

# **The Sorong Fault Zone Kinematics: The Evidence of Divergence and Horsetail Structure at NW Bird's Head and Salawati Basin, West Papua, Indonesia\***

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## **Abstract**

The Sorong Fault Zone (SFZ) is an active left-lateral fault system that has been active since the late Miocene, confirmed by its activities during deposition of the late Miocene sequence. The SFZ is located in the northern margin of Papua, Indonesia, extending a thousand kilometers from the eastern part of the island to the Bird's Head region. Our new model indicates that SFZ moved the Bird's Head area, including Salawati Basin to the west in association with the movement of the Pacific Plate. The movement of SFZ involves rotation and translation that separates Salawati Basin from the Bird's Head region with basement high as the boundary of the basin.

More than 200 seismic lines have been interpreted in the Seram, Misool, and Salawati offshore. These interpretations show the development of NE-SW-trending listric and planar normal faulting in the western part of Misool Island and NE-SW-trending flower structure at NW Bird's Head region. This faulting activity was interpreted to be a result of SFZ activities which cut Paleozoic through the Tertiary formations. The listric and planar normal faults in the Salawati Basin explain the block rotation mechanism related to the Bird's Head movement to the west. The listric and normal faults are also related to the development of a pull-apart basin and en echelon faulting that involved the formation of the Salawati Basin. In addition, flower structures observed at NW Bird's Head indicate the shortening effect of the SFZ activities. These flower structures are also interpreted as a part of restraining fault in the SFZ strike-slip system, whereas, the releasing fault is also shown as a package of NE-SW normal faulting. These releasing and restraining faults are related to the horsetail mechanism that is also a part of SFZ strike-slip system.

New seismic interpretations combined with palinspastic reconstruction suggest that rotation and translation phases in relation to SFZ mechanism developed the Salawati Basin. These deformation mechanisms have been active since the late Miocene and are related to the collision between Pacific island arc complexes and passive margin of the NW Australian plate.

## References Cited

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# **THE SORONG FAULT ZONE KINEMATICS: THE EVIDENCE OF DIVERGENCE AND HORSETAIL STRUCTURE AT NW BIRD'S HEAD AND SALAWATI BASIN, WEST PAPUA, INDONESIA**

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**\*\*Institute of Technology Bandung, Bandung, Indonesia**

# **BACKGROUND AND OBJECTIVES**

## **BACKGROUND**

Sorong Fault Zone (SFZ) is an active major strike-slip fault system marking the interaction between Australian and Pacific plates; this is key in controlling Tertiary basin development and deformation in Bird's Head area, such as Salawati Basin.

## **OBJECTIVE**

To understand kinematics and to propose new mechanism of the Sorong Fault as implication for the evolution of Tertiary basin in the Bird's Head area

## **METHOD OF STUDY**

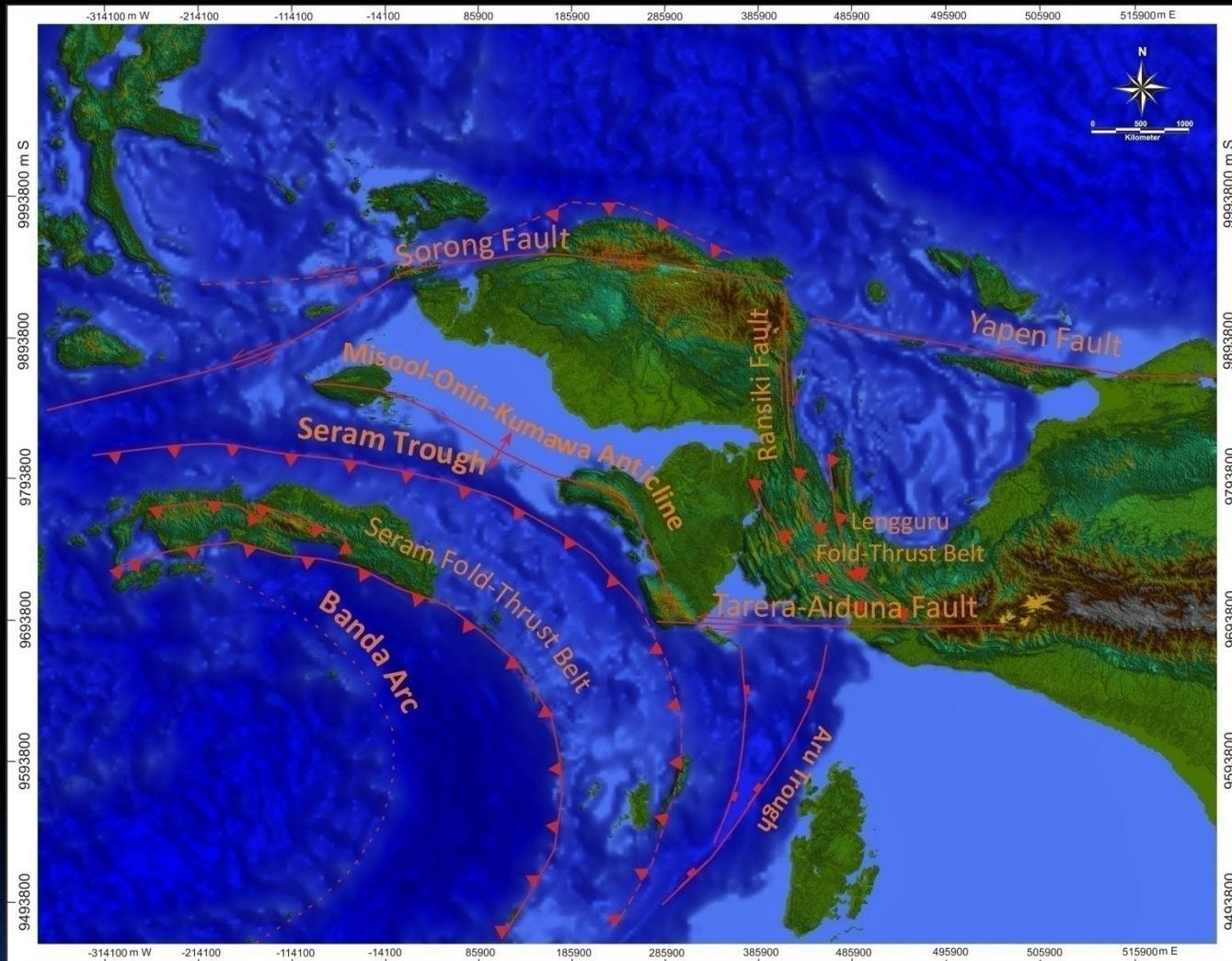
- Interpretation of new acquired 2D seismic data sets (TGS-NOPEC GEOPHYSICAL COMPANY, 2007)
- Conducted 2D/3D Palinspastic reconstructions using Move software package from Midland Valley (2009)



# **OUTLINE**

- **INTRODUCTION**
- **REGIONAL TECTONIC SETTING**
- **STRATIGRAPHY**
- **RESULT OF NEW INTERPRETATION**
- **2D/3D PALINSPASTIC RECONSTRUCTION**
- **CONCLUSION**

# INTRODUCTION

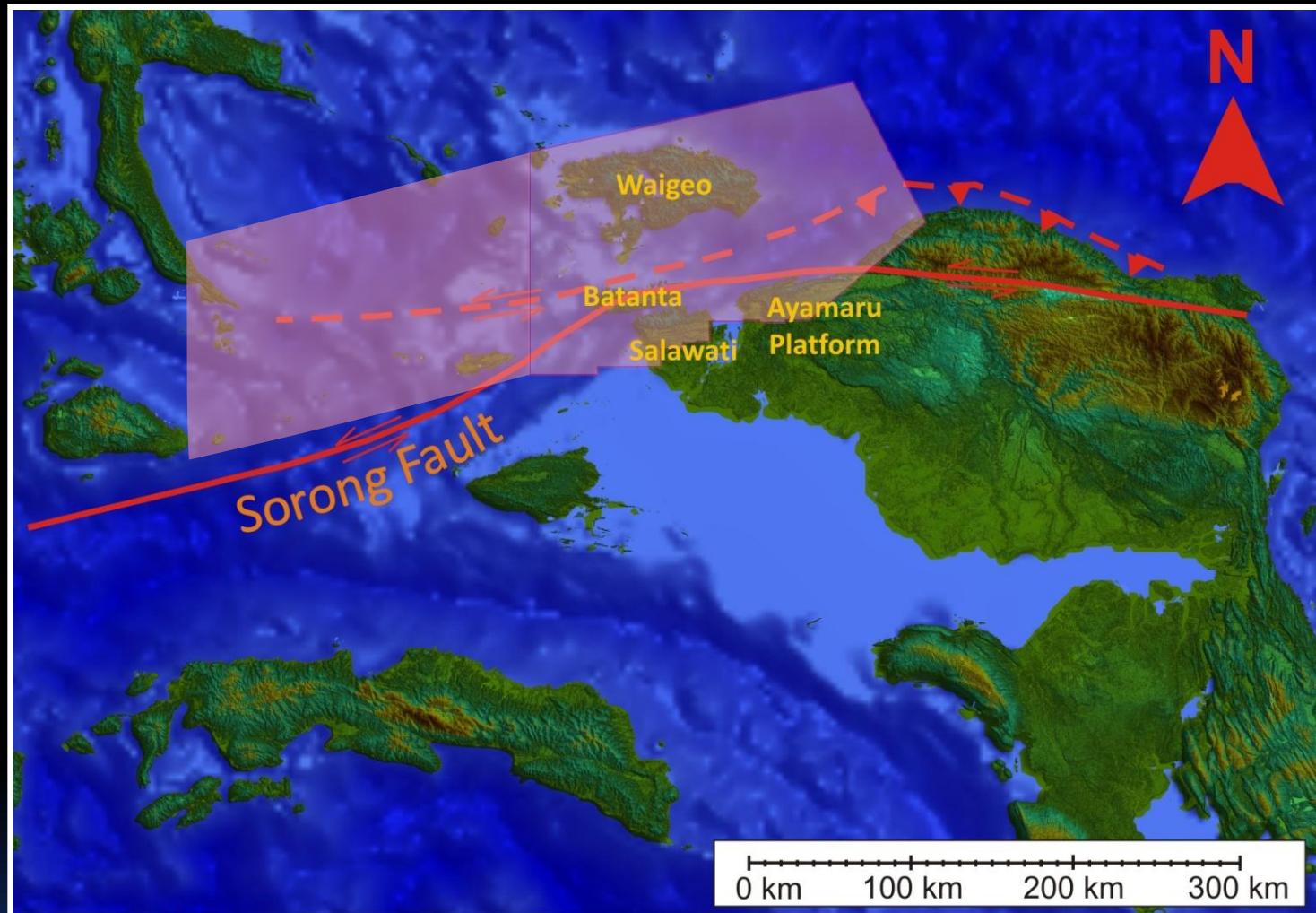


## Sorong Fault Zone (SFZ):

(Riadini, 2009)

- Left-lateral strike-slip fault system
- The direction changes from NW-SE to NE-SW at the western part
- Transform fault and a boundary of the Pacific and Australian plate

# INTRODUCTION

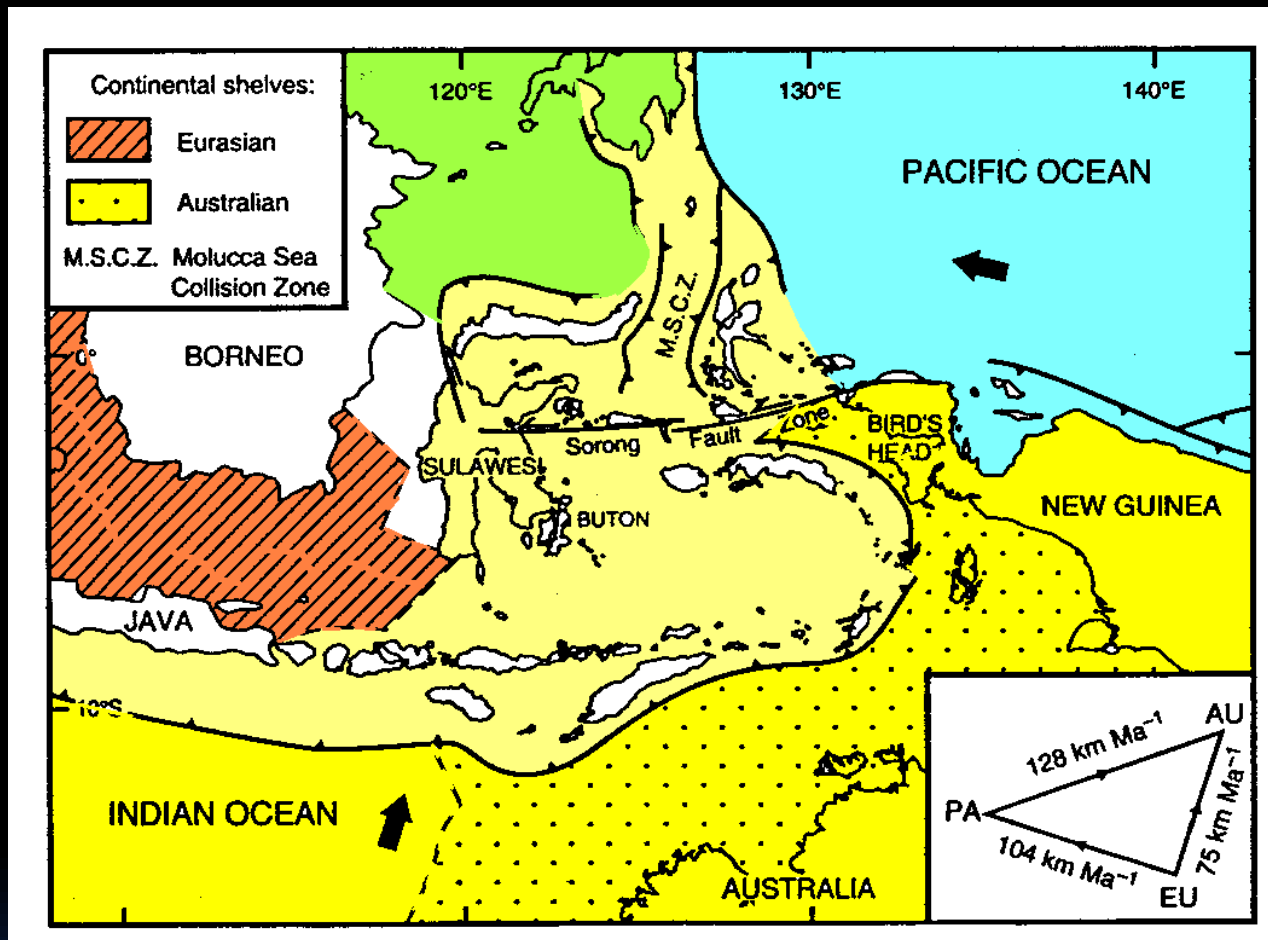


## The area of main concern:

- Bounded by Waigeo island on the NW; Ayamaru Platform, Salawati, and Batanta & Misool Island on the SE, S, and SW, respectively
- Affected by NE-SW-trending segment of the Sorong Fault



