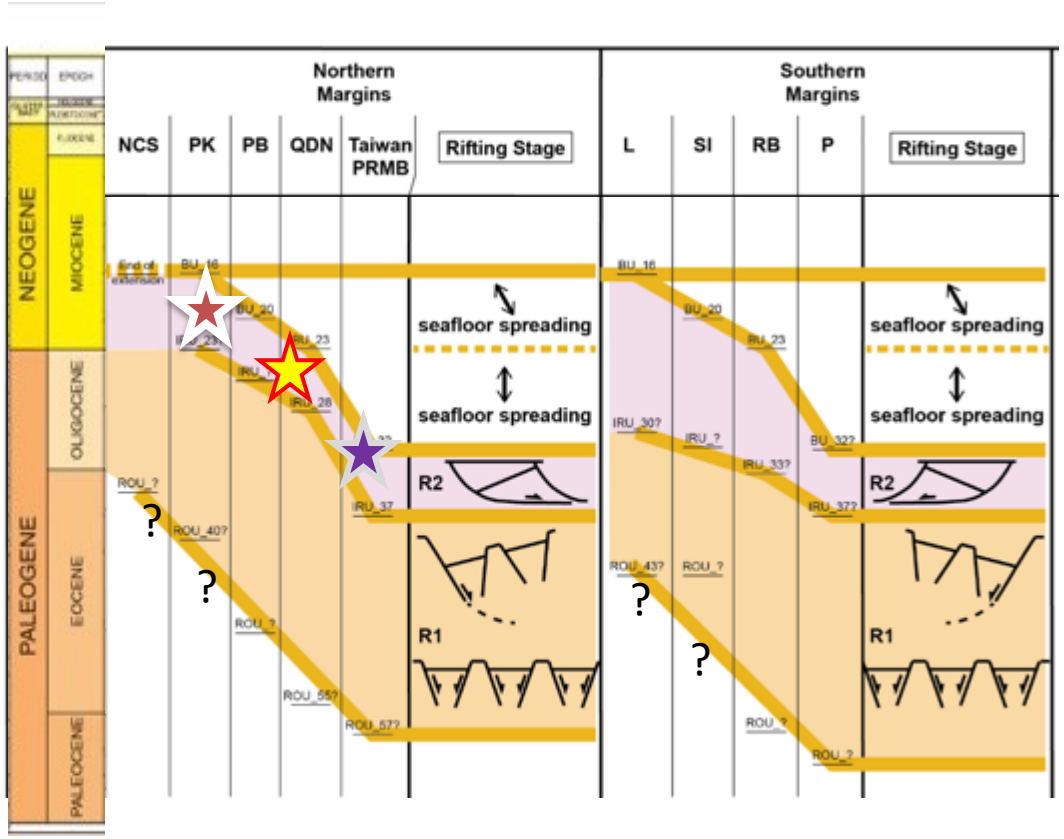
NCS Basin

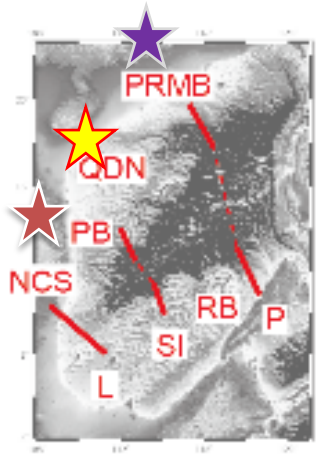


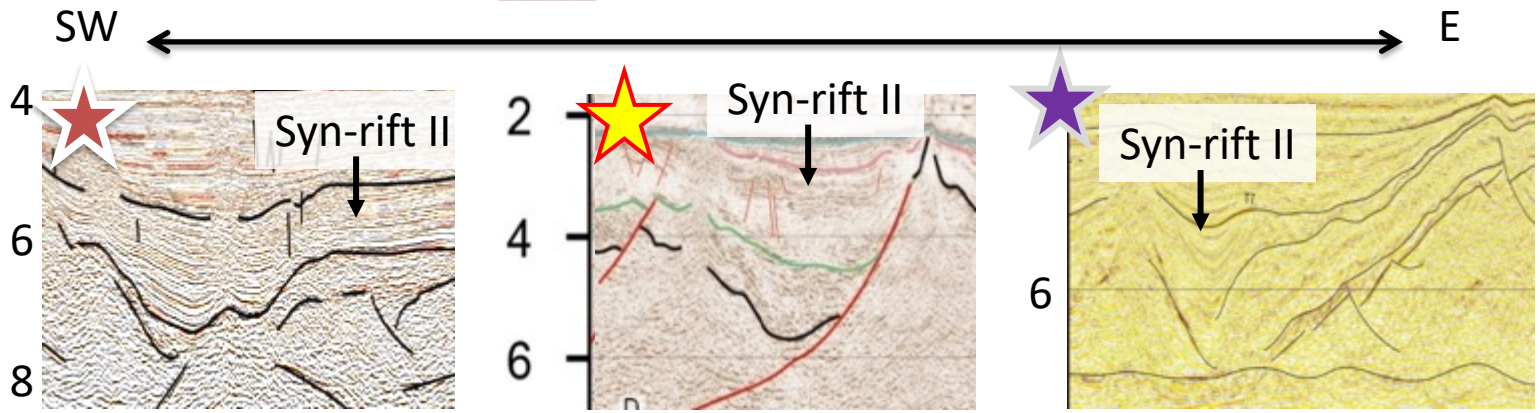
Clerc et al. (2018)

Two Rifting Stages with Ages Diachronism along the SCS

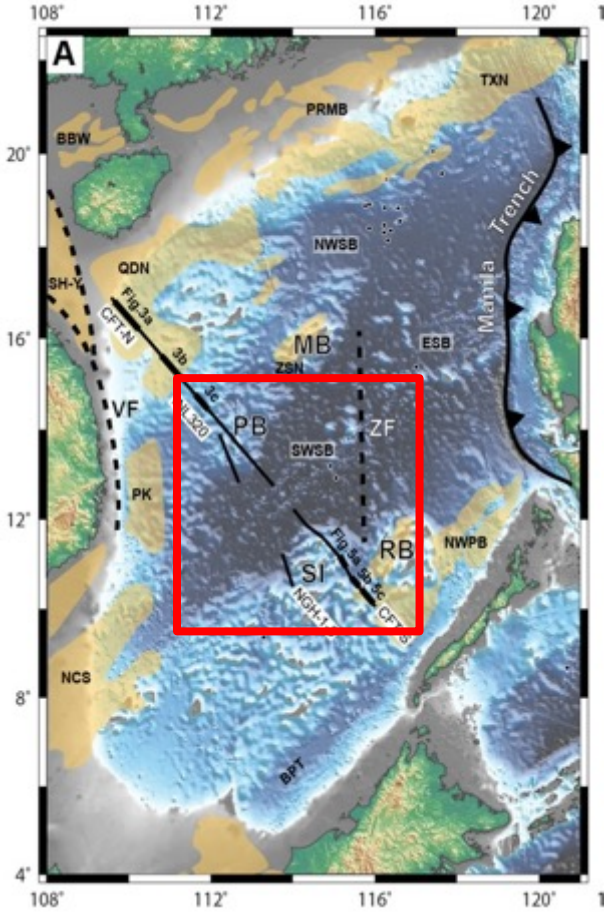




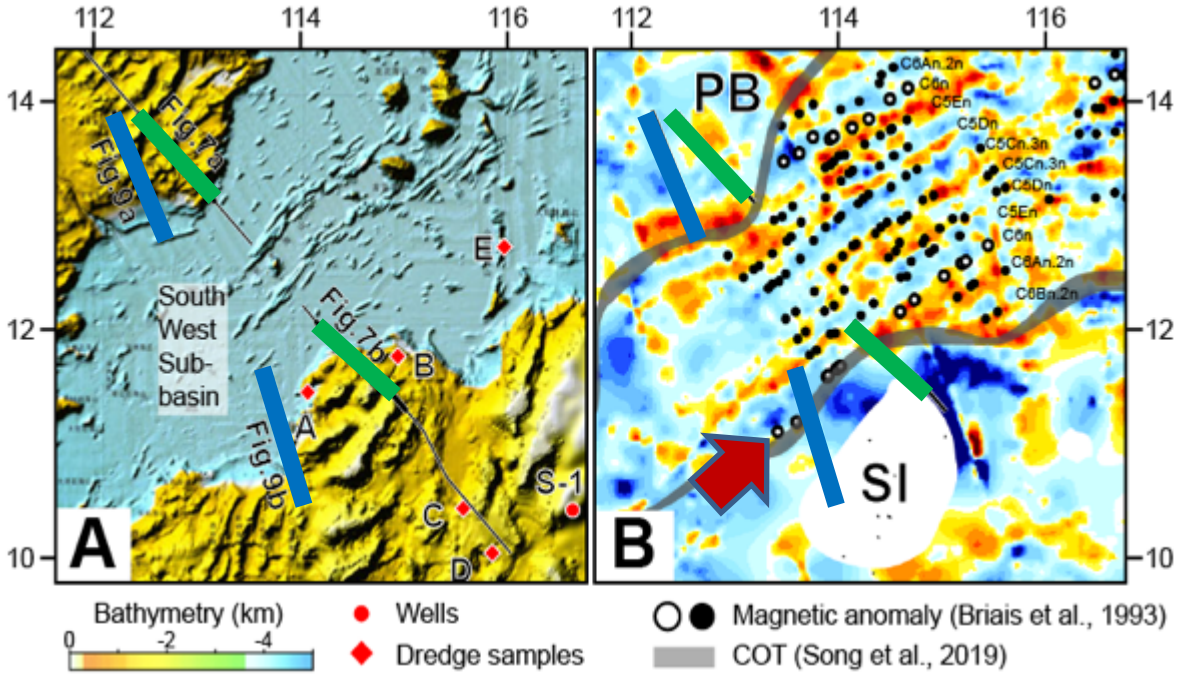




Structure of the Distal Margin and COT

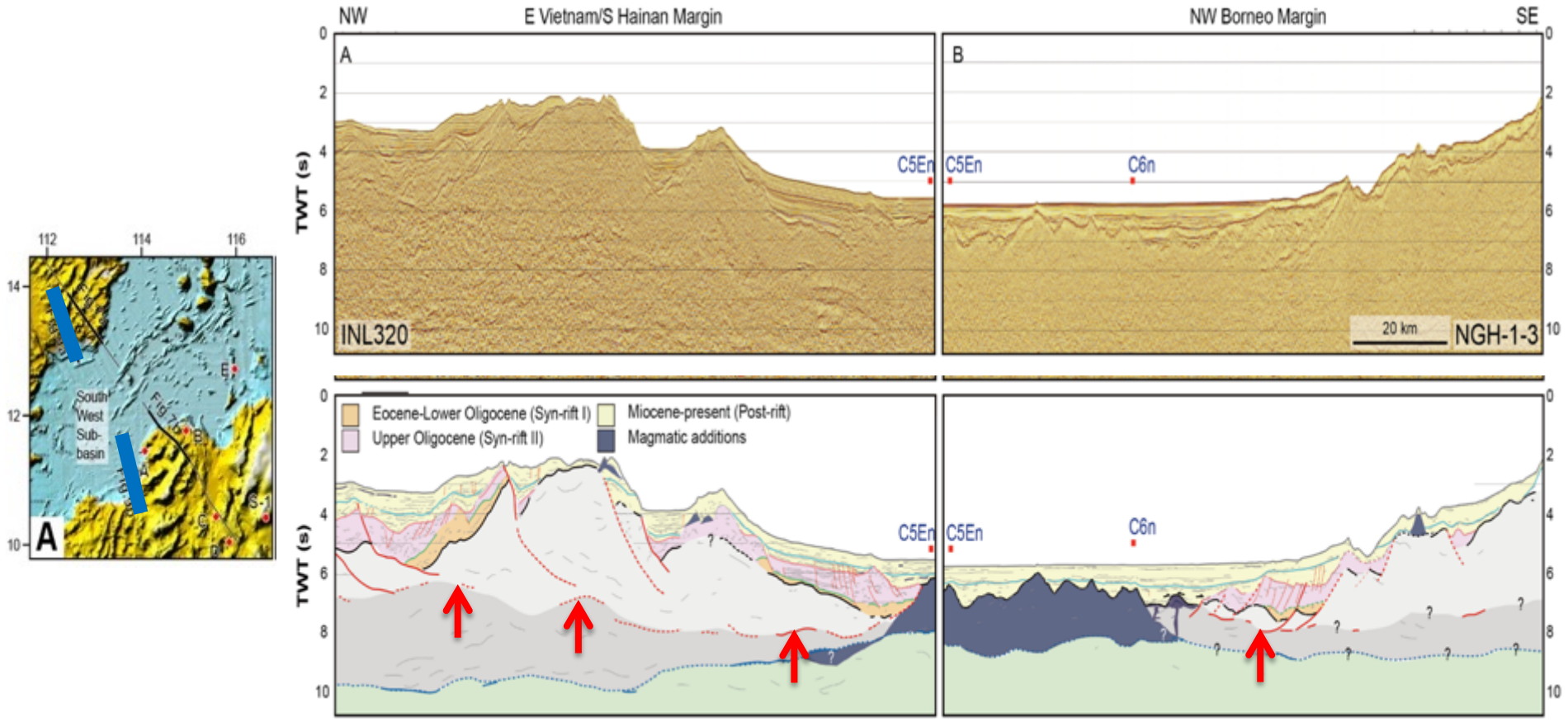


- Steep (green) and stretched (blue) segments
- The earliest magnetic anomaly (C6n, red thick arrow) is clear in the southern margin only



Chang et al. (in revision)

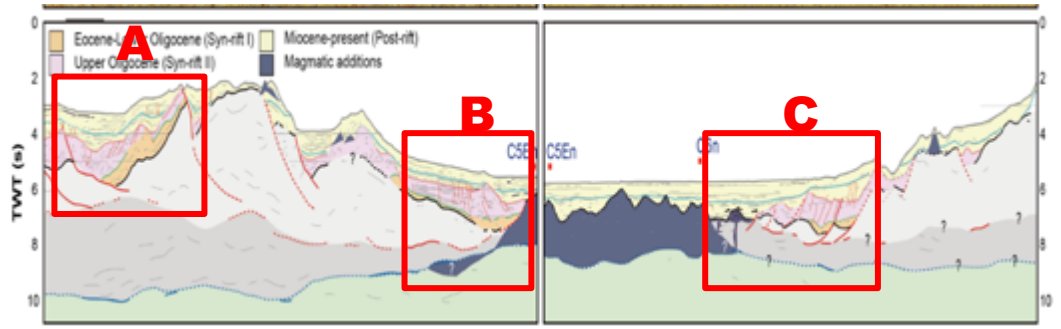
Juxtaposed Conjugate E Vietnam-NW Borneo Margins



Chang et al. (in revision)

