NORTH SUMATRA BASIN: *ITS EVOLUTION AND SEDIMENTATION EVOLUTION*

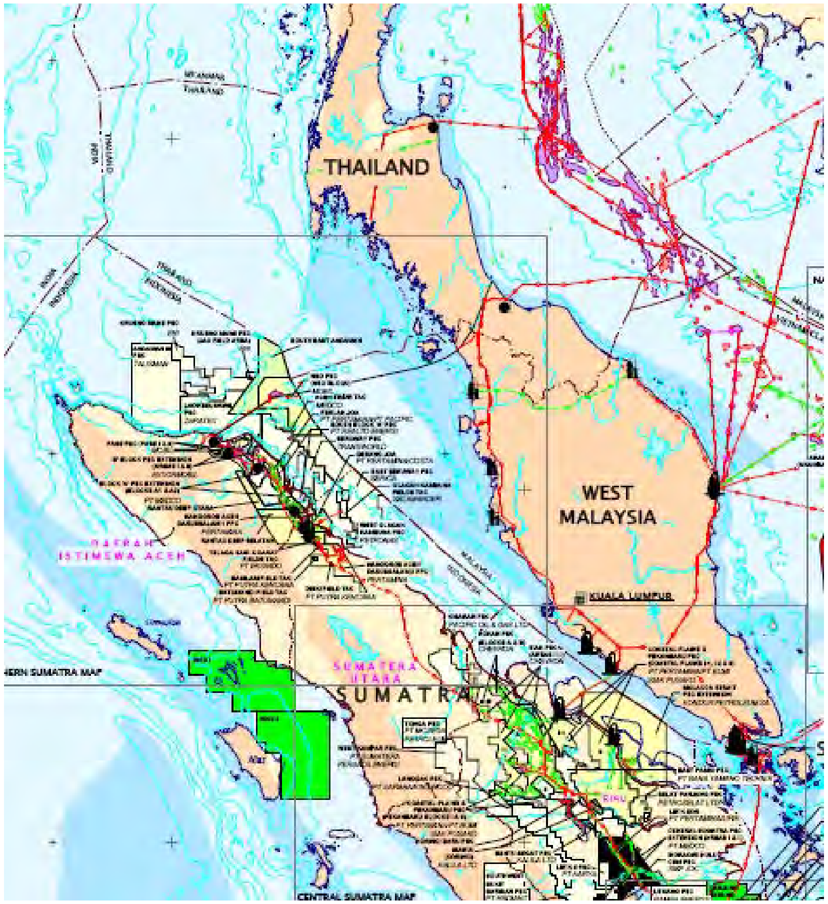
ALIT ASCARIA Ph.D.

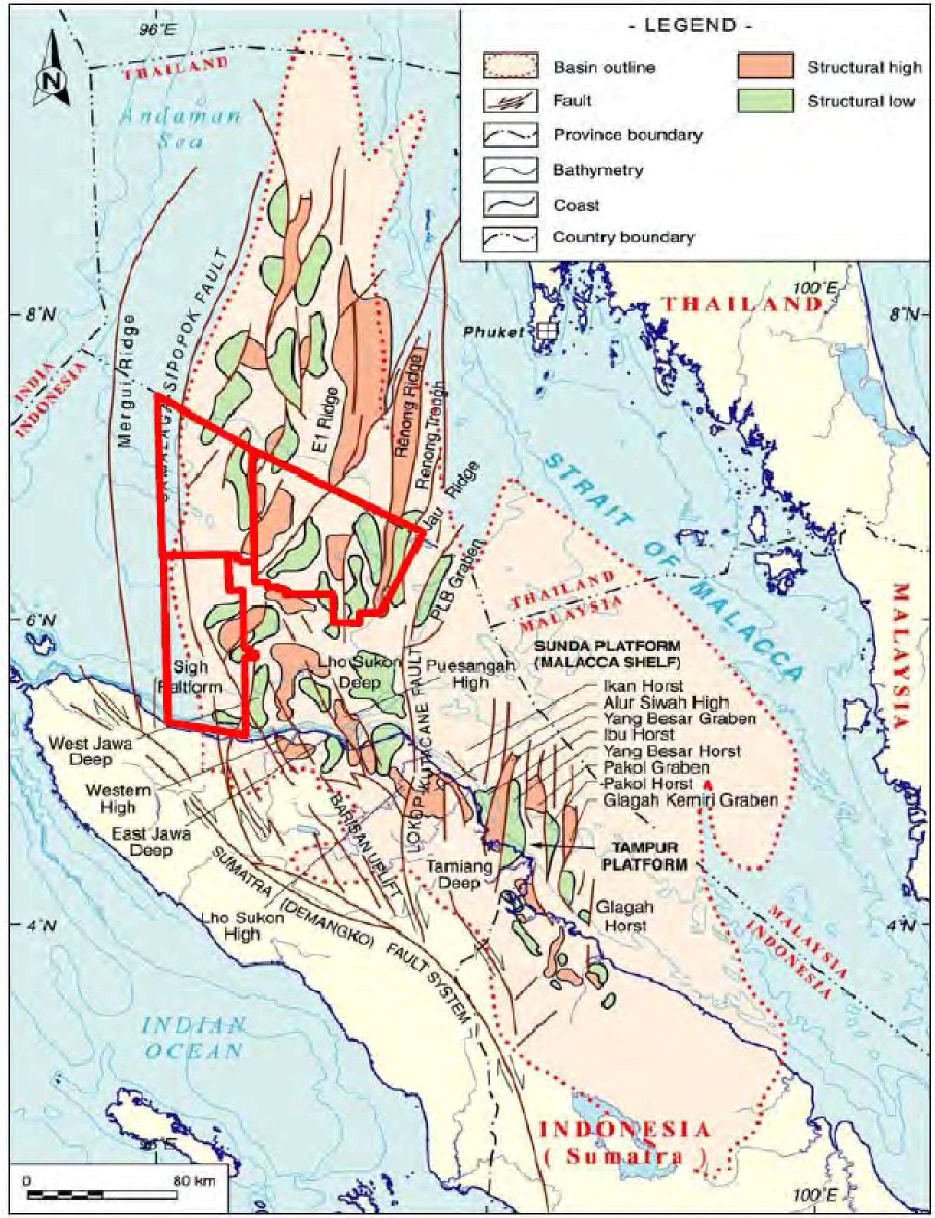
CCOP. P1W2: North Sumatra-Mergui Basin Case Study.
Medan & Parapat, 27 – 30 April 2010