# REGIONAL TECTONIC SETTING

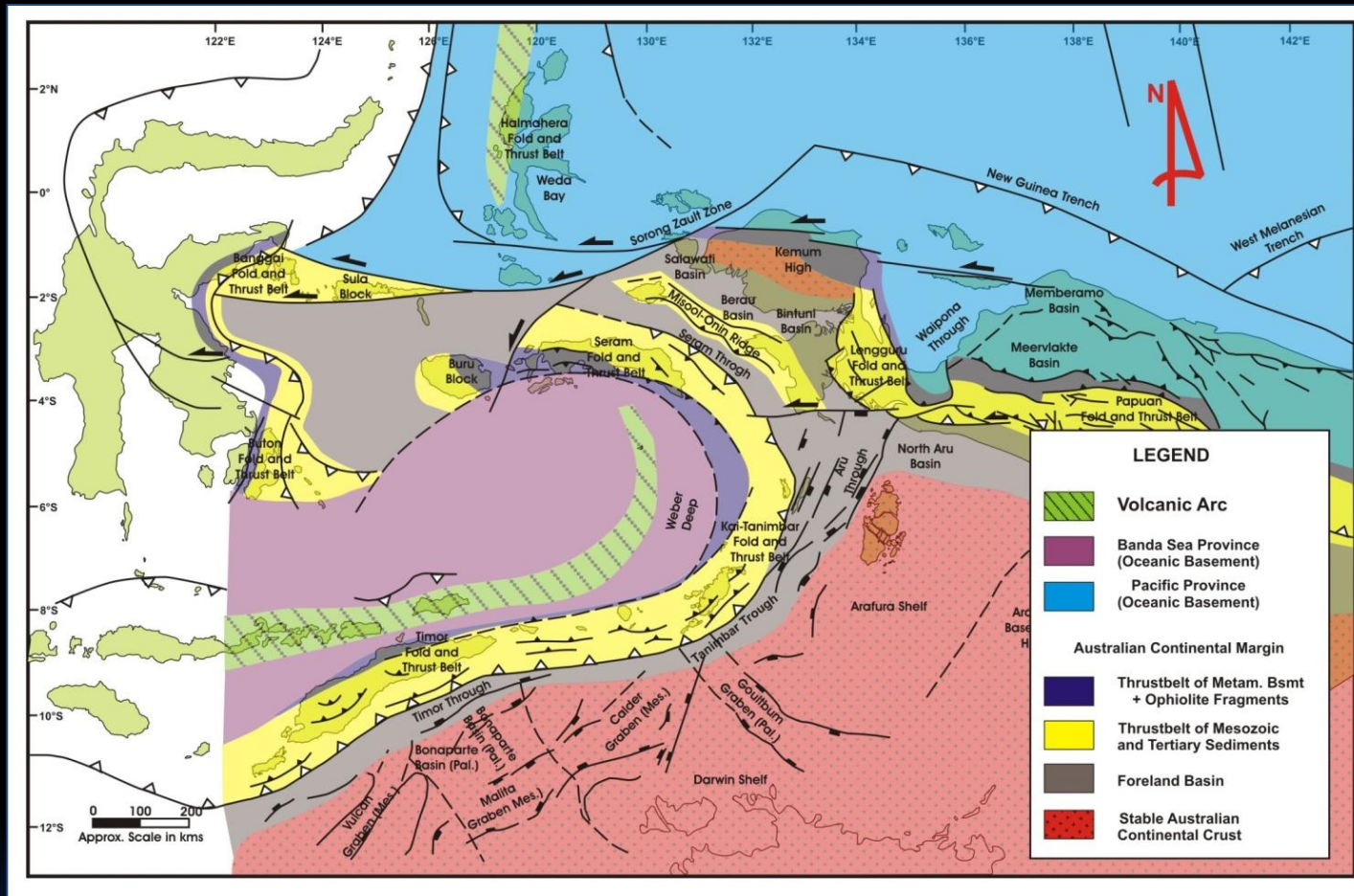


Present-day plate tectonic setting of Eastern Indonesia (Hall, 2004)

## Eastern Indonesia:

- Interaction of two major plates; Pacific plate moving to SW at 7 cm/year and Australian plate moving to N at 10cm/year
- Collisional orogeny since the late Miocene (Cloos et al., 2005)

# REGIONAL TECTONIC SETTING



Tectonic elements and structural provinces of Eastern Indonesia region (Barber, et . al, 2003)

## Eastern Indonesia:

- Plate movement created a convergent strike-slip system and resulting wrench and thrust fault system
- The plate activities caused reactivation; the N 300 E pre-existing faults became a sinistral strike-slip fault, and the E-W and NNW-SSE paleo faults became a thrust fault

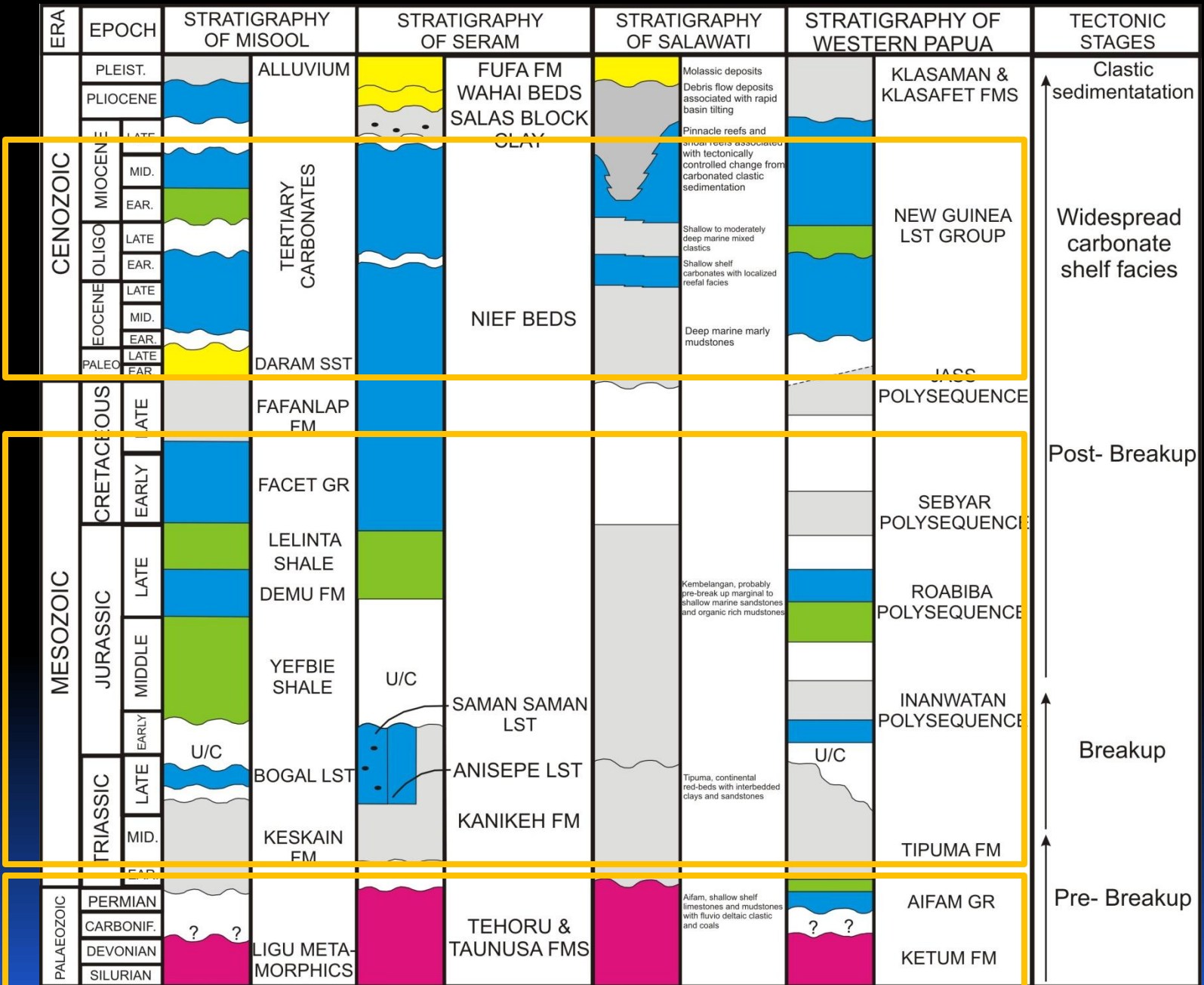
# REGIONAL TECTONIC SETTING

ERA	EPOCH	STRUCTURAL EVENT OF BIRD'S HEAD	STRUCTURAL EVENT OF MISOOL	STRUCTURAL EVENT OF SERAM	STRUCTURAL EVENT OF SALAWATI
CENOZOIC	PLEIST.	wrench faulting activities	Early Pliocene unconformity	Seram fold-thrust belt	wrench faulting/SFZ activities
	PLIOCENE				
	MIOCENE	wrench faulting	wrench faulting (reactivated the Triassic extensional fault)	wrench faulting (reactivated the Triassic extensional fault)	wrench faulting/SFZ
	OLIGO	the end of extension arc-continent collision	starting of Misool-Onin anticline; Late Oligocene unconformity	Late Oligocene unconformity	Late Oligocene unconformity
	EOCENE	the end of extension arc-continent collision	starting arc-continent collision	starting arc-continent collision	
	PALEO	the end of extension arc-continent collision	starting arc-continent collision	starting arc-continent collision	
MESOZOIC	CRETACEOUS	intracontinental extension		phases of continental rifting (E-W extension)	
	JURASSIC	phases of rifting on western margin of Australia	extensional phase (relative tectonic quiescence)	phases of continental rifting (E-W extension)	uplifted and eroded
	TRIASSIC	extensional faulting	minor angular unconformity	distal passive continental margin	
	TRIASSIC	extensional faulting	minor angular unconformity	distal passive continental margin	
PALAEOZOIC	PERMIAN	Pre-Breakup (rift system and a major phase of regional extension)	rift graben	rift graben; block faulted structure; series of rotated normal fault blocks on north Berau	rift graben
	CARBONIF.				
	DEVONIAN				
	SILURIAN				

(Riadini, 2009)

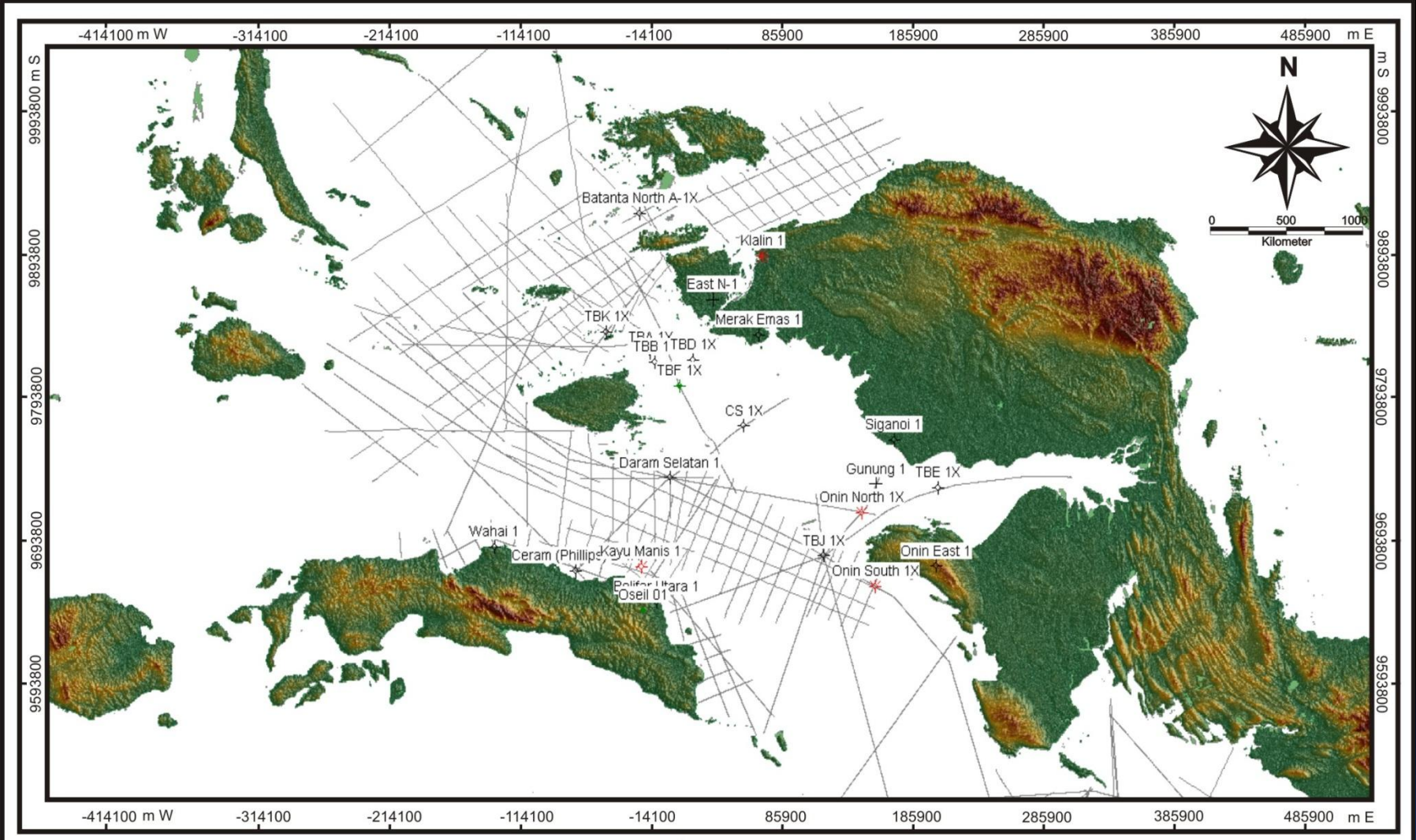


# STRATIGRAPHY



(Modified from Fraser et al., 1993; Pairault et al., 2003 and Satyana, 2003)