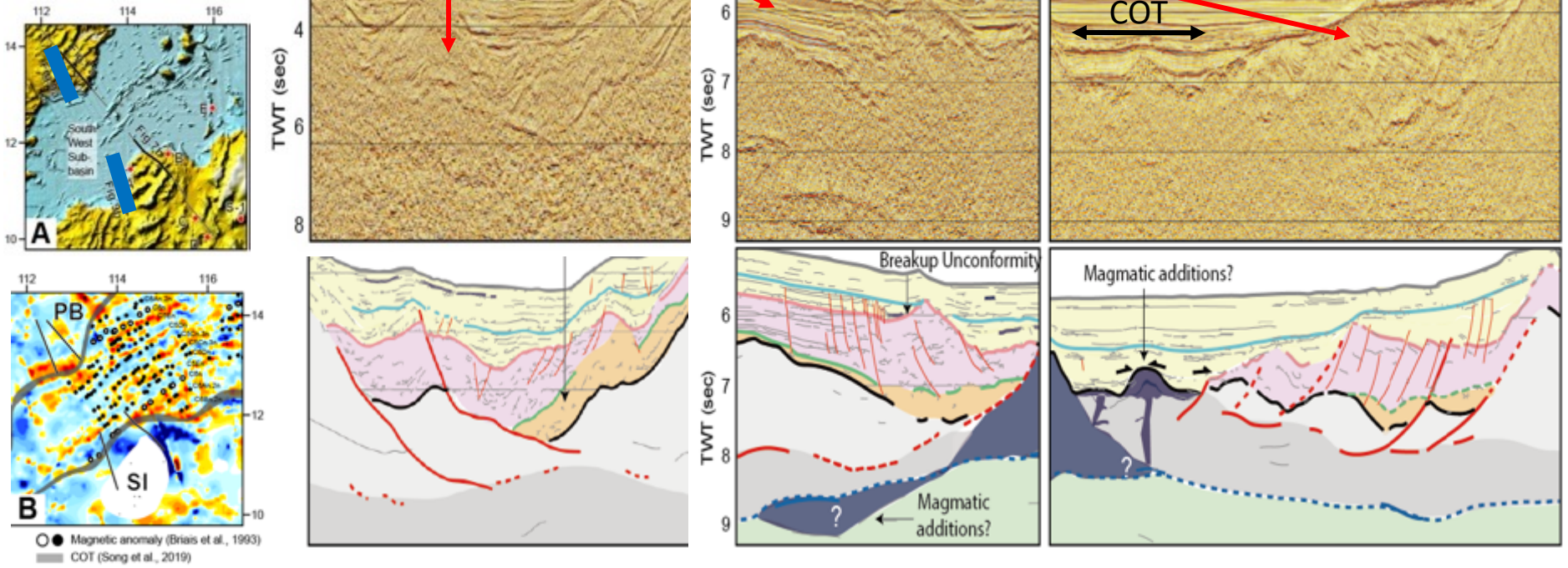
Characteristics of the syn-rift II at the COT

- Very thick syn-rift II collapse in the axial zone (B and C)



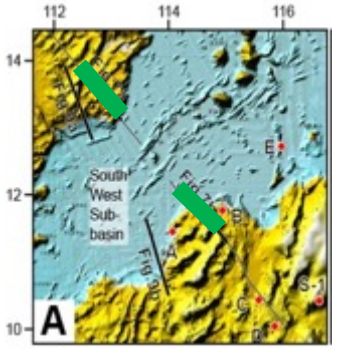
Chang et al. (in revision)

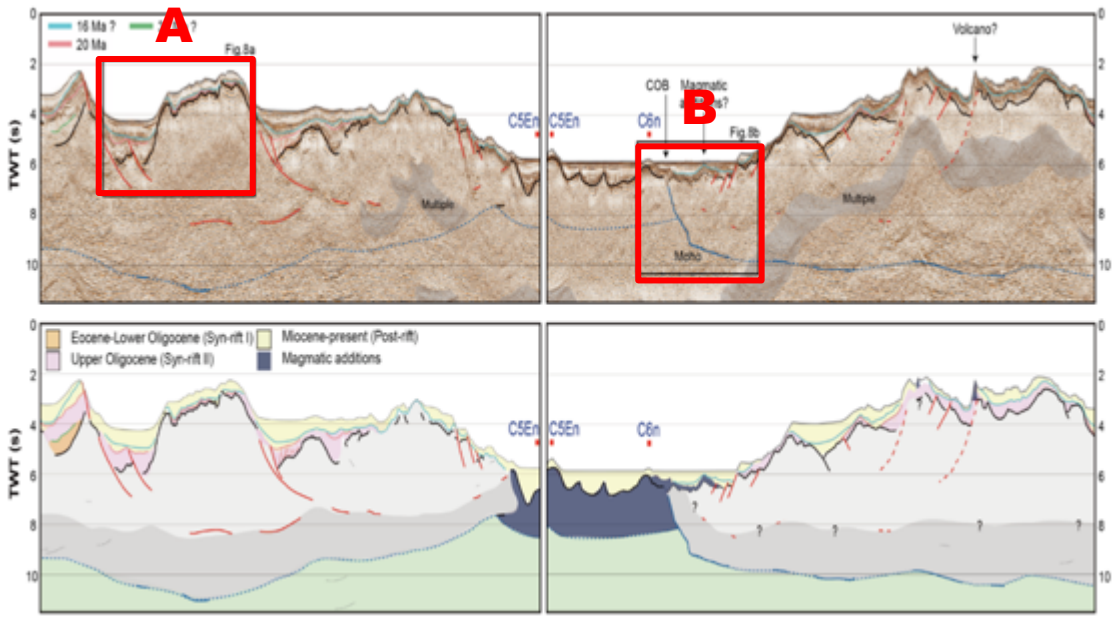
Syn-rift II

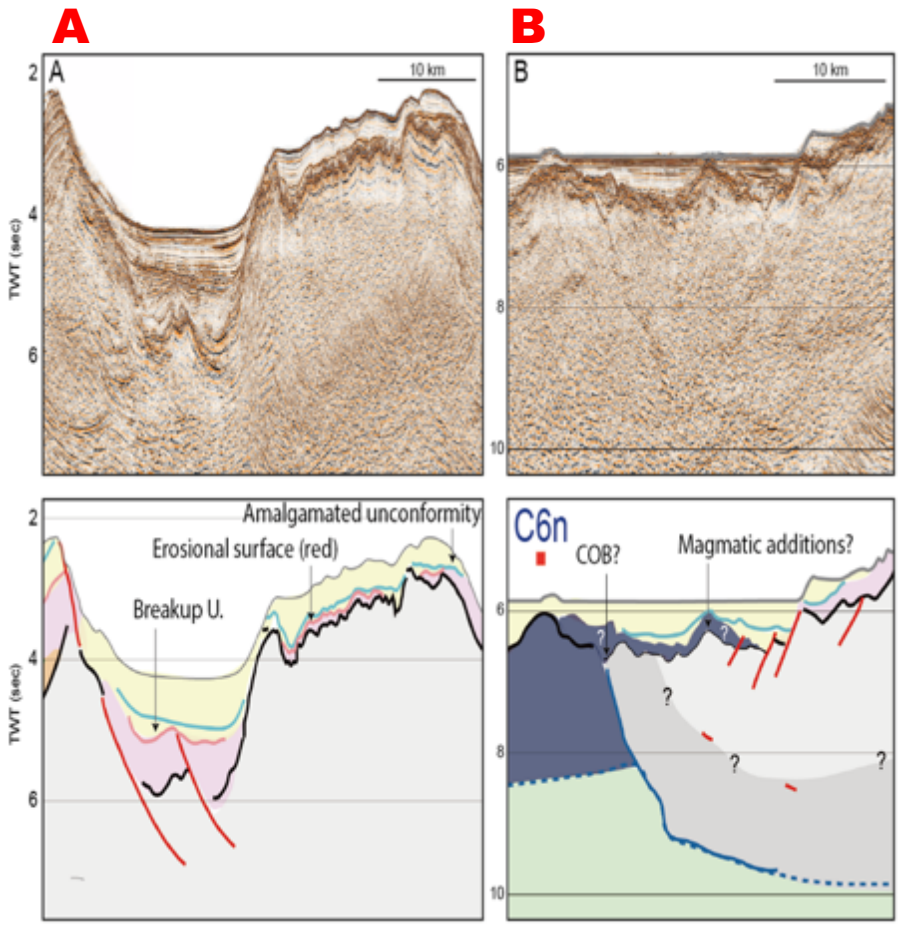


Conjugated Margin across the N-S Segment

- Steep (abrupt) margin
- Relatively starved syn-rift succession at the COT



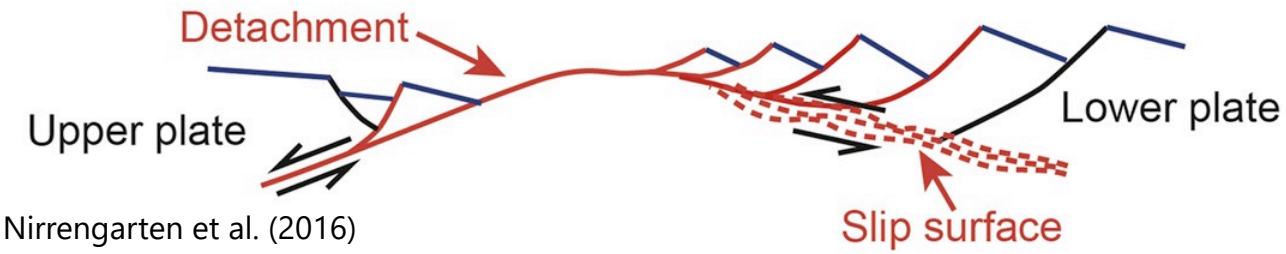




Chang et al. (in revision)

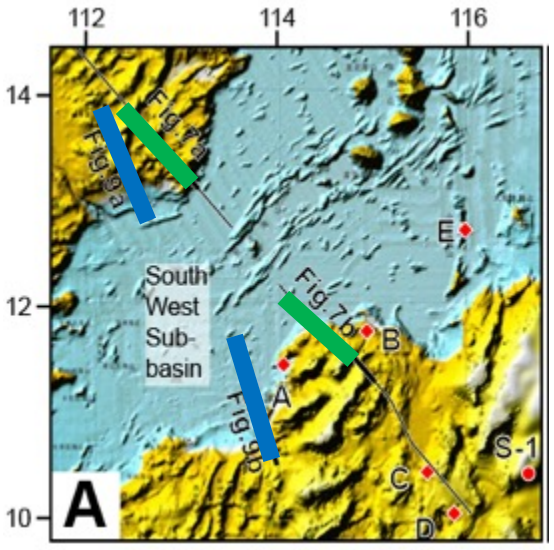
Implications on the Breakup Process

Hangingwall **Footwall**

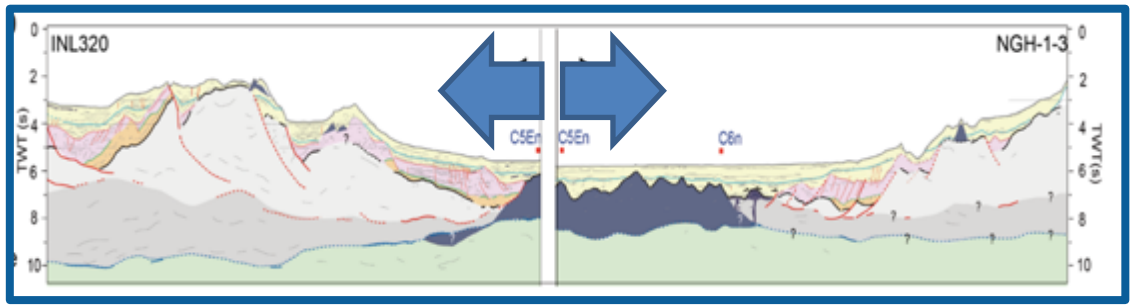


Nirrengarten et al. (2016)

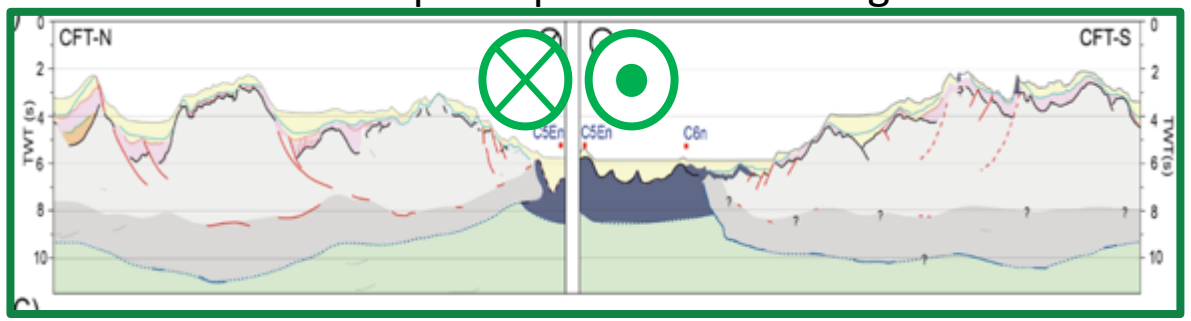
- A series of en echelon pull-apart basins at 23 Ma
- These coalesced around 20 Ma