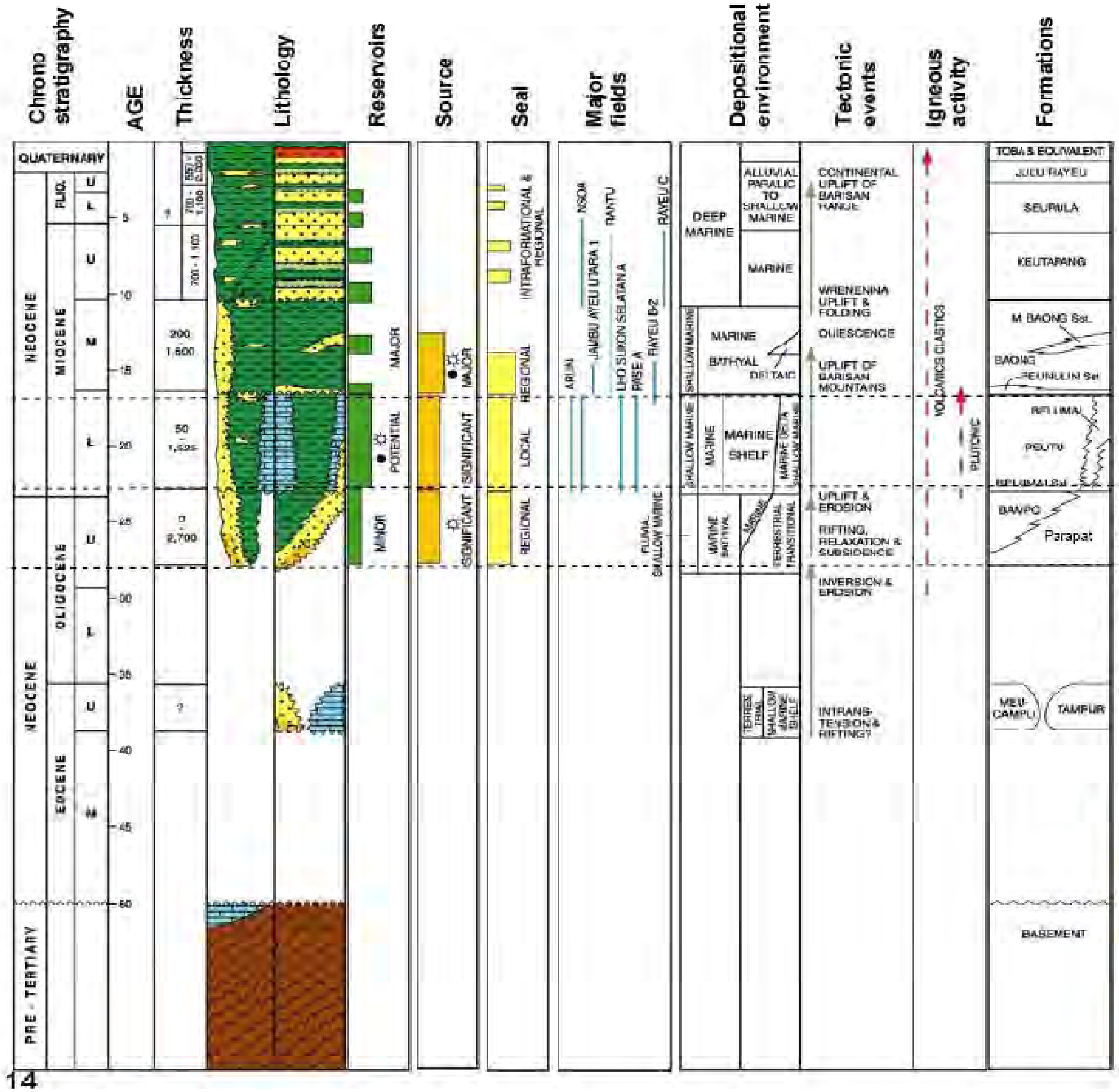
Agenda

- Introduction
- Regional Geology of North Sumatra
- Paleogeography
- Petroleum Systems
- Conclusion

INTRODUCTION







Plio-Pleistocene **volcanism** (tuffaceous beds in Keutapang and Seurula formations)

Middle Miocene: major **compressional regime**

Hemi-pelagic deposition

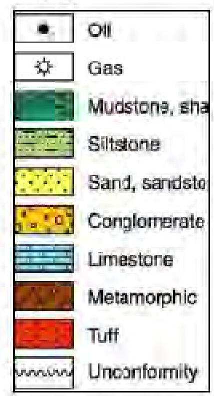
Barisan Range uplifted and overthrust

Basin subsidence & transgression (Crustal relaxation). Open marine deposit

Syn-rift (second phase) basal clastic sequence, separated from sediments of the phase I synrift (Foreland Margin Unit) by a regional unconformity

