

Geology and Tectonic Evolution of Bird Head Region Papua, Indonesia: Implication for Hydrocarbon Exploration in the Eastern Indonesia*

Benyamin Sapiie¹, W. Naryanto³, Aileron C. Adyagharini², and Astyka Pamumpuni²

Search and Discovery Article #30260 (2012)**

Posted December 31, 2012

*Adapted from oral presentation given at AAPG International Convention and Exhibition, Singapore, 16-19 September 2012, AAPG©2012

**AAPG©2012 Serial rights given by author. For all other rights contact author directly.

¹Geology, Institut Teknologi Bandung, Bandung, Indonesia (bsapiie@gc.itb.ac.id)

²Geology, Institut Teknologi Bandung, Bandung, Indonesia

³Exploration, DITJEN MIGAS, Jakarta, Indonesia

Abstract

The Bird Head Region is located in the western part of Papua Island and is one of the most geological complex regions in the eastern part of Indonesia. This region is known as one of the most hydrocarbon prolific areas in Indonesia. Two major oil and gas producing basins were discovered in the region namely the Salawati and Bintuni Basins. Numerous work and publications have been done in the area to ramification geologic history of the region. However, the geology and structural evolution of the region are poorly known due to limited data over the region, particularly in relation to hydrocarbon distribution. In addition, several recent results of exploration drilling have generated major disappointment for continuity of future exploration in the region. One of the main problems is related to the origin and tectonic evolution of the Bird Head Region. This paper is presenting results of the ongoing study in ramification of the problems using tectono-stratigraphy approach generated from integrated fieldwork and subsurface data evaluation (2D seismic and well data).

There are several different published proposed models of the origin of the Bird Head Region. However, most of the models were not supported by enough subsurface data. Understanding stratigraphy from various different locations within the region and detail structural evolution is one of the most important tasks in solving the origin of Bird Head. Our newly proposed model generated from conducting numerous 2D and 3D palinspatic reconstructions from several different locations in the regions using integrated surface and subsurface geological information. It is clear that deformation of the region varies from area to area indicating that the region experienced several translations and rotations during their history. Using structural reconstructions we developed several

representative paleogeographies of the region showing distribution of Jurassic and Tertiary reservoirs including their petroleum system. Hopefully, our new model can help in locating new exploration target areas.

Selected References

Hall, R., and C.K. Morley, 2004, Sundaland basins, *in* P.D. Clift, P. Wang, W. Kuhnt, and D. Hayes, (Eds.), *Continent-ocean interactions within east Asian marginal seas: Geophysical Monograph 149*, p. 55-85.

Lowell, J.D., 1985, *Structural styles in petroleum exploration: Oil & Gas Consult. Int.*, Tulsa, Oklahoma, USA, 460 p.

Sapiie, B., 1998, Strike-slip faulting, breccia formation and porphyry Cu-Au mineralization in the Gunung Bijih (Ertsberg) mining district, Irian Jaya, Indonesia: PhD dissertation, University of Texas at Austin, Austin, Texas, USA, 304 p.

Sapiie, B., and M. Hadiana, 2012, 3D fault evolution in oblique convergent strike-slip fault deformation: 74th EAGE/SPE Europec Conference, June 4-7, 2012, extended abstract 5 p.

Sapiie, B., and M. Hadiana, 2007, Mechanism of some rift basins in Western Indonesia, *in* *Proceedings, Indonesian Petroleum Association, 31st Annual Convention and Exhibition, May 2007: IPA07-G-138*, unpaginated, 9 p.

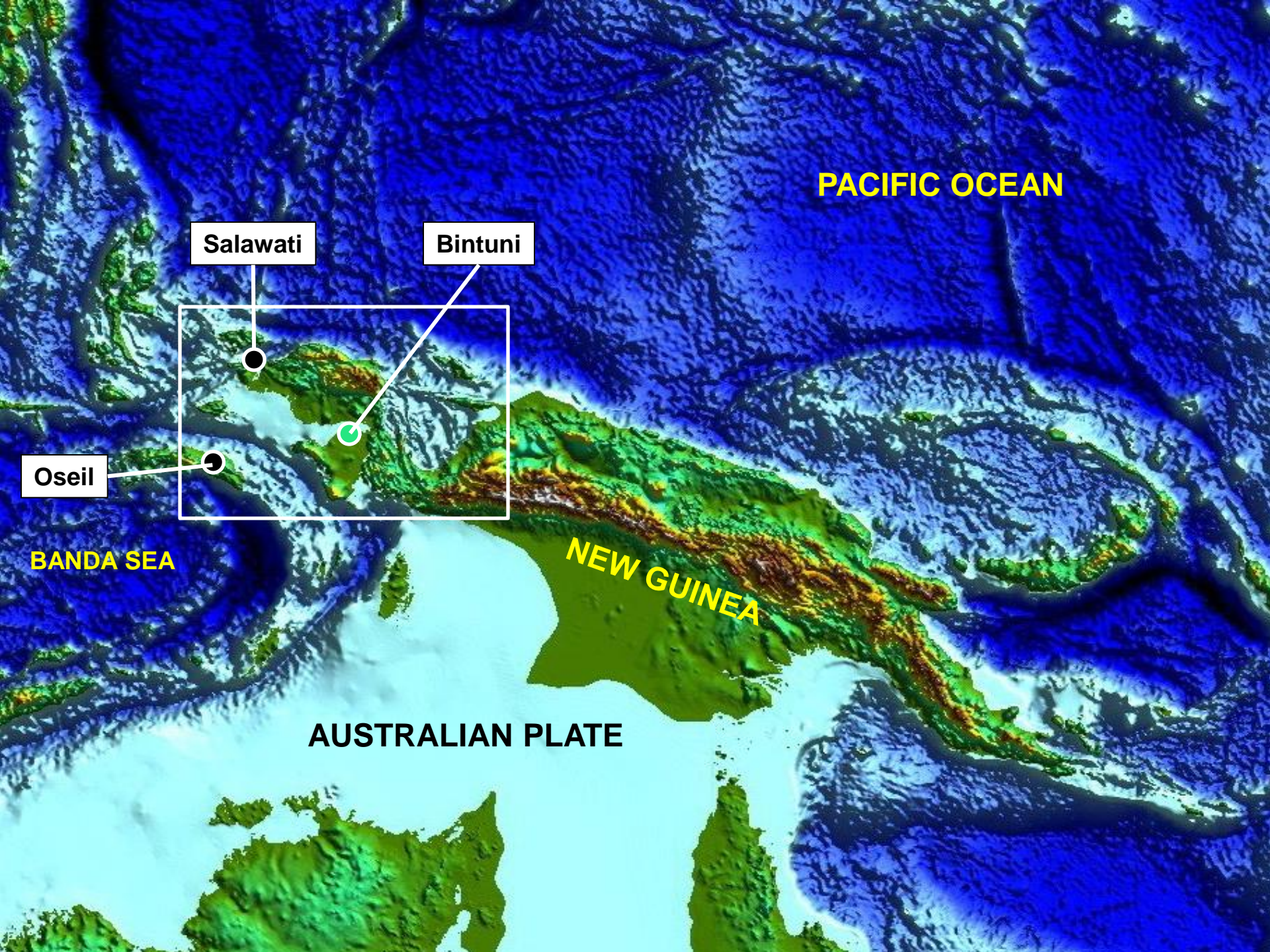
GEOLOGY AND TECTONIC EVOLUTION OF BIRD HEAD REGION PAPUA, INDONESIA: IMPLICATIONS FOR HYDROCARBON EXPLORATION IN THE EASTERN INDONESIA

**BENYAMIN SAPIIE *)
NARYANTO W. **)
A.C. ADYAGHARINI *)
ASTYKA PAMUMPUNI *)**

***) GEODYNAMIC RESEARCH GROUP ITB
) DIRJEN MIGAS, INDONESIA



**AAPG 2012 INTERNATIONAL CONFERENCE AND EXIBITION
13 SEPTEMBER - SINGAPORE**



PACIFIC OCEAN

Salawati

Bintuni

Oseil

BANDA SEA

NEW GUINEA

AUSTRALIAN PLATE

Overview of Problems

- Eastern Indonesia is tectonically and structurally extremely complex, comprising slivers of continental blocks, arc fragments and trapped ocean basins.
- Many potential petroleum basins are recognized; however geologically poorly understood.
- Origin of **Bird Head** ? (*Micro-continent*)
- The origin peculiar triangular deep embayment of the **Cendrawasih Bay (Basin)** are still growing debate.



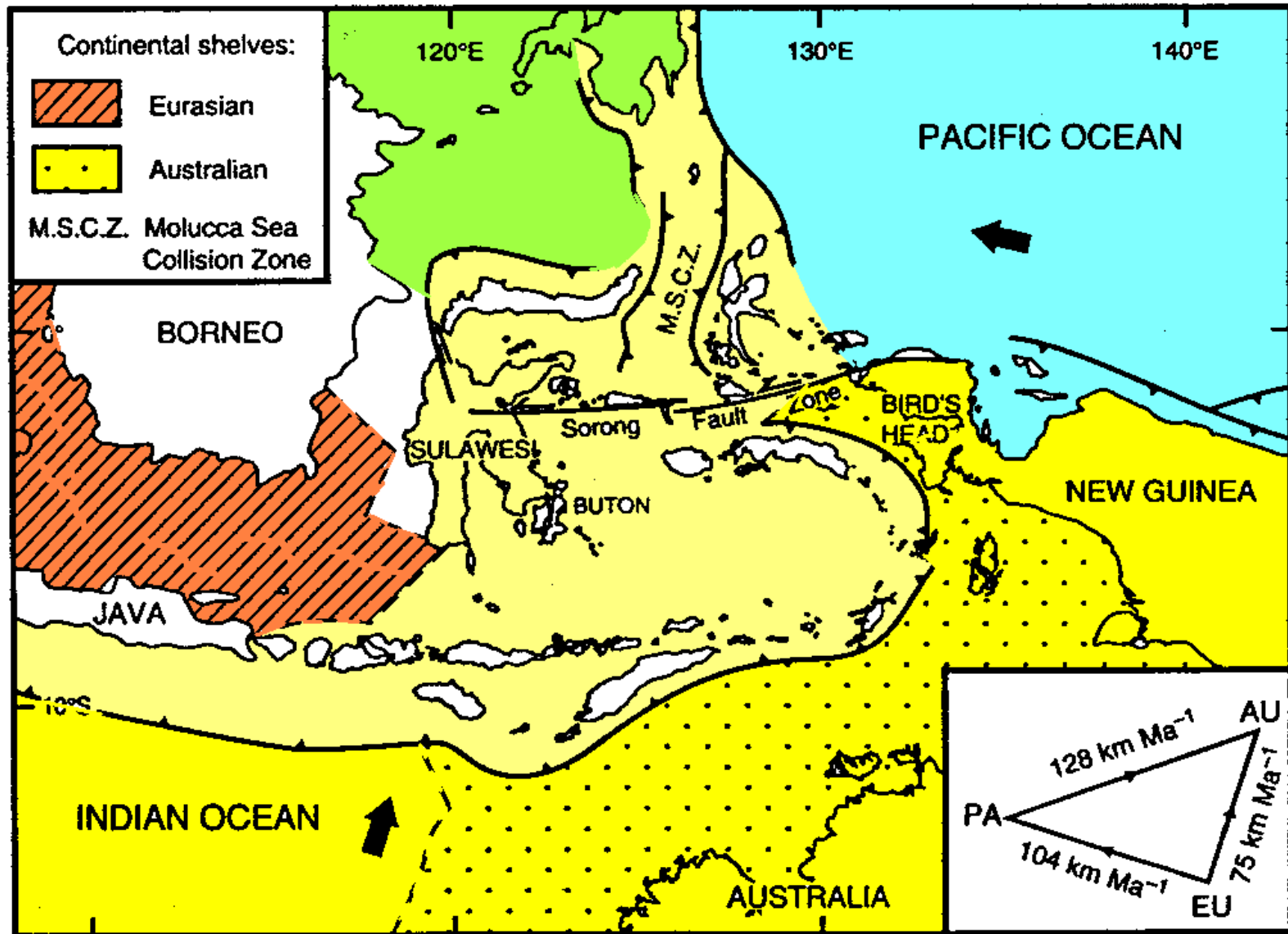
TECTONIC EVOLUTION - PALEOGEOGRAPHY



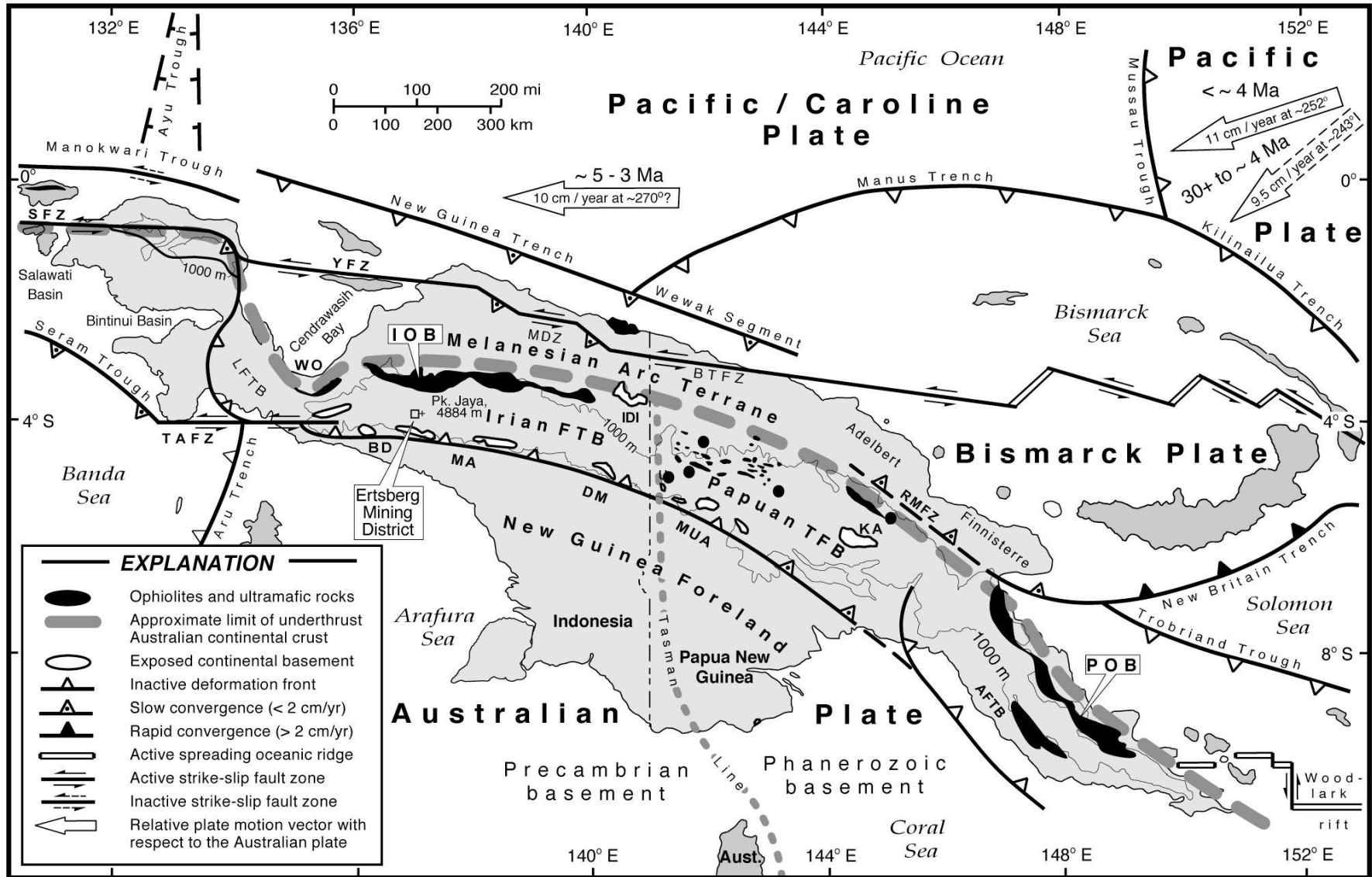
OUTLINE

- REGIONAL TECTONIC SETTING
- CURRENT BIRD HEAD GEOLOGY
- DEFORMATION AND STRUCTURAL PATTERN
- EXPLORATION CONCEPT AND DIRECTIONS
- CONCLUSIONS