## NEW INTERPRETATION

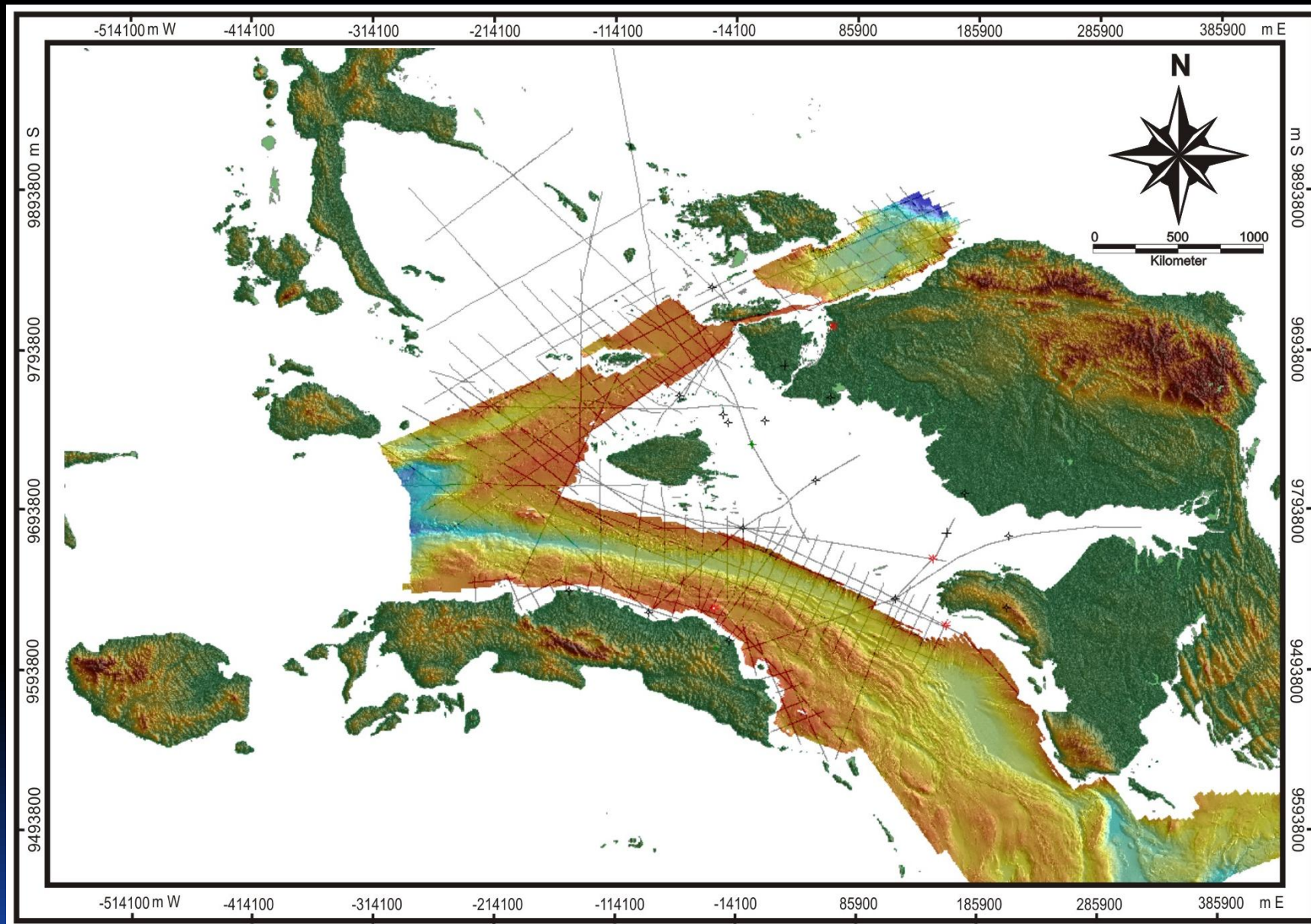


Available data (on Seram, Misool, Salawati) provided by TGS-NOPEC Geophysical Company (1998, 1999, 2007) :

204 seismic lines  
22 wells

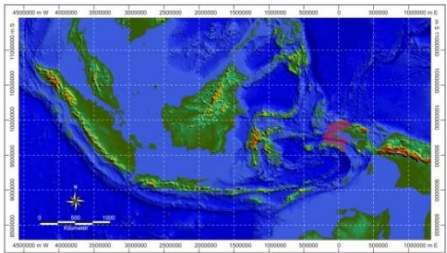
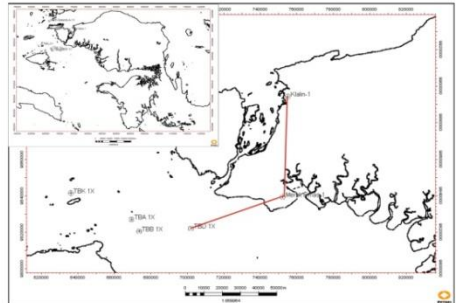
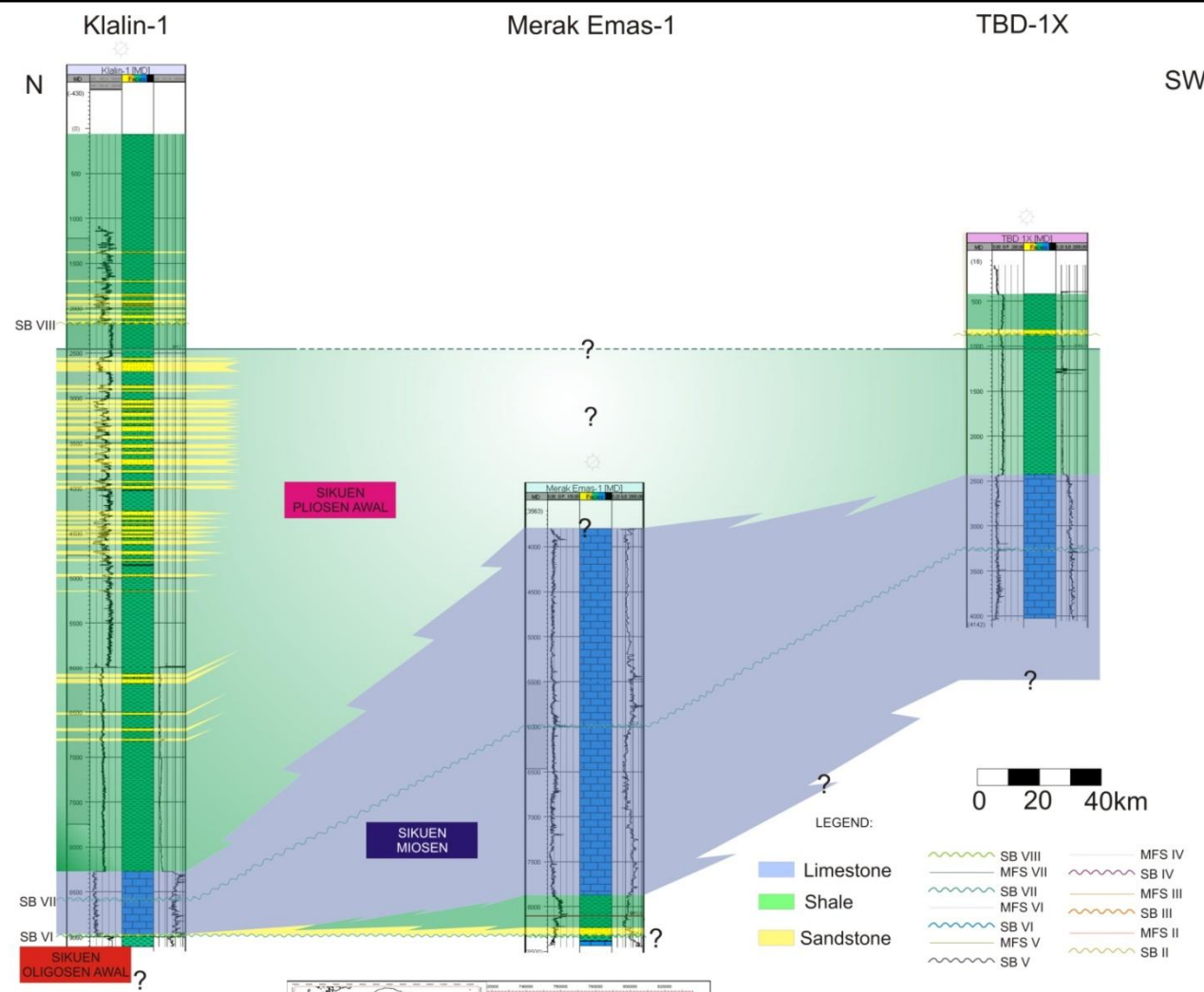


# NEW INTERPRETATION



Multibeam data (on Seram, Misool, Salawati)  
provided by TGS-NOPEC Geophysical Company (2007)

# NEW INTERPRETATION



The figure is a geological map of the Toba region, showing four stratigraphic columns (North Batanta-1, TBA-1X, Daram Selatan-1, Bolifar Utara-1) and a geological cross-section. The map includes a legend for Limestone (blue), Shale (green), and Sandstone (yellow). It also features a scale bar (0-60km) and two inset maps: a regional map of Indonesia and a detailed geological map of the Toba area. The stratigraphic columns show various stages (SB II to SB VIII) and fossiliferous stages (MFS II to MFS IV). The cross-section shows the relationship between these stages and the underlying basement.

**LEGEND:**

- Limestone (Blue)
- Shale (Green)
- Sandstone (Yellow)

**Stratigraphic Columns:**

- North Batanta-1:** SB VIII, SB VII, SB VI, BASEMENT.
- TBA-1X:** SB VIII, SB VII, SB VI, SB V, SB IV, SB III, SB II.
- Daram Selatan-1:** SB VIII, SB VII, SB VI, SB V, SB IV, SB III, SB II.
- Bolifar Utara-1:** SB VIII, SB VII, SB VI, SB V, SB IV, SB III, SB II.

**Geological Cross-section:**

- SB VIII
- SB VII
- SB VI
- SB V
- SB IV
- SB III
- SB II

**Geological Features:**

- SIKUN PLOSSEN AWAL
- SIKUN MIOSSEN
- SIKUN KAPUR
- SIKUN JURA AKHIR
- SIKUN KPA AWAL TENGAH
- SIKUN TRIAS

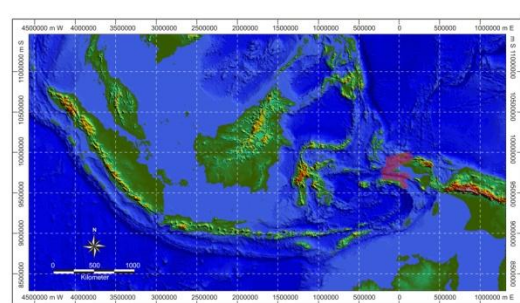
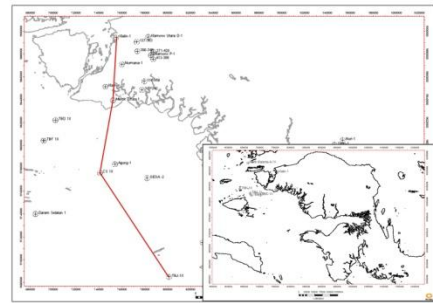
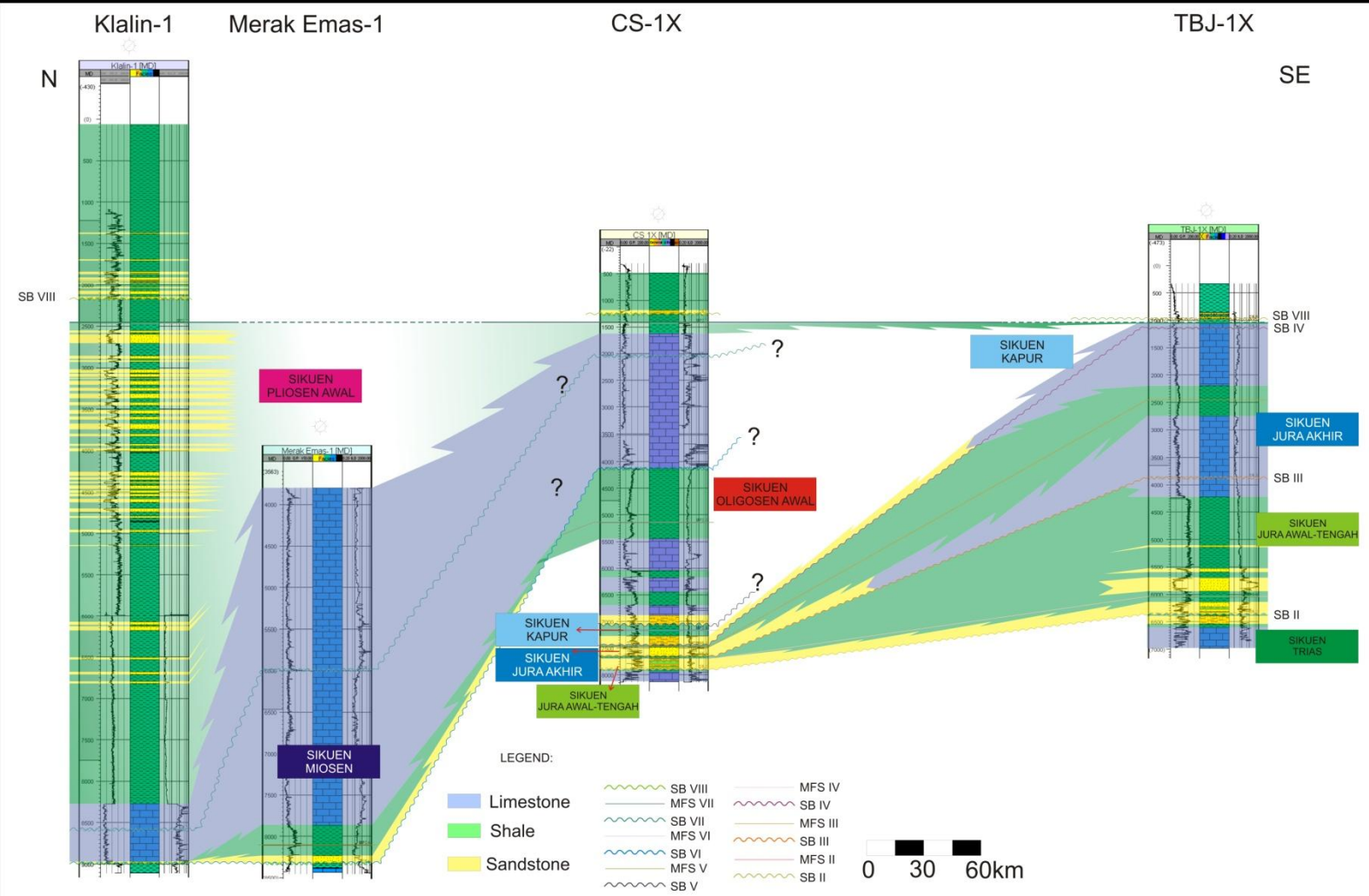
**Scale:** 0 30 60km

**Inset Maps:**

- Regional map of Indonesia showing the location of the Toba region.
- Detailed geological map of the Toba area showing the distribution of geological units.