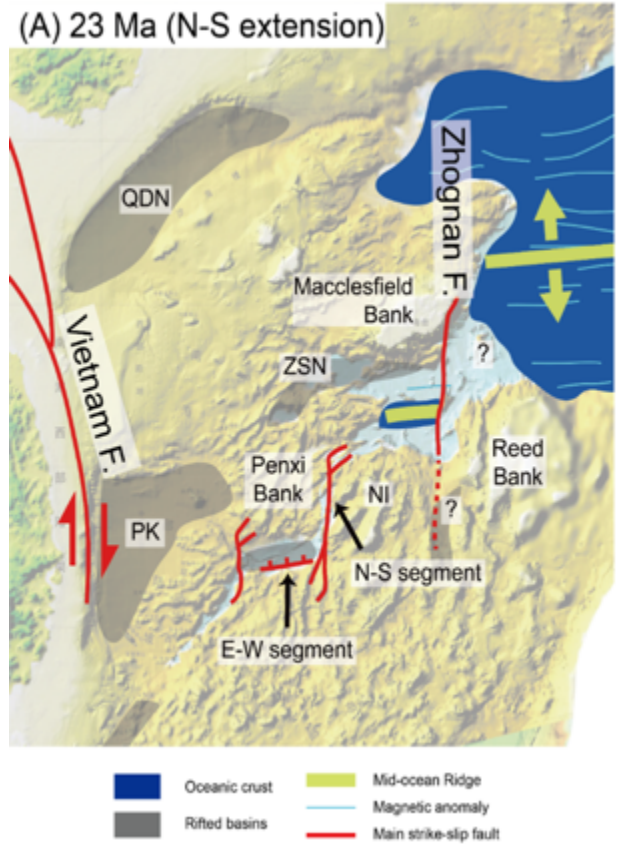


More finite extension on E-W segment



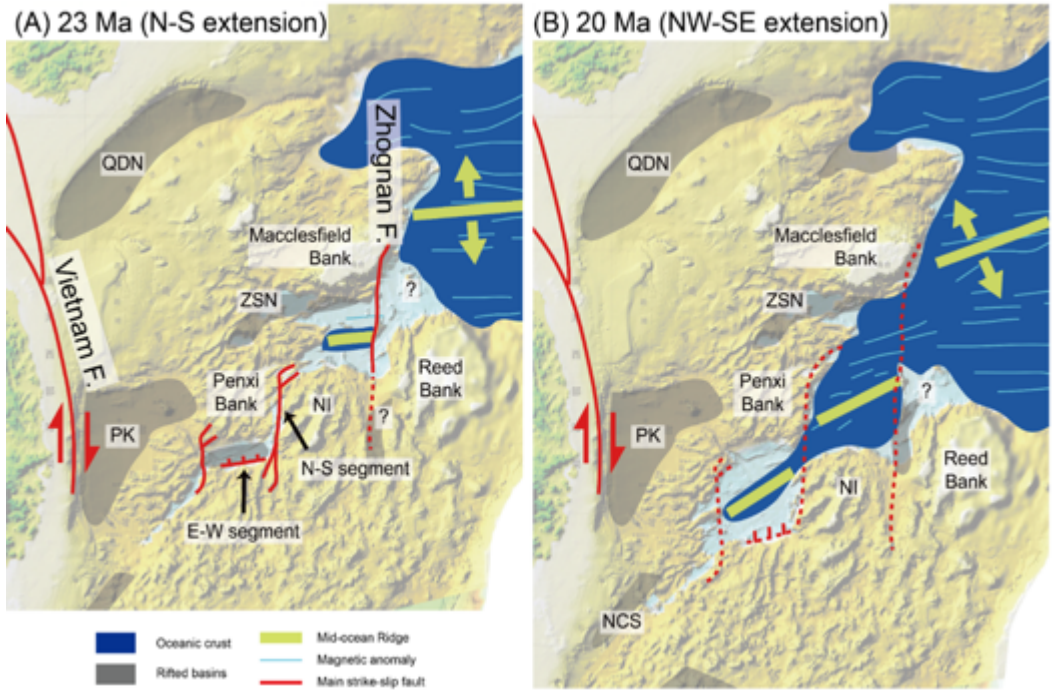
Strike-slip component on N-S segment

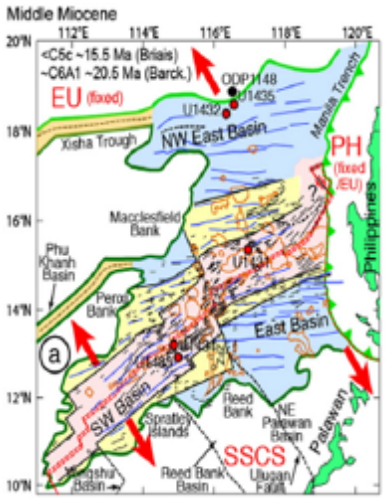




Changing Rifting and Spreading Directions

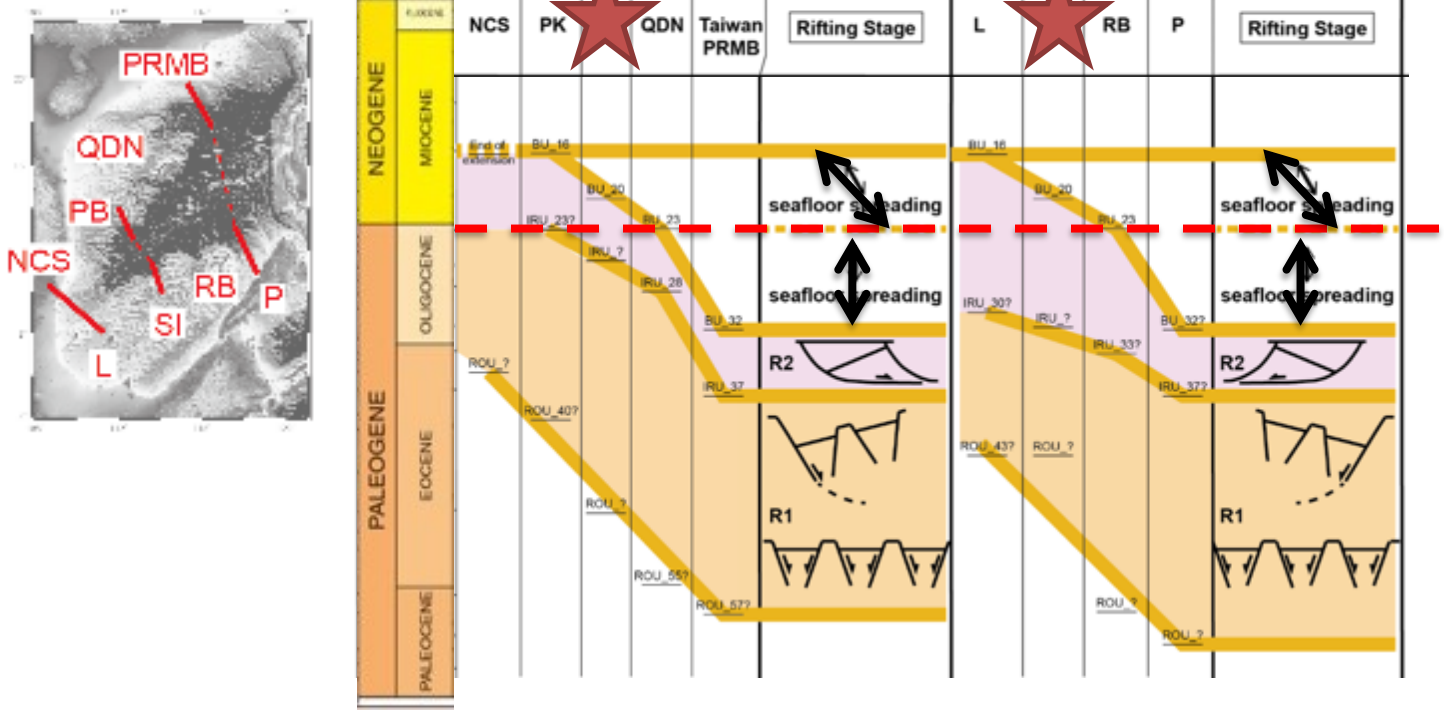
- From en echelon pull-apart basins to coalesced
- Comparison of transition stage of Sibuet et al. (2016) around 23 Ma





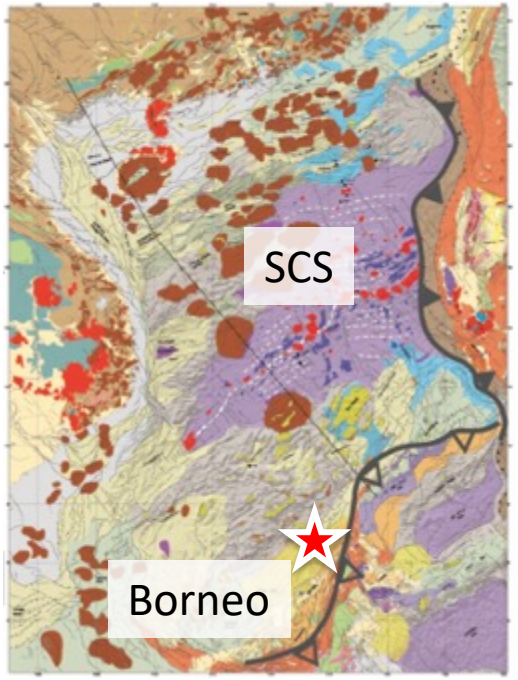
Sibuet et al. (2016)
Tectonophysics

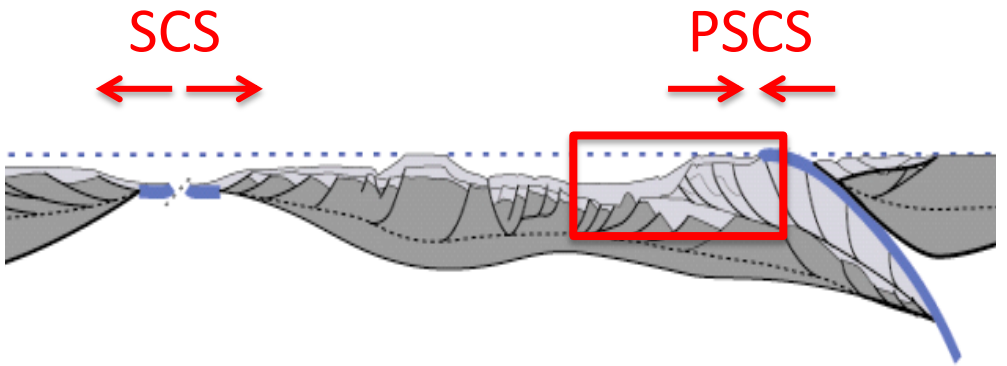
Rifting-Breakup through Space and Time



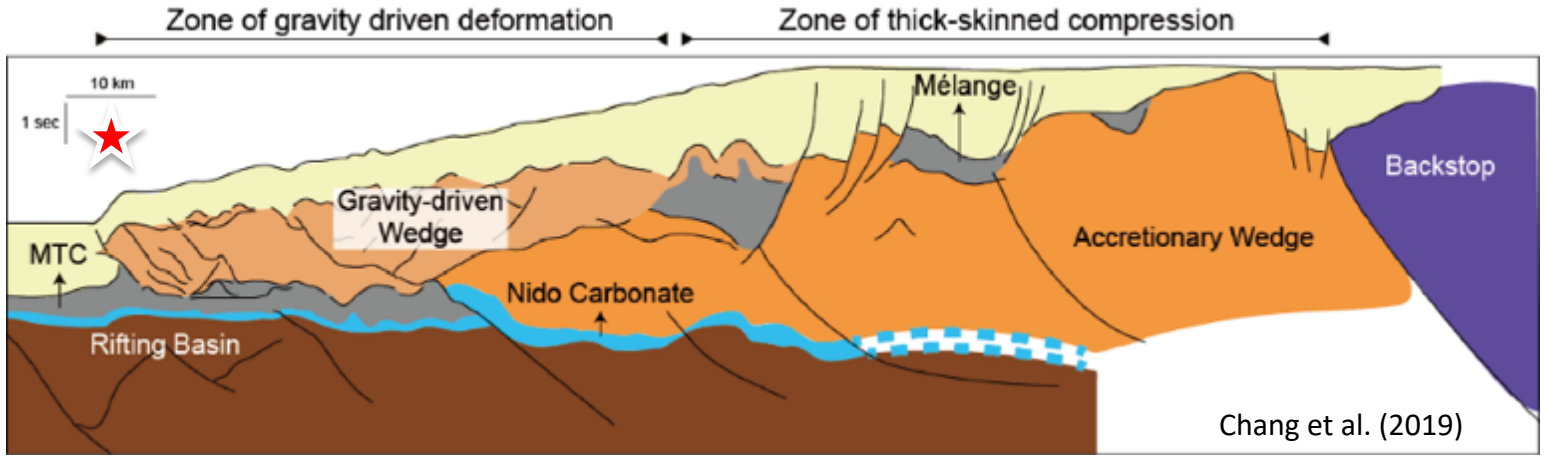
Rearrangement of Extensional direction (23 Ma)

PART 2 - Collision at Southern Margin: MTC, Melange, Circular Basins



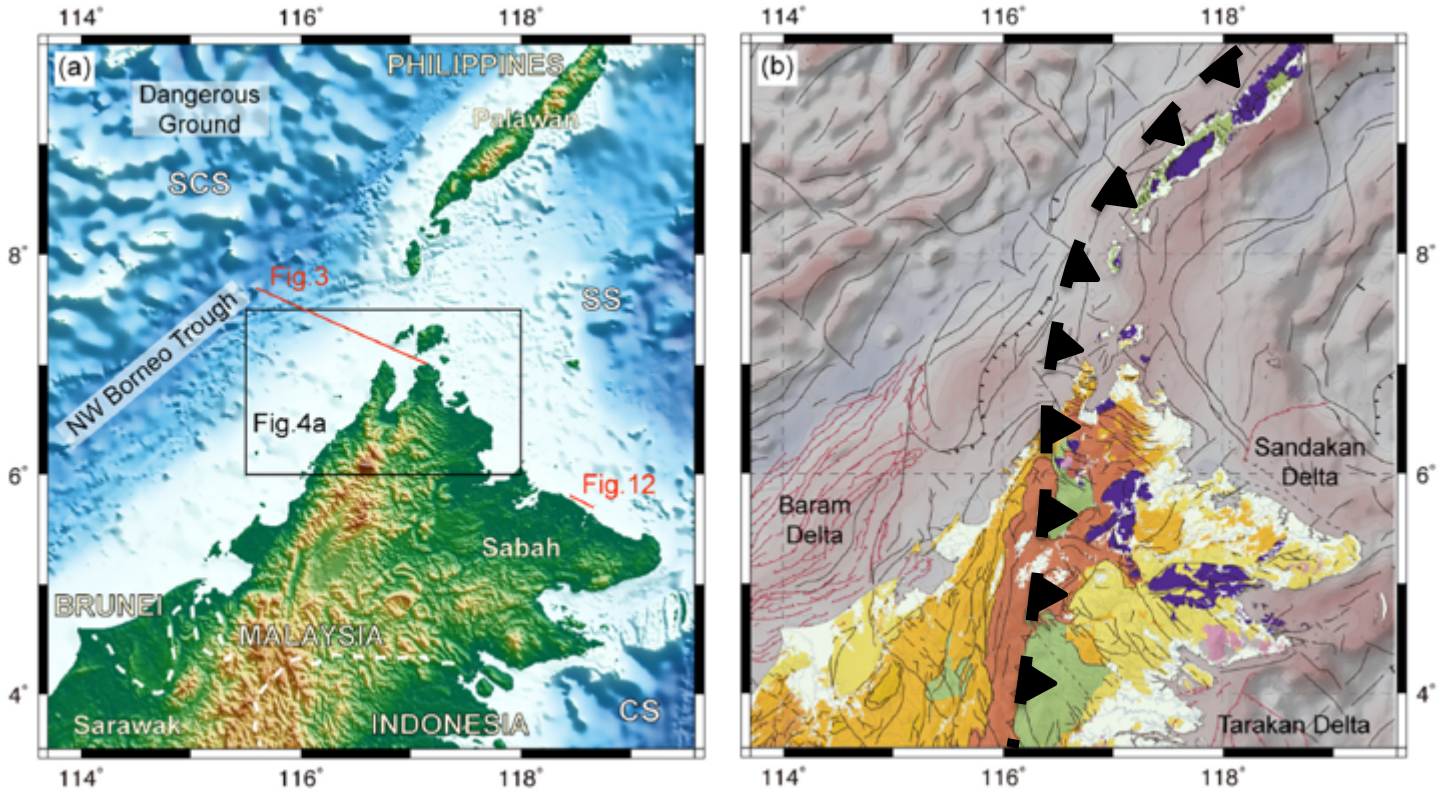


Pubellier and Meresse (2013)



Chang et al. (2019)

Proto-South China Sea Subduction



PSCS Subduction
(or Sarawak Orogeny): ca. 37 Ma

Eocene: 34-55 Ma

Early Cretaceous

Triassic

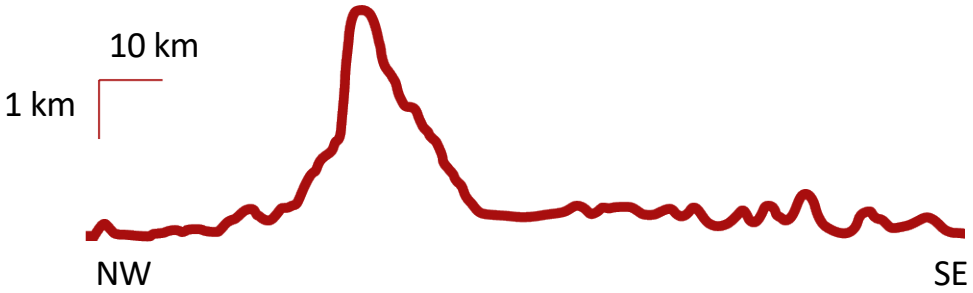
Ages of the Ophiolite Complex
(Keenan et al., 2016; Chien et al., 2020; Rahmat et al., 2020)