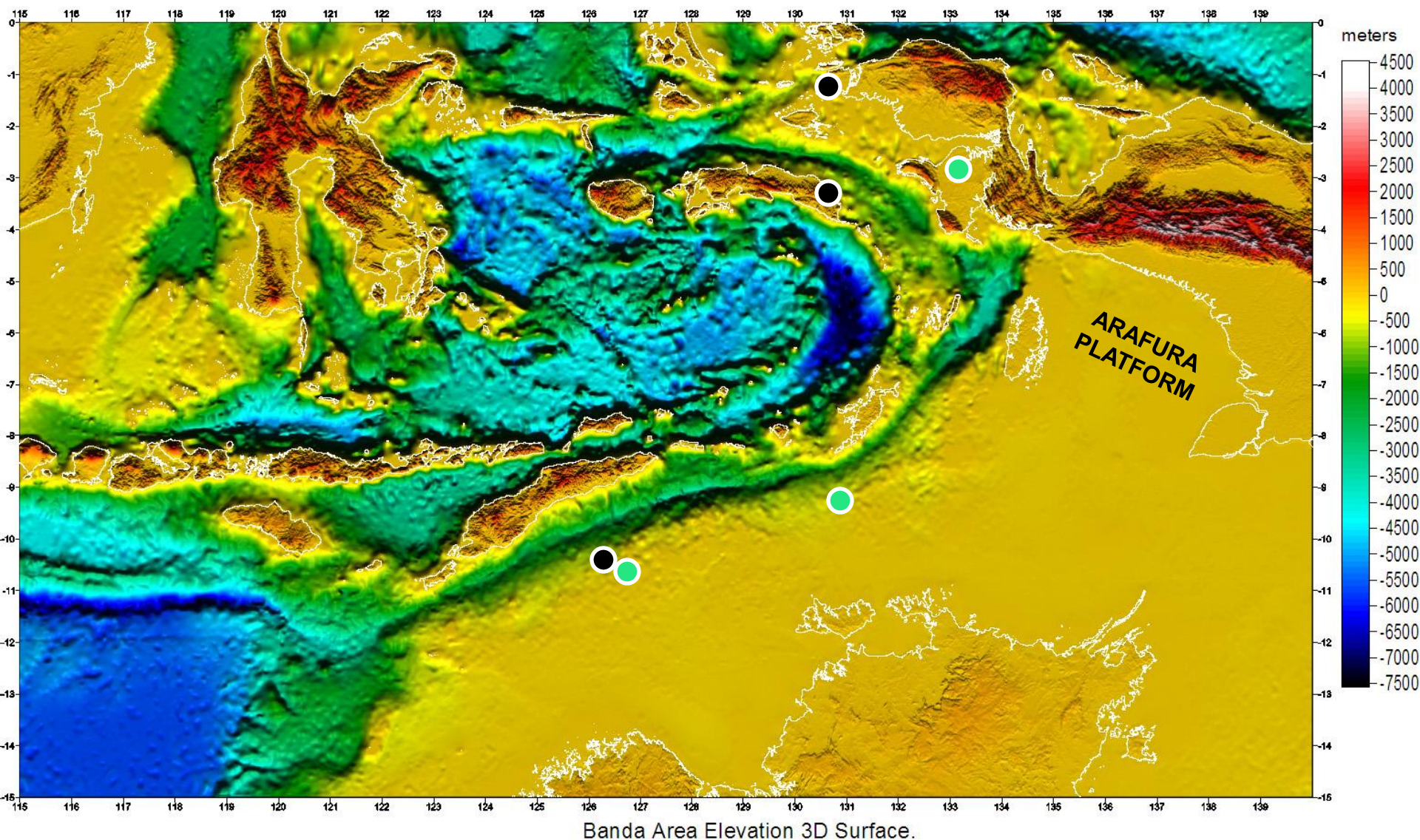
REGIONAL TECTONIC SETTING



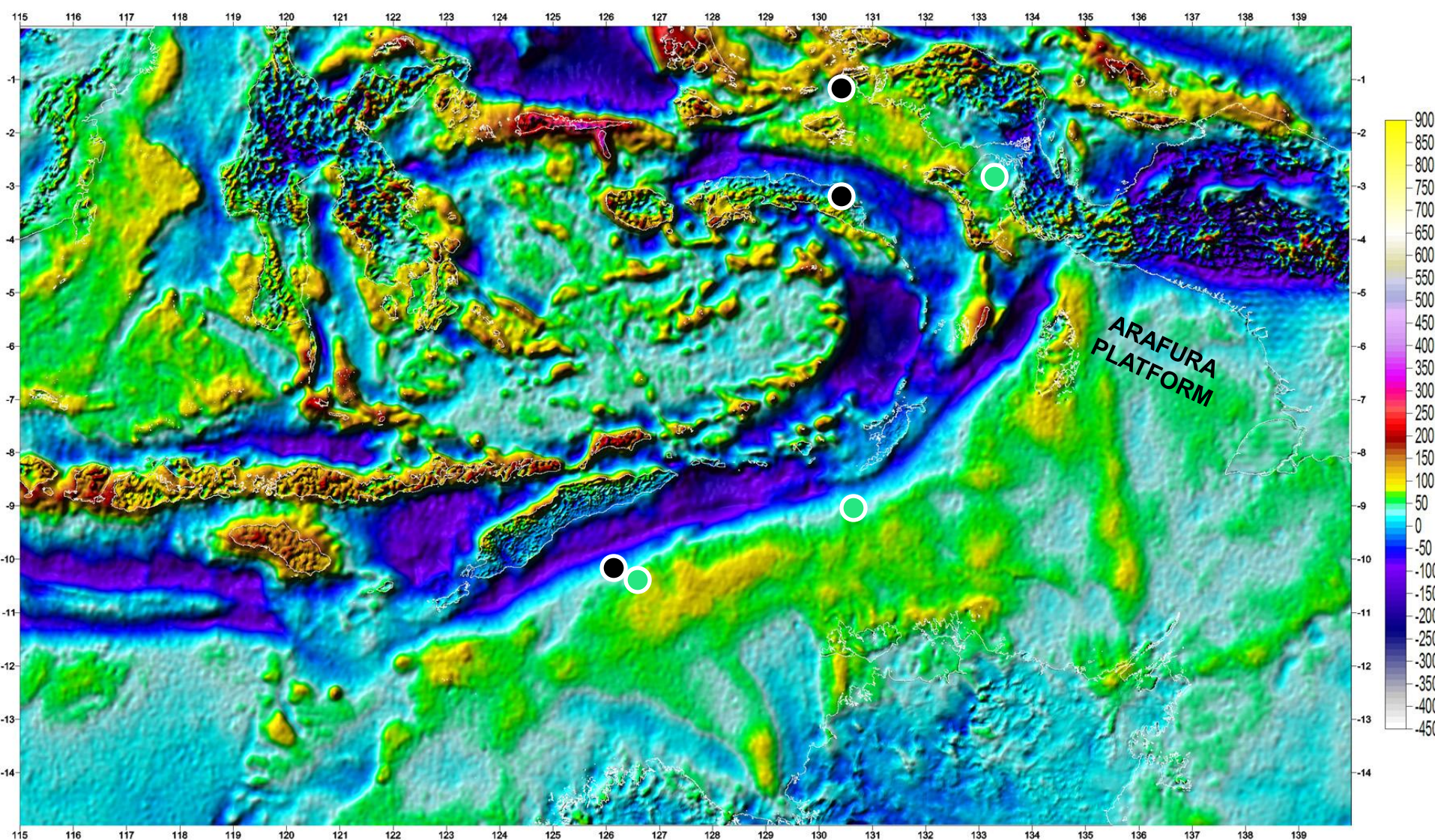
Tectonic Map of New Guinea



EASTERN INDONESIA TOPOGRAPHY AND BATHYMETRY



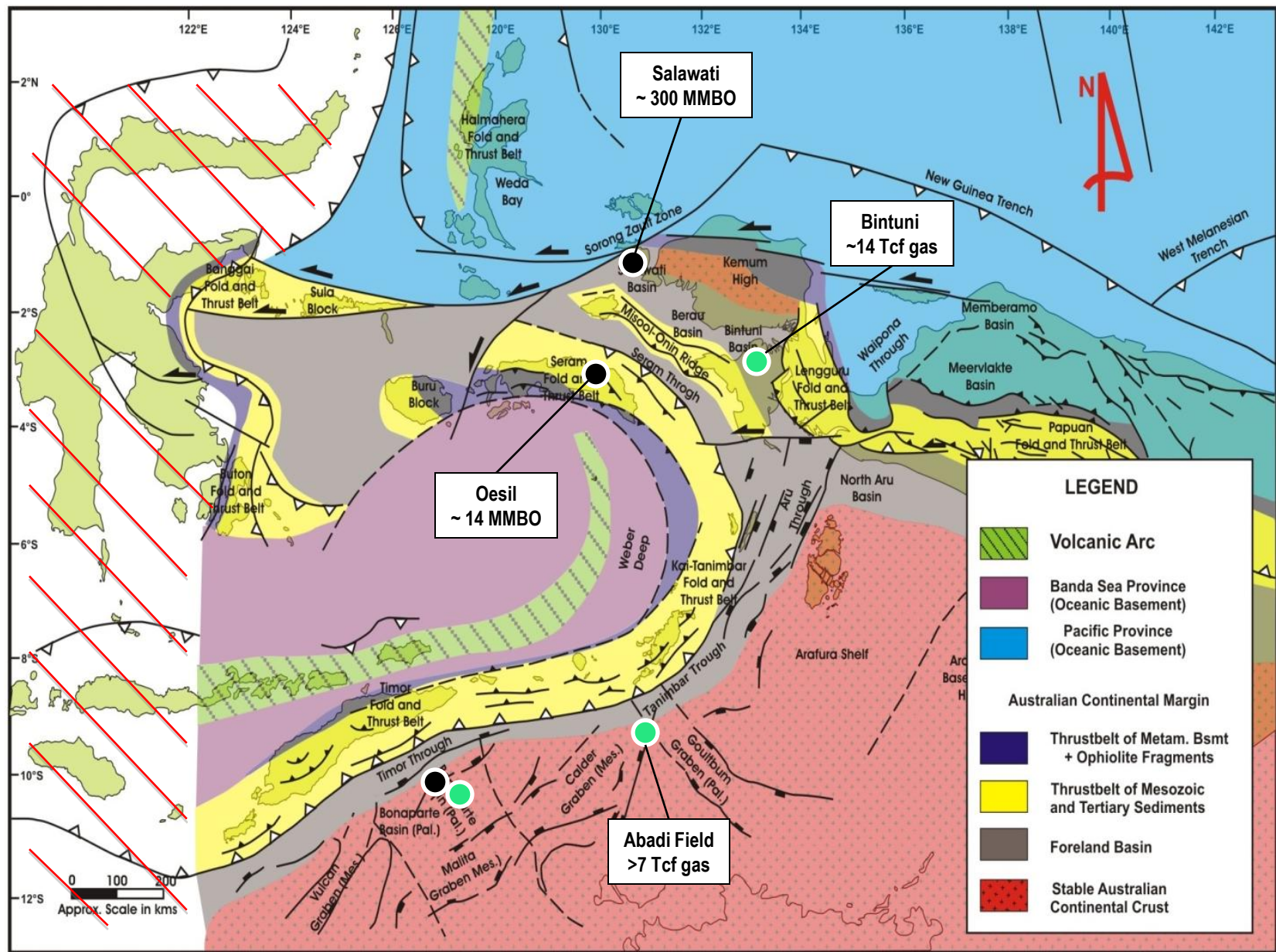
REGIONAL GRAVITY ANOMALY



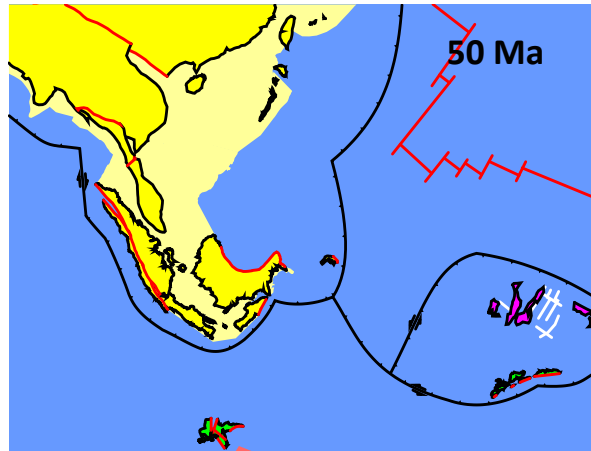
Banda area complete Bouguer anomaly on-shore,
height correction anomaly off-shore, mGals.
3D image sunlit from the NW at 45 degrees.

BANDA ARC GEOPHYSICS (2011)

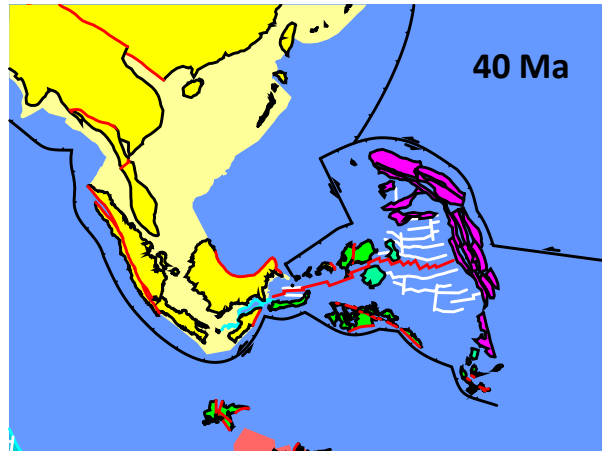
REGIONAL GEOLOGY AND HC OCCURENCES



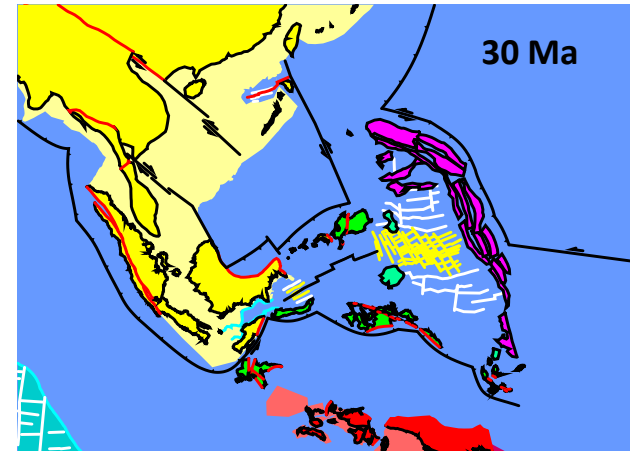
SE ASIA: Cenozoic Tectonic Reconstruction (Hall, 2004)