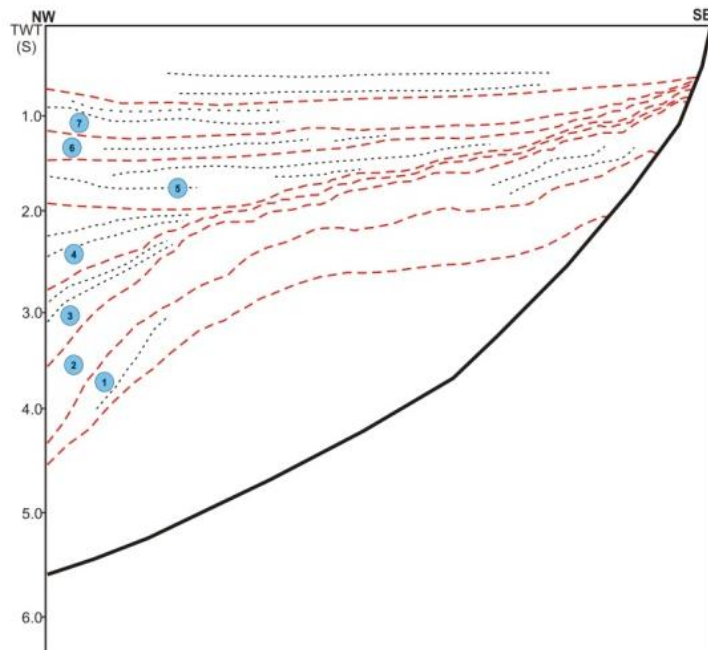
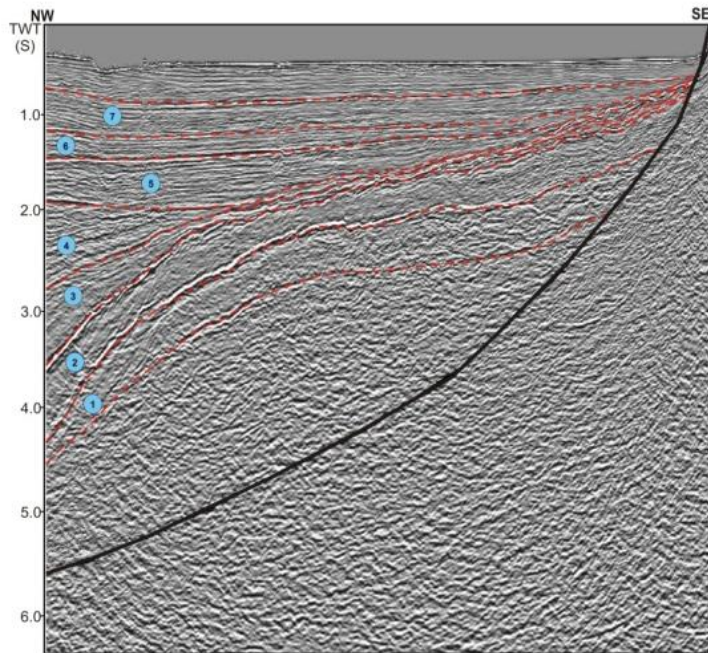


# NEW INTERPRETATION





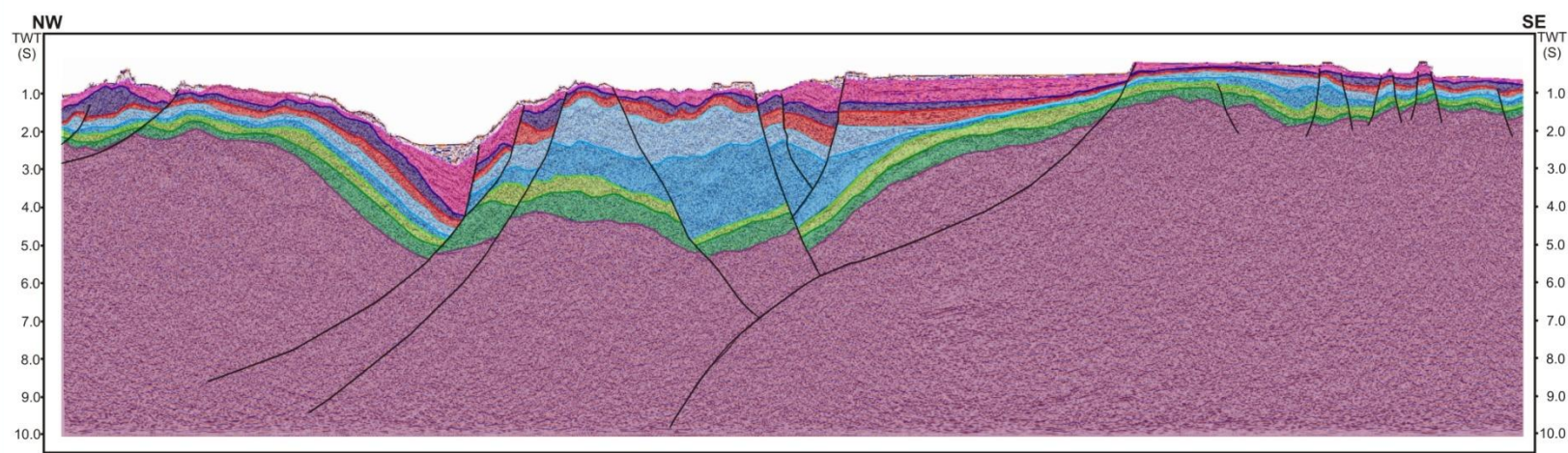
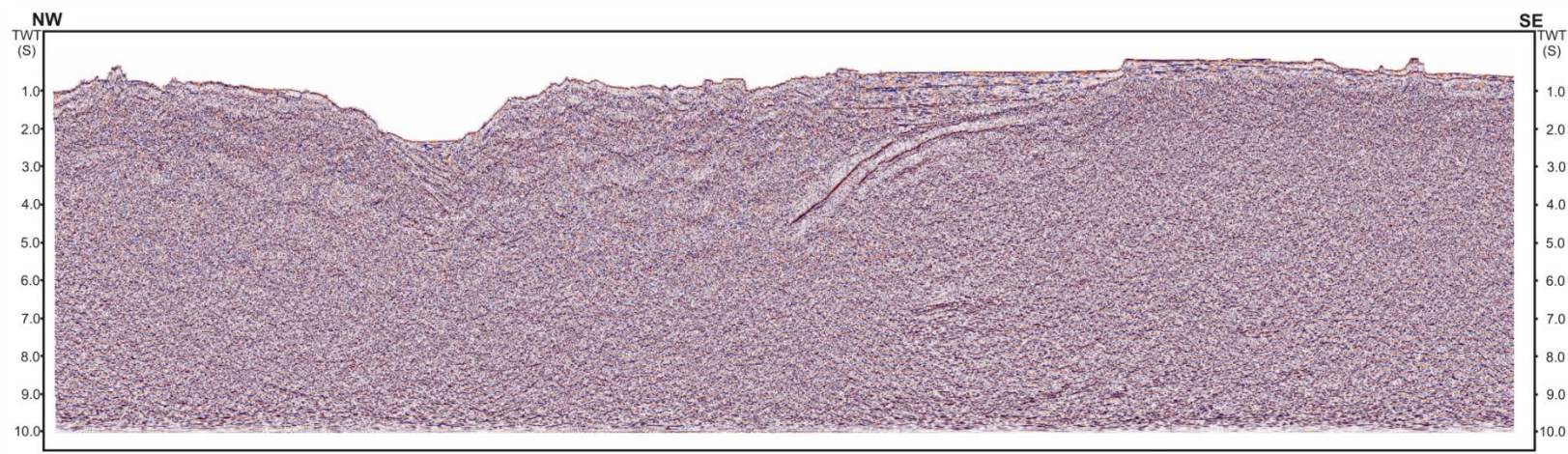
# NEW INTERPRETATION



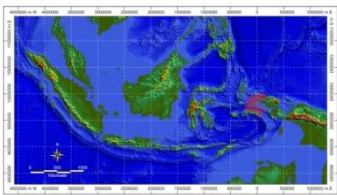
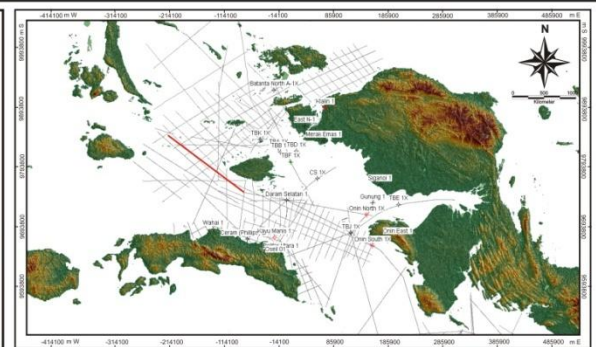
- Unit 7 – Top Early Pliocene  
Continuous, low – medium amplitude, medium – high frequency
- Unit 6 – Top Miocene  
Not continuous, medium – high amplitude, medium – high frequency
- Unit 5 – Top Early Oligocene  
Not continuous, low – medium amplitude, low – medium frequency
- Unit 4 – Top Early Cretaceous  
Not continuous, low – medium amplitude, low – medium frequency
- Unit 3 – Top Late Jurassic  
Not continuous, low – medium amplitude, low frequency
- Unit 2 – Top Early – Middle Jurassic  
Not continuous, low amplitude, low frequency
- Unit 1 – Top Triassic  
Not continuous, low amplitude, low frequency



# NEW INTERPRETATION

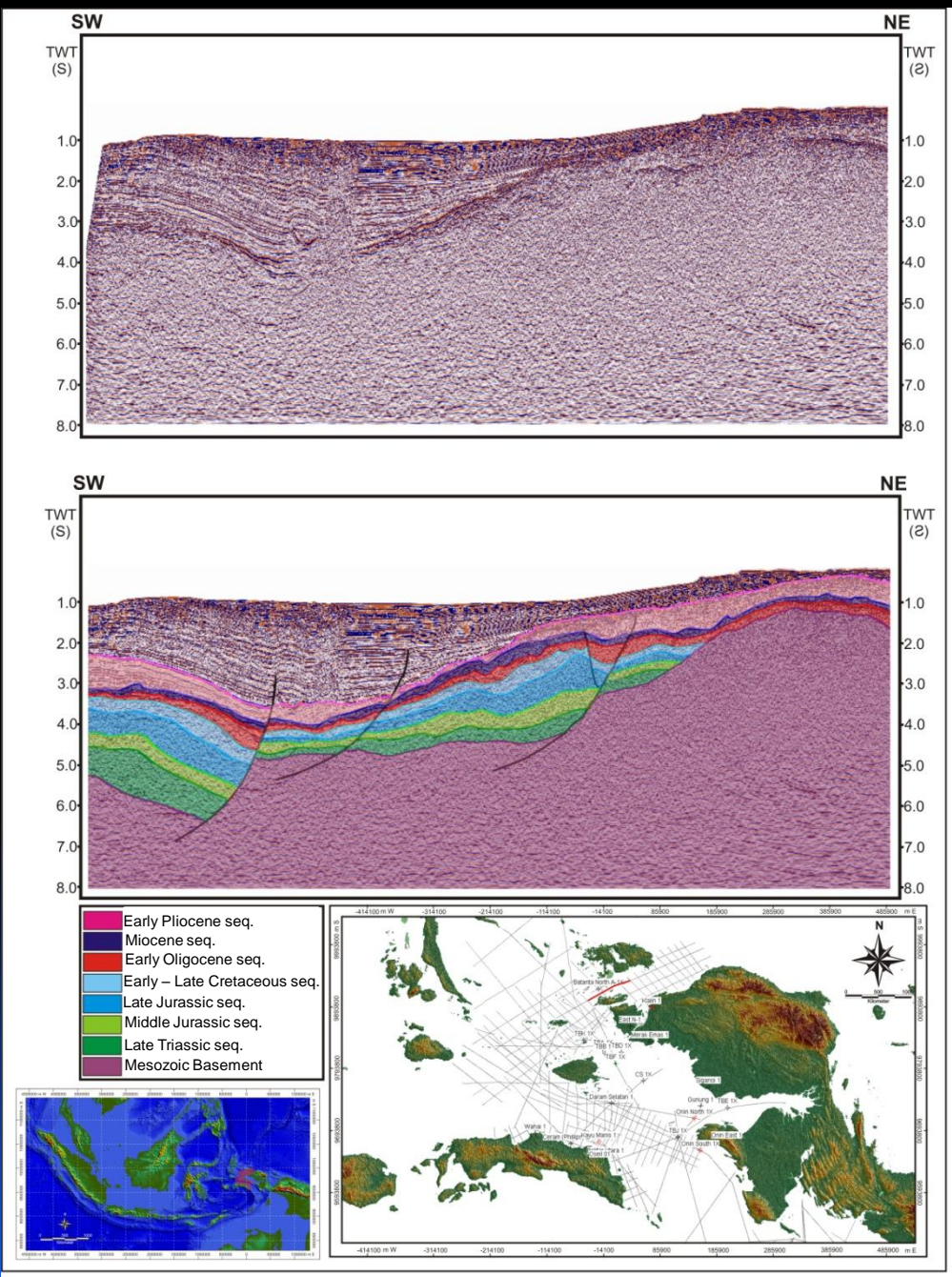


- Early Pliocene seq.
- Miocene seq.
- Early Oligocene seq.
- Early - Late Cretaceous seq.
- Late Jurassic seq.
- Middle Jurassic seq.
- Late Triassic seq.
- Mesozoic Basement

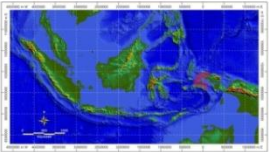
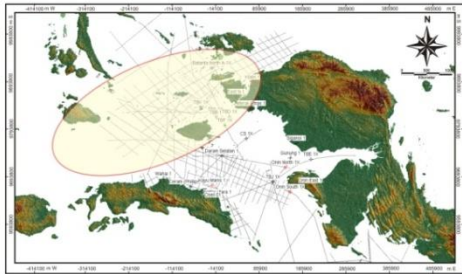
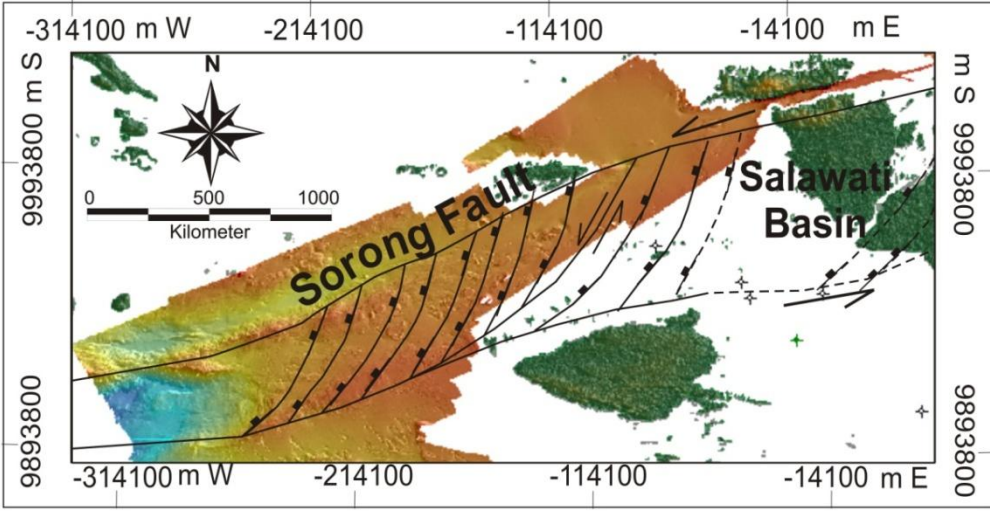
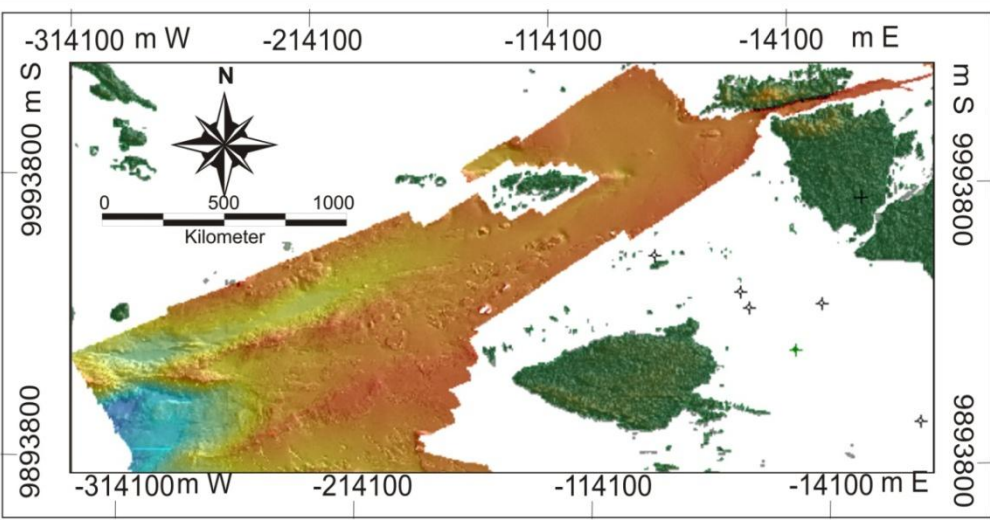