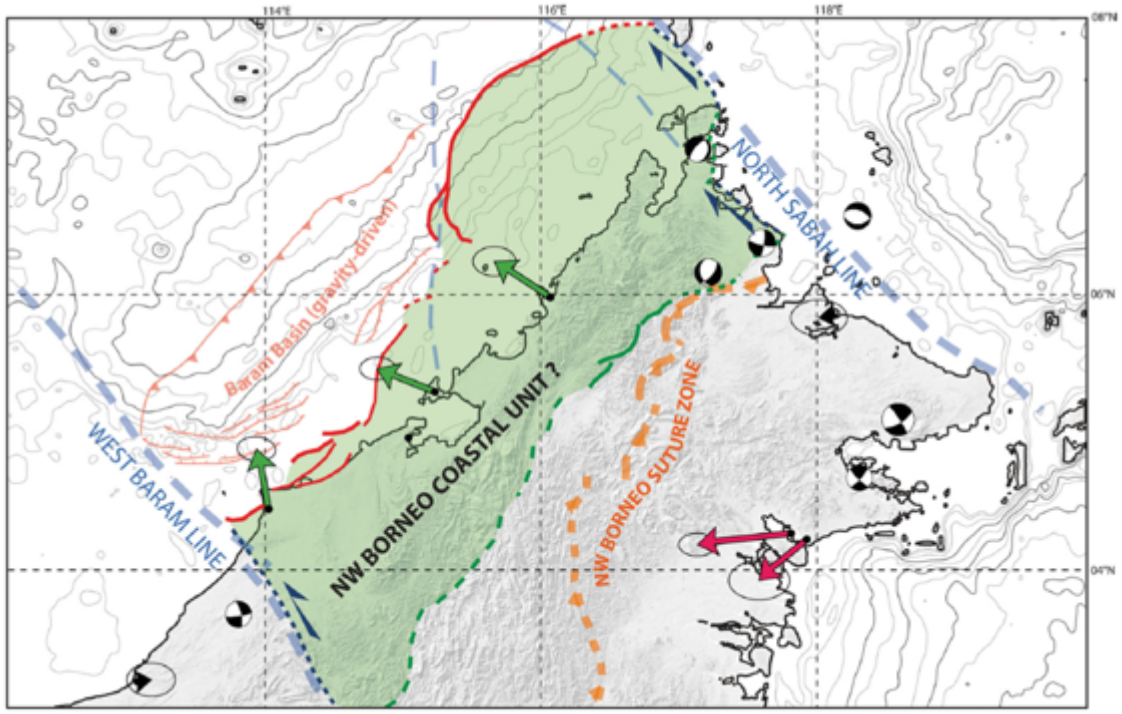
Termination of the Orogeny: Slab Breakoff (or Slab Detachment)

Mt. Kinabalu: 4,095 m

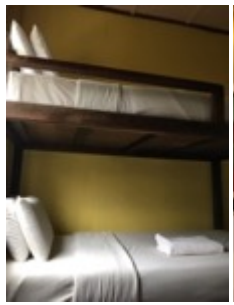
- U-Pb: **7.85 ± 0.08 – 7.22 ± 0.07 Ma**
- ca. 10km uplifting

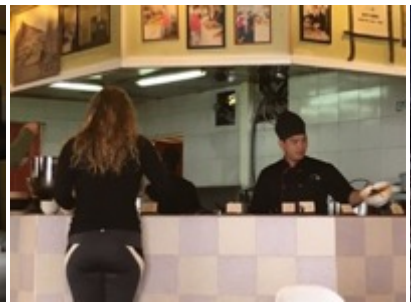
(Swauger et al., 2000; Cottam et al., 2010, 2013)

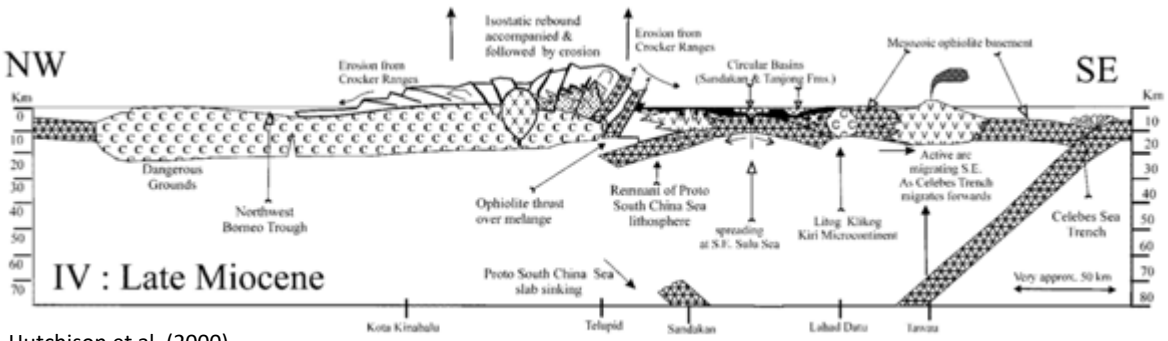




Sapin et al. (2013)

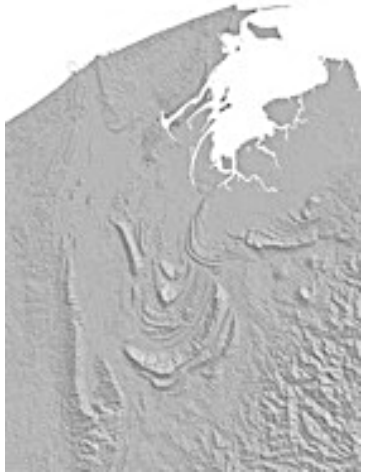


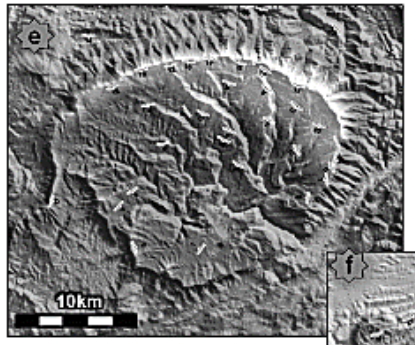


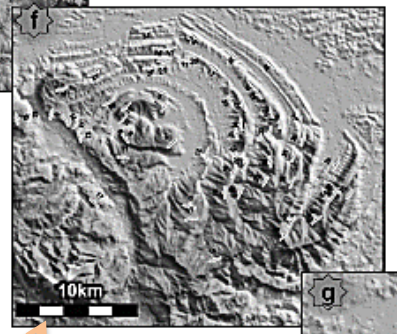


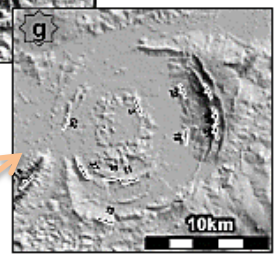
Hutchison et al. (2000)

Mobile Shale and Circular Basins around Sabah

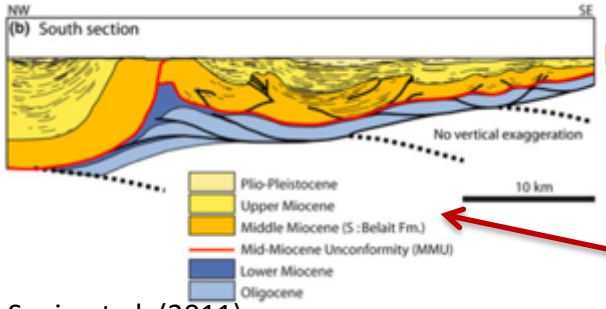




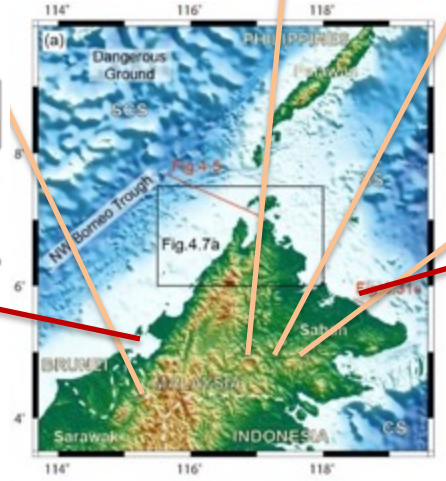


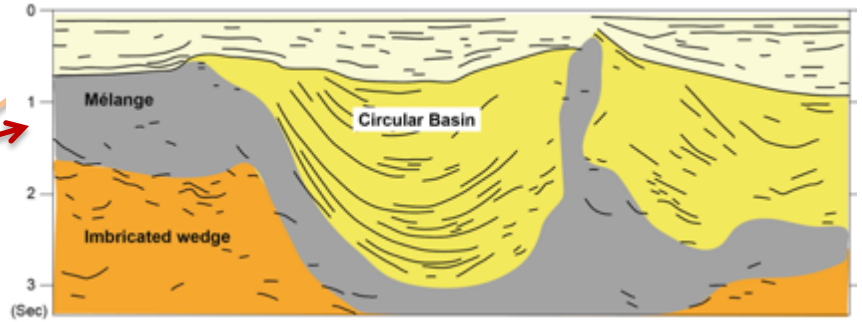


Clark (2017)



Sapin et al. (2011)

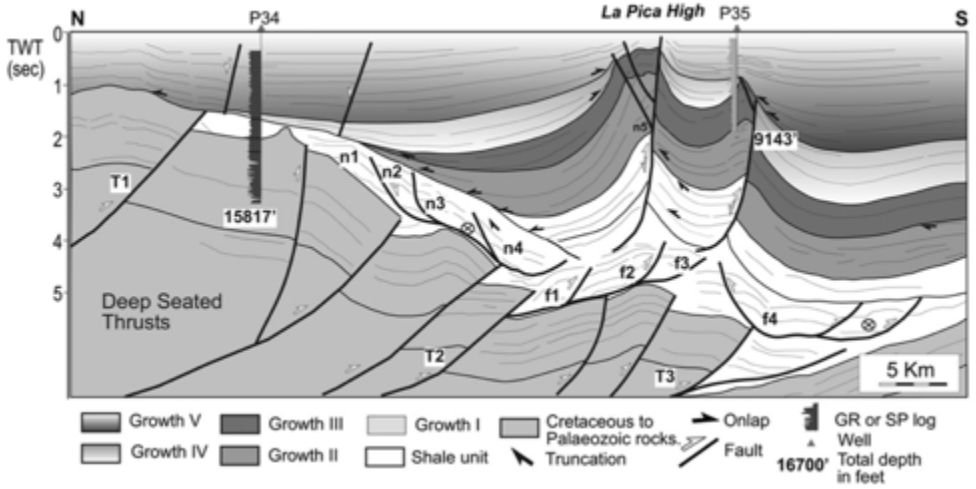




Chang et al. (2019)

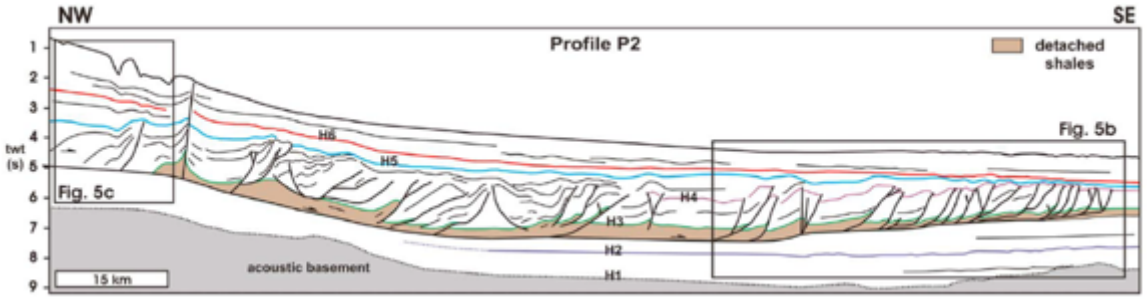
Shale Tectonics: Induced by the Overpressure due to the Loading from Wedge or Sediments

Venezuela



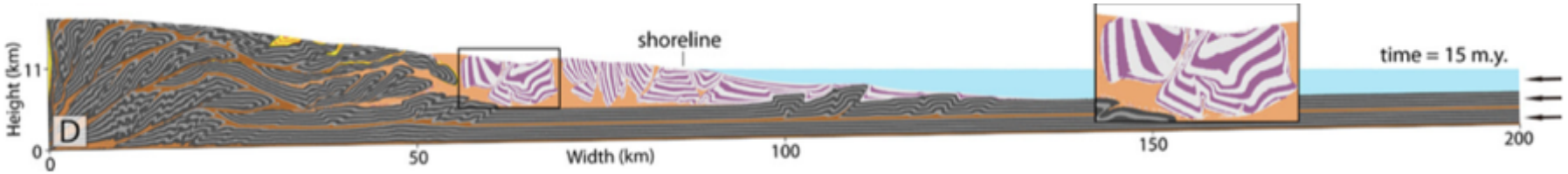
Duerto and MaClay (2011)

Kenya



Cruciani and Barchi (2016)

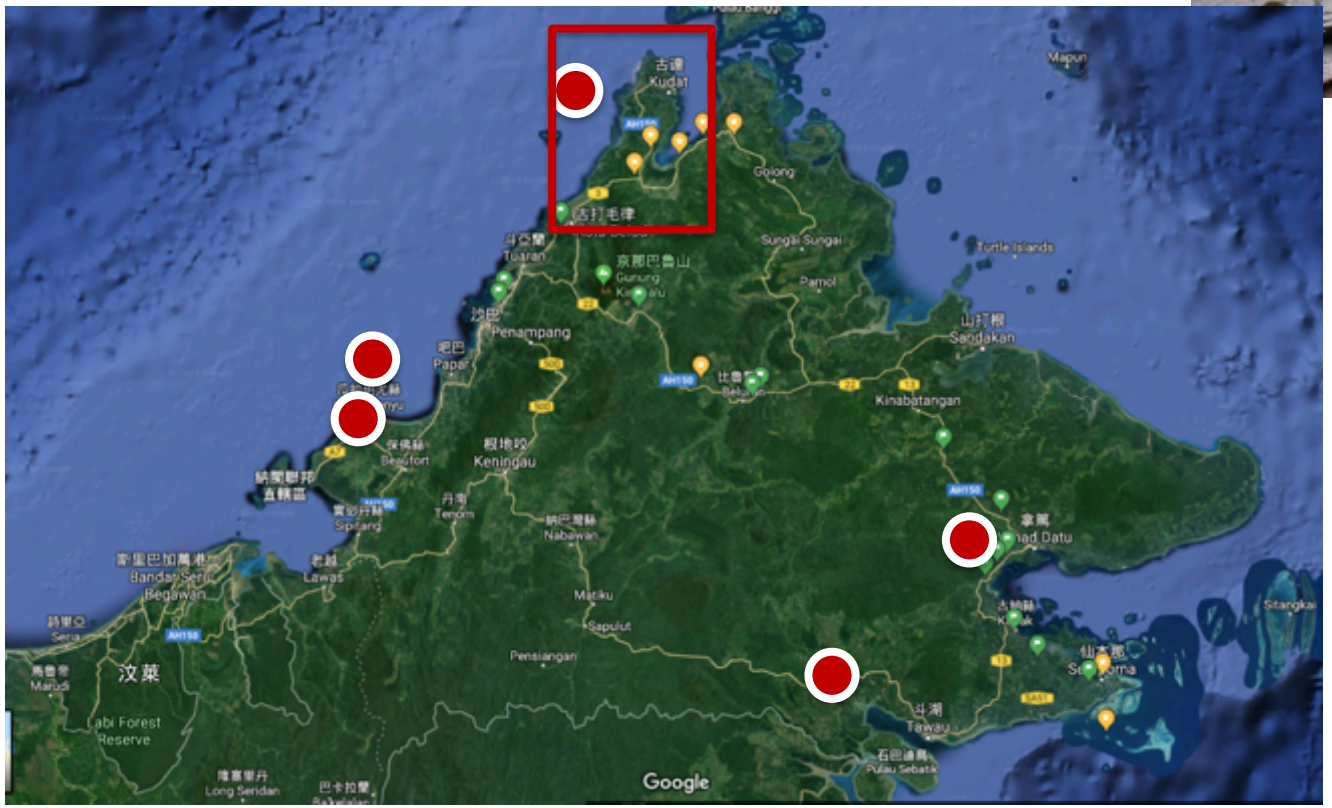
Makkran

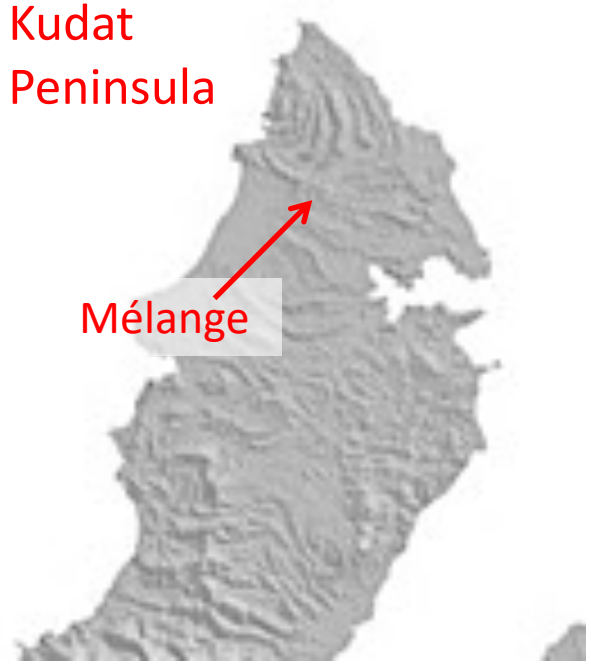


Ruh et al. (2018)