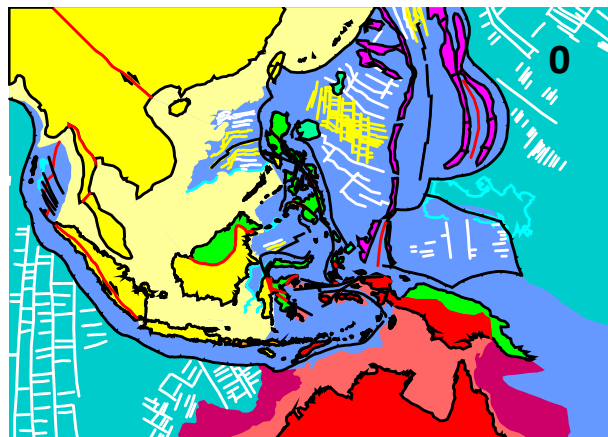
middle Eocene



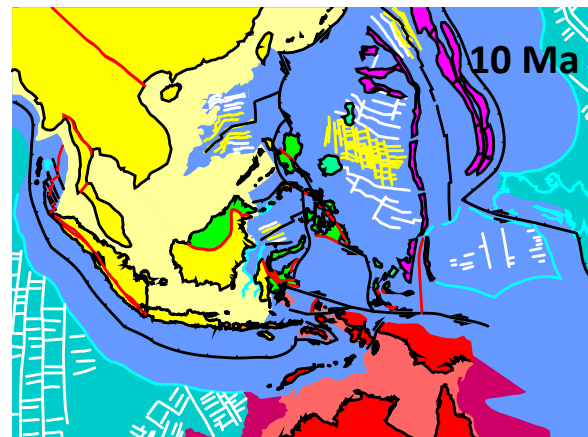
late Eocene



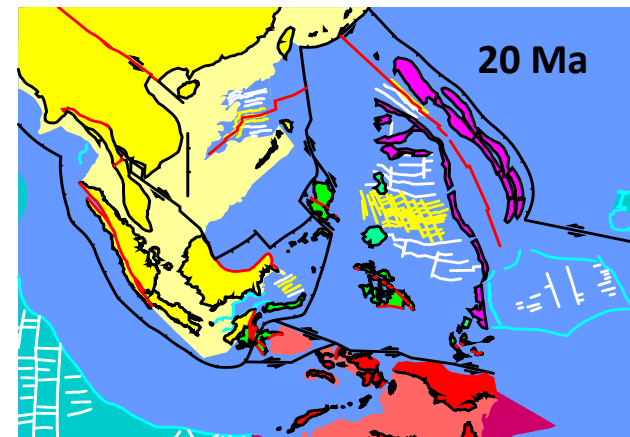
mid - Oligocene



Present

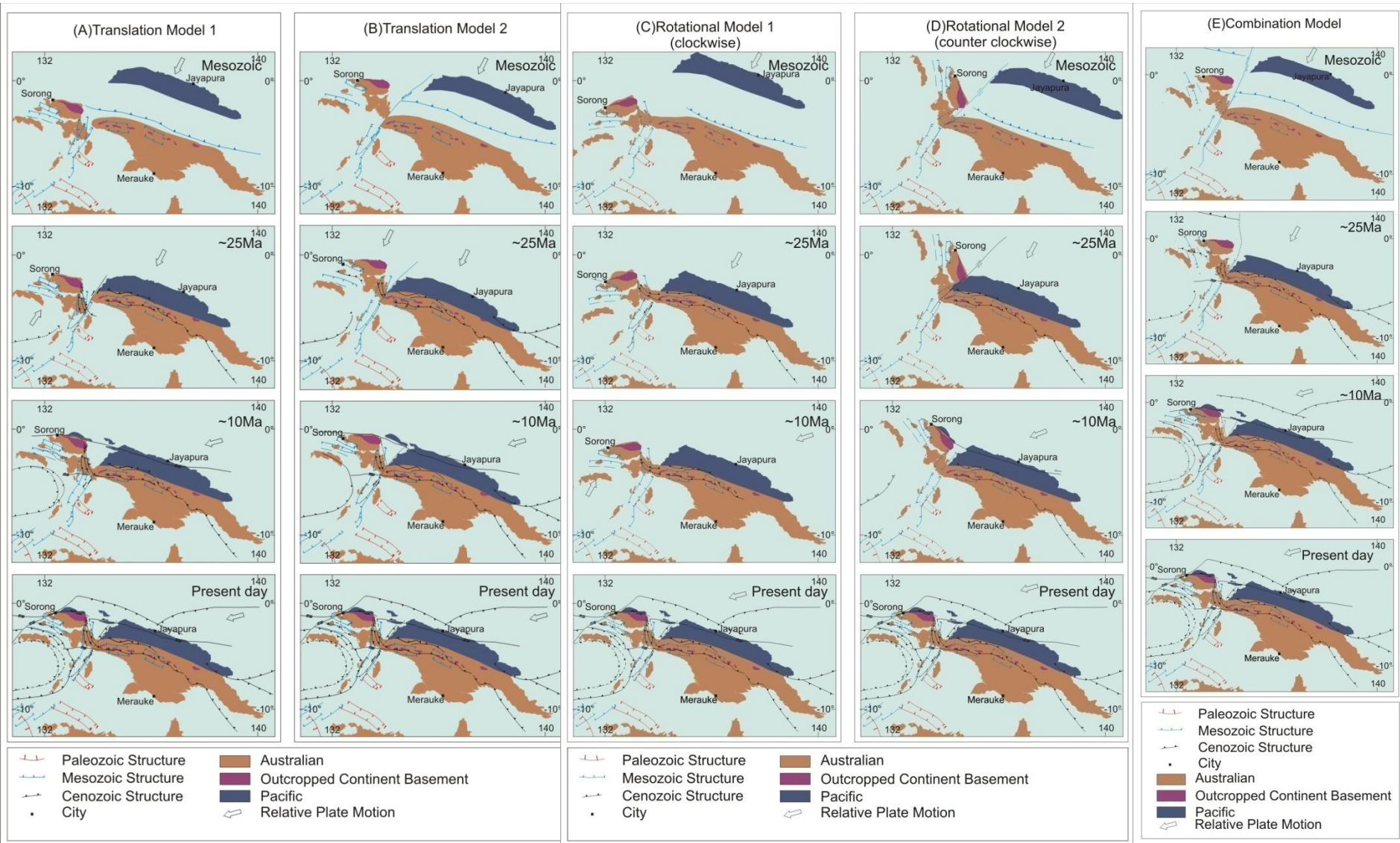


late Miocene

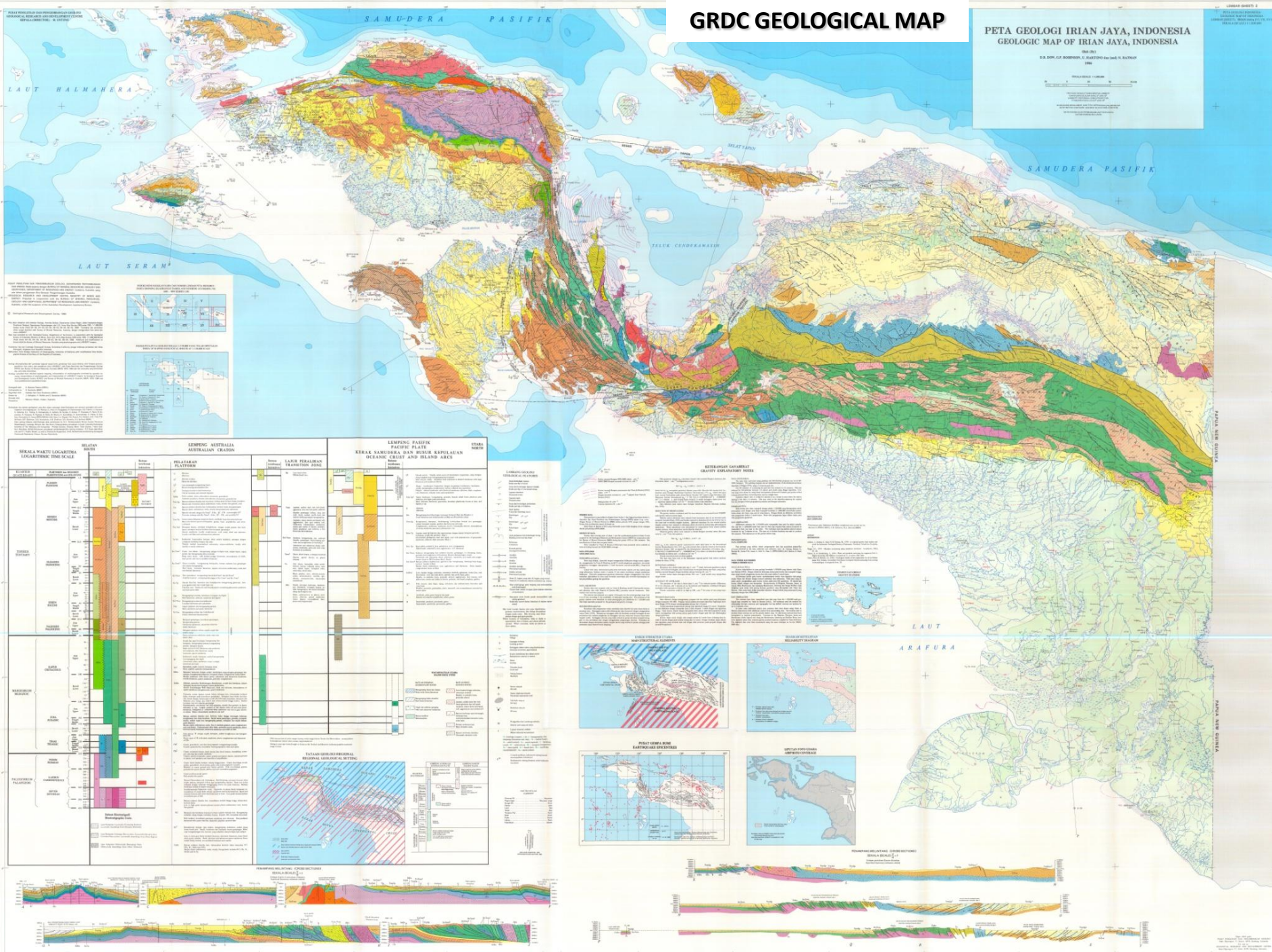


early Miocene

TECTONIC EVOLUTION OF BIRD HEAD REGION

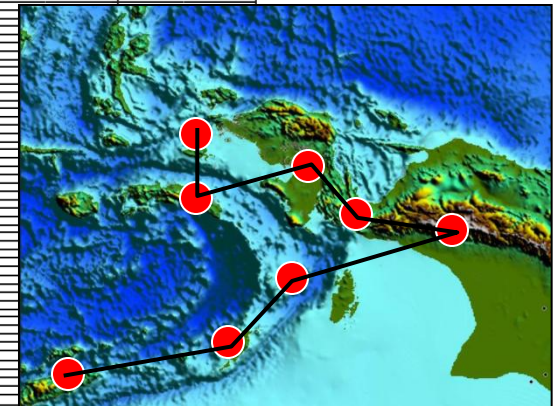


PETA GEOLOGI IRIAN JAYA, INDONESIA
GEOLOGIC MAP OF IRIAN JAYA, INDONESIA



REGIONAL LITHOSTRATIGRAPHY NOMENCLATURES

ERA	PERIOD	EPOCH	MISOOL	SERAM	BIRD'S HEAD		BIRD'S NECK LENGURU	BIRD'S BODY CENTRAL RANGE	KAI	TANIMBAR	TIMOR		
					SALAWATI	BINTUNI							
Cenozoic	Quaternary	Recent, or Holocene			Sele				Kai Kecil				
		Pleistocene	Transitional Sedimentary Deposition Formation	Fufa-Wahai	Klasaman	Steenkool	Steenkool	Buru					
	Tertiary	Neogene	Pliocene	Atkari	Upper Nief Beds	Klasafet	Klasafet	Klasafet		Weryahan			
			5.3	Openta					Weduar	Batimafudi	Siu		
			Miocene	Kasim		Kais Sirga	Kais Sirga	Kais	Yawee	Tamangil		Kokneo Cg	
			23.7					Adi / Sirga					
		Paleogene	Oligocene						Elat				
			36.6	Zaag		Faumai	Faumai	Imskin	Faumai	Vanitimur	Tangustabun		
			57.8	Daram		Waripi	Waripi			Unnamed			
			66.4										
Mesozoic	Cretaceous	Fatanlap	Lower Nief Beds	Jass	Jass	Ekmai Sandstone	Ekmai Sandstone	Ungar	Relationship Unknown				
	144	Facet Lst	Kola Shale			Pinya Mudstone	Pinya Mudstone	Unnamed Formation					
	Jurassic	Demu			Undifferentiated Kembelangan	Woniwogi Sandstone	Woniwogi Sandstone	Unnamed Formation					
	208	Yelbie Shale				Kopai	Kopai	Unnamed Formation					
Paleozoic	Triassic		Bogal Lst		Tipuma	Tipuma	Tipuma	Tipuma	Selu	Selu			
		24.5											
	Permian		Keskain		Aifam Group	Ainim		Aiduna					
		286											
		320	Ligu Metamorphic	Kobipoto Complex		Aifat							
	Carboniferous	Pennsylvanian											
		360											
	Paleozoic	Mississippian											
			408										
		Devonian											
438													
Silurian													
Paleozoic	Ordovician												
		503											
	Cambrian												
Paleozoic	Pre Cambrian												
		570											
		2500											
Author			(Pigram & Panggabean, 1982; Pieters et al 1983; Fraser et.al 1993)	(Nillandaroe and Barracrough, 2003)	(Sapiie, 2000)			(Achdan & Turkandi, 1994; Union Texas, 1997)	(Charlton, 2004)	(Charlton, 2001)			

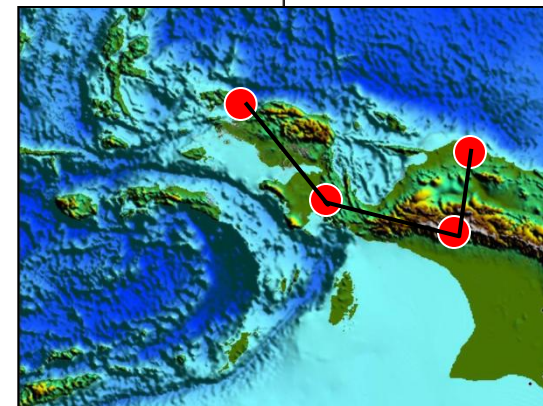


STRATIGRAPHY COMPARISON BIRD'HEAD – NORTHERN PAPUA/CWB?

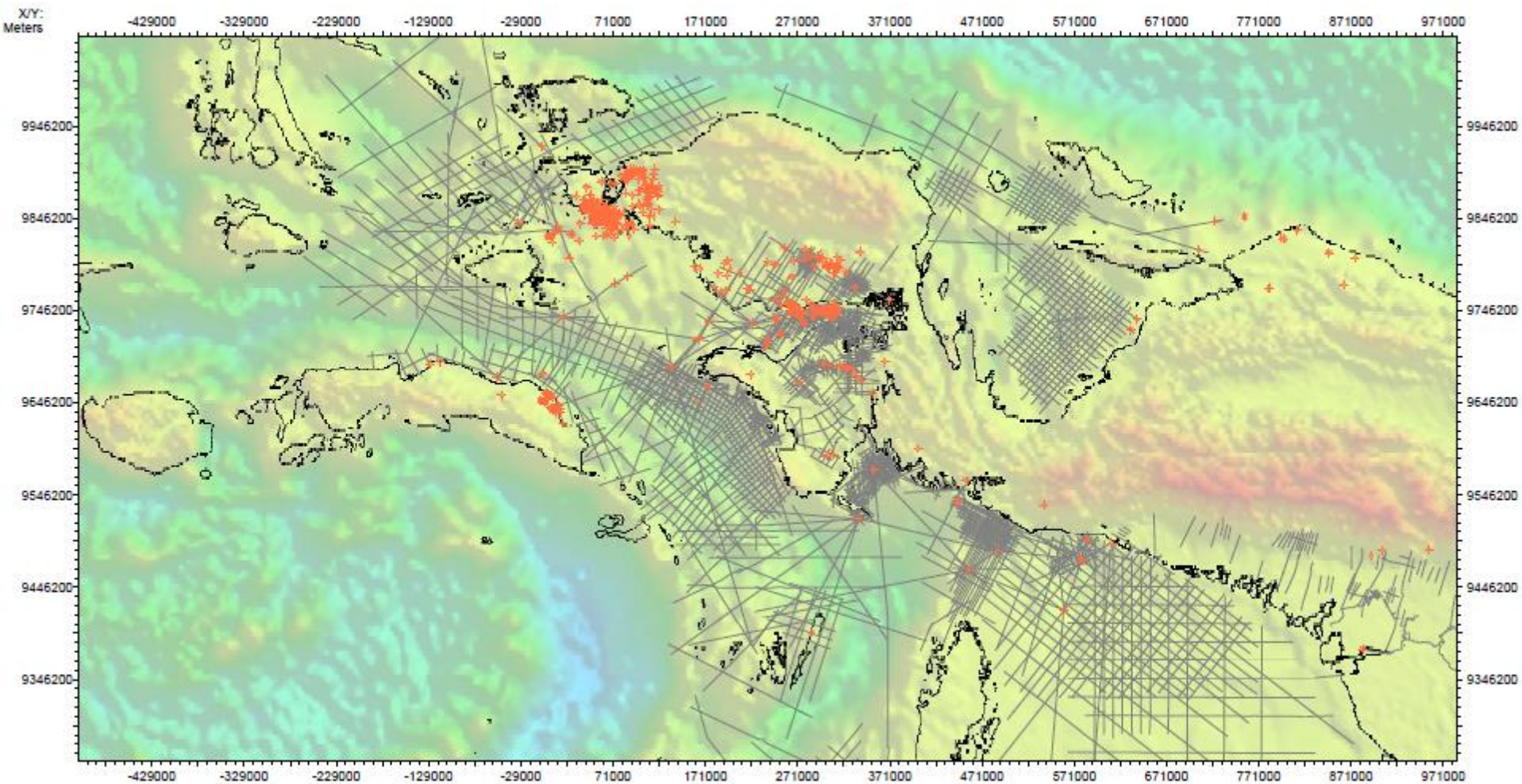
ERA	PERIOD	EPOCH	BIRD'S HEAD		BIRD'S NECK LENGURU	BIRD'S BODY CENTRAL RANGE	TECTONIC PHASE	North Irian (Pacific Affinity)	TECTONIC PHASE	
			SALAWATI	BINTUNI						
Cenozoic	Quaternary	Recent, or Holocene	Sele	Steenkool	Steenkool	Buru	UP LIFT PLIO - PLEIST SQ. OLIGO - MIOCENE SEQUENCE EOCENE SEQUENCE 'UPPER' KEMBELANGAN SEQUENCE. (UPLIFT IN SALAWATI) POST BREAK UP SUB MARINE EROSION RIFT BREAK UP RIFT INFRA RIFT VARISCAN OROGENY POST BREAK UP BREAK UP PRE BREAK UP INFRA RIFT	Koekoendoeri / Adja	REGIONAL UPLIFT & FAULTING BANDA ARC FORMED. LOCALIZED UNCONFORMITIES OBSERVED REGIONAL HIATUS MAJOR UNCONFORMITY BASIN WIDE, ONSET OF RAPID SUBSIDENCE REGIONAL HIATUS COMPRESSIONAL TECTONIC EVENT, FOLDING AND METAMORPHISM. MARKS COLLISION OF INDO-AUSSIE PLATE WITH CAROLINE PACIFIC.	
		Pleistocene	Klasaman	Steenkool	Steenkool	Buru		Mamberamo		
	Neogene	1.6	Klasafet	Klasafet	Klasafet					
		5.3	Klasafet	Klasafet	Klasafet					
		Miocene	23.7	Sirga	Kais	Kais		Yawee		Makats
	Paleogene	Oligocene	36.6	Sirga	Sirga			Adi / Sirga		Darante
		Eocene	57.8	Faumai	Faumai	Imskin		Faumai		
		Paleocene	66.4	Waripi	Waripi					Auwewa
	Mesozoic	Cretaceous	144	Jass	Jass	Ekmai Sandstone		Ekmai Sandstone		POST BREAK UP SUB MARINE EROSION RIFT BREAK UP RIFT
Jurassic		208		Undifferentiated Kembelangan	Pinya Mudstone Woniwogi Sandstone Kopai	Pinya Mudstone Woniwogi Sandstone Kopai				
Triassic		24.5	Tipuma	Tipuma	Tipuma	Tipuma				
Paleozoic	Permian	286	Aifam Group	Ainim		Aiduna	INFRA RIFT	UNDIFFERENTIATED OCEANIC CRUST CRYSTALLINE BASEMENT COMPLEX		
		Pennsylvanian	320	Aifat						
	Carboniferous	360	Aimau							
		Mississippian								
	Devonian	408				Modio	BREAK UP			
	Silurian	438	Kemum	Kemum			PRE BREAK UP			
	Ordovician	503	Ligu Metamorphic	Ligu Metamorphic			INFRA RIFT			
	Cambrian	570				Tuaba				
	Pre Cambrian						Kariem			
		2500					Awigatoh			