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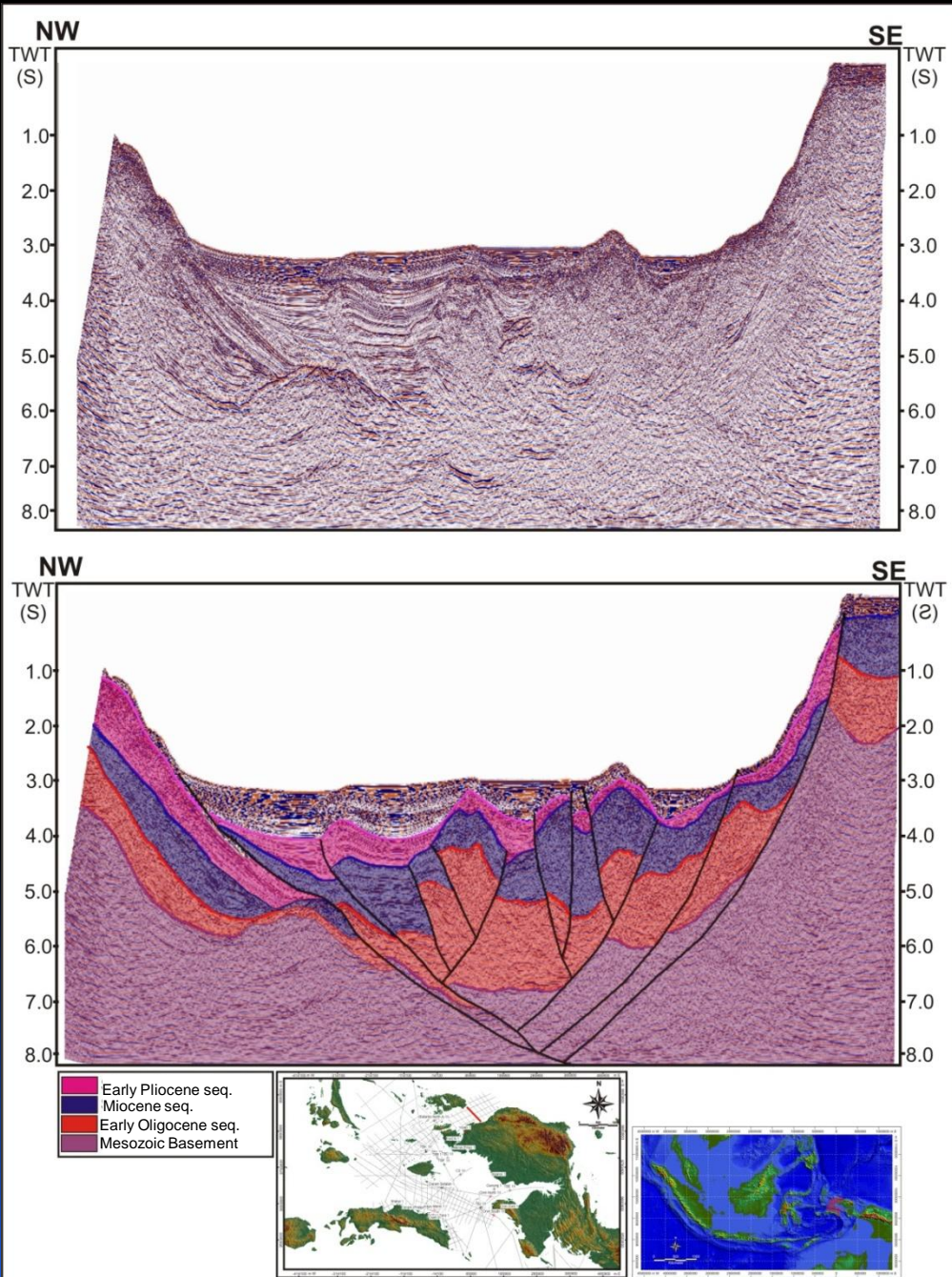


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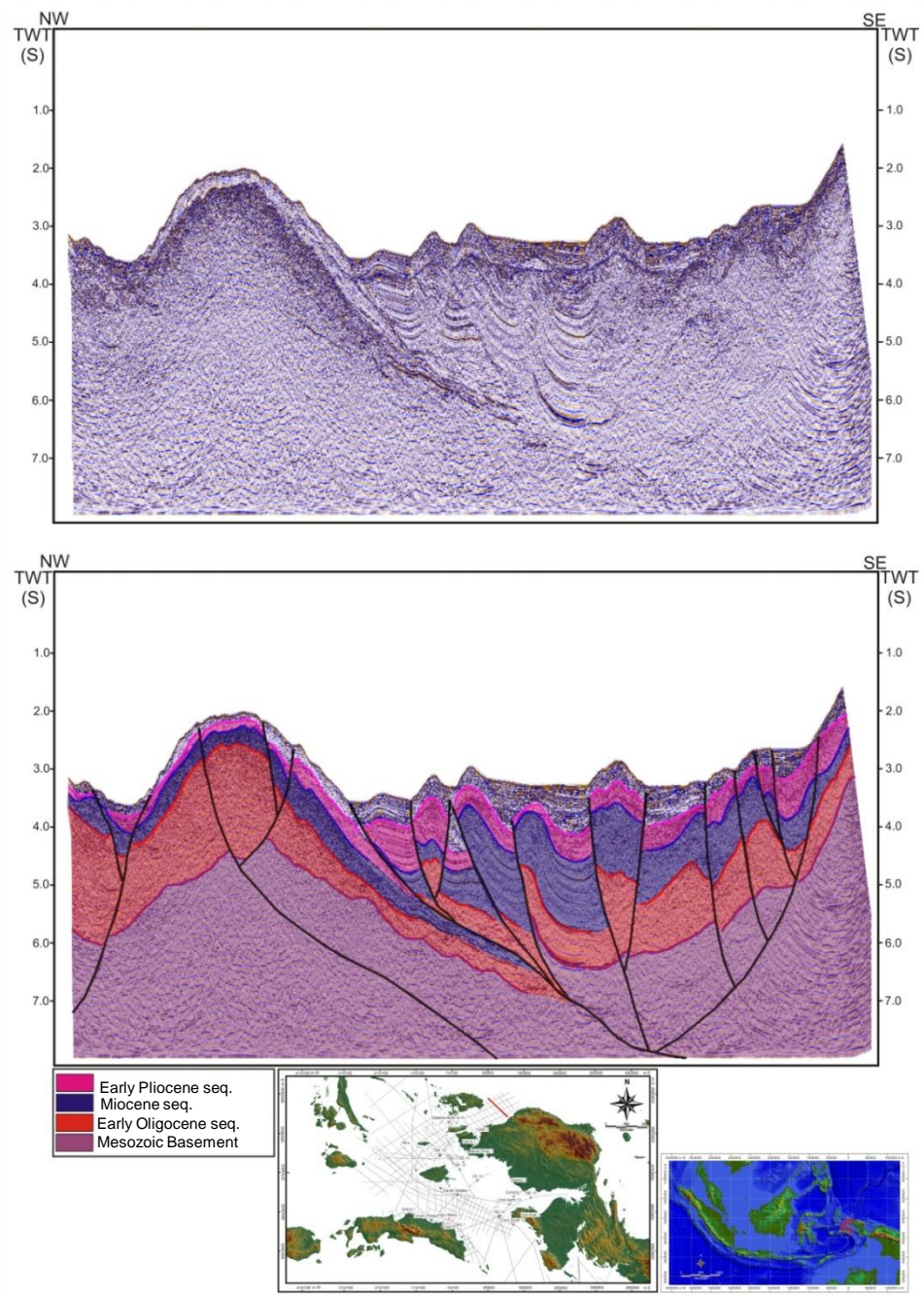




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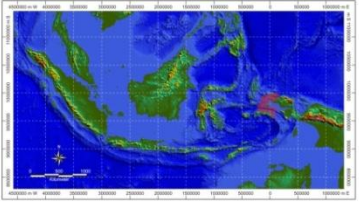
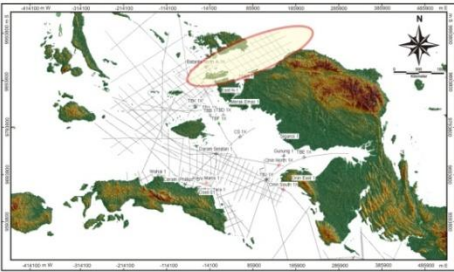
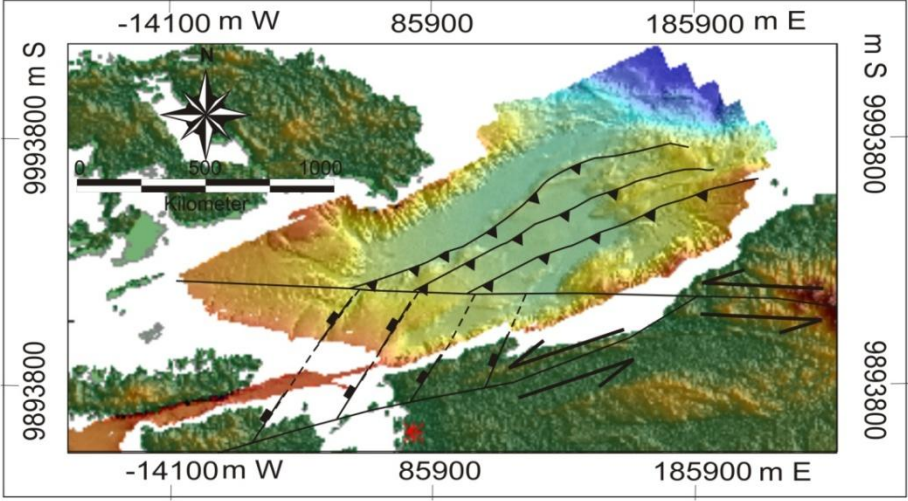
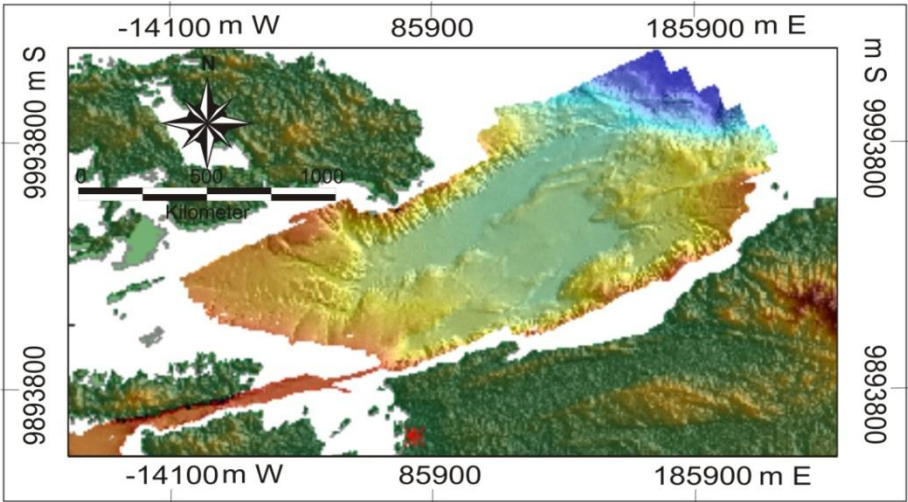


# NEW INTERPRETATION





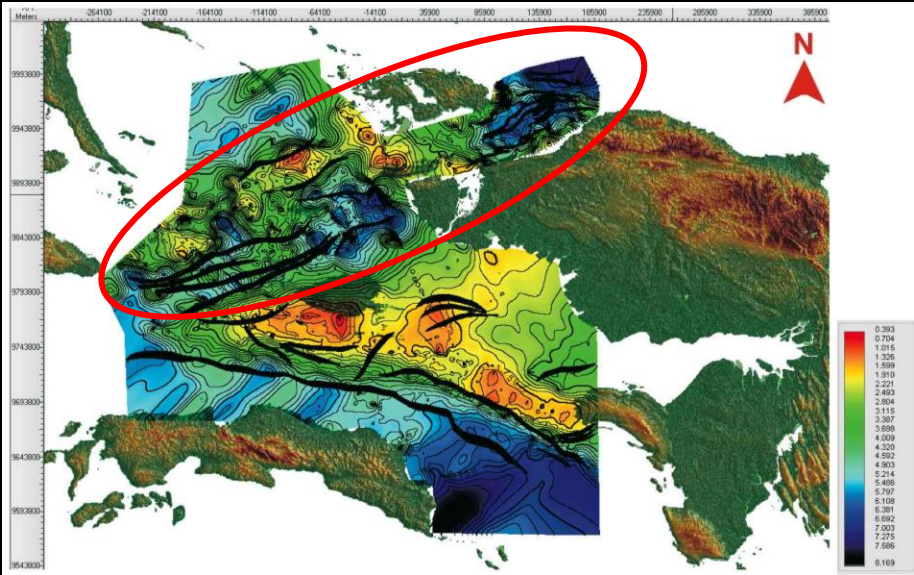
# NEW INTERPRETATION



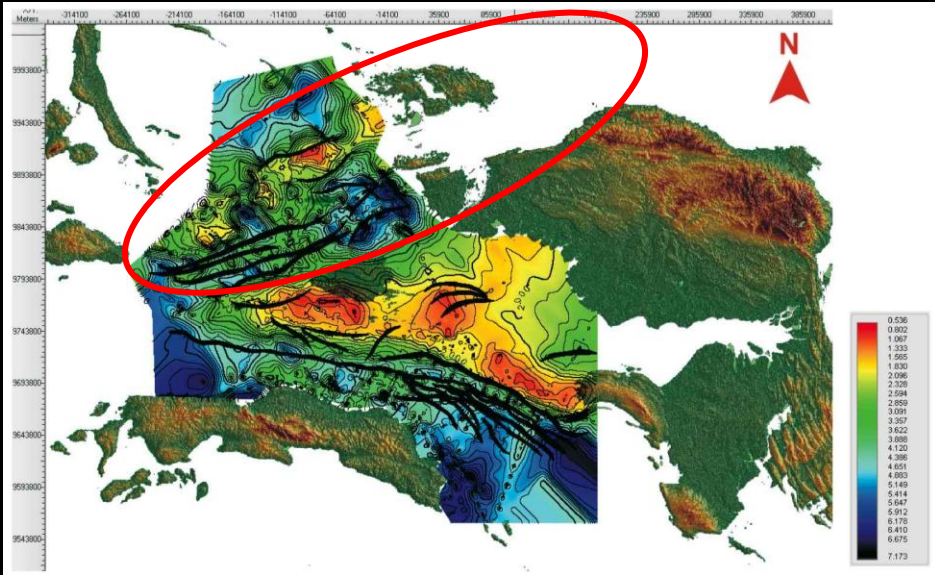


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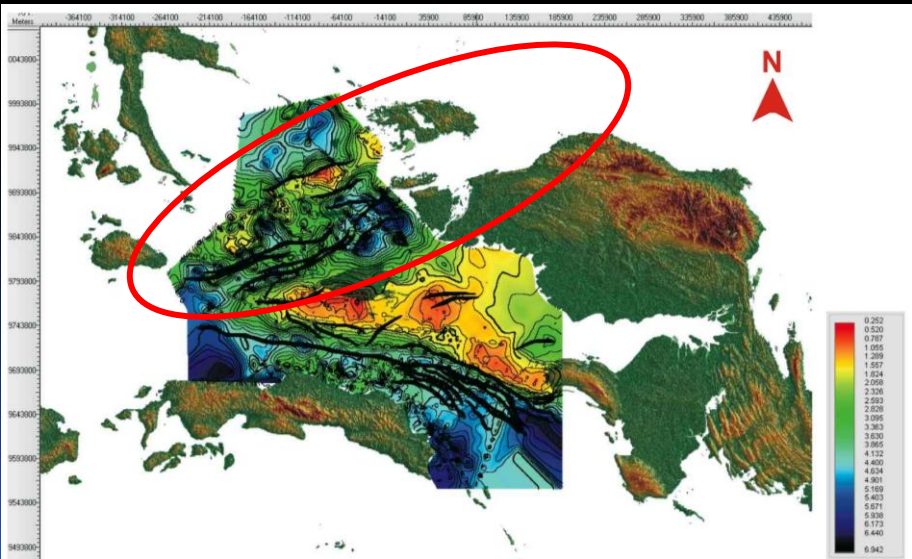
## Isochore Map of Seram, Misool, and Salawati areas