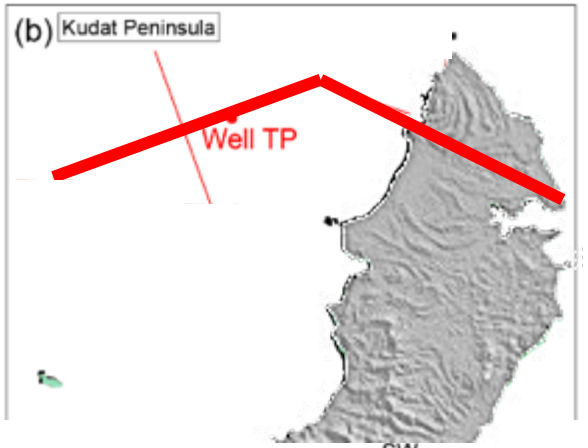
Therapeutic Volcanic Mud around Sabah

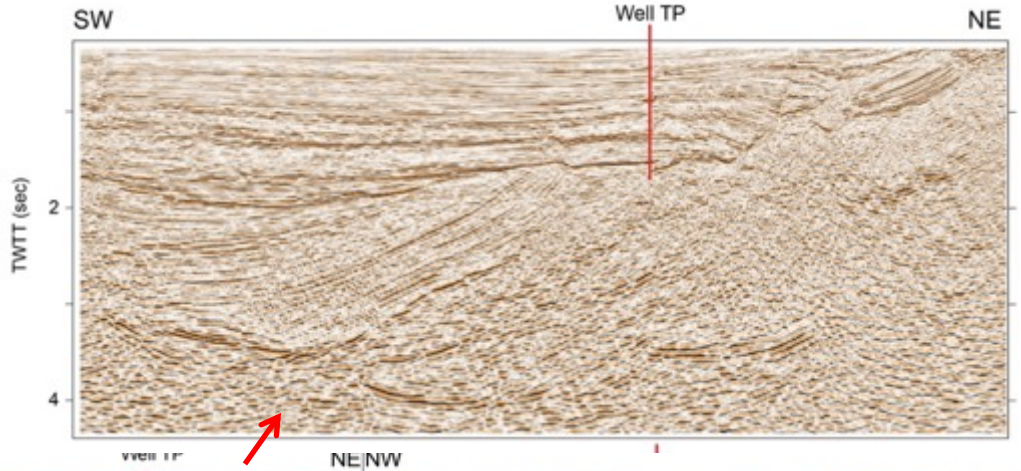
mineral-rich mud and gas slowly bubble up from deep underground.



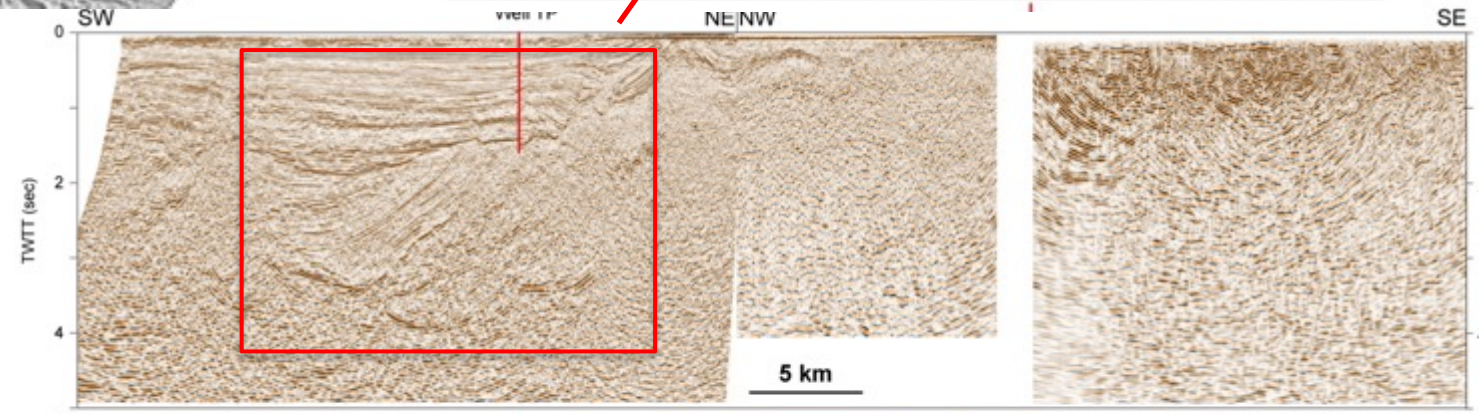


Seismic Interpretation of Accretionary Wedge





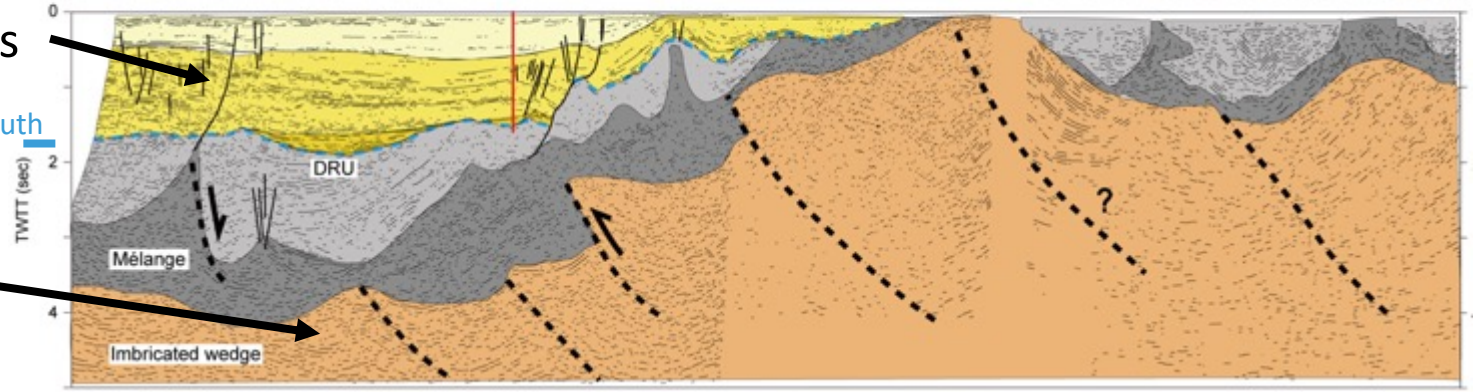
Chang et al. (2019)



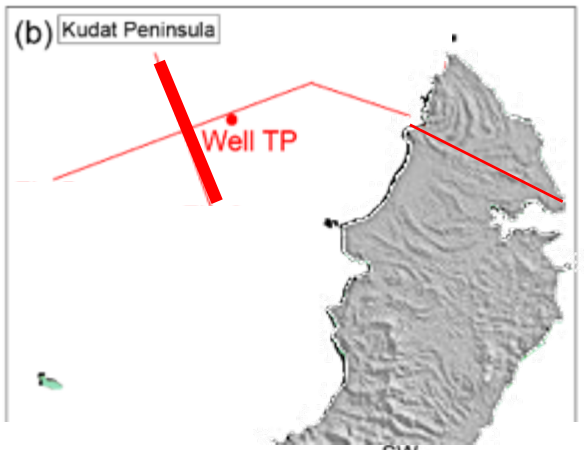
Gravity Tectonics

DRU
~14 Ma 16 Ma in the South

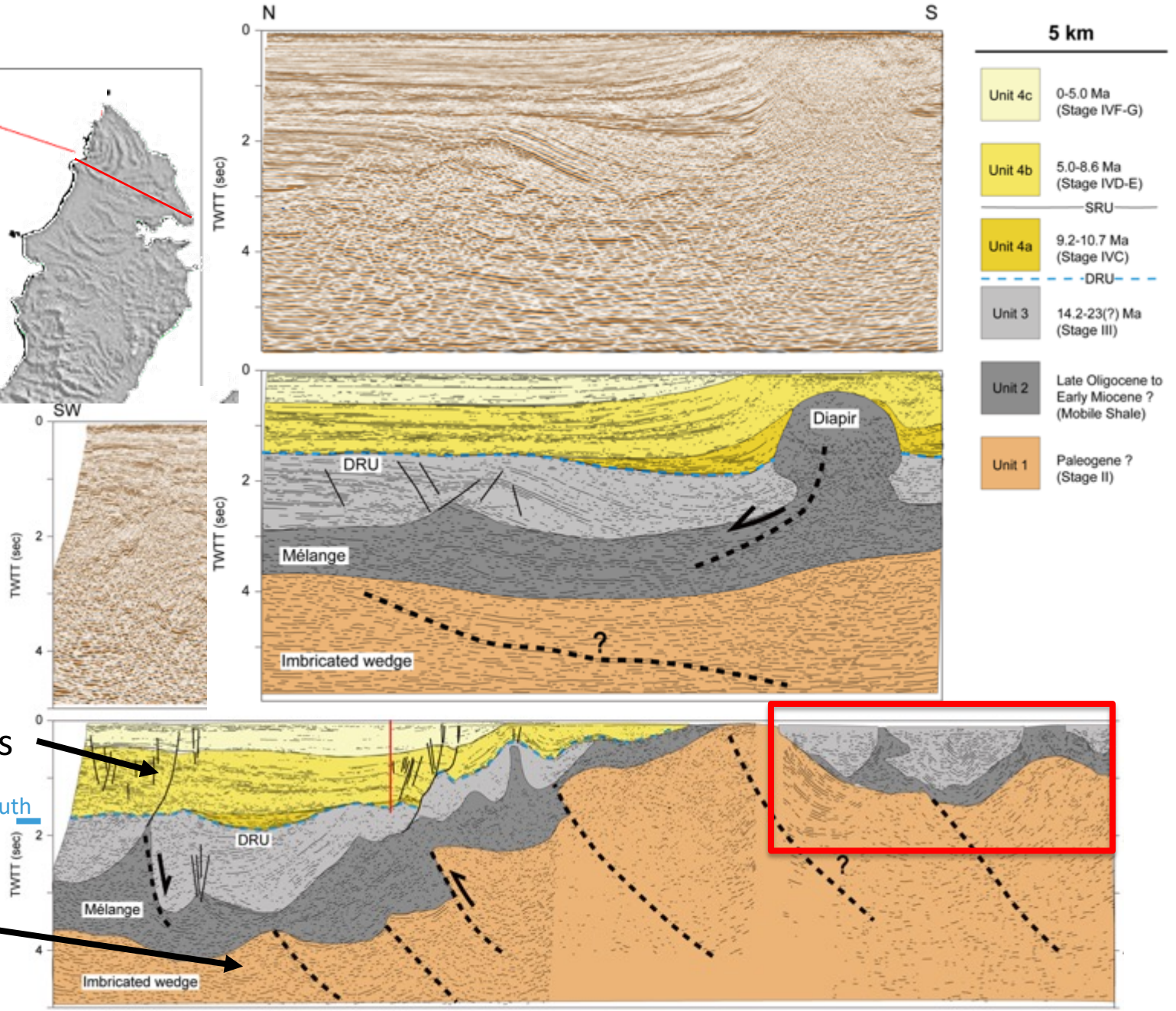
Fold-and-thrust Belt (FTB)



Seismic Interpretation of Accretionary Wedge



Chang et al. (2019)

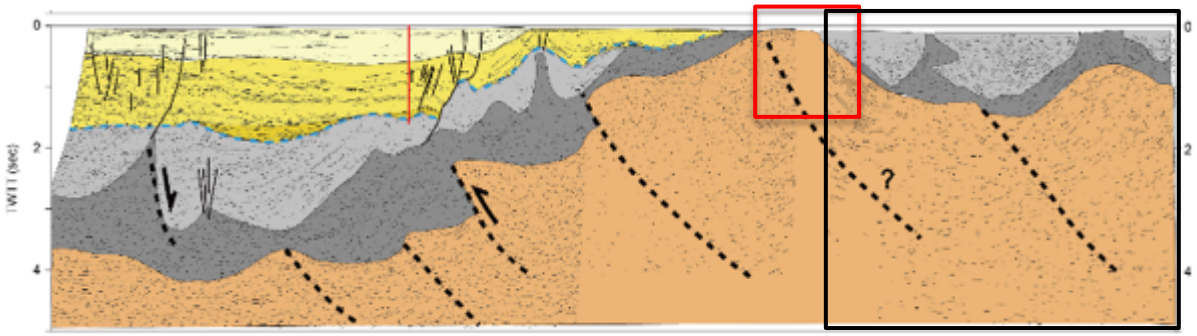


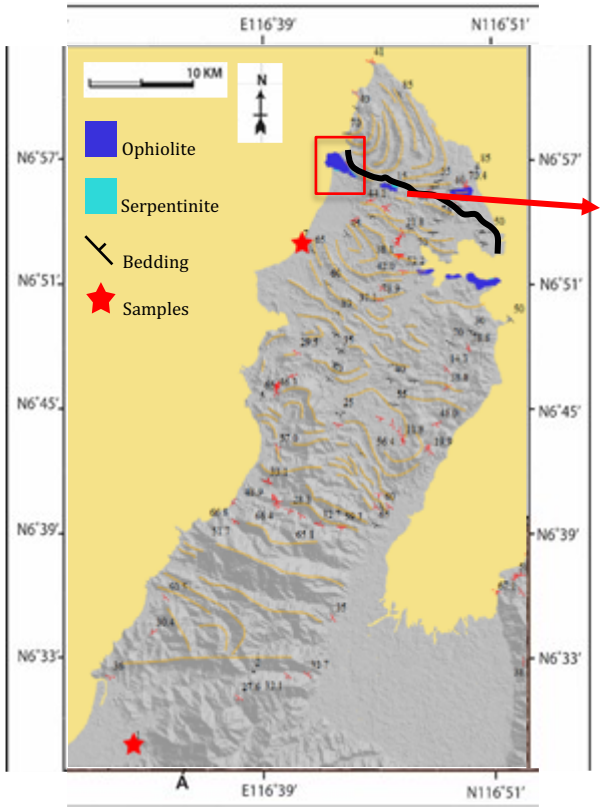
Gravity Tectonics

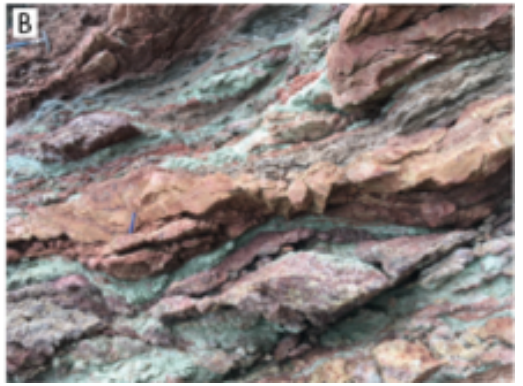
~14 Ma 16 Ma in the South

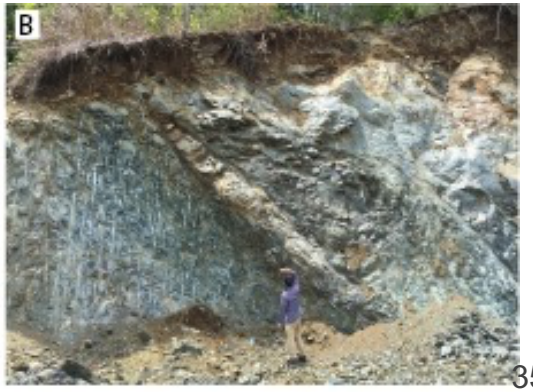
Fold-and-thrust Belt (FTB)