(Sapiie, 2000)

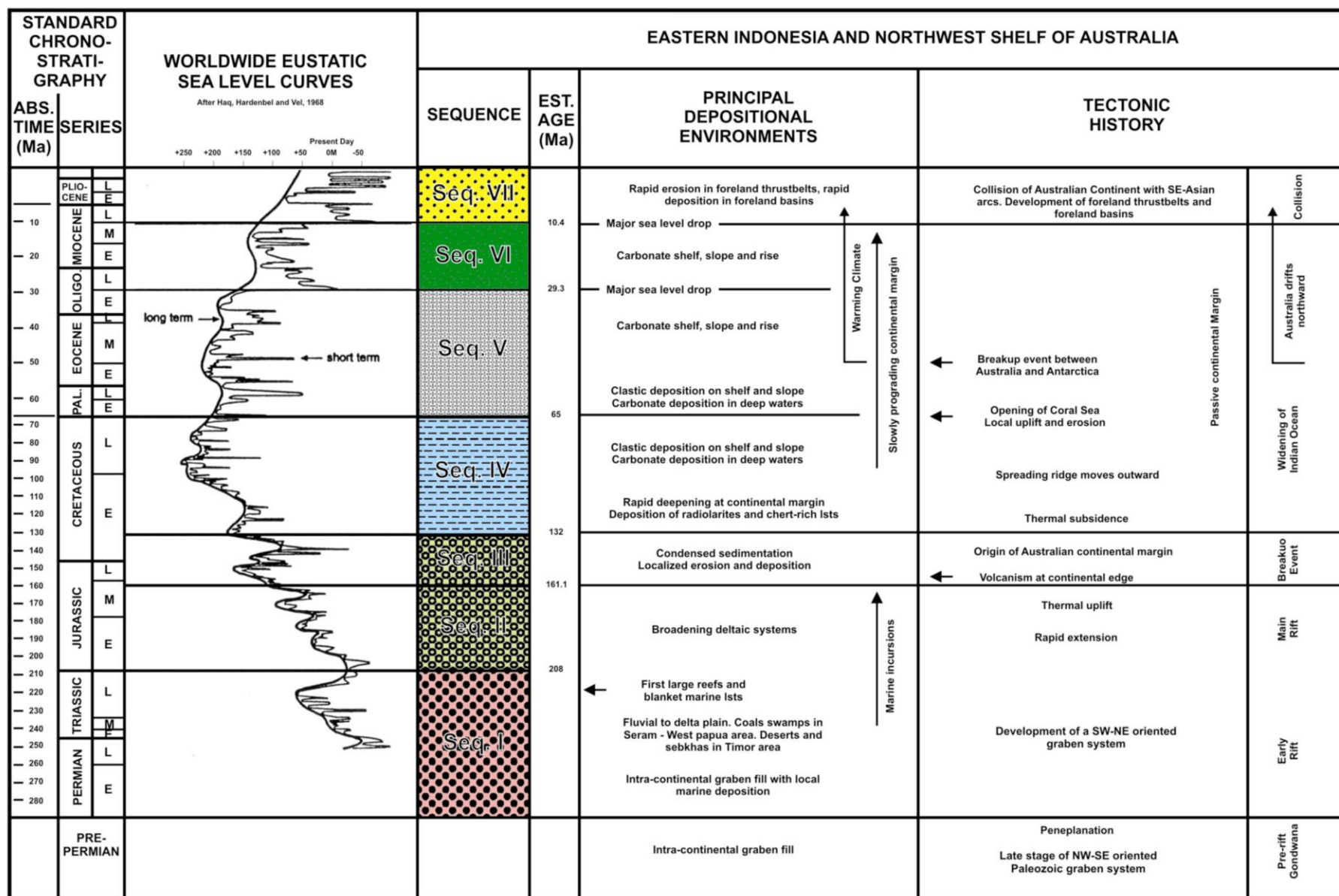
(McAdoo dan Haebig, 1999)



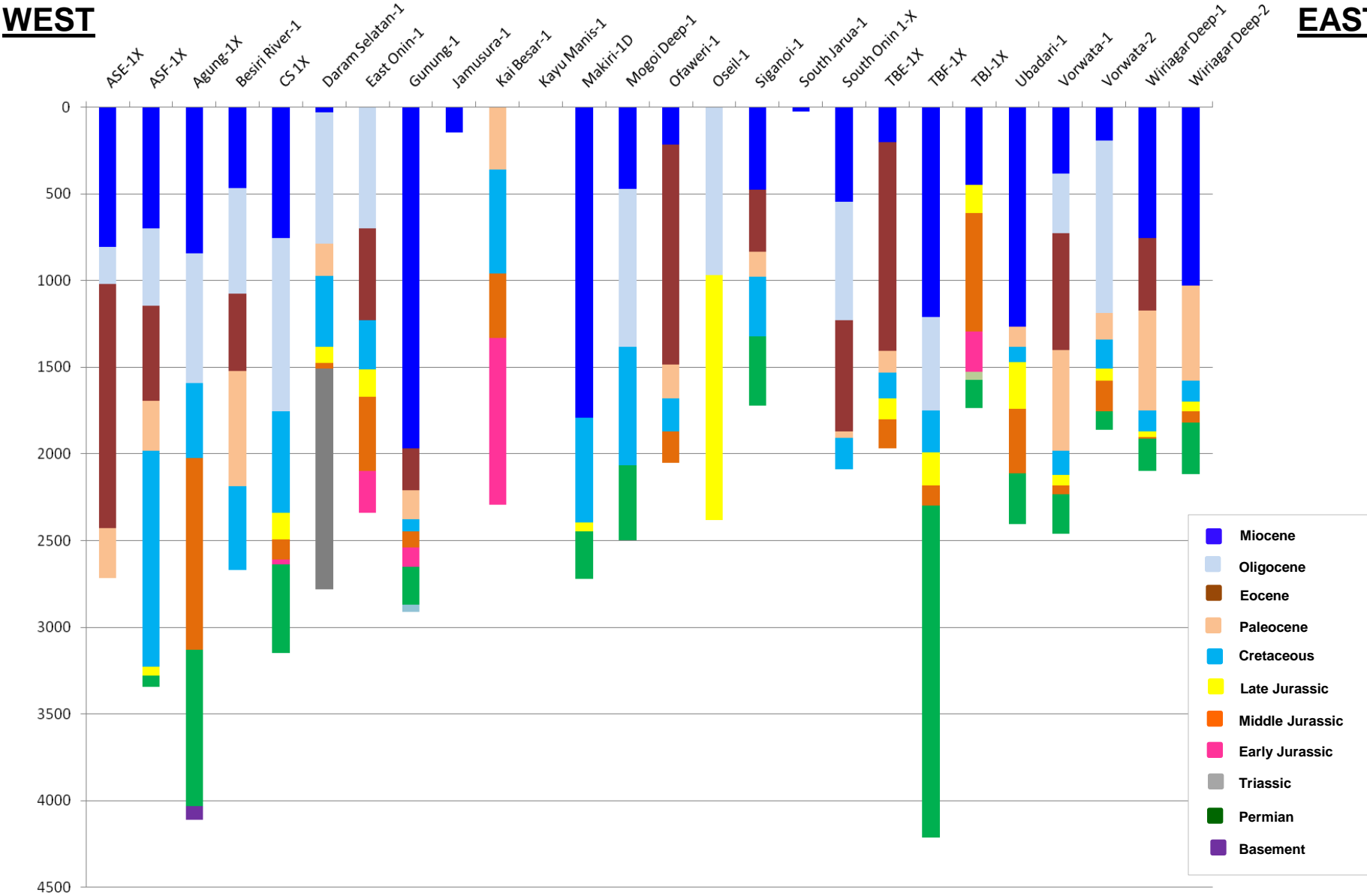
SUBSURFACE DATABASE OF BIRD HEAD REGION



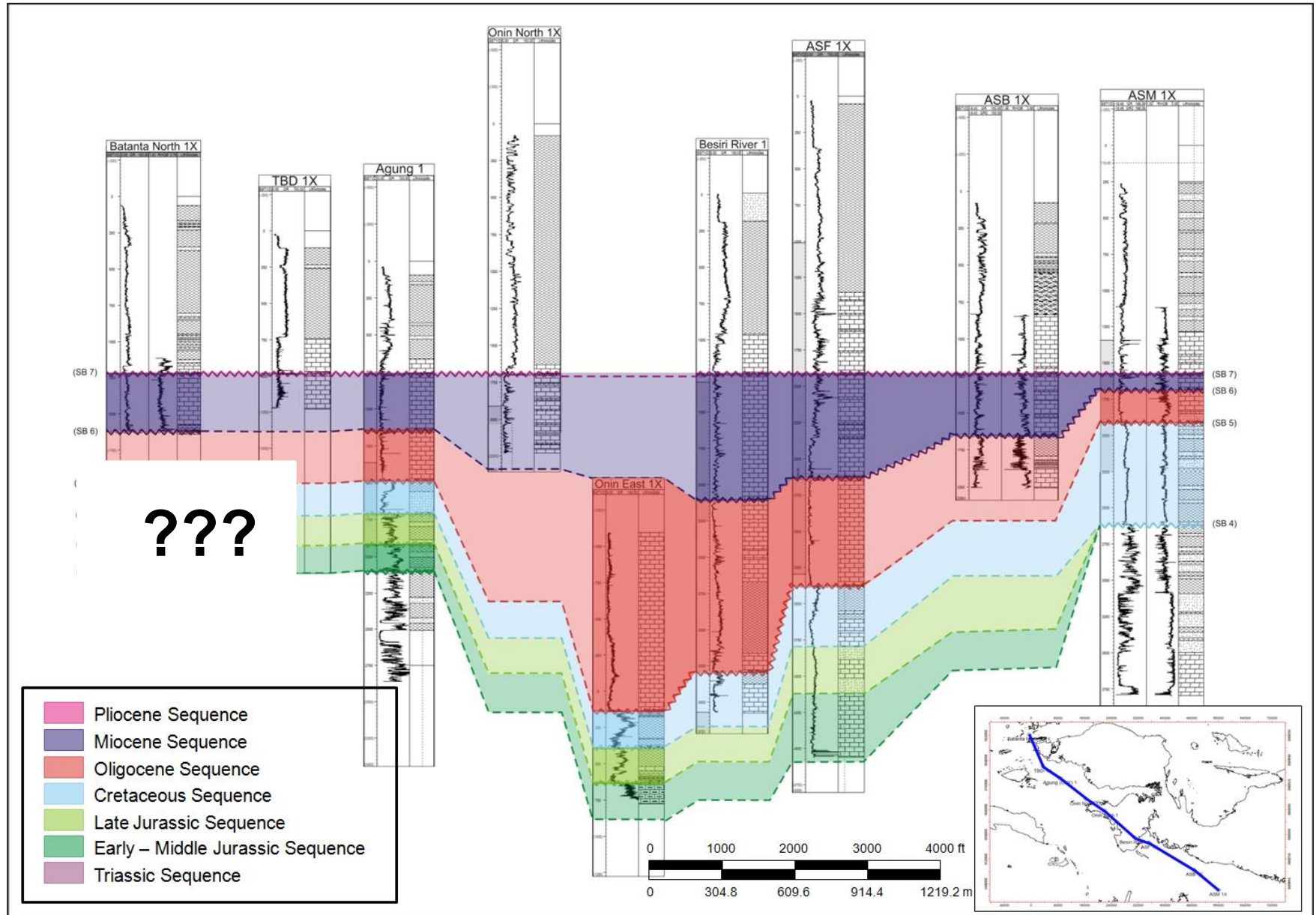
Sequence Scheme Eastern Indonesia & NW Shelf of Australia