Early to Middle Oligocene: **Inversion/erosion** removing much Late Eocene fill.

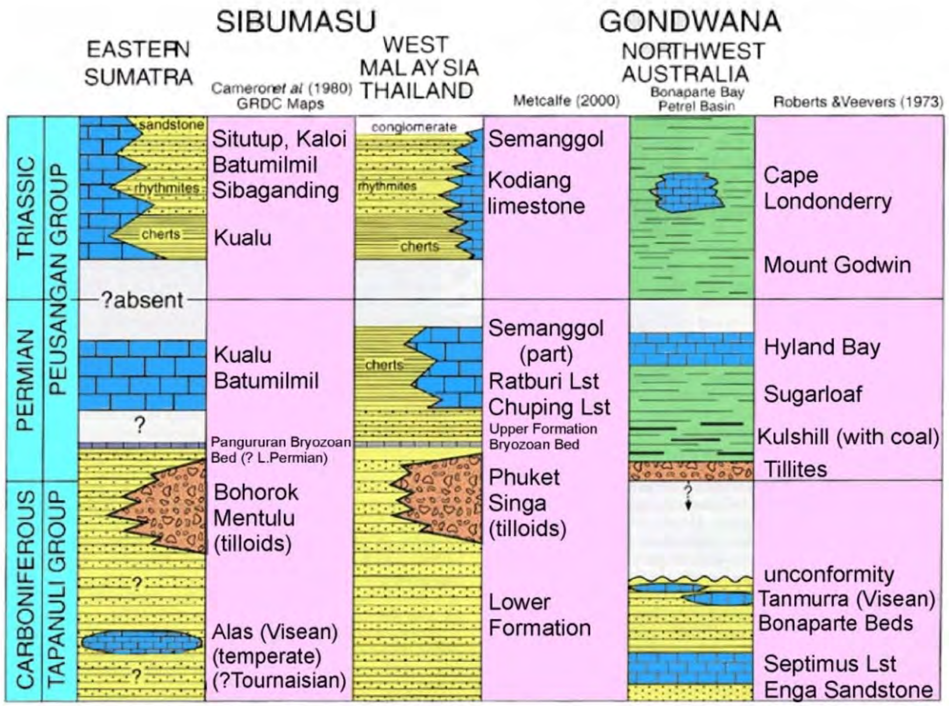
Initial rifting phase (transgressive fluviatile to fully marine foreland margin).



Accretion, suturing and deformation of the exotic terrains underlying the Tertiary sedimentary cover commenced in Late Triassic times in response to oblique subduction of the Indian Ocean plate beneath the proto-Sunda margin. The main tectonic regime from Late Jurassic to Late Cretaceous times was compressional as a result of this convergence.