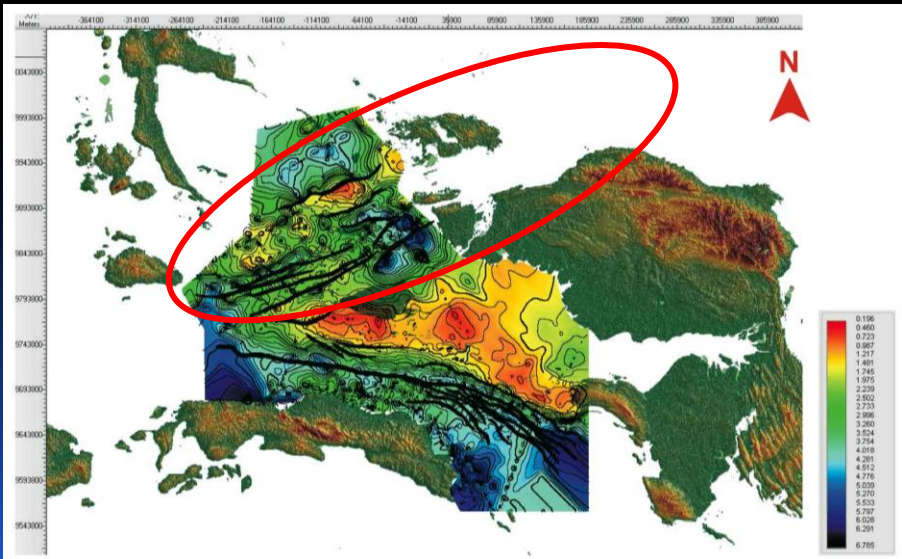
Mesozoic Basement



Triassic Sequence



Early-Middle Jurassic Sequence

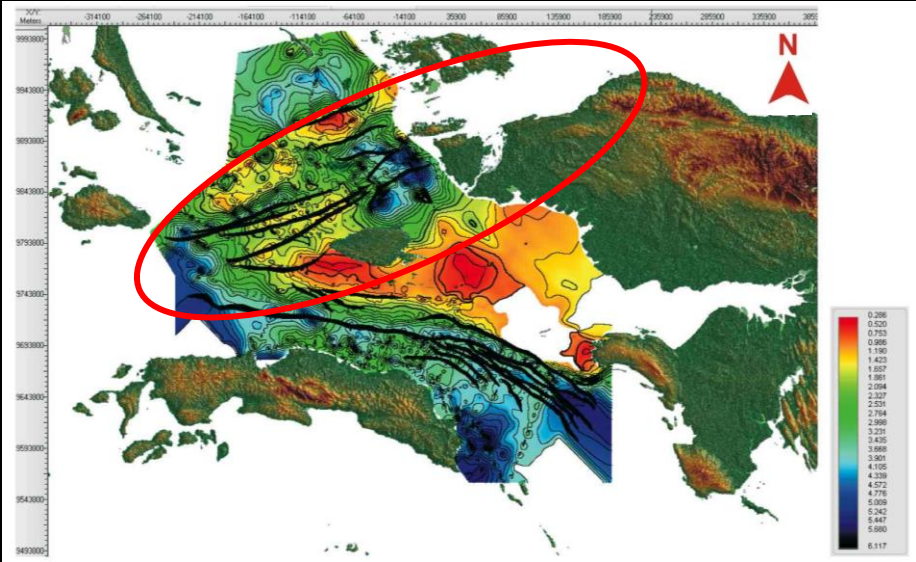


Late Jurassic Sequence

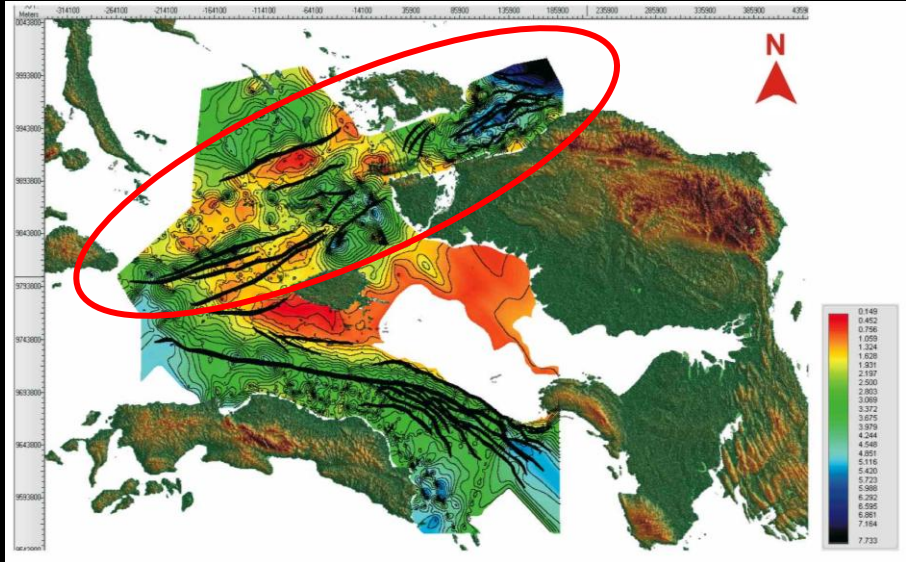


# NEW INTERPRETATION

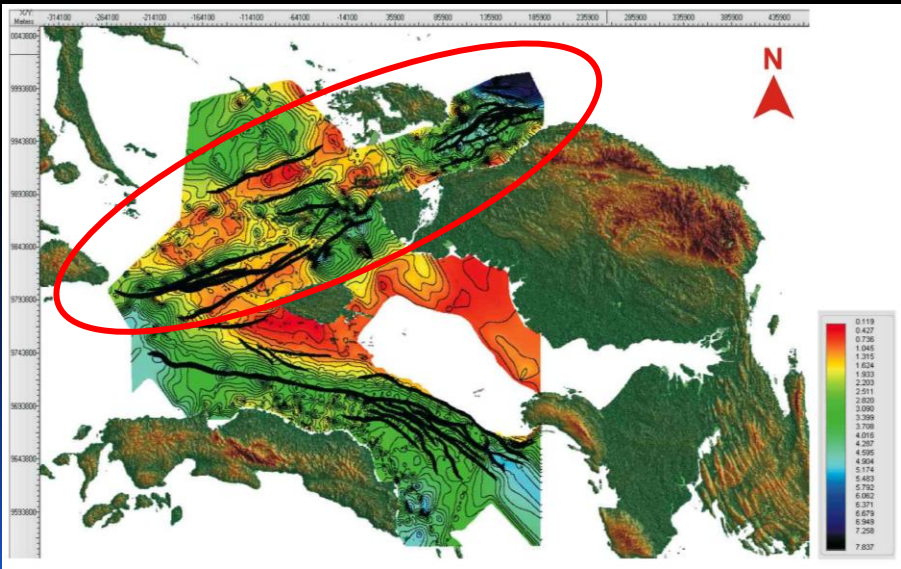
## Isochore Map of Seram, Misool, and Salawati areas



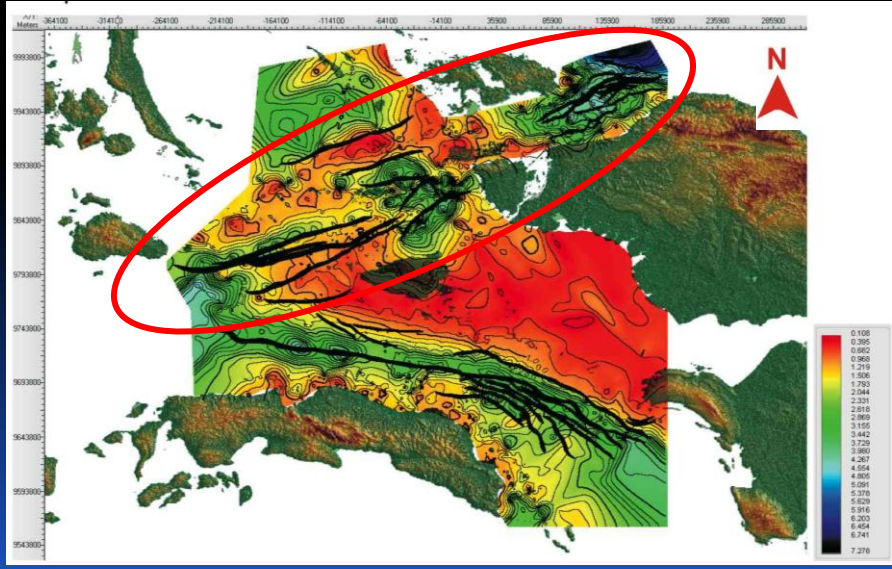
Early Cretaceous Sequence



Early Oligocene Sequence



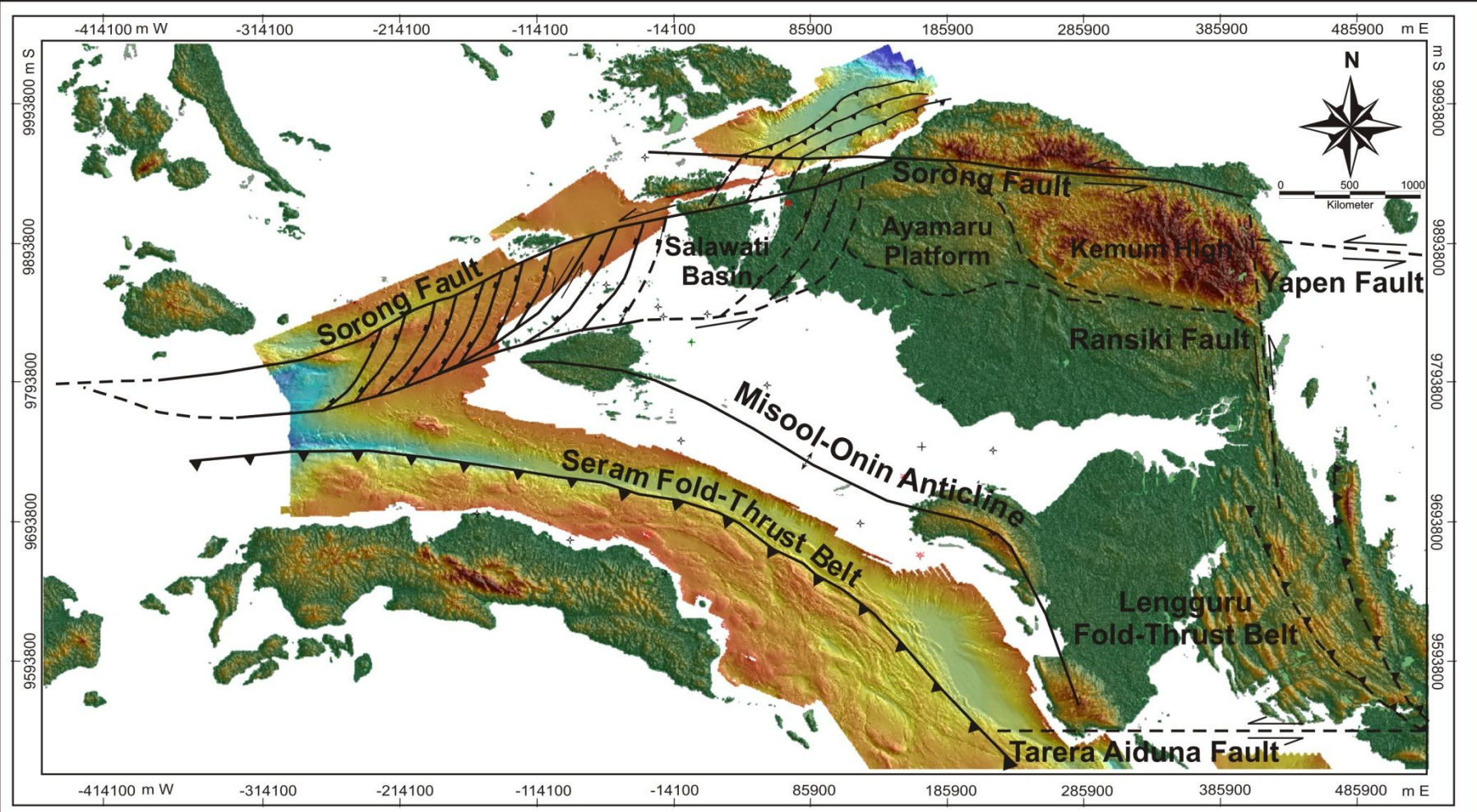
Miocene Sequence



Early Pliocene Sequence



**NEW INTERPRETATION**



# PALINSPATIC RECONSTRUCTION

A Balanced Cross Section is a deformed-state cross section that is both admissible and viable (Marshak & Mitra, 1988).