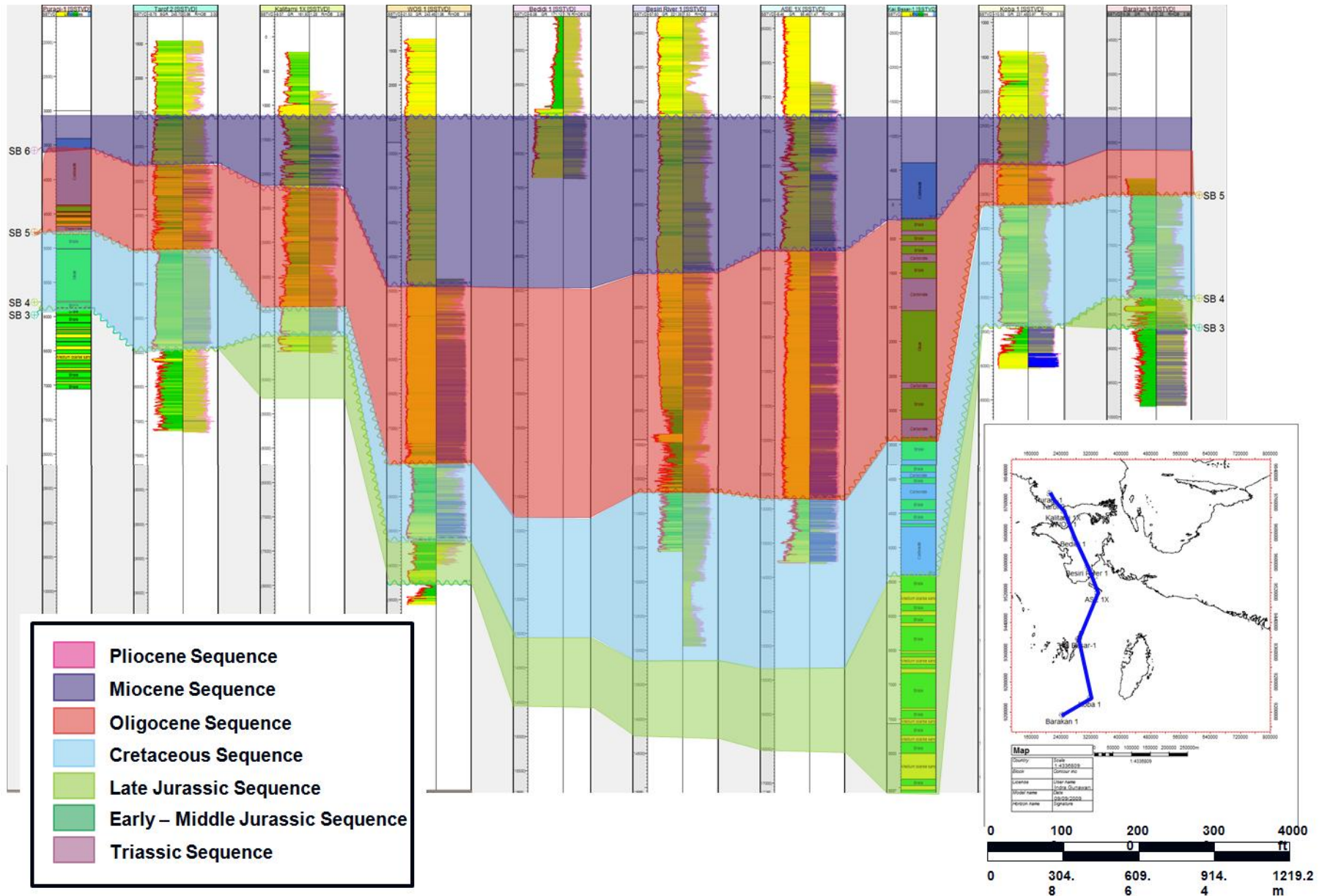
LITHOLOGY DISTRIBUTIONS IN WELL DATA



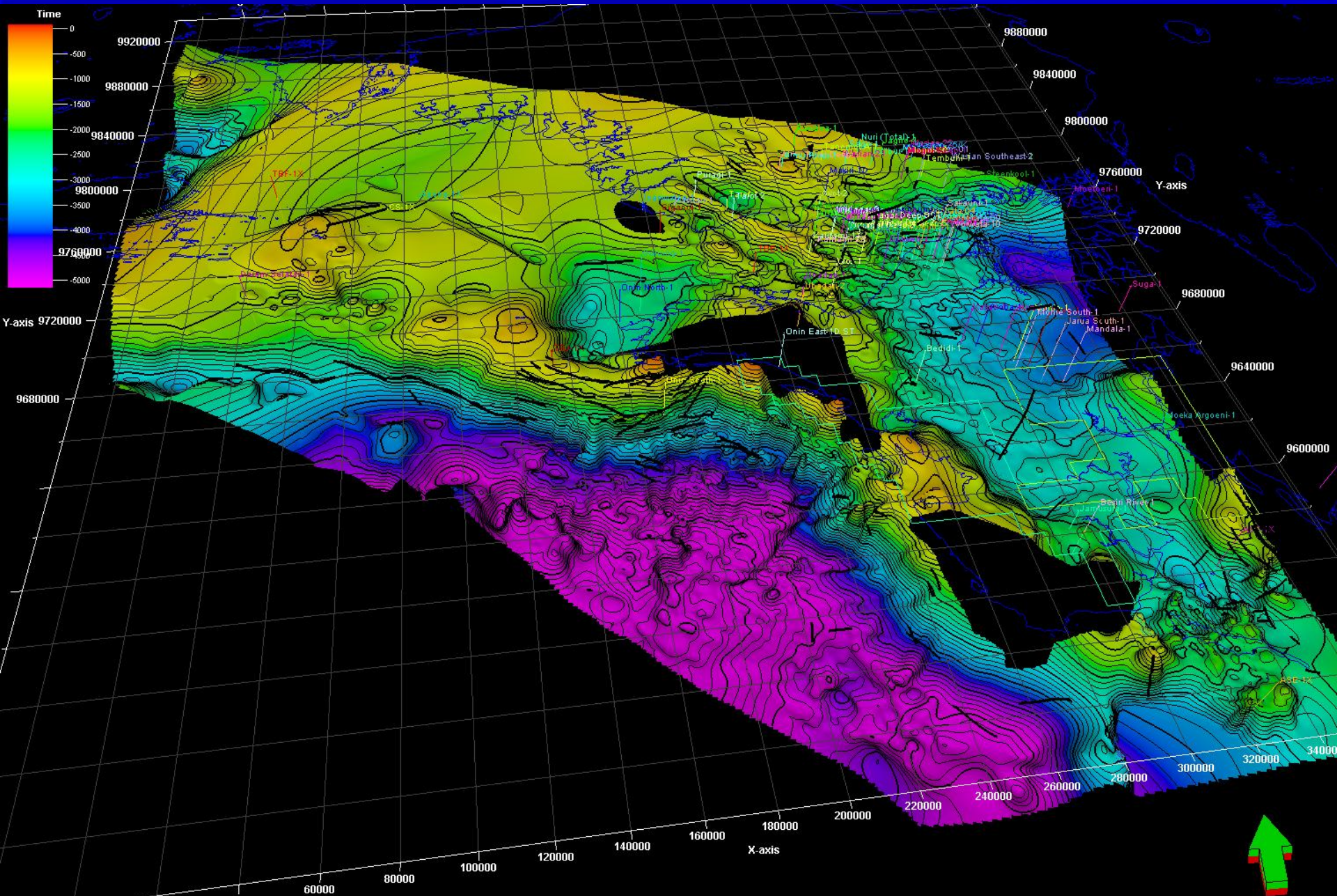
Regional Correlations



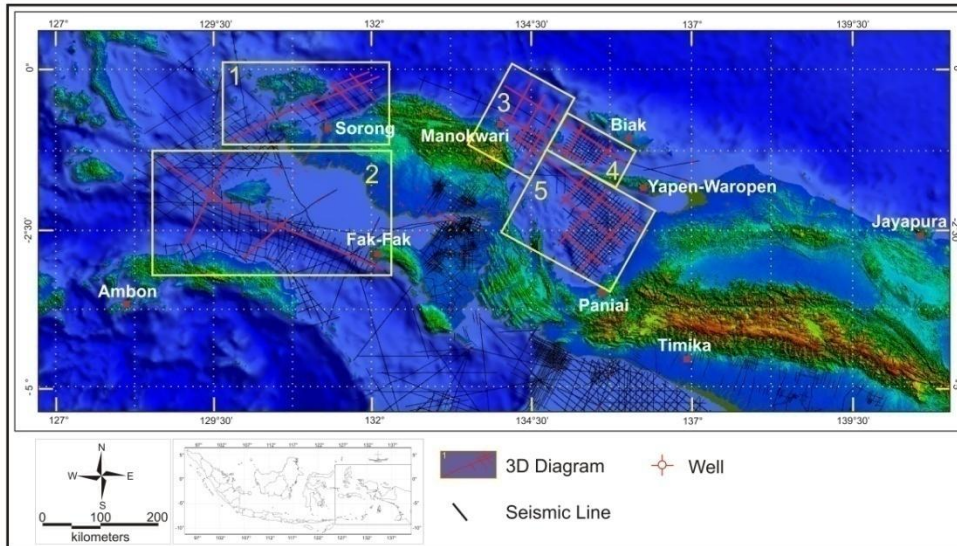
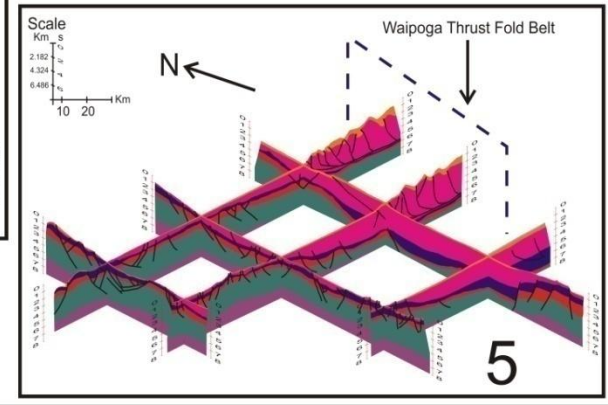
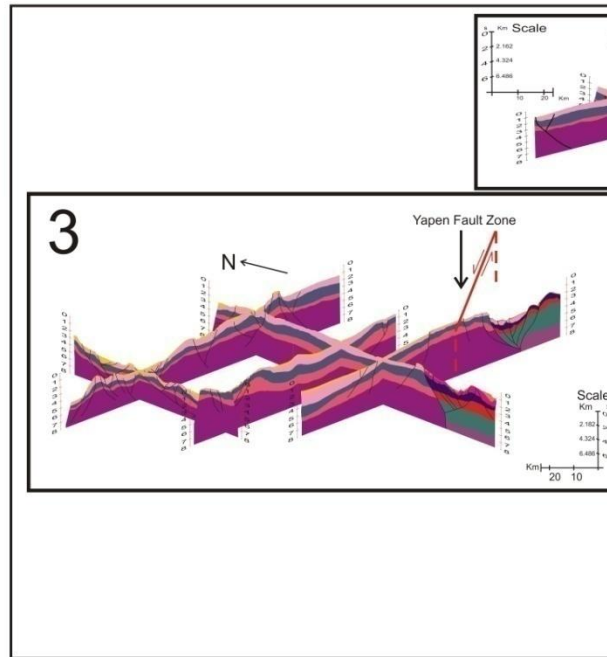
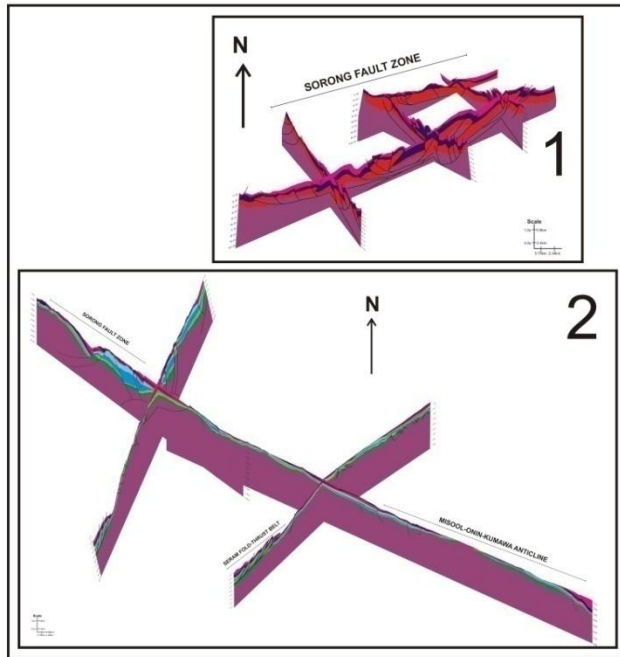
Regional Correlations



REGIONAL TIME STRUCTURE MAP – TOP JURASSIC

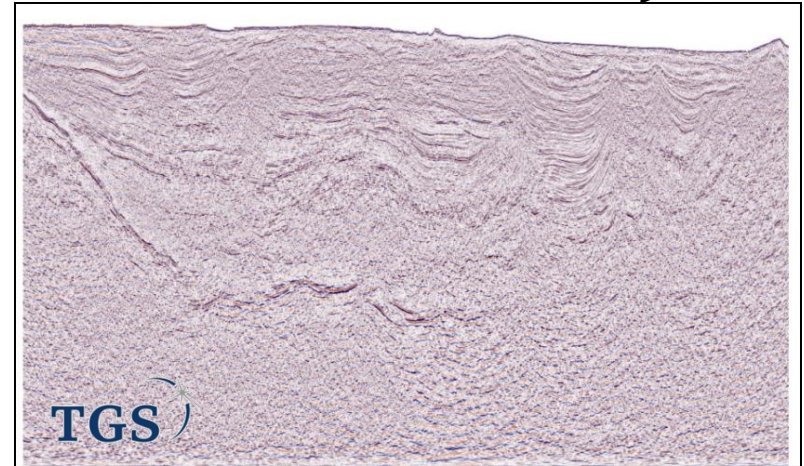
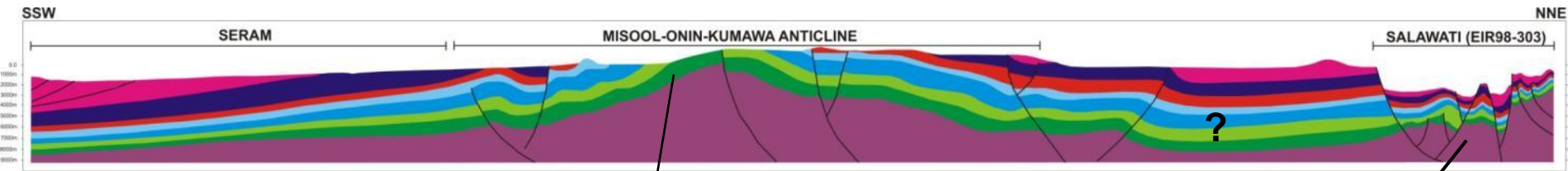


DEFORMATION OF BIRD HEAD REGION

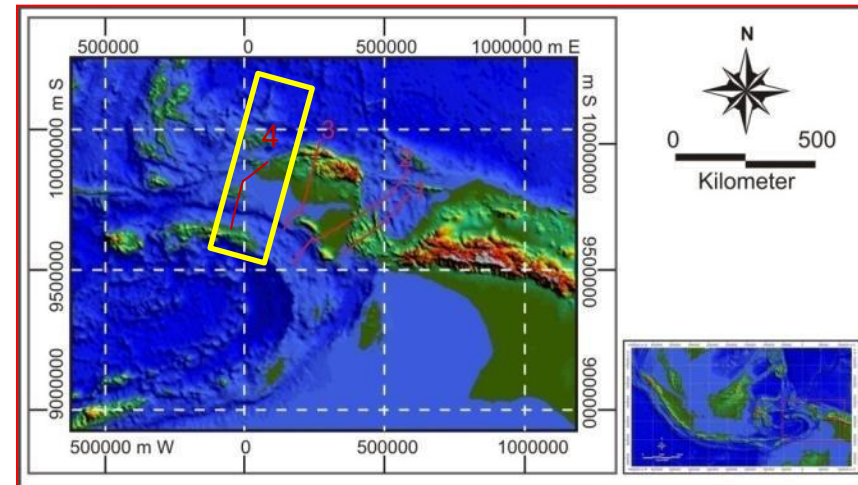


ERA	PERIOD	EPOCH	PLATE	
			AUSTRALIA	PACIFIC
Cenozoic	Quaternary	Recent, or Holocene		
		Pleistocene		
	Tertiary	Pliocene		
		Neogene		
		Miocene		
		Oligocene		
		Eocene		
		Paleocene		
	Mesozoic	Cretaceous		
		Jurassic		
		Triassic		
Paleozoic	Carboniferous	Permian		
		Pennsylvanian		
		Mississippian		
	Devonian	Silurian		
		Ordovician		
		Cambrian		

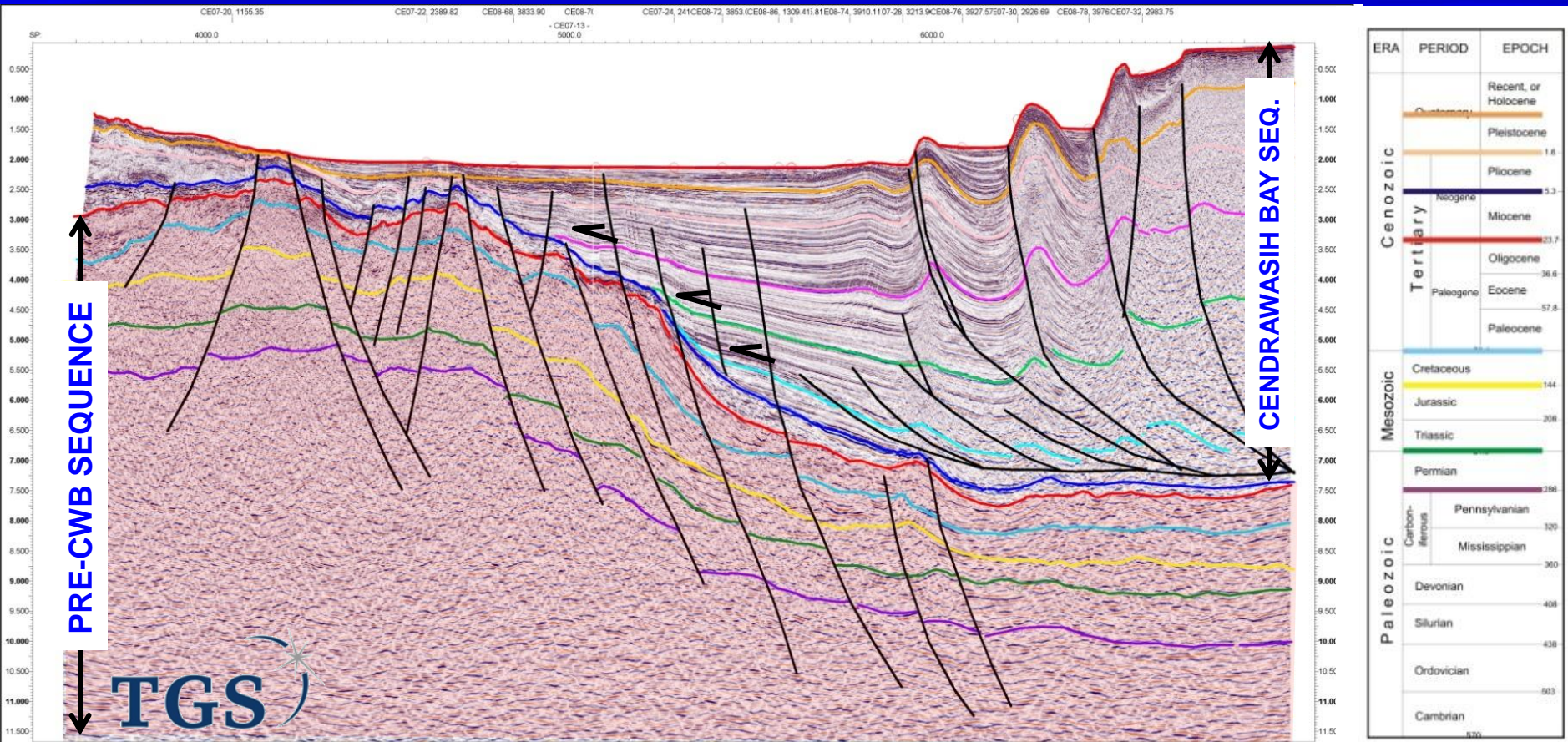
SALAWATI – MISOOL DEFORMATION



ERA	PERIOD	EPOCH	PLATE	
			AUSTRALIA	PACIFIC
Cenozoic	Quaternary	Recent, or Holocene		
		Pleistocene		
	Neogene	Pliocene		
		3.5		
		Miocene		
	Tertiary	23.5		
		Oligocene		
		34.5		
	Paleogene	Eocene		
		57.5		
	Paleocene			
	66.4			
Mesozoic	Cretaceous			
	144			
	Jurassic			
	209			
	Triassic			
	24.9			
Paleozoic	Carboniferous	Permian		
		280		
	Pennsylvanian			
		320		
	Mississippian			
		360		
	Devonian			
	420			
	Silurian			
	430			
	Ordovician			
	521			
Cambrian				

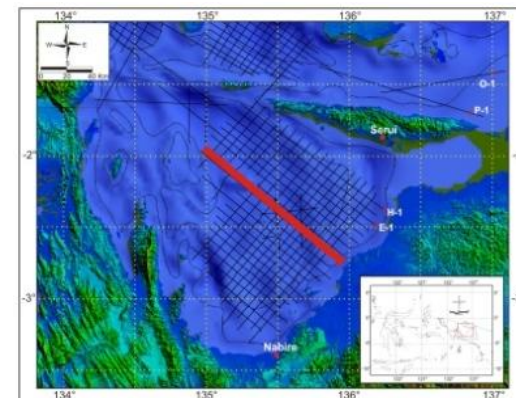


Seismic Interpretation of Cendrawasih Bay – Basement Issue?