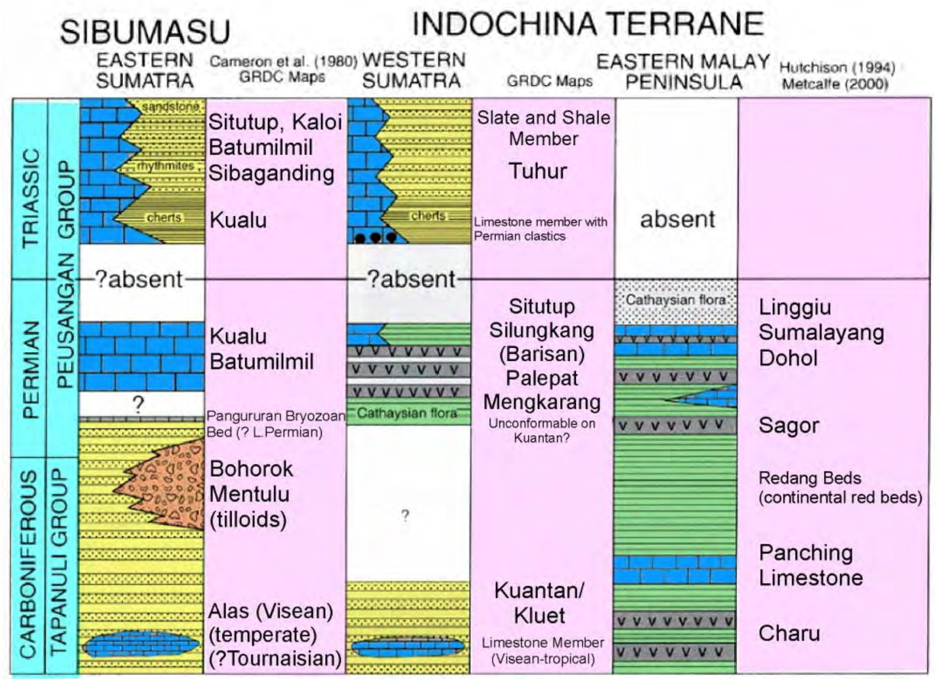
BASEMENT LITHOLOGY

Comparison of the Carboniferous, Permian, and Triassic sequences in the Sibumasu terranes of eastern Sumatra, West Malaysia and Thailand, and Gondwana Terrane in NW Australia