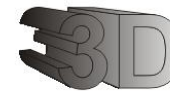
## 2D

Bed-length conservation

Bed area conservation

Applies to plane strain in:

- Thrust and fold belts
- Extensional regimes
- Inversion tectonics
- Salt tectonics



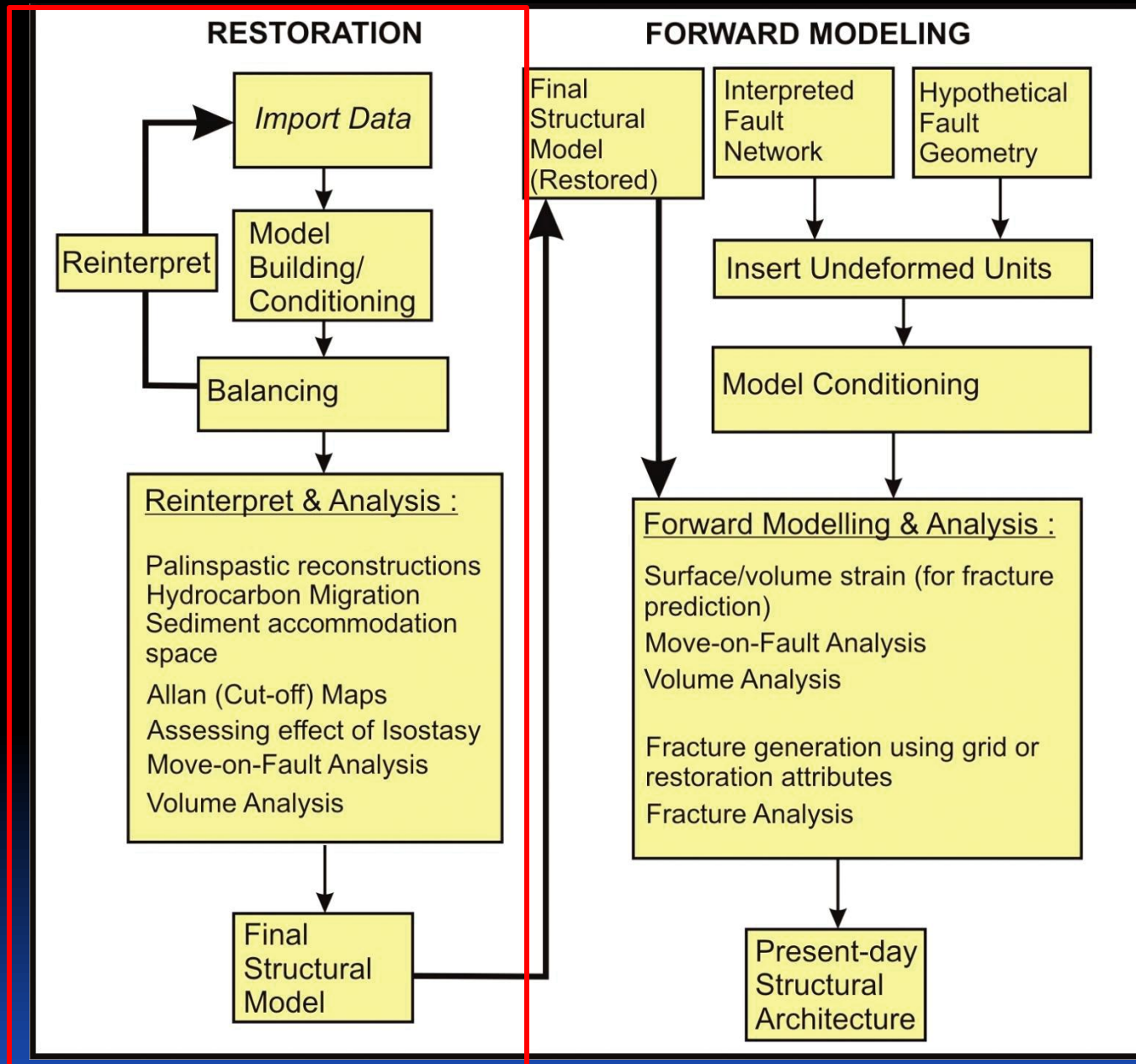
Bed surface area conservation

Bed volume conservation

Applies to:

- Thrust and fold belts
- Extensional regimes
- Inversion tectonics
- Salt tectonics
- Strike-slip tectonics

# PALINSPASTIC RECONSTRUCTION



Structural Modelling Workflows provided by Midland Valley (2009 Move)

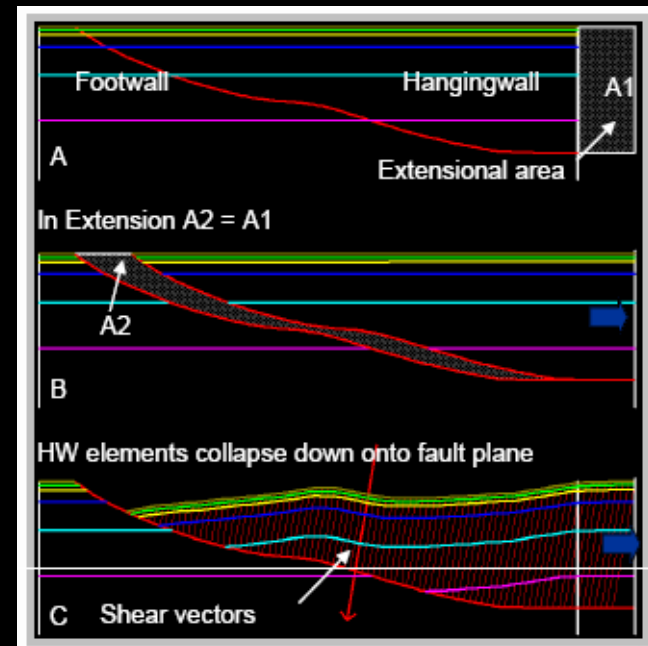


# PALINSPASTIC RECONSTRUCTION

## Inclined Shear

Principle: Restore or forward model the relationships between fault geometry and hangingwall deformation using vertical/inclined shear vector

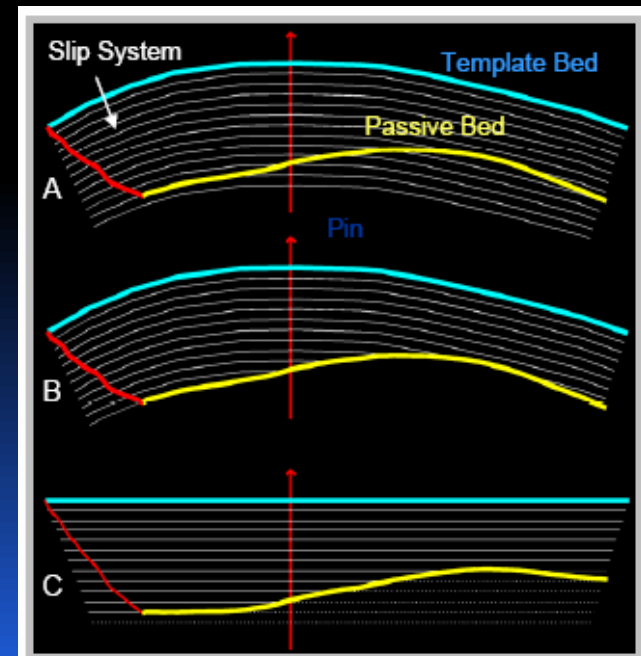
Applicable to: Extensional Tectonics, Inversion, Growth Faults



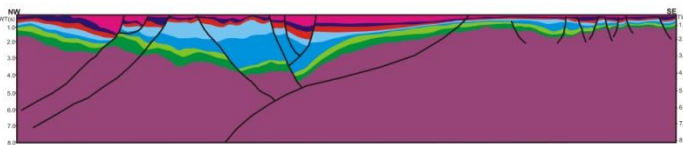
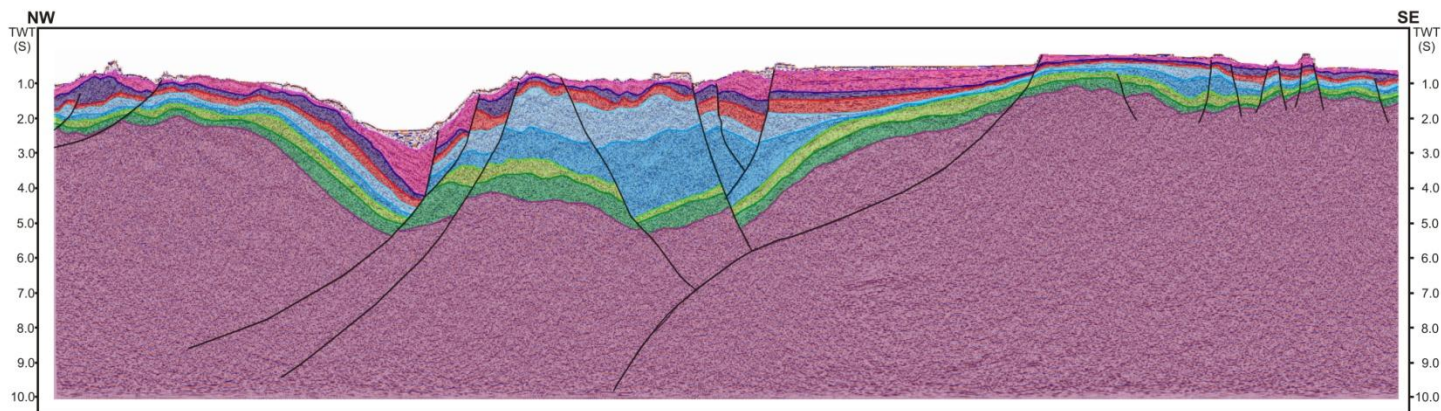
## Flexural Slip Unfolding

Principle: Restore or forward model folds generated by a flexural slip mechanism

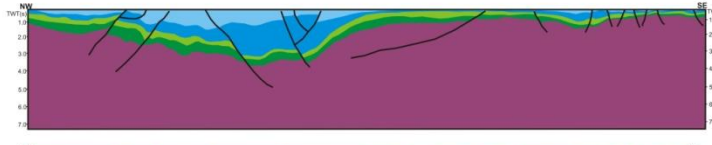
Applicable to: Fold & Thrust Belts, Inversion, Salt Tectonics



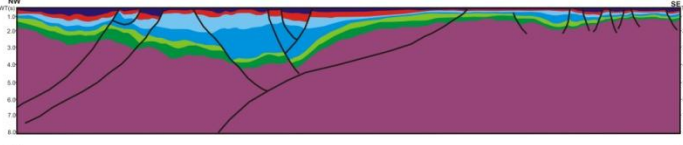
# PALINSPASTIC RECONSTRUCTION



Shortening  
**0.33%**



Extension  
**0.14%**



Shortening  
**1.06%**



Extension  
**0.18%**

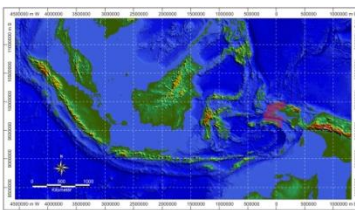
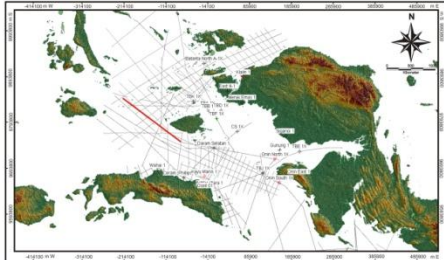