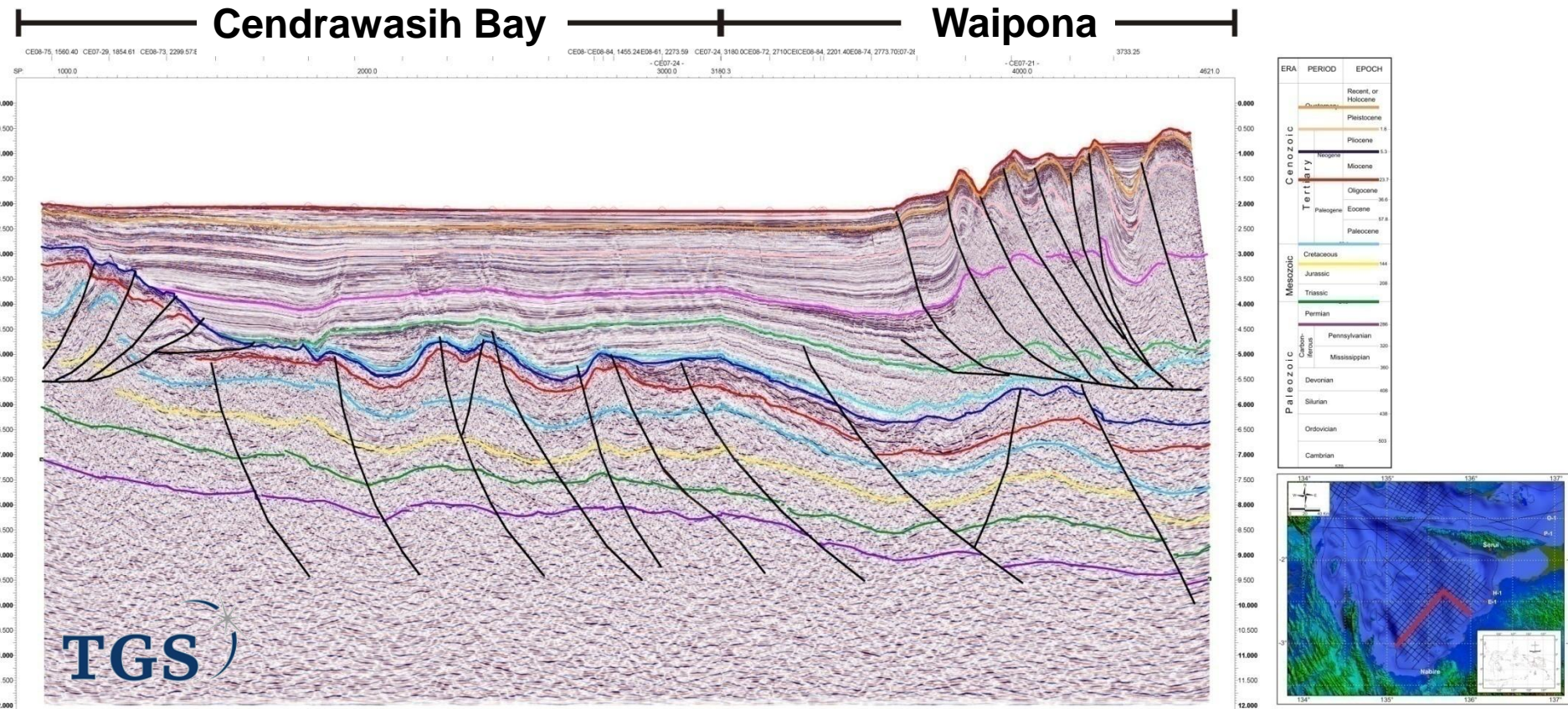


- Tied to O-1 well for Pliocene – Pleistocene
 - Divided into two major sequences
 - Angular unconformity relationship

Sapiie, et al. (2007)

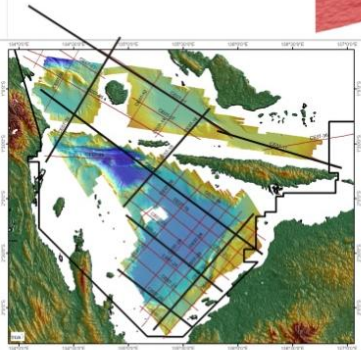
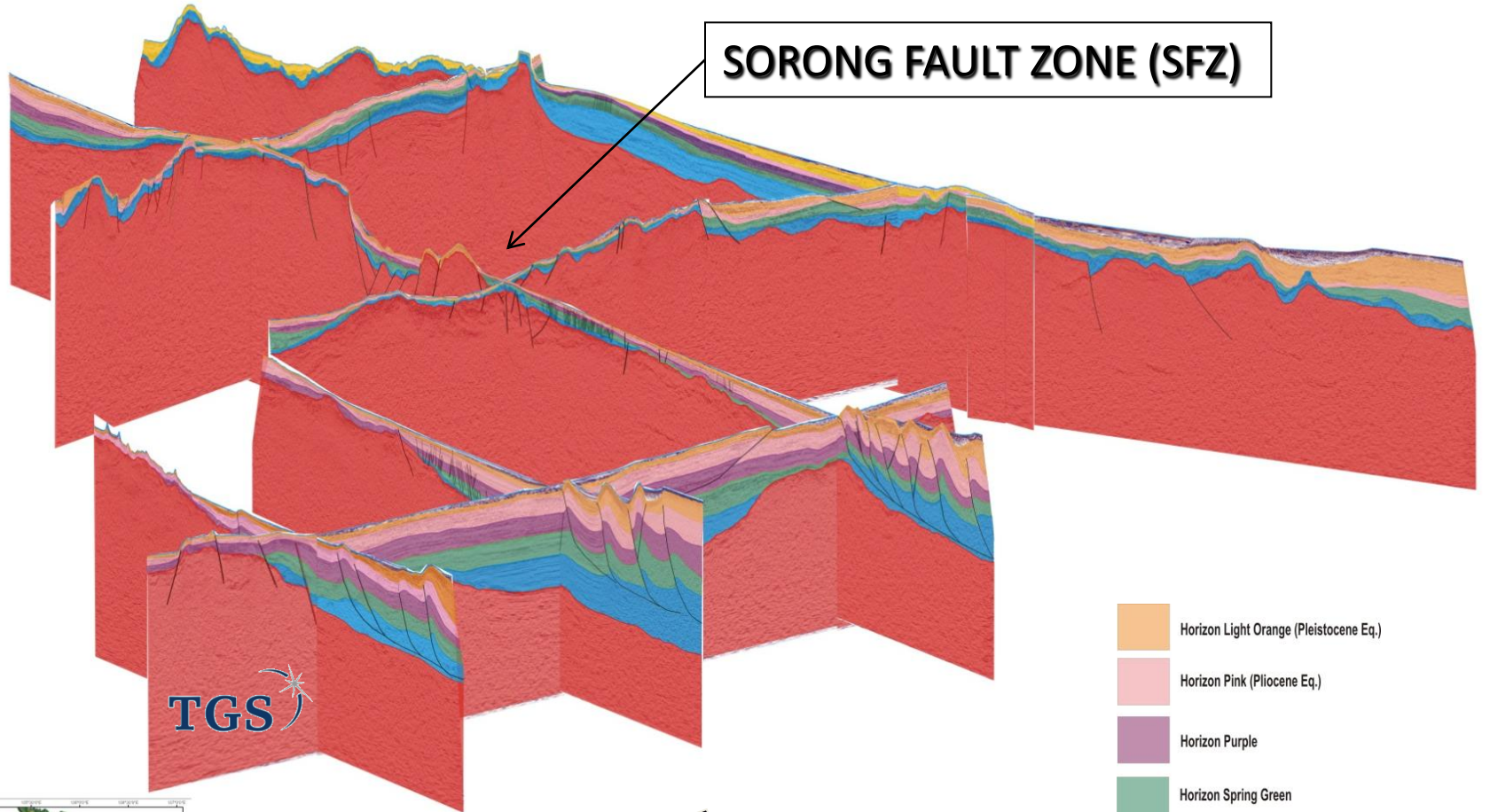


Seismic Interpretation of Cendrawasih Bay

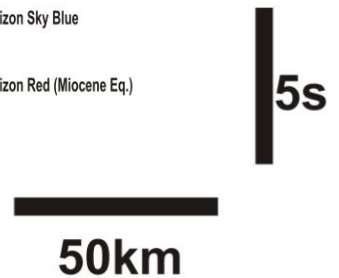
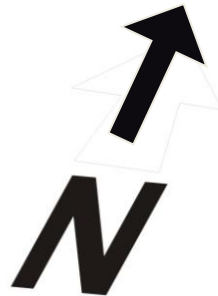


- Three Deformation Styles:
 - Early normal faults
 - Late Miocene (?) Thrust-Folds system
- Younger thin-skinned Thrust-Fold system

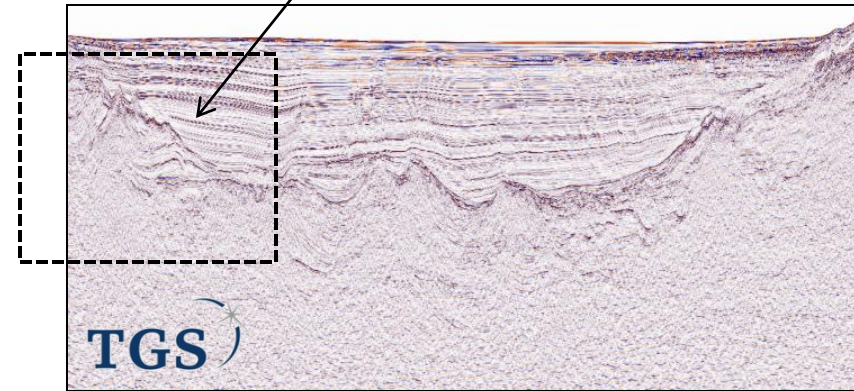
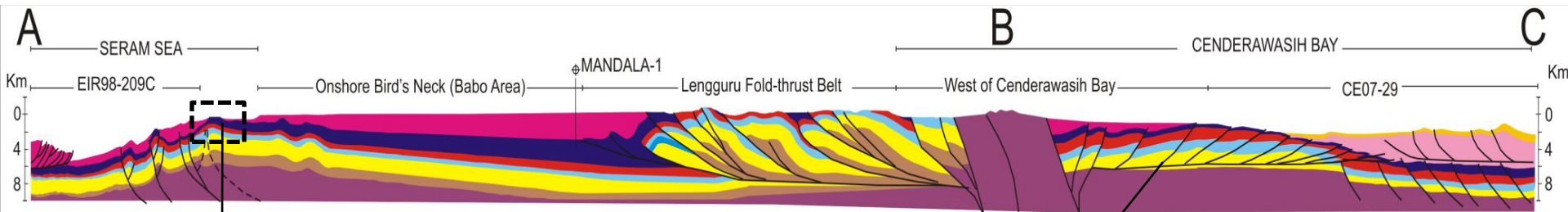
REGIONAL STRUCTURES - 3D VIEW – *continental vs. oceanic basement?*



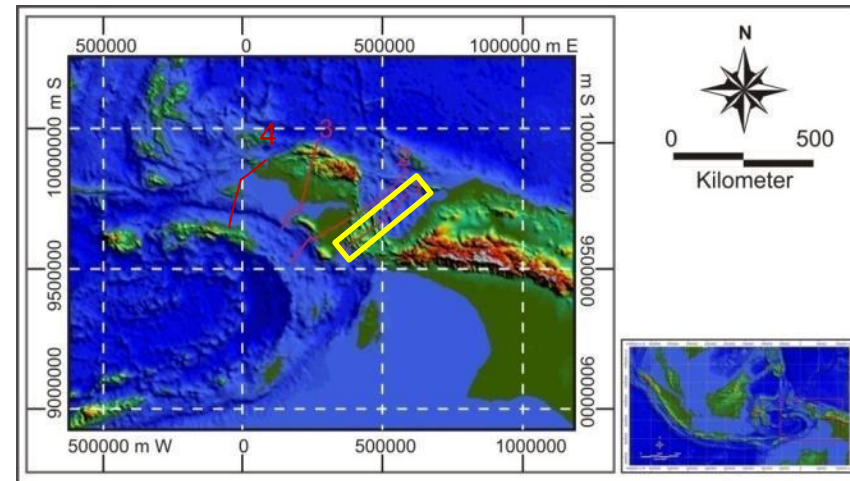
Sapiie, et al. (2007)



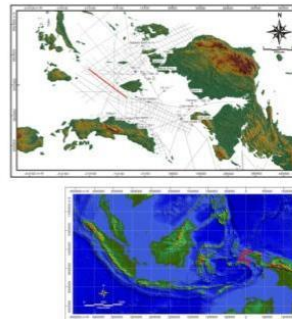
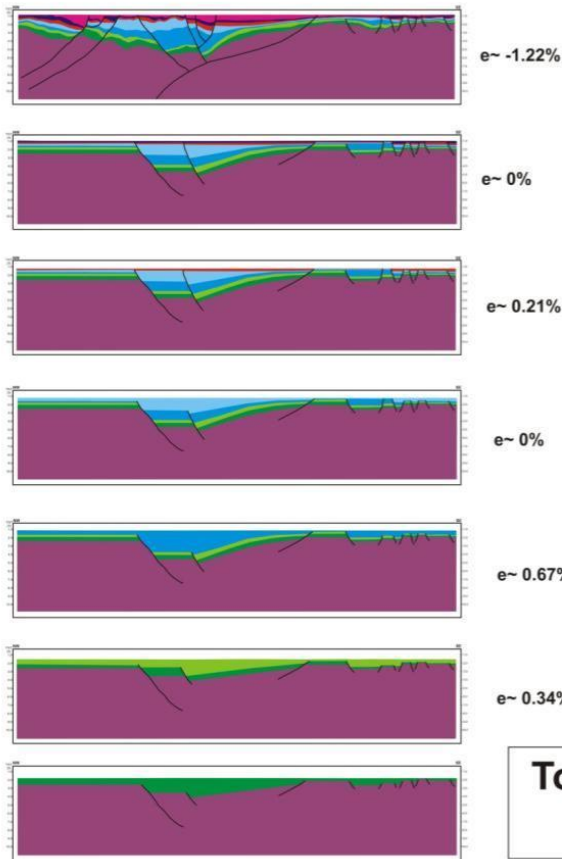
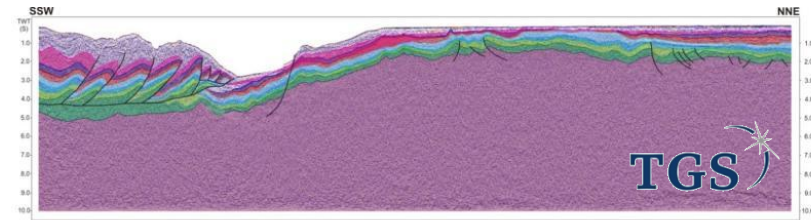
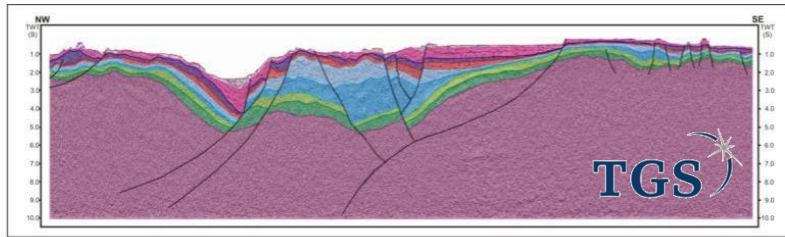
LENGGURU FTB – CENDRAWASIH BAY DEFORMATION



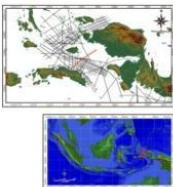
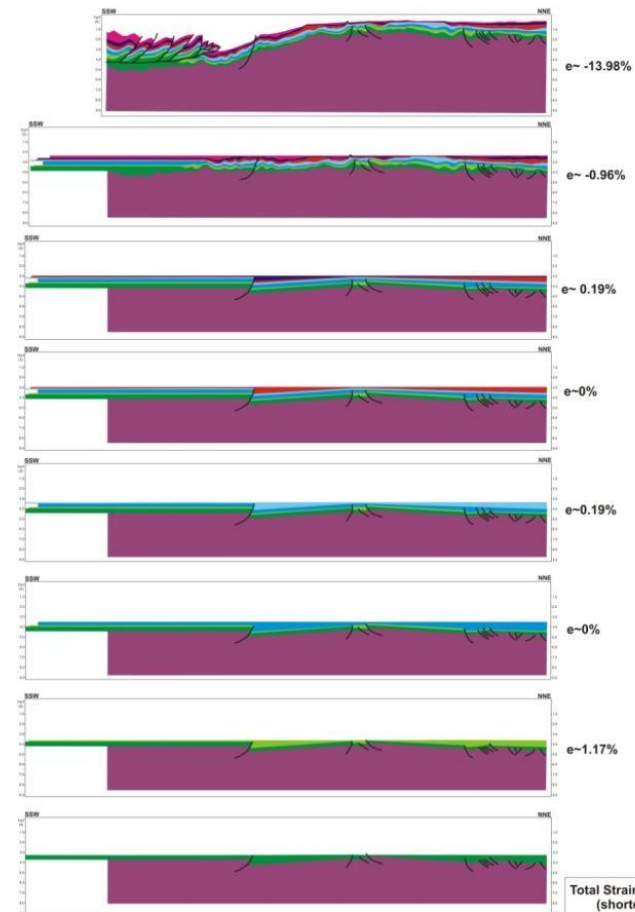
ERA	PERIOD	EPOCH	PLATE	
			AUSTRALIA	PACIFIC
Cenozoic	Quaternary	Recent, or Holocene		
		Pleistocene		
		Pliocene		
		Neogene		
		Miocene		
	Tertiary	Oligocene		
		Eocene		
		Palaeogene		
		Paleocene		
Mesozoic	Cretaceous			
	Jurassic			
	Triassic			
	Permian			
Paleozoic	Carboniferous	Permian		
		Mississippian		
		Devonian		
	Silurian			
	Ordovician			
	Cambrian			