Sheared and Undeformed Ophiolitic Basement









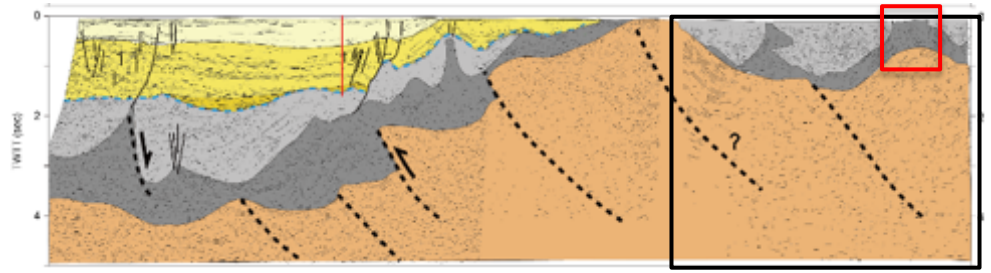
Deformation Associated with a Mud-Prone Body

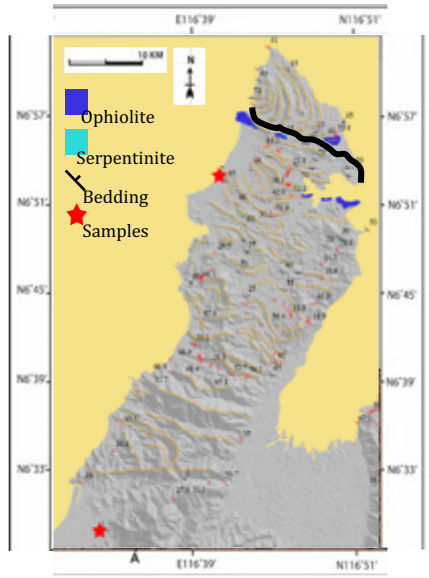
Mud Injection

Broken Formation

Mud-prone Core

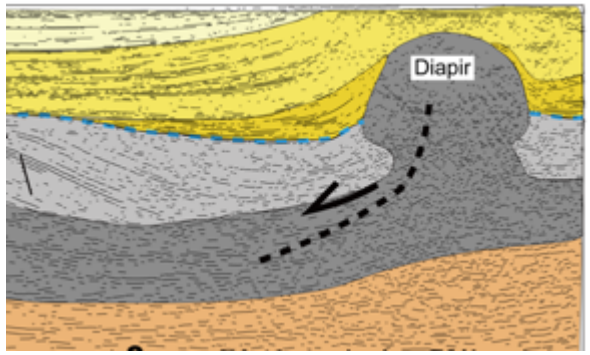
Festa et al. (2019)

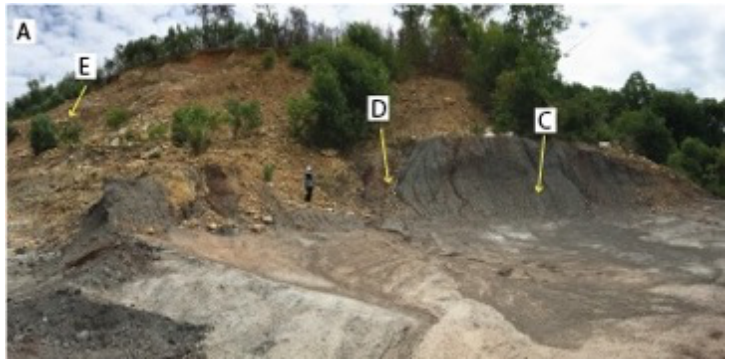


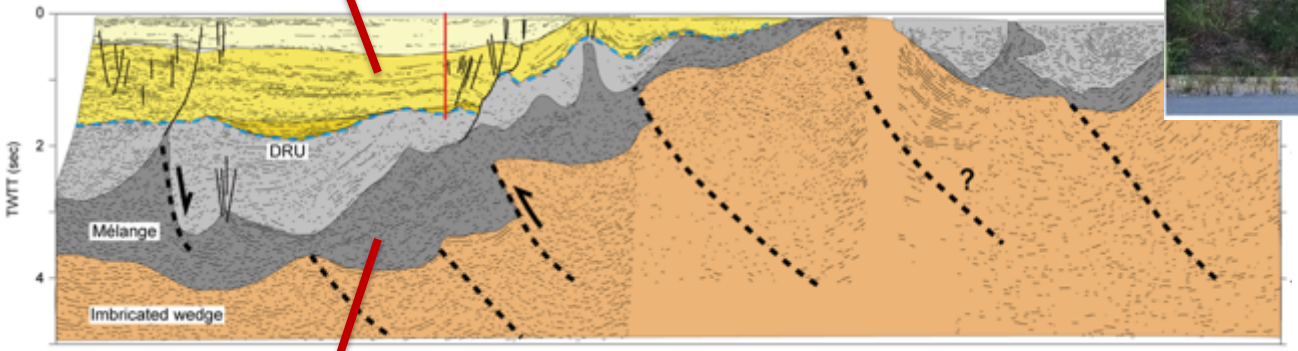


Deposition and Remobilization of Sedimentary Mélange

Gravity-driven Period





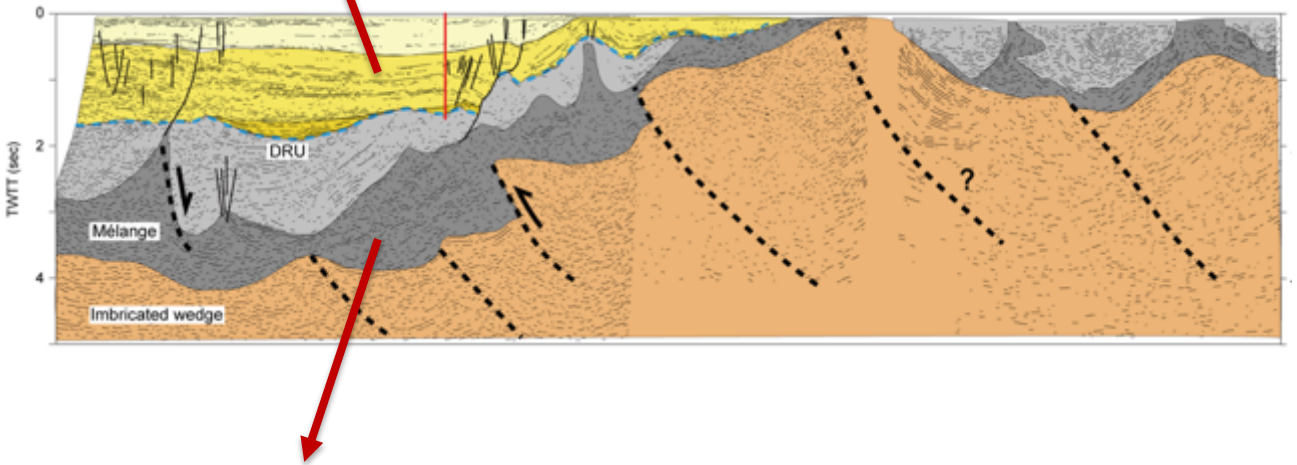


Tectonic-driven Period

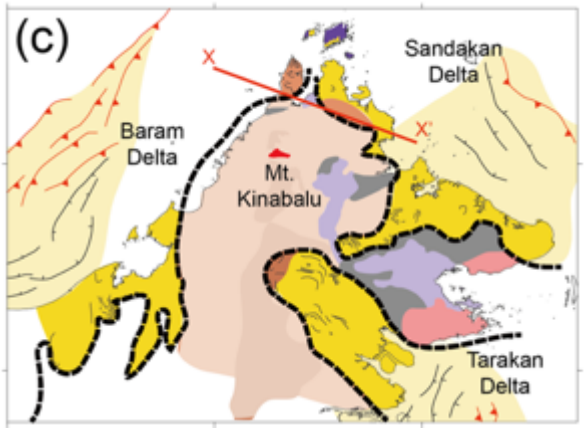
Deposition and Remobilization of Sedimentary Mélange prior to the DRU

Slope Instability

Gravity-driven Period

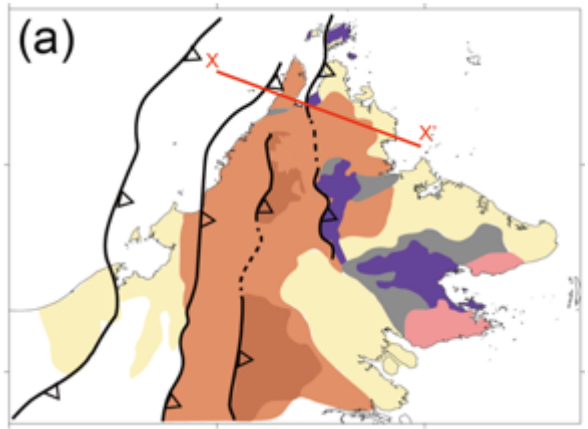


Tectonic-driven Period



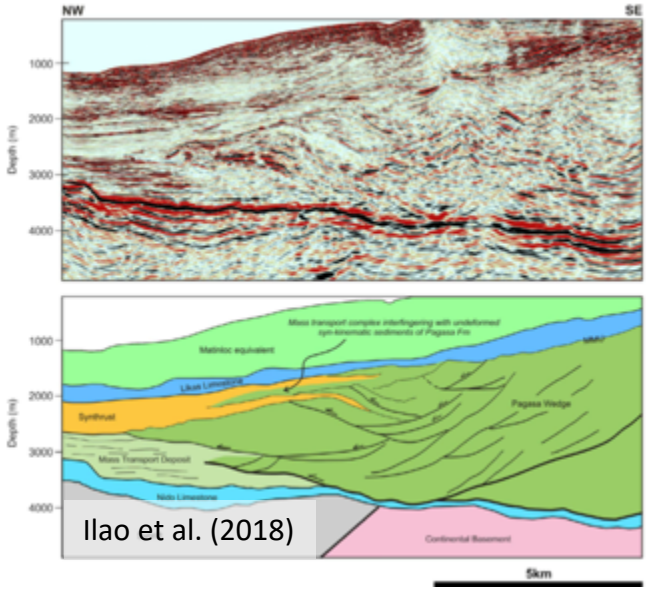
DRU: ~14 Ma

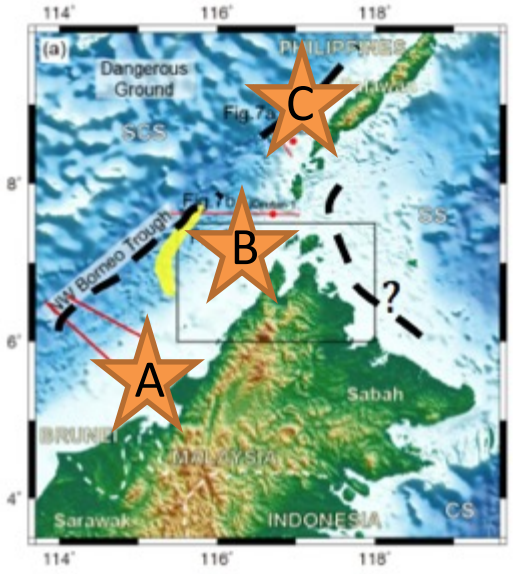
16 Ma in the South

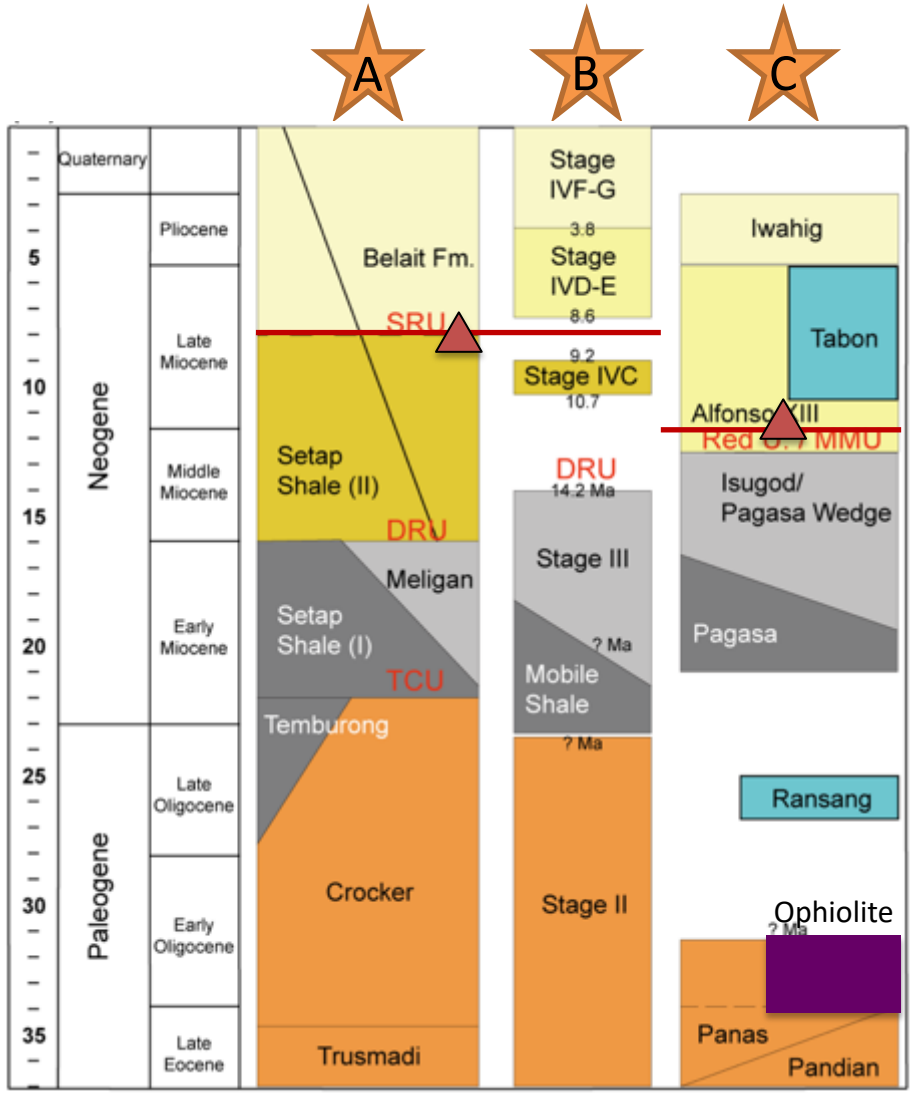


Chang et al. (2019)

Accretionary Wedge along Borneo and Palawan







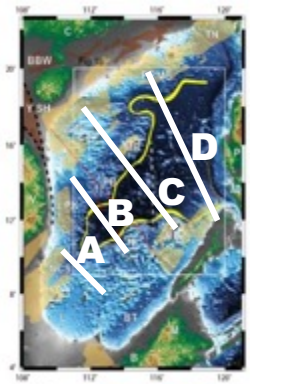
Chang et al. (2019)