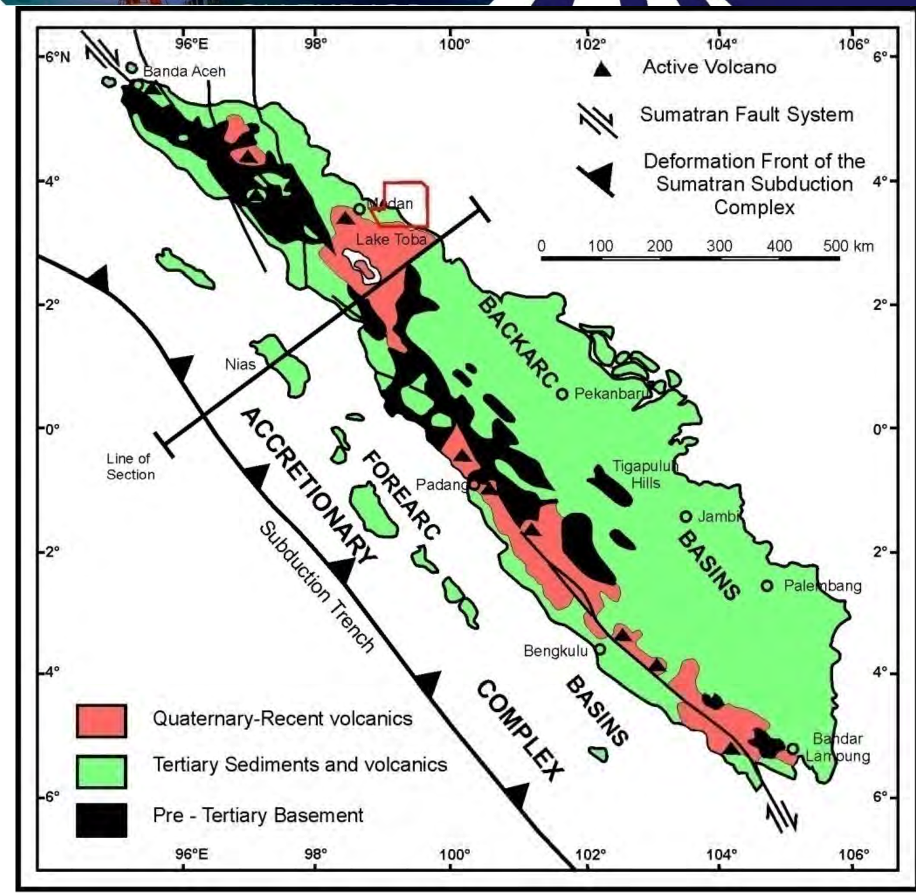


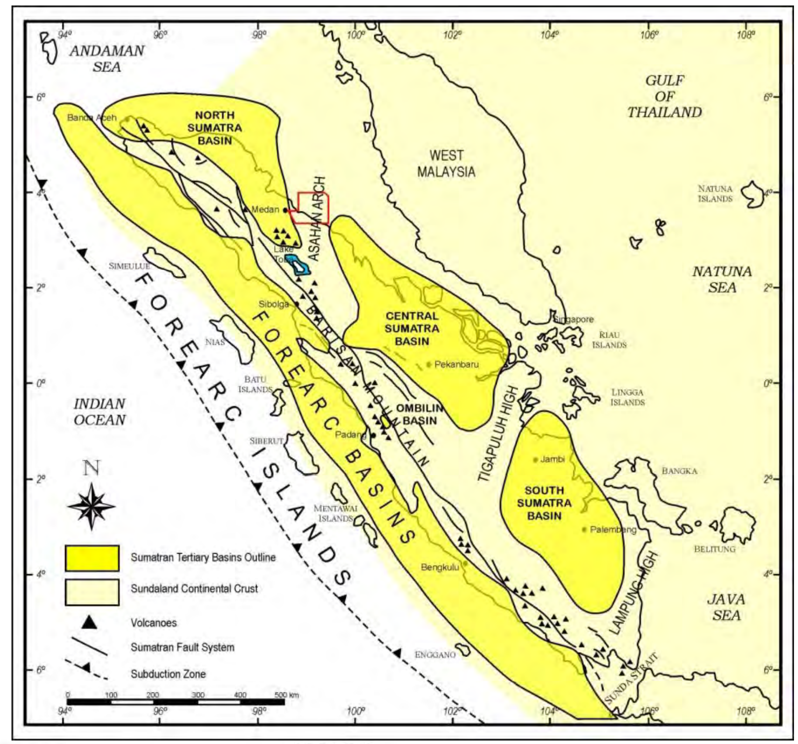
(Barber *et al*., 2005)

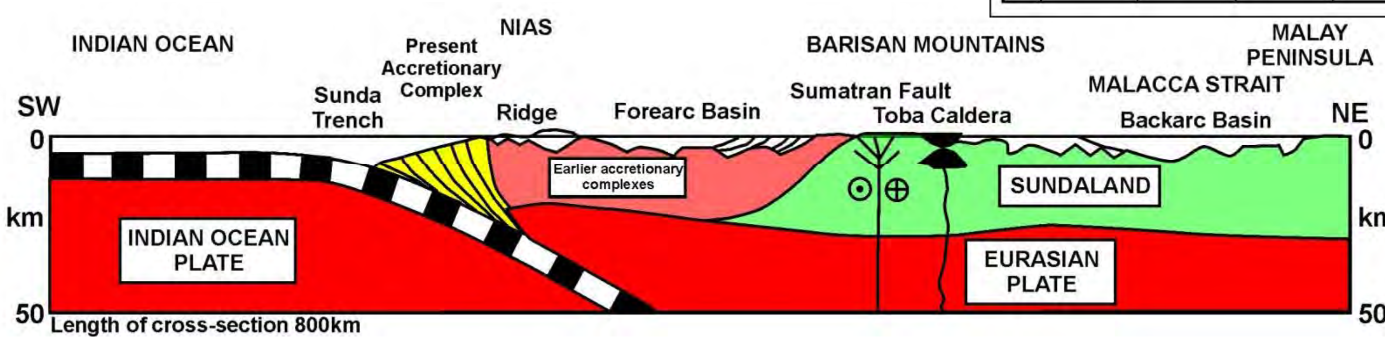
Comparison of the Carboniferous, Permian, and Triassic sequences of the eastern Sumatra Sibumasu Terrane and GRDC map sheets, the Indochina Terranes of west Sumatra and the eastern Malay Peninsula