PALINOSPATIC RECONSTRUCTIONS – BALANCING CROSS-SECTION



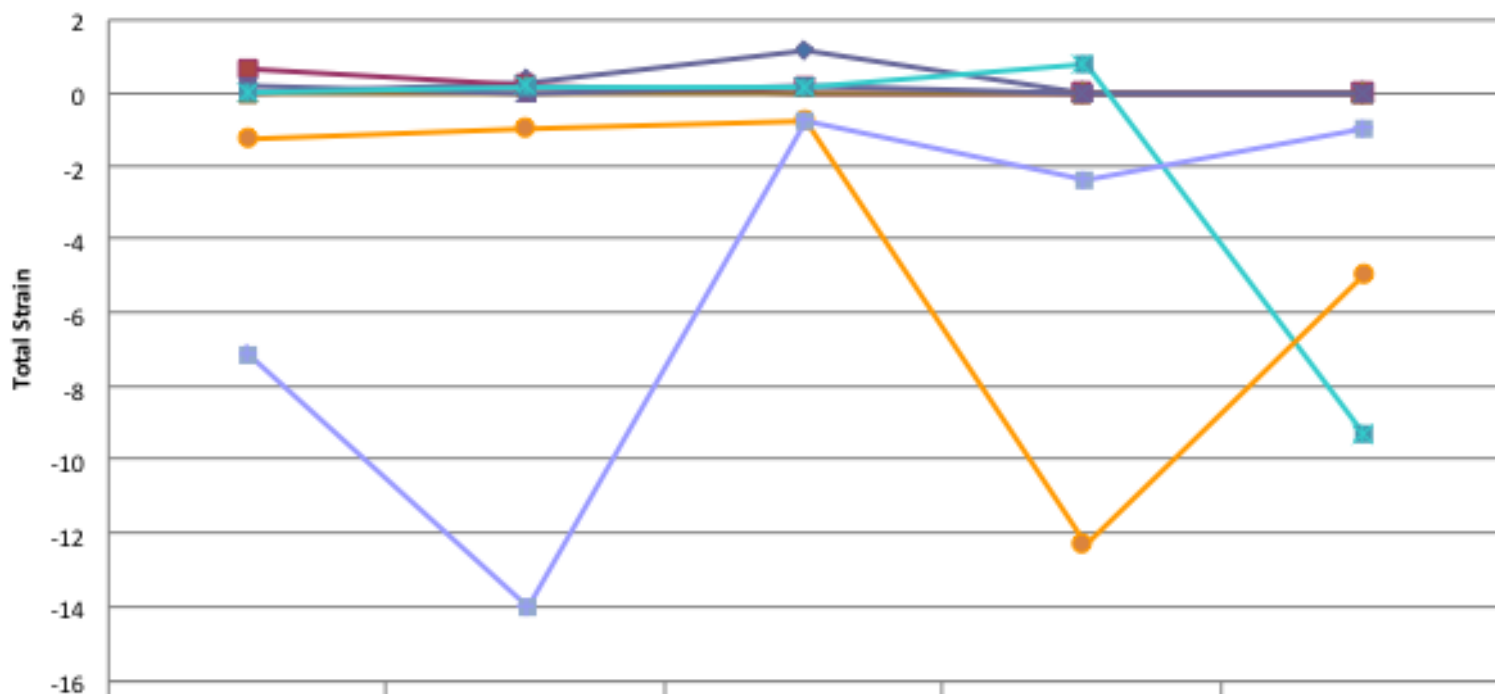
**Total Strain = 3.89%
(shortening)**



**Total Strain = 13.39%
(shortening)**

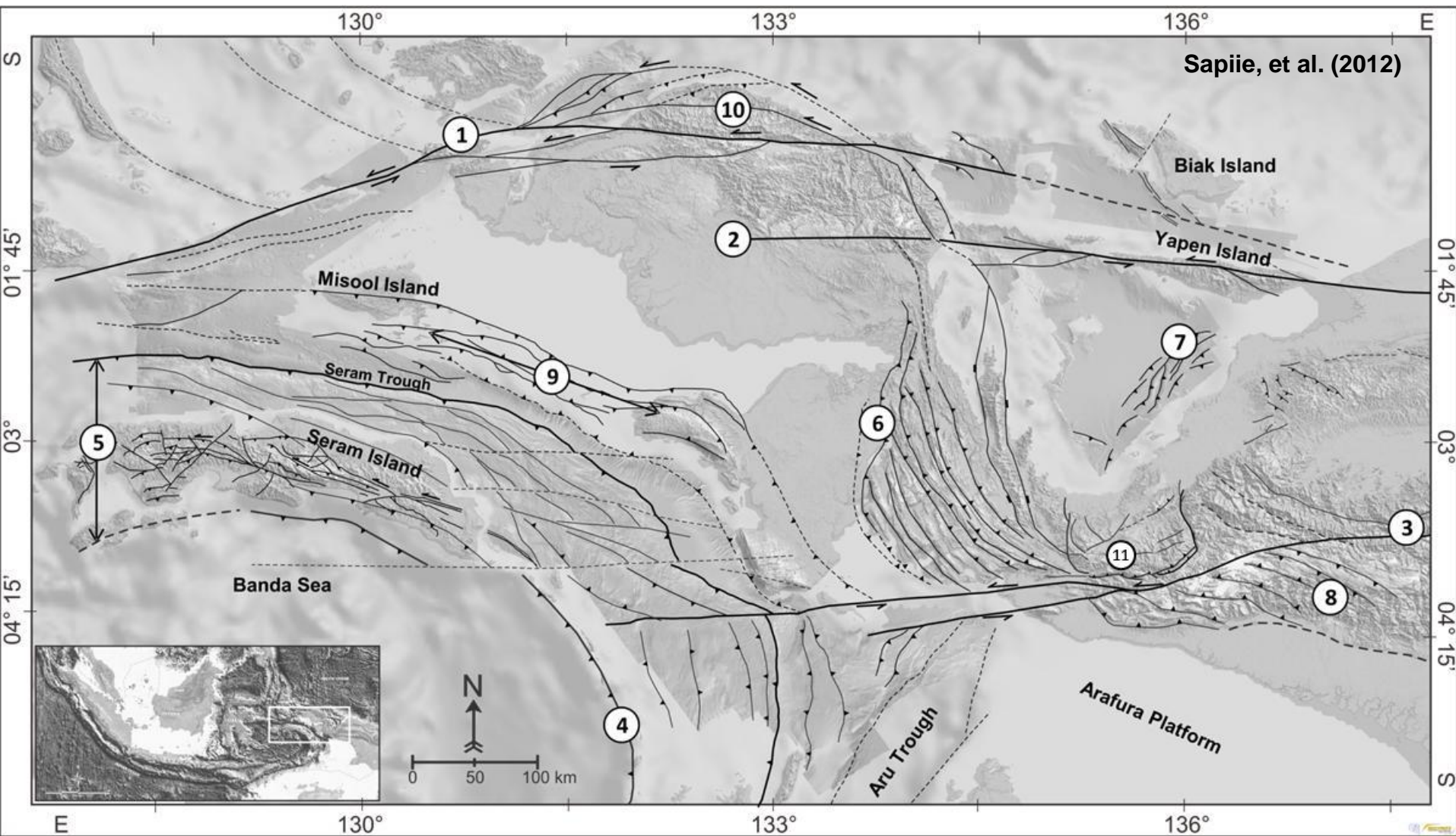
PALINSPATIC RECONSTRUCTIONS – *BALANCING CROSS-SECTION*

Total Strain Distribution at Bird's Head Area



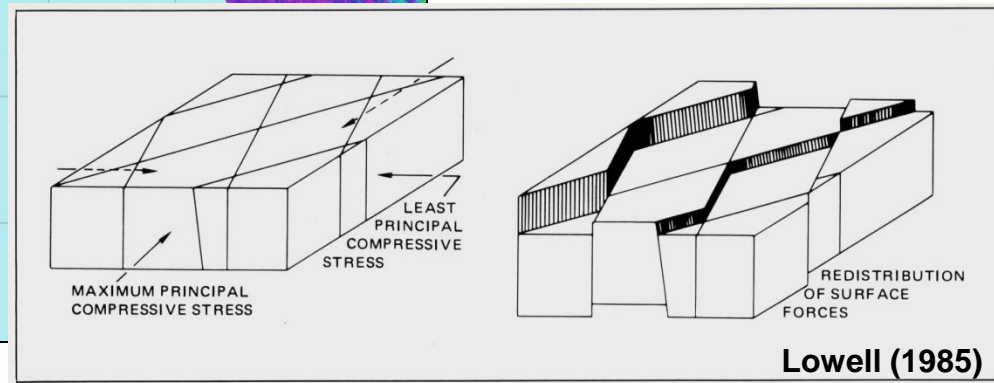
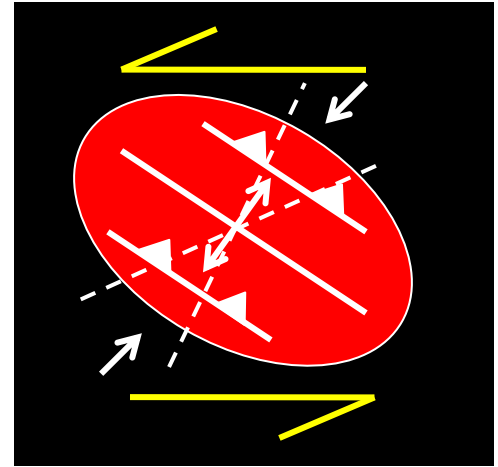
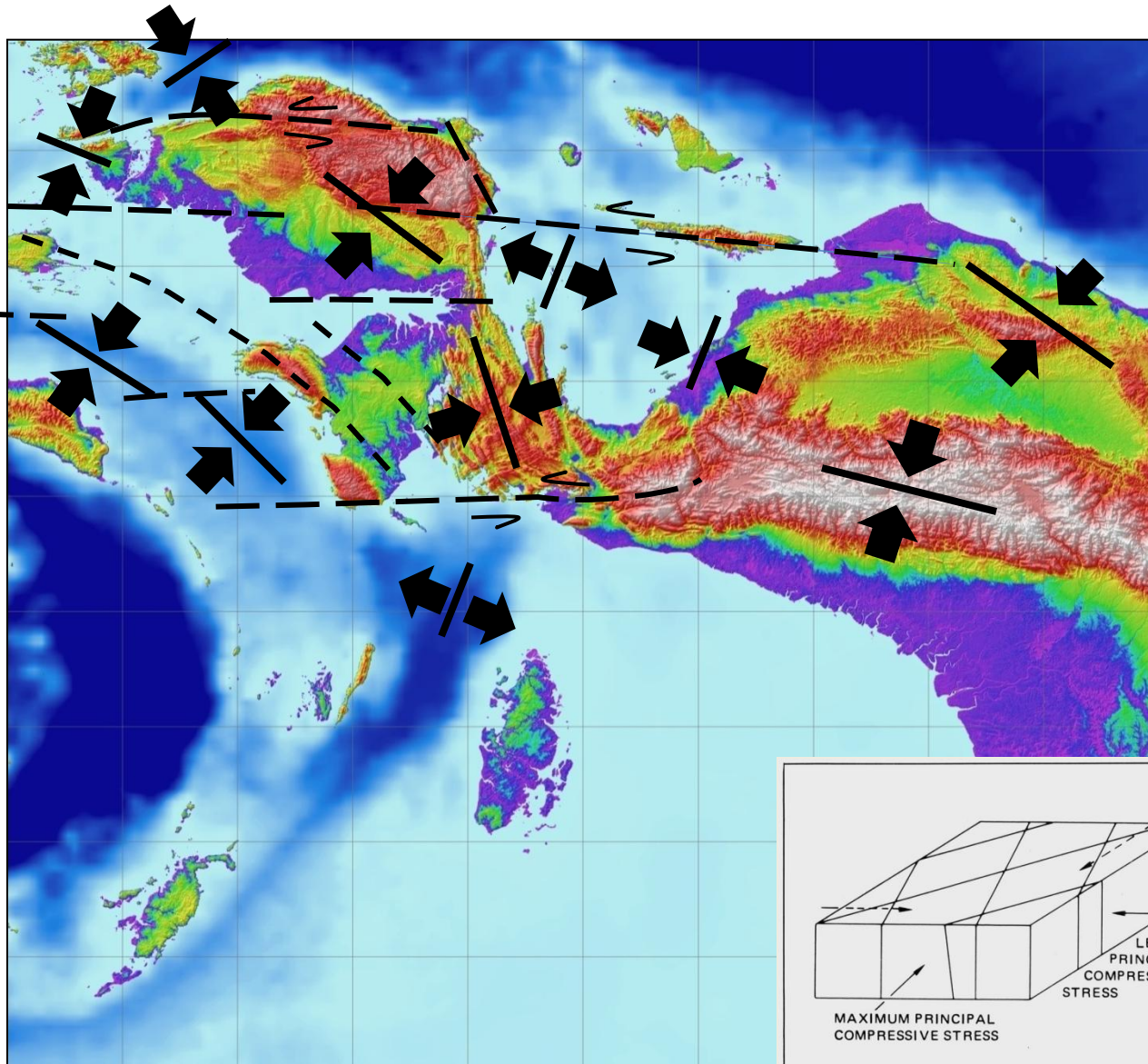
	West Misool	Seram	East Seram	NW Salawati	Cendrawasih Bay
Triassic-Early Jurassic	0.2	0.34	1.17	0	0
Early-Late Jurassic	0.67	0.25	0.15	0	0
Late Jurassic-Cretaceous	0	0.19	0.15	0	0
Cretaceous-Early Oligocene	0.21	0.07	0.19	0	0
Early Oligocene-Miocene	0	0.19	0.15	0.8	-9.27
Miocene-Early Pliocene	-1.22	-0.96	-0.75	-12.28	-4.97
Early Pliocene-Present	-7.09	-13.98	-0.75	-2.37	-0.98

DEFORMATION PATTERN AND FAULT STYLE

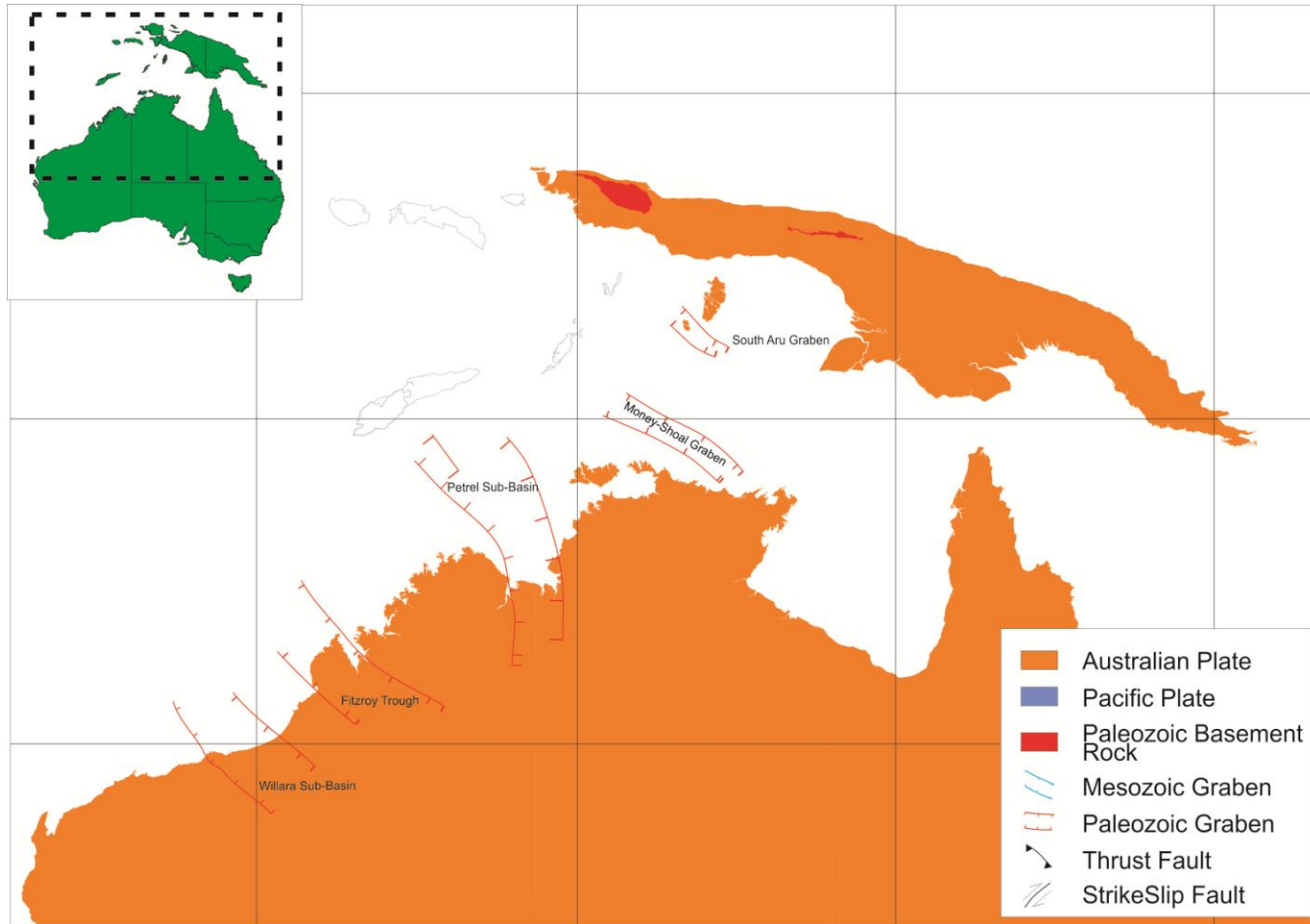


1. Sorong Fault Zone (SFZ), 2. Yapen Fault Zone (YFZ), 3. Tarera-Aiduna Fault Zone (TAFZ), 4. Banda Trench, 5. Seram Fold-Thrust-Belt (SFTB), 6. Lengguru Fold-Thrust-Belt (LFTB), 7. Cendrawasih Bay Fold-Thrust-Belt (CBFTB), 8. Central Range Fold-Thrust-Belt (CRFTB), 9. Misool-Onin-Kumawa Ridge (MOKR), 10. Kemum High, 11. Weyland Overthrust.