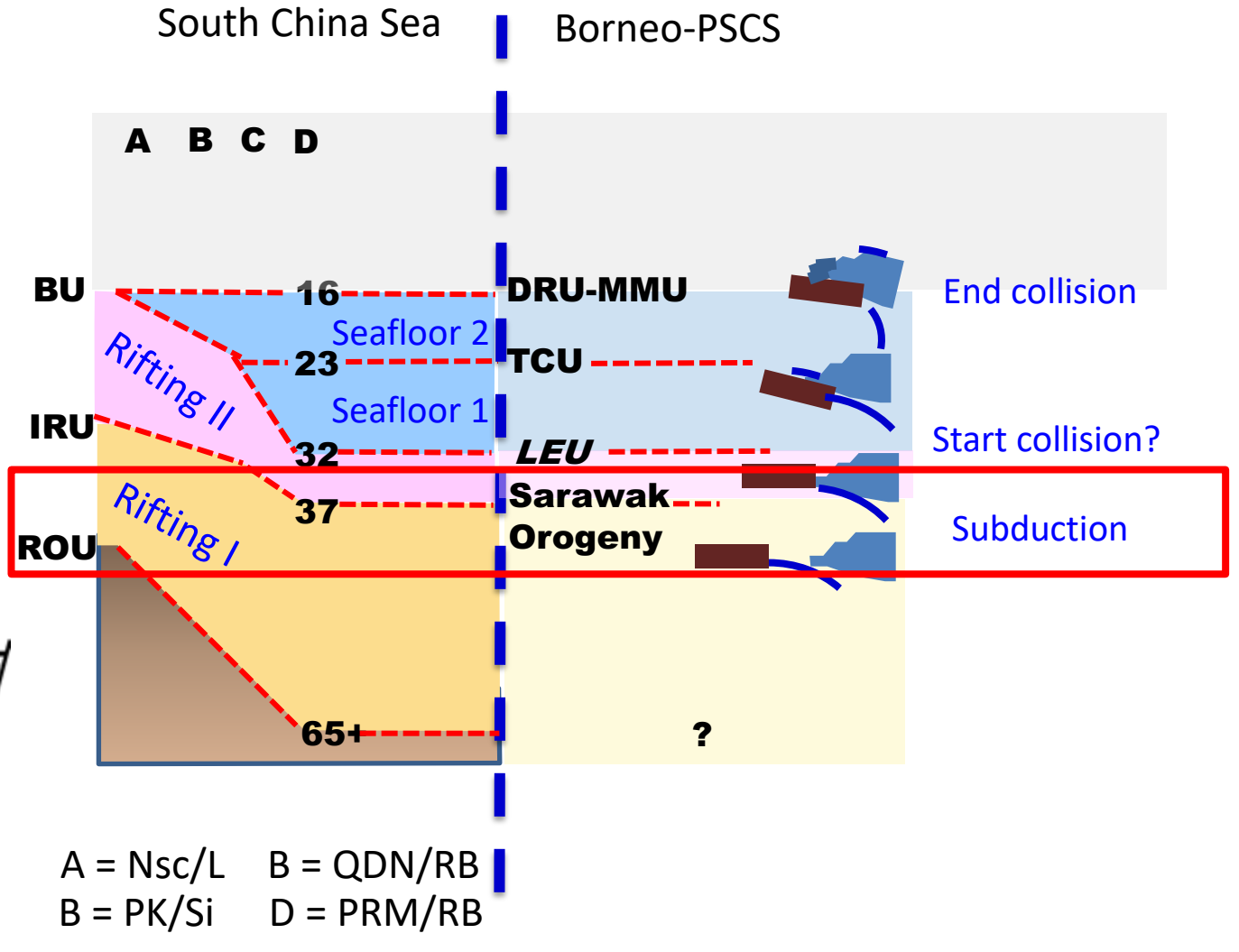
Slab detachment

Post-orogeny

Orogeny

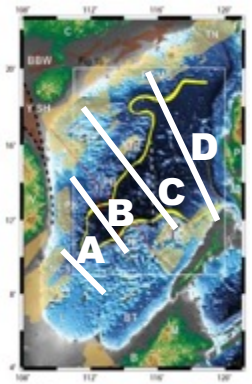
Final Part: Correlation?





A = Nsc/L B = QDN/RB
B = PK/Si D = PRM/RB

Final Part: Correlation?



South China Sea | Borneo-PSCS

A B C D

BU — 16 — DRU-MMU — End collision

Seafloor 2

Rifting II

23 — TCU

Seafloor 1

IRU — 32 — *LEU* — Start collision?

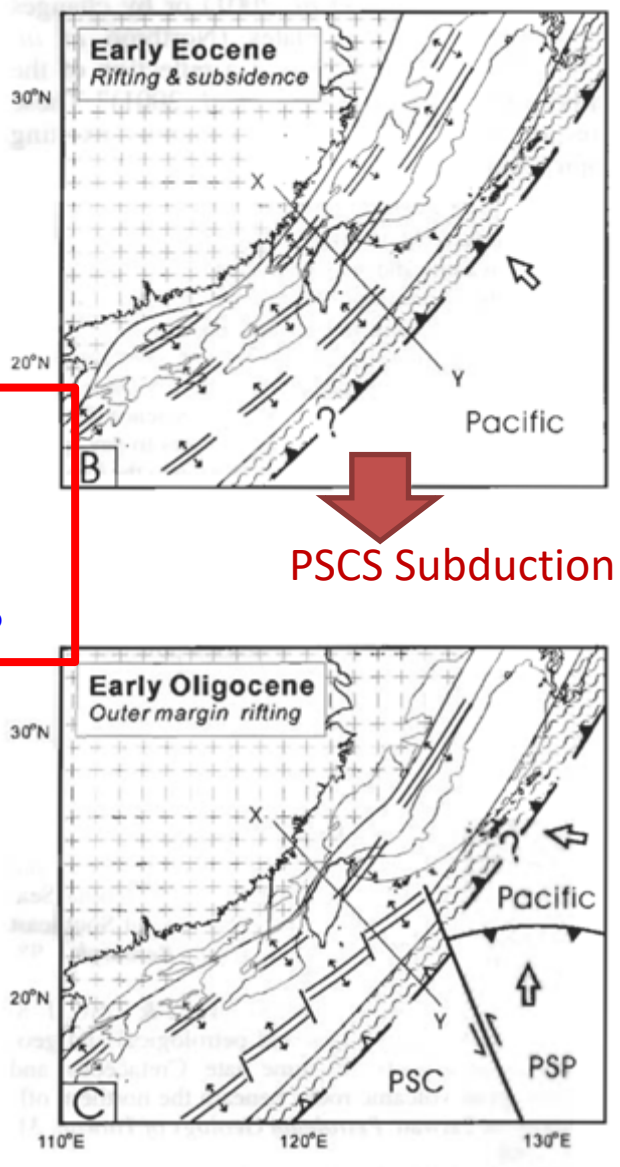
Rifting I

37 — Sarawak Orogeny — Subduction

ROU

65+ — ?

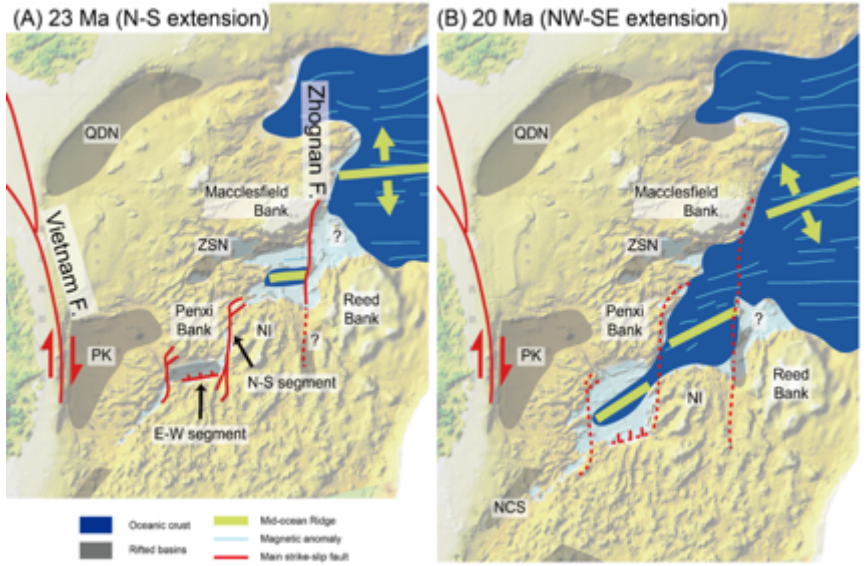
A = Nsc/L B = QDN/RB
B = PK/Si D = PRM/RB



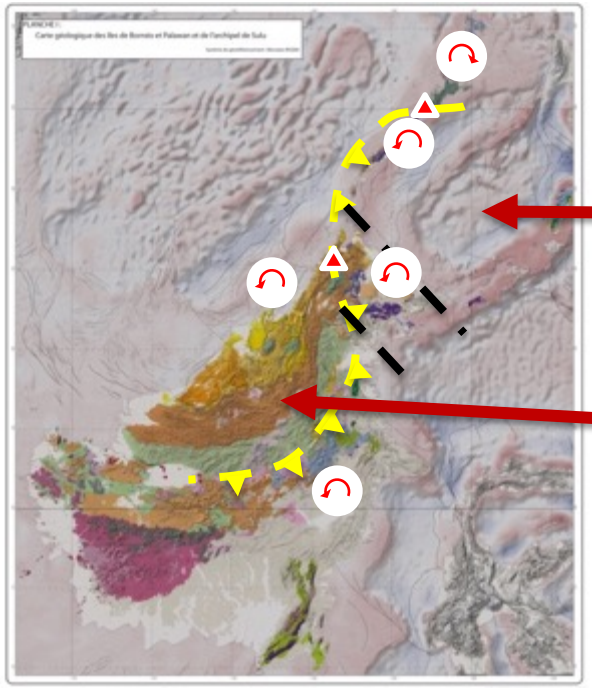
Teng and Lin (2004)

What Happened from 23 to 16 Ma?

Direction Rearrangement



Borneo Rotation

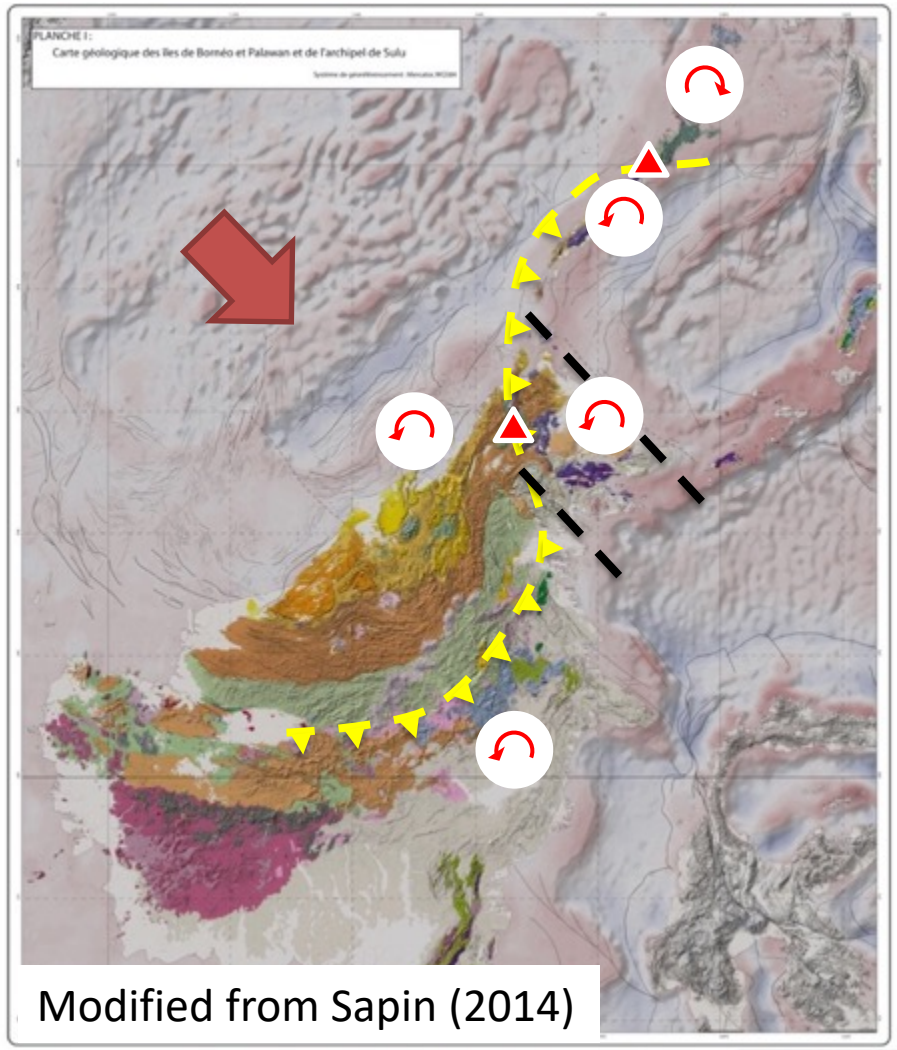


Sulu Sea Opening (12-17 Ma)

Collision
(Hennig-Breitfeld et al., 2019)

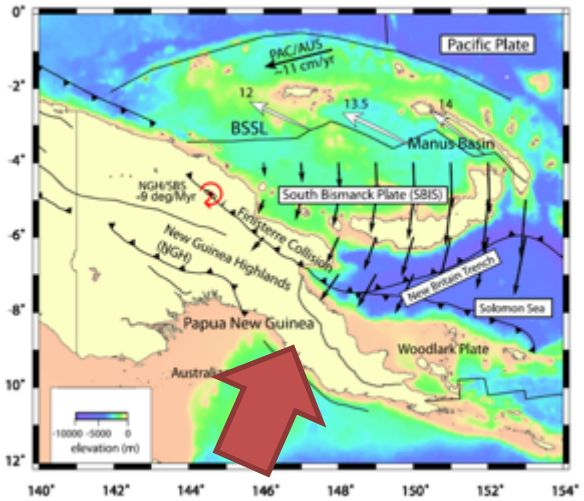
Modified from Sapin (2014)

Heterogeneity on the Subducting Plate

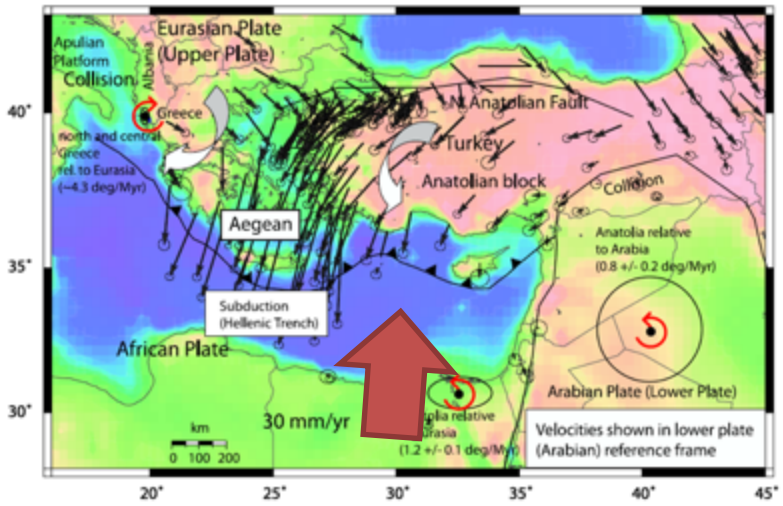


Modified from Sapin (2014)