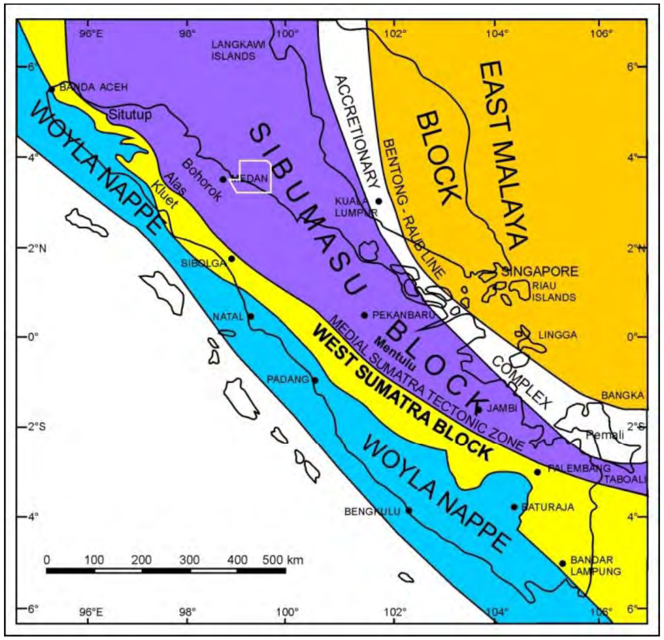
Cross section of the Sumatra Subduction System from the floor of the Indian Ocean to the Malay Peninsula





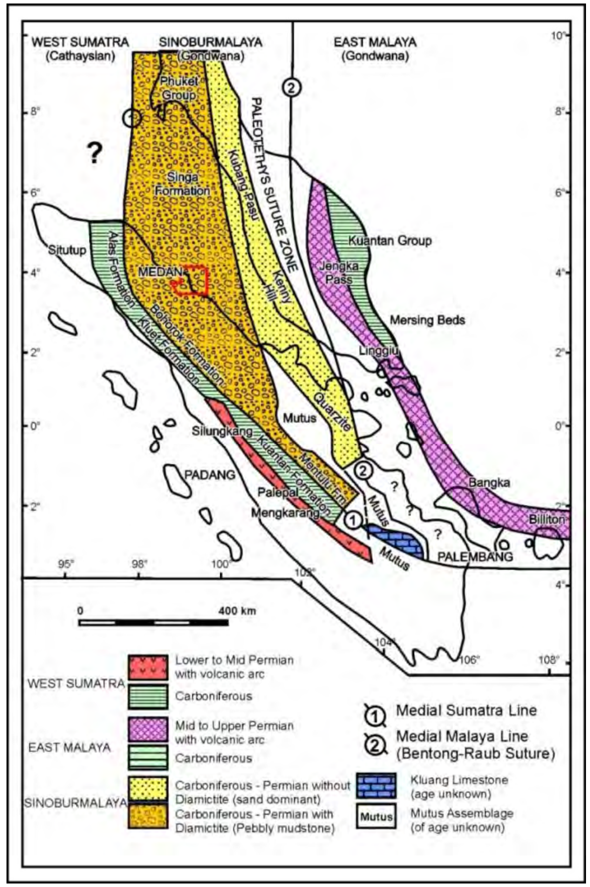


(Barber *et al*., 2005)



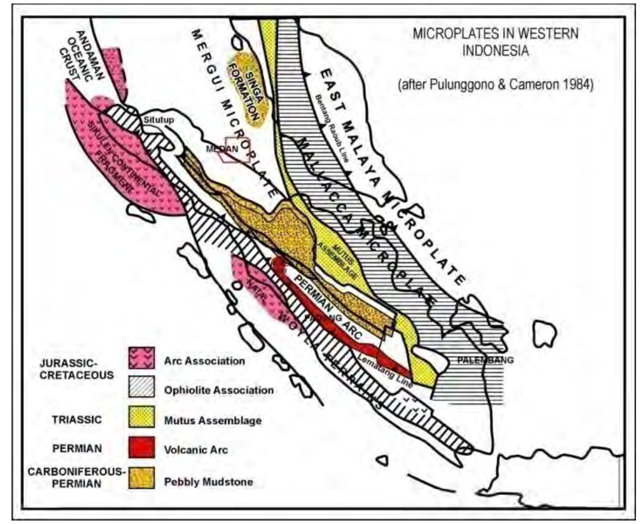
(Hutchison,1994)