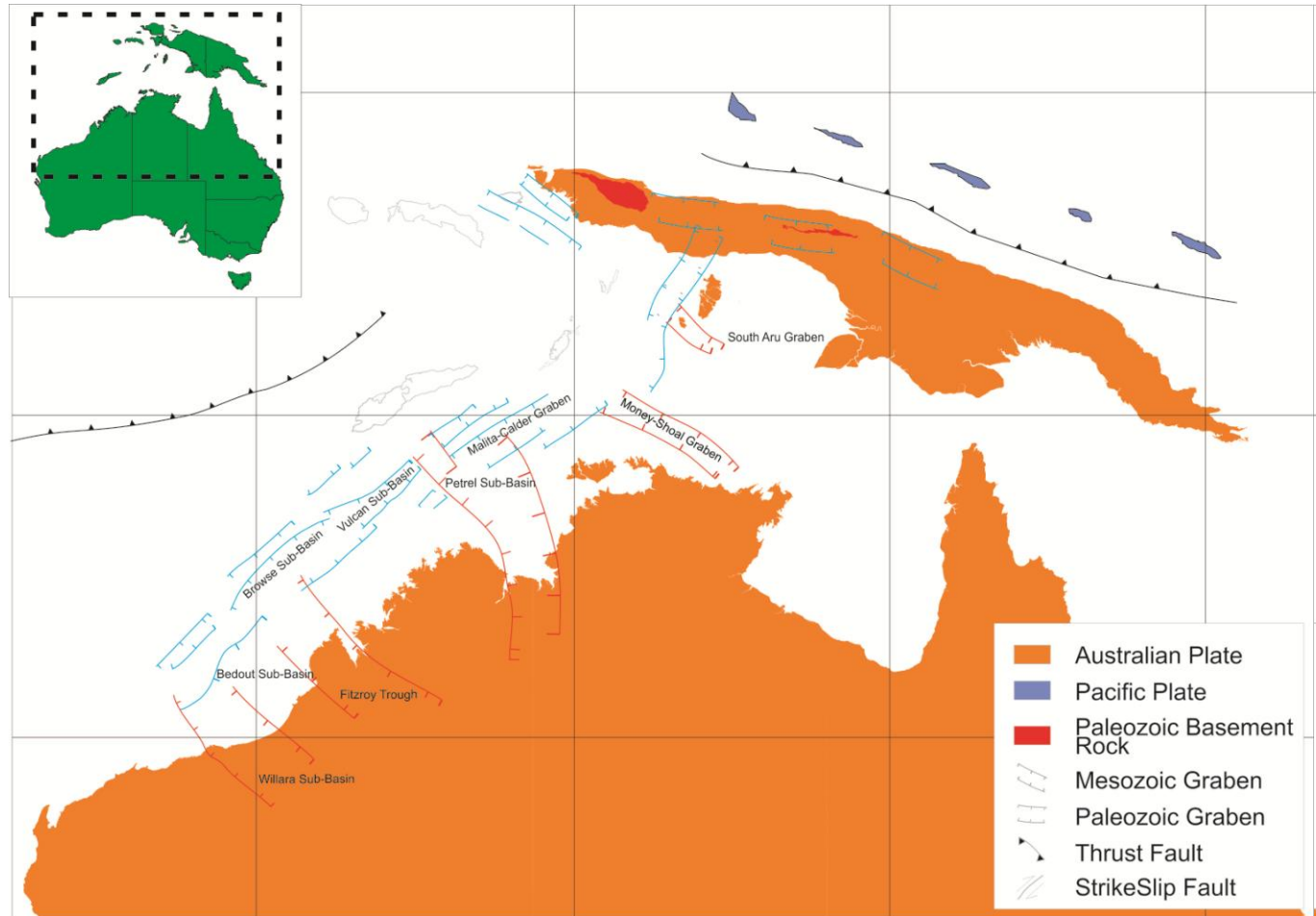
STRAIN ANALYSIS BIRD REGION – *STRIKE SLIP DEFORMATION*



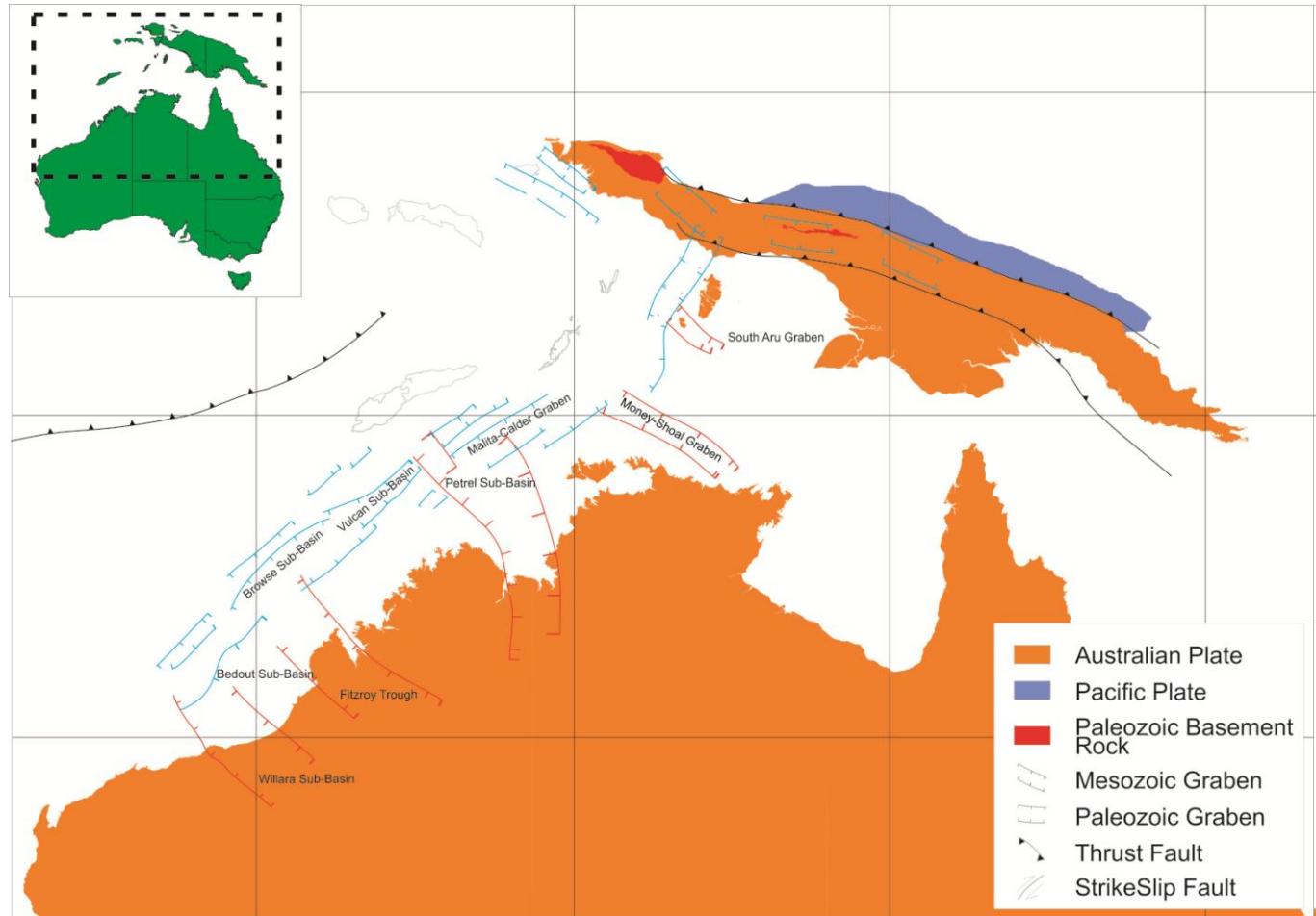
BIRD HEAD RECONSTRUCTIONS



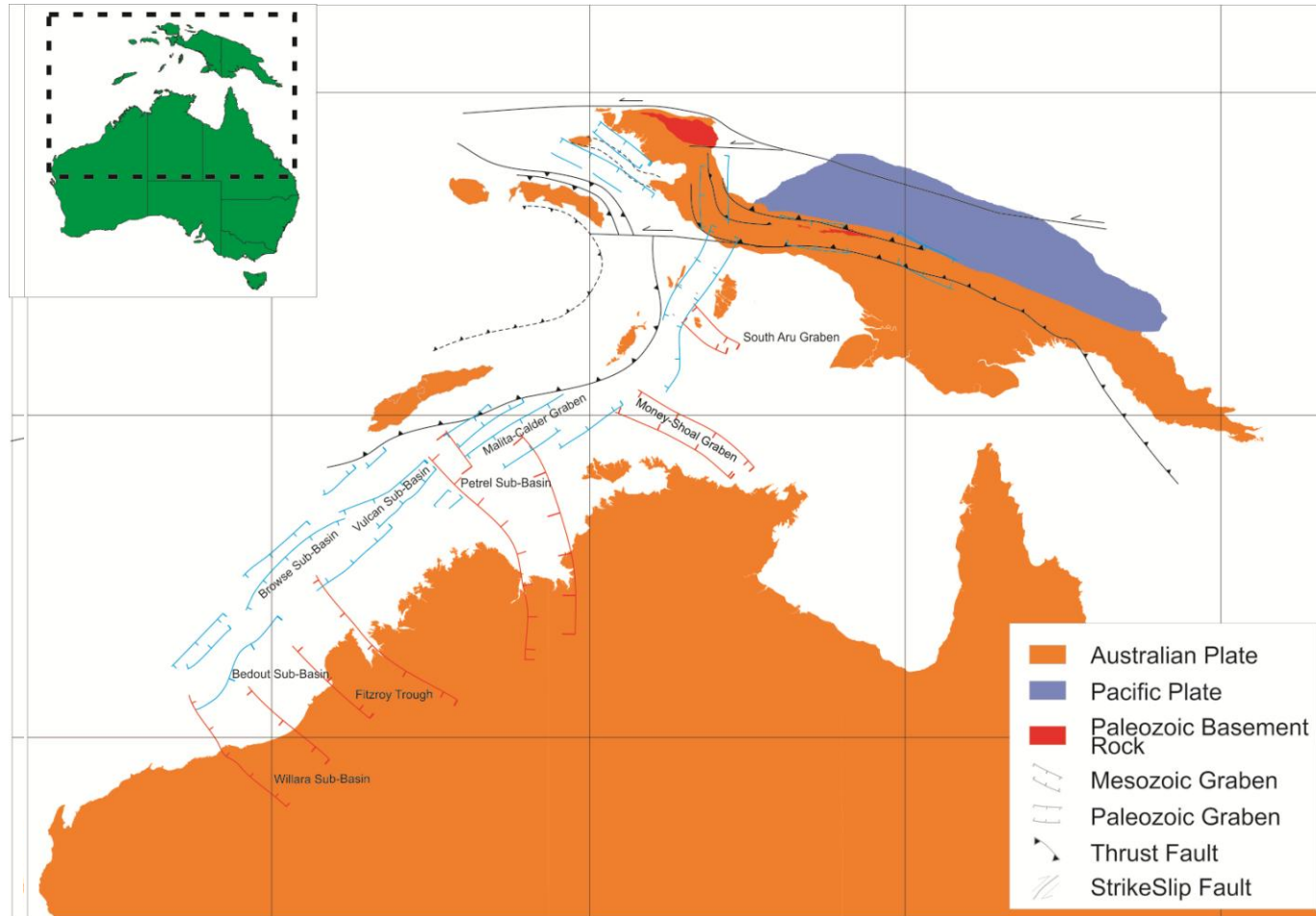
BIRD HEAD RECONSTRUCTIONS



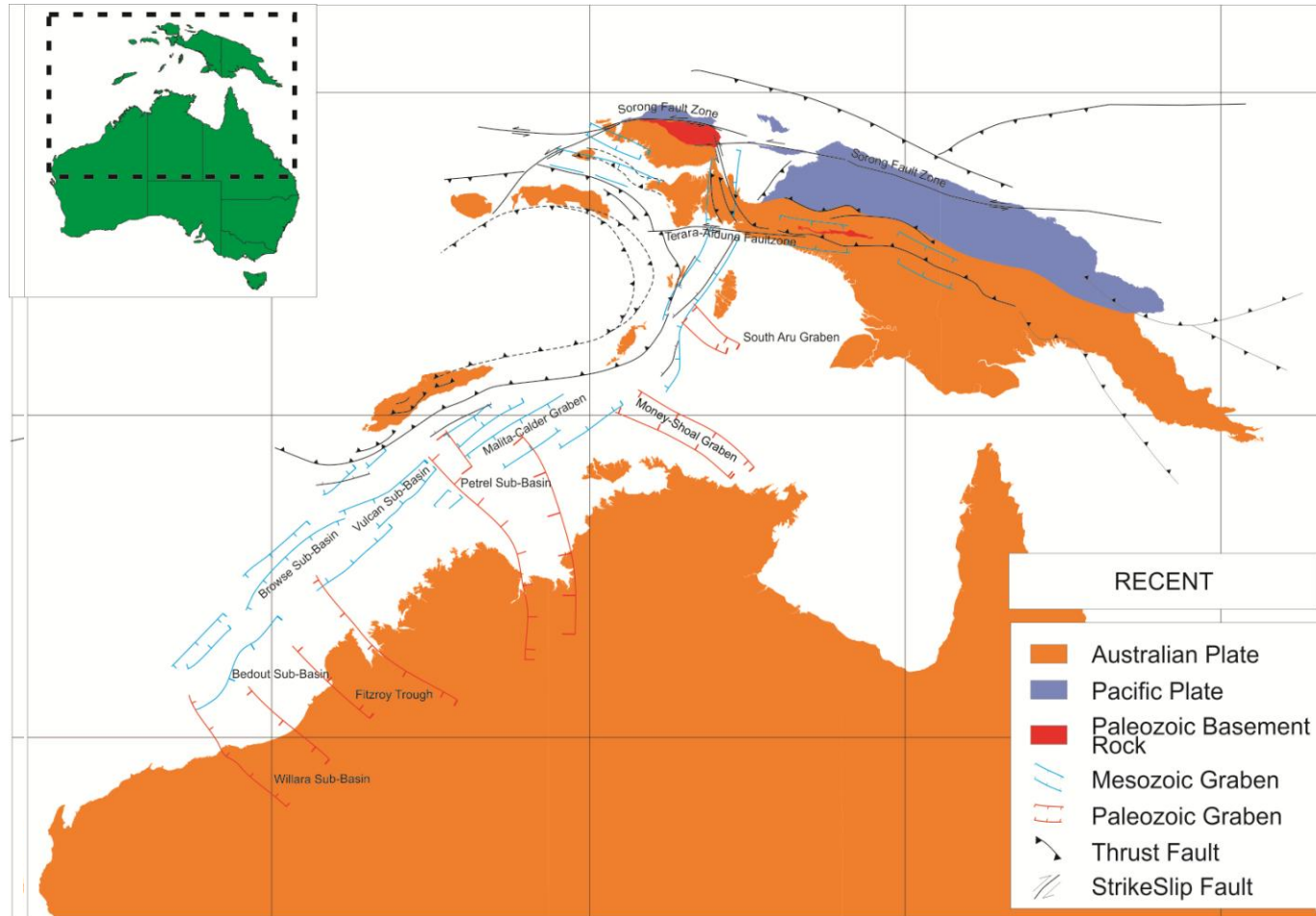
BIRD HEAD RECONSTRUCTIONS



BIRD HEAD RECONSTRUCTIONS



BIRD HEAD RECONSTRUCTIONS



CONCLUSIONS OF BIRDHEAD REGIONS

- BIRD HEAD REGION IS VERY COMPLEX STRUCTURES AND KINEMATICS AT PRESENT-DAY IT MOVING AS PART OF GREAT PACIFIC PLATES.
- DEFORMATION WITHIN CENDRAWASIH, SALAWATI AND SERAM BASINS IS CONTROLLED BY ACTIVITY OF SORONG FAULT ZONE.
- COMPLEX GEOMETRY OF SORONG FAULT ZONE CONTROLLED BY PRE-EXISTING FAULT SUCH AS LEFT OR RIGHT-STEPPING CAUSED LOCAL ASYMETRY DEFORMATION PATTERN RESULTED IN SHORTENING AND EXTENSION WITHIN CENDRAWASIH BAY AND SURROUNDING BIRD HEAD REGION.
- *SIMPLE SHEAR MECHANISM INVOLVING RIGID BODY with TRANSLATION AND ROTATION AS THE MAIN MECHANISM*

SPECIAL THANKS TO:

- DIRECTORATE GENERAL OIL AND GAS INDONESIA
 - BPMIGAS INDONESIA
 - TGS NOPEC
 - NIKO INDONESIA
- 2D/3D MOVES SOFTWARE – MIDLAND VALLEY
 - GEODYNAMIC RESEARCH GROUP ITB
- FACULTY OF EARTH SCIENCES AND TECHNOLOGY ITB