Shortening  
**0.29%**

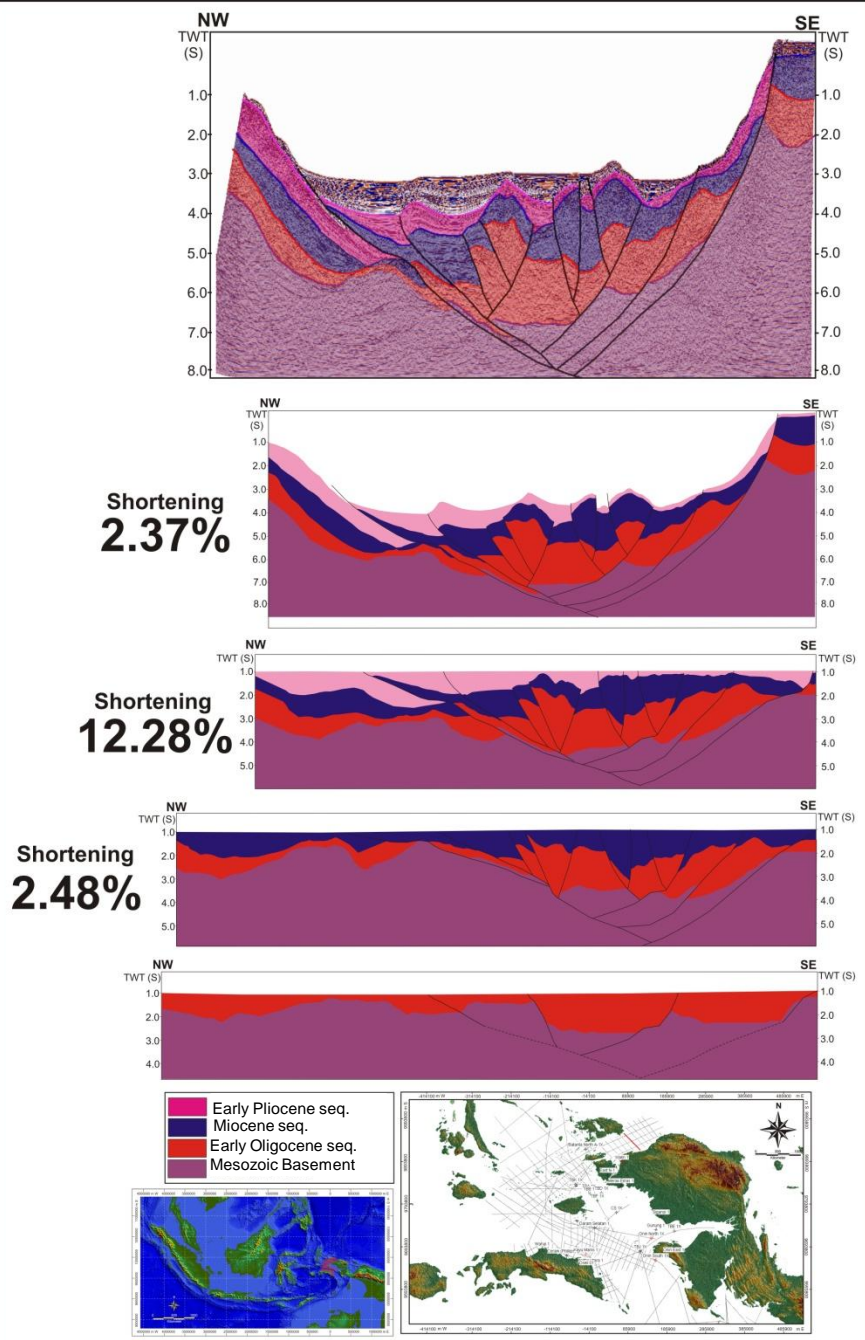


Extension  
**0.26%**

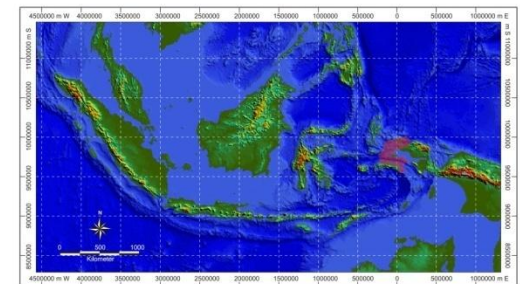
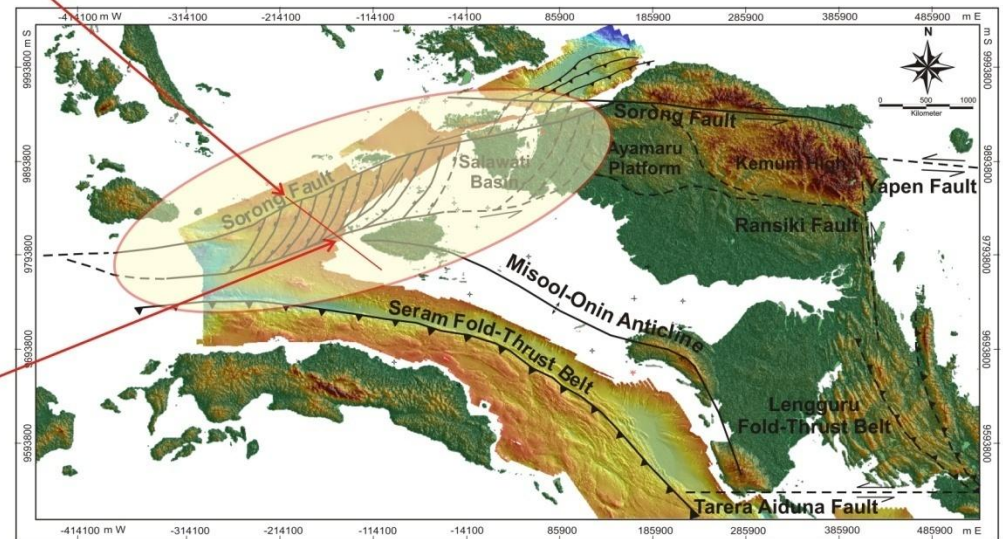
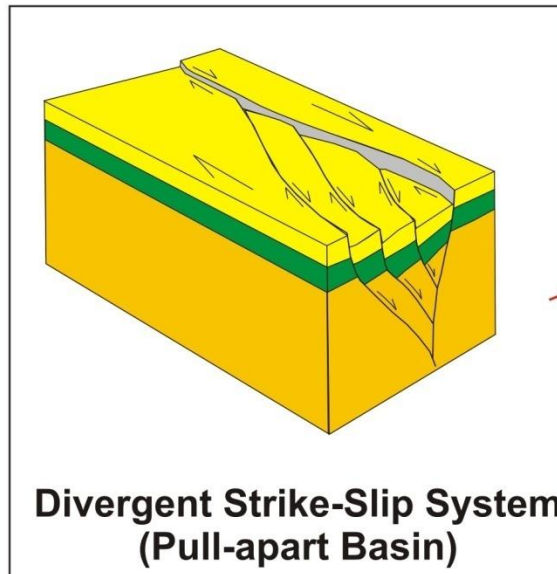
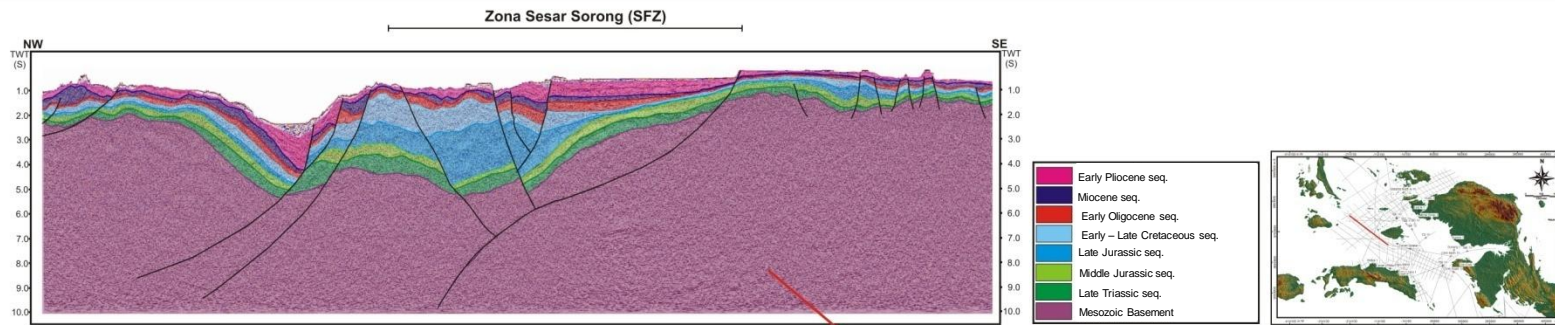
- Early Pliocene seq.
- Miocene seq.
- Early Oligocene seq.
- Early – Late Cretaceous seq.
- Late Jurassic seq.
- Middle Jurassic seq.
- Late Triassic seq.
- Mesozoic Basement

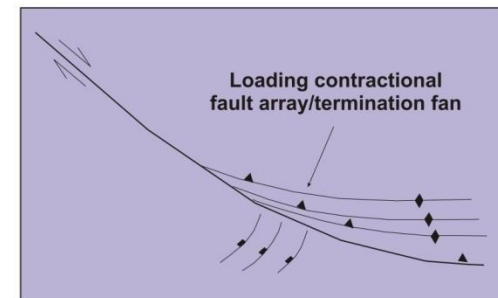
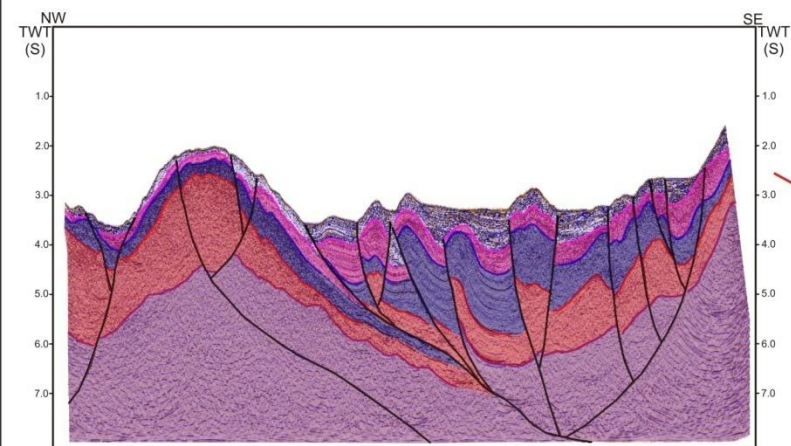


# PALINSPASTIC RECONSTRUCTION

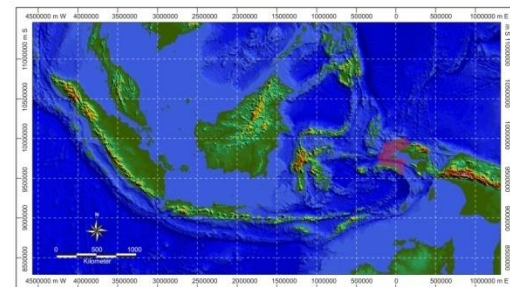
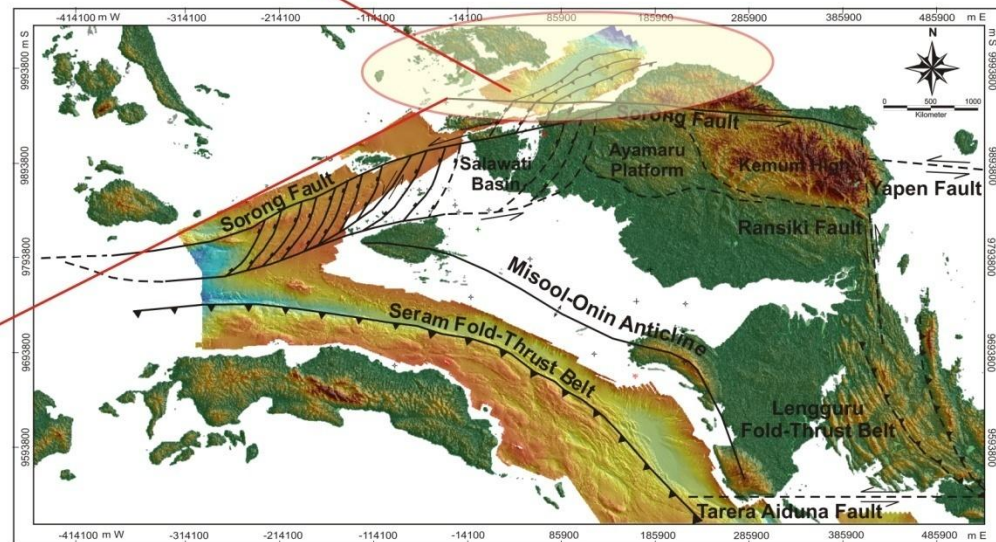
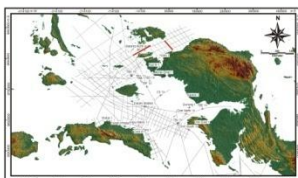
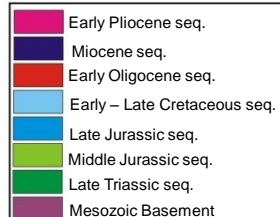
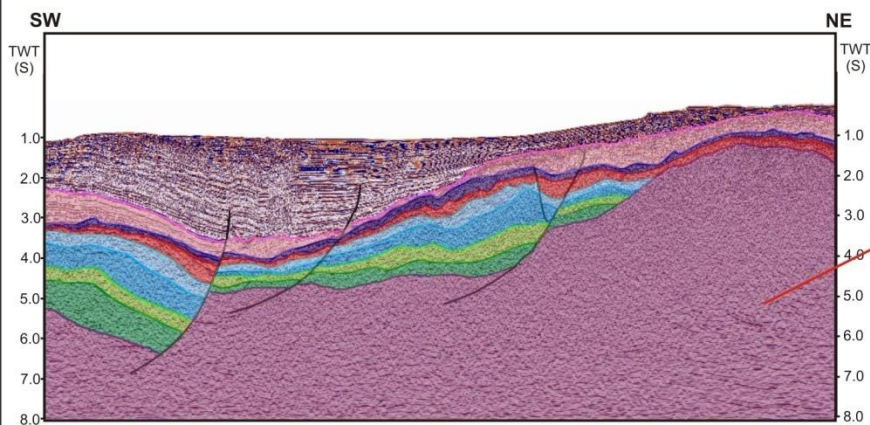




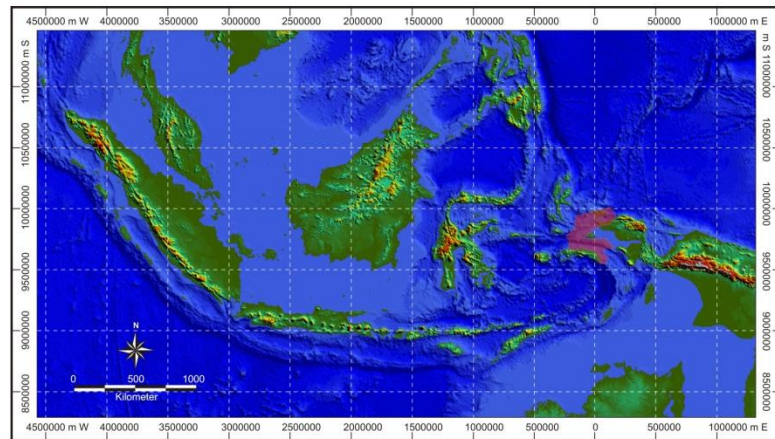
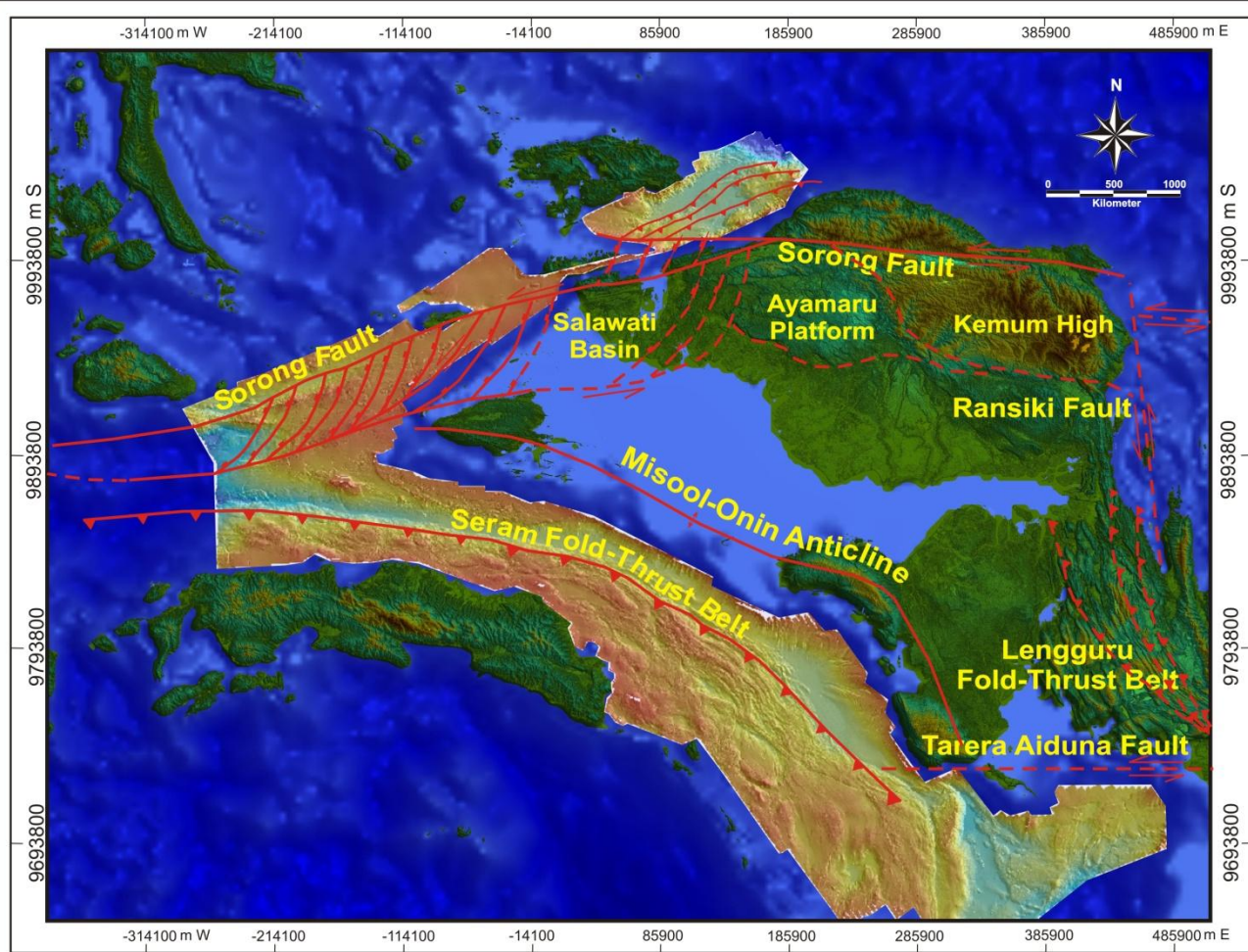




**Restraining bend/fault termination  
and associated structures**









# CONCLUSION

- The SFZ strike-slip system in the NW-SW Bird's Head area formed during the deposition of middle-late Miocene sequence as a growth fault and has remained active during the deposition of early Pliocene to Quaternary sequences.
- The SFZ mechanism at SW Bird's Head area developed as a package of normal faults as a part of divergent strike-slip system that confirmed the development of pull-apart basin around Salawati basin area
- The SFZ mechanism at NW Bird's Head area developed as a package of reverse and normal faults as a part of horsetail structure and showed the restraining and releasing fault system
- The SFZ is still active; the deformation has continued until deposition of the youngest sequence in this area and has developed into some splays

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