BASEMENT CONFIGURATION

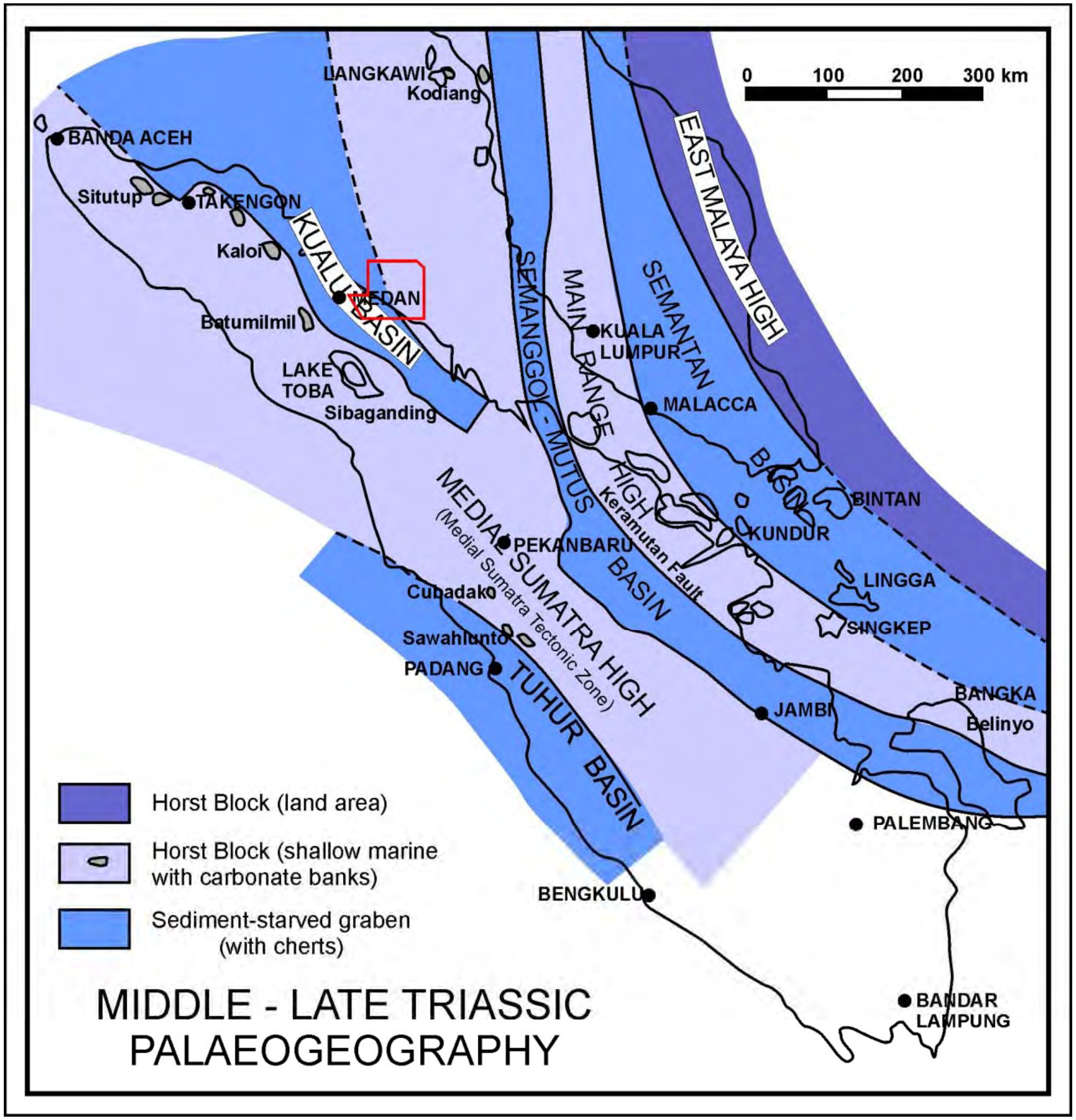


(Barber *et al*., 2005)