Papua New Guinea



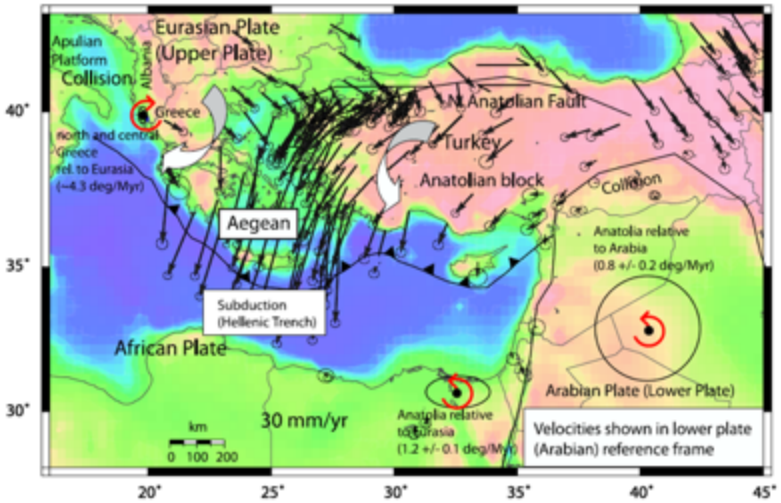
E Mediterranean Sea



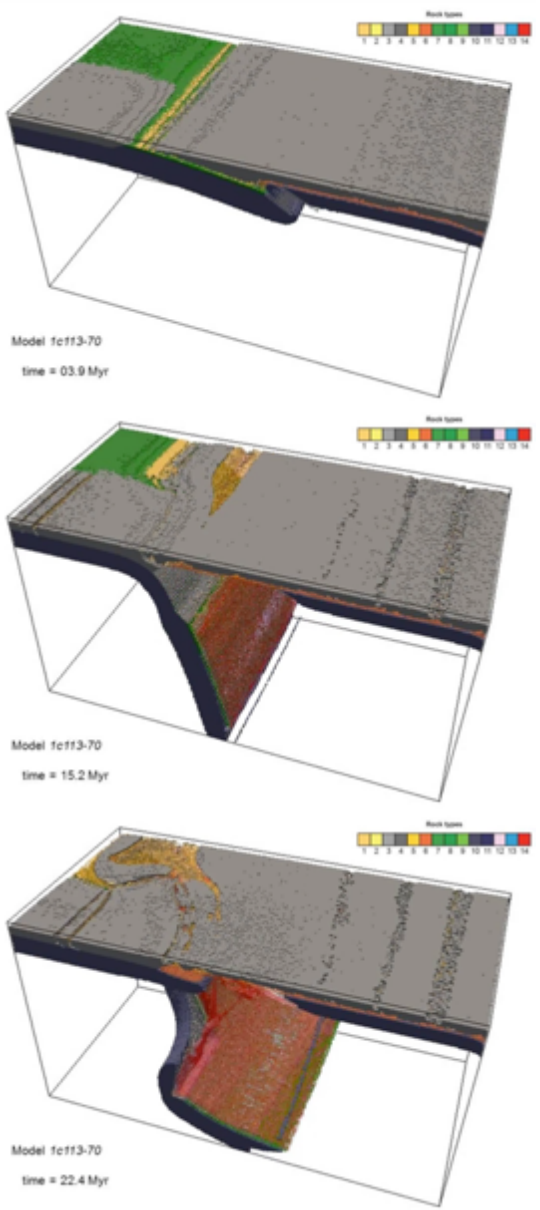
Wallace et al. (2009)

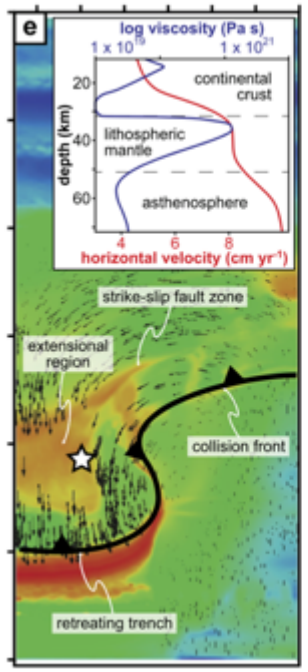
Block Rotation Induced by Subducting the Heterogeneity of Plate

E Mediterranean Sea

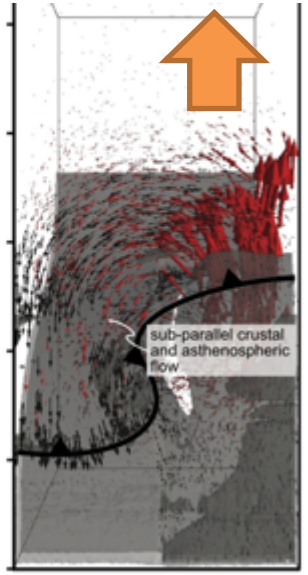


Wallace et al. (2009)





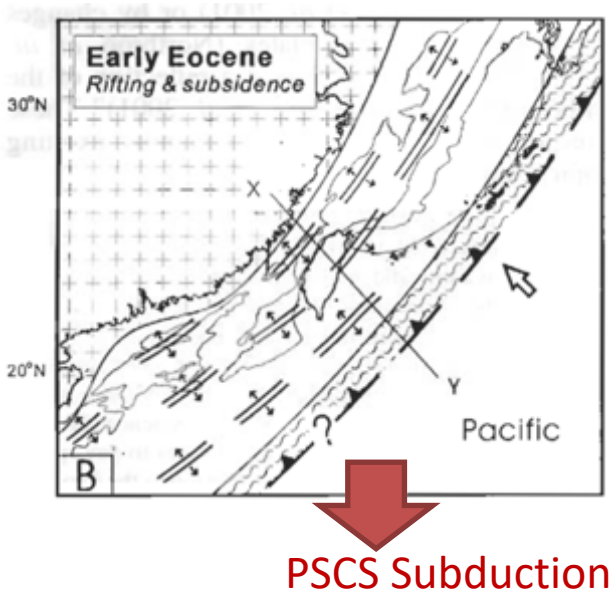
Toroidal flows



Menant et al. (2016)

Evolution of the South China Sea Opening

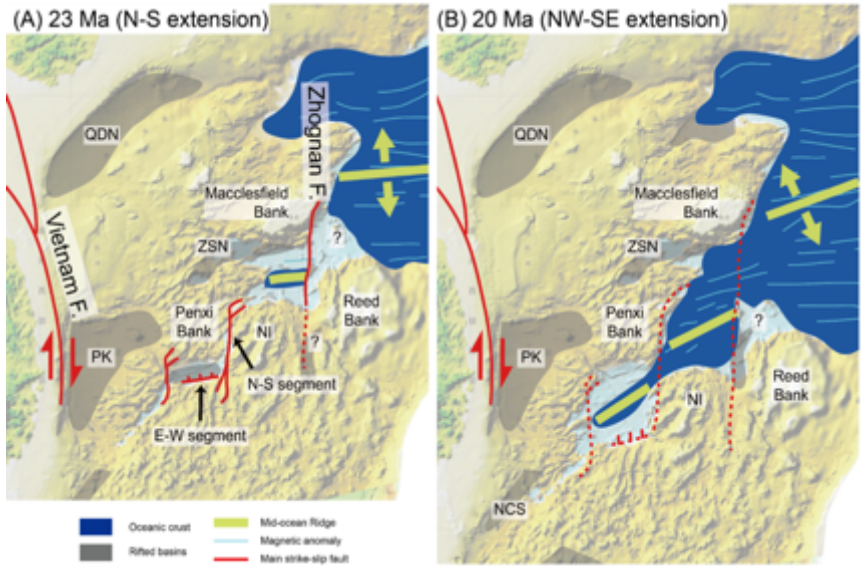
Subduction-induced?



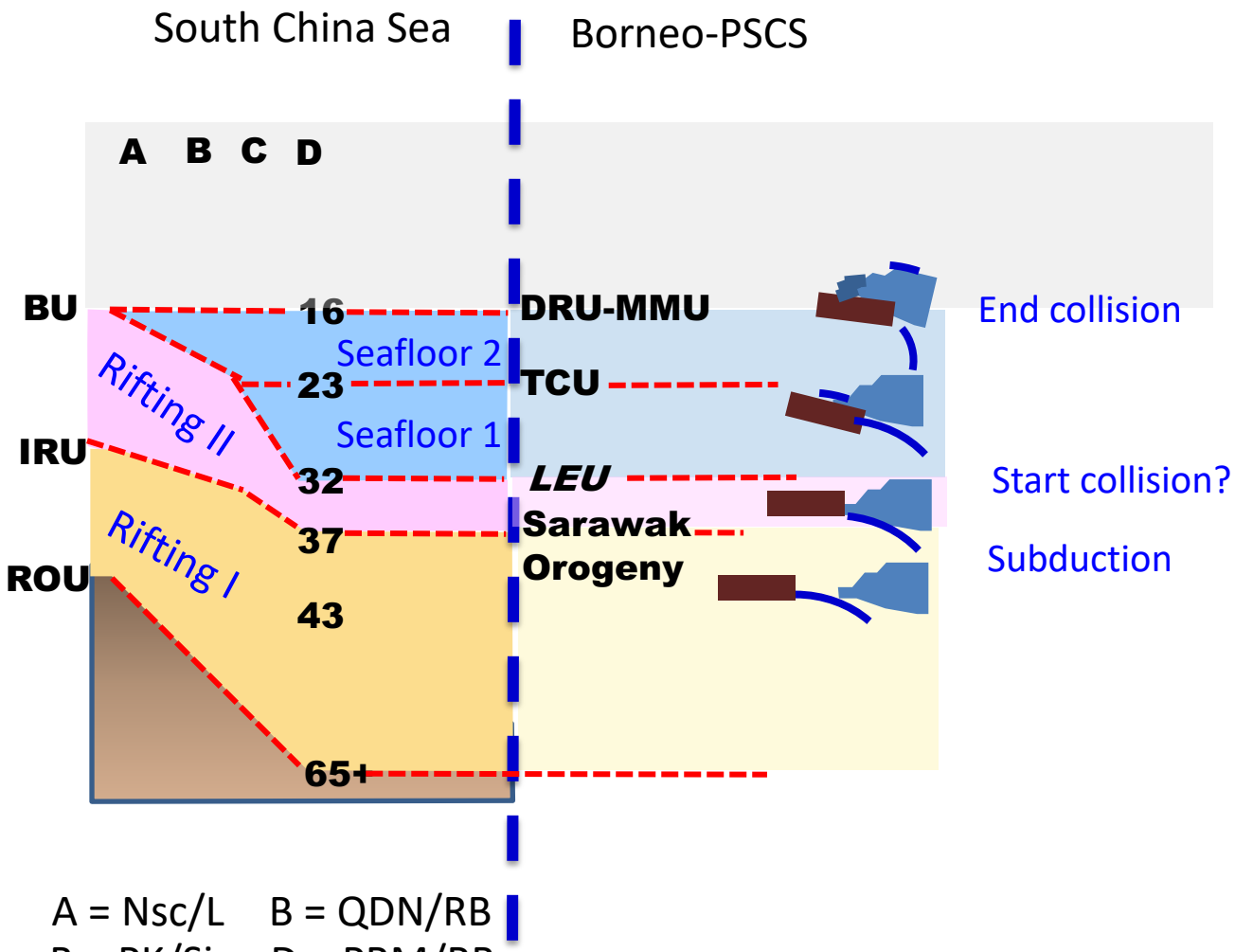
PSCS Subduction

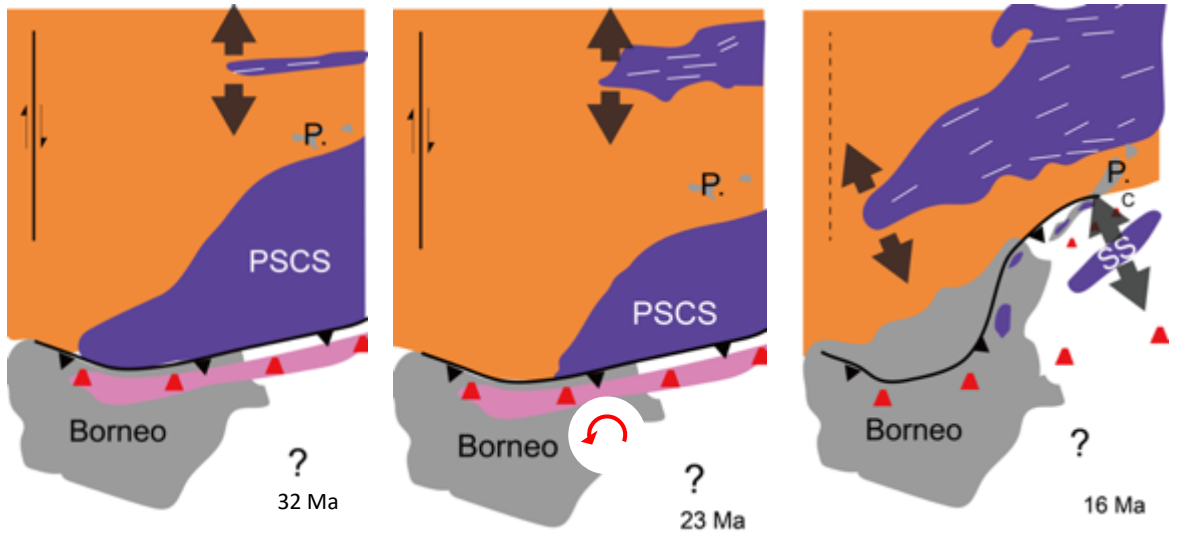
Teng and Lin (2004)

Collision-induced?



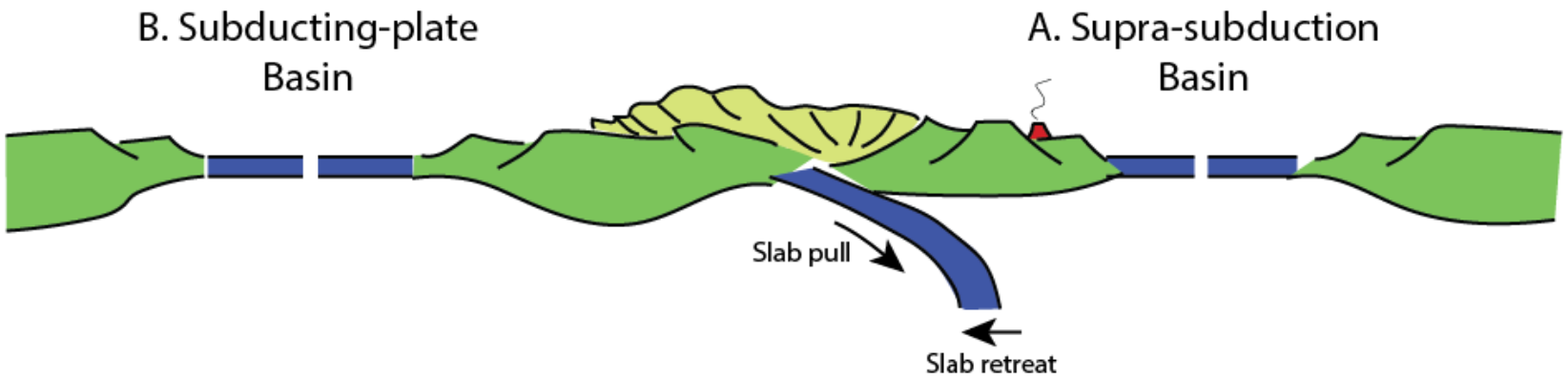
Correlation and Preliminary Plate Reconstruction for SCS and PSCS Margins





A = Nsc/L B = QDN/RB
B = PK/Si D = PRM/RB

Conclusion



- There is a good correlation between divergent and convergent margins
- Collision influenced the rearrangement of seafloor spreading in the South China Sea
- Vertical motion after 16 Ma corresponded to the slab detachment

Thank You for Your Attention