BASEMENT TYPE



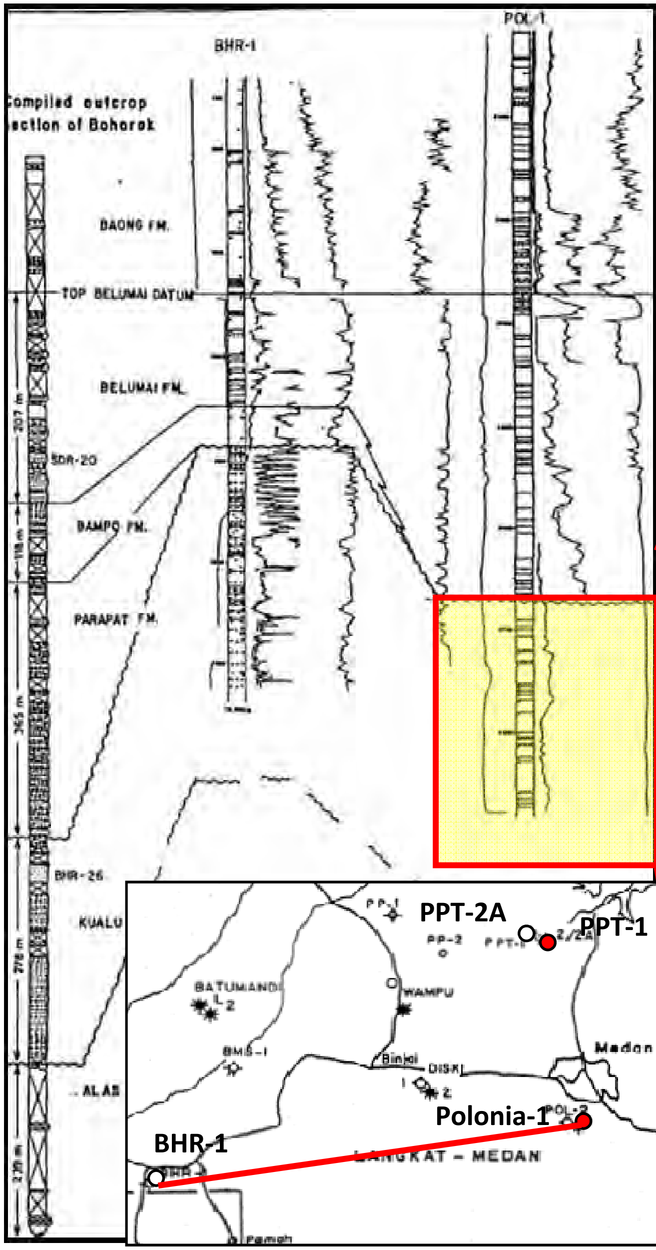
(In Barber *et al*., 2005)



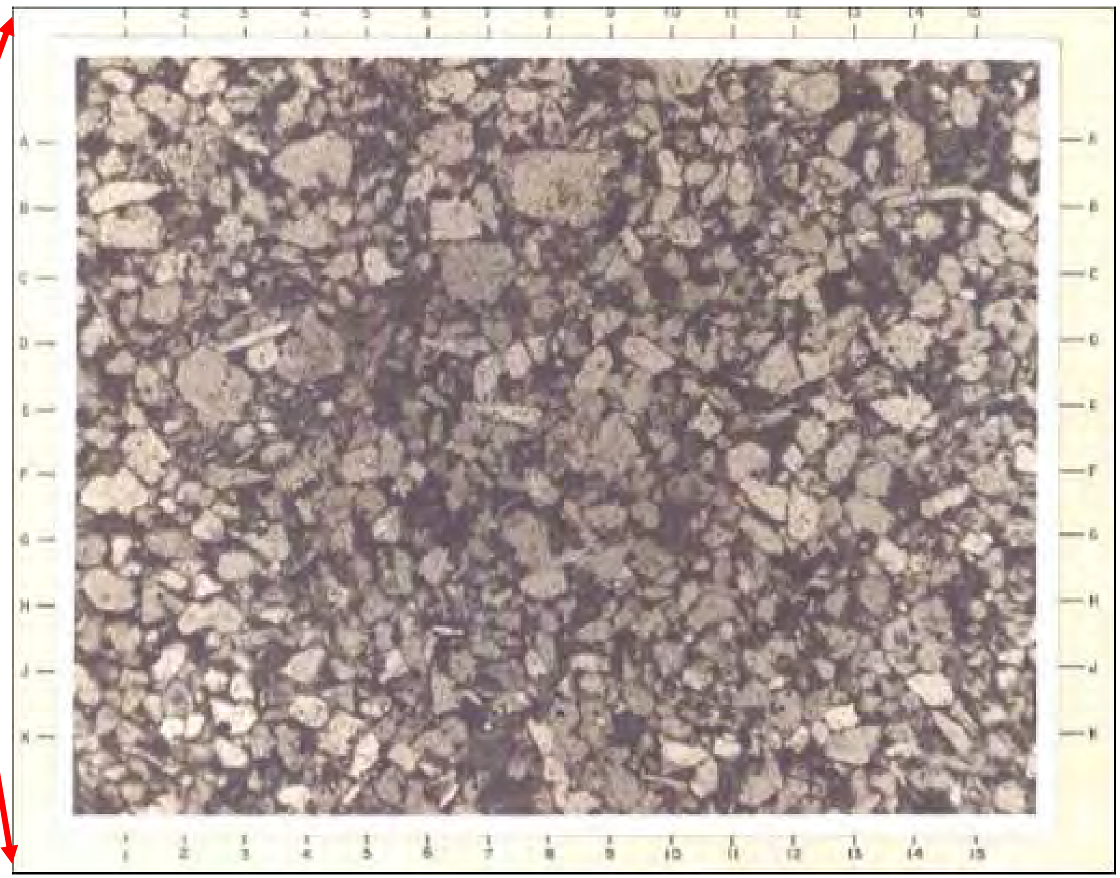
(Barber *et al.*, 2005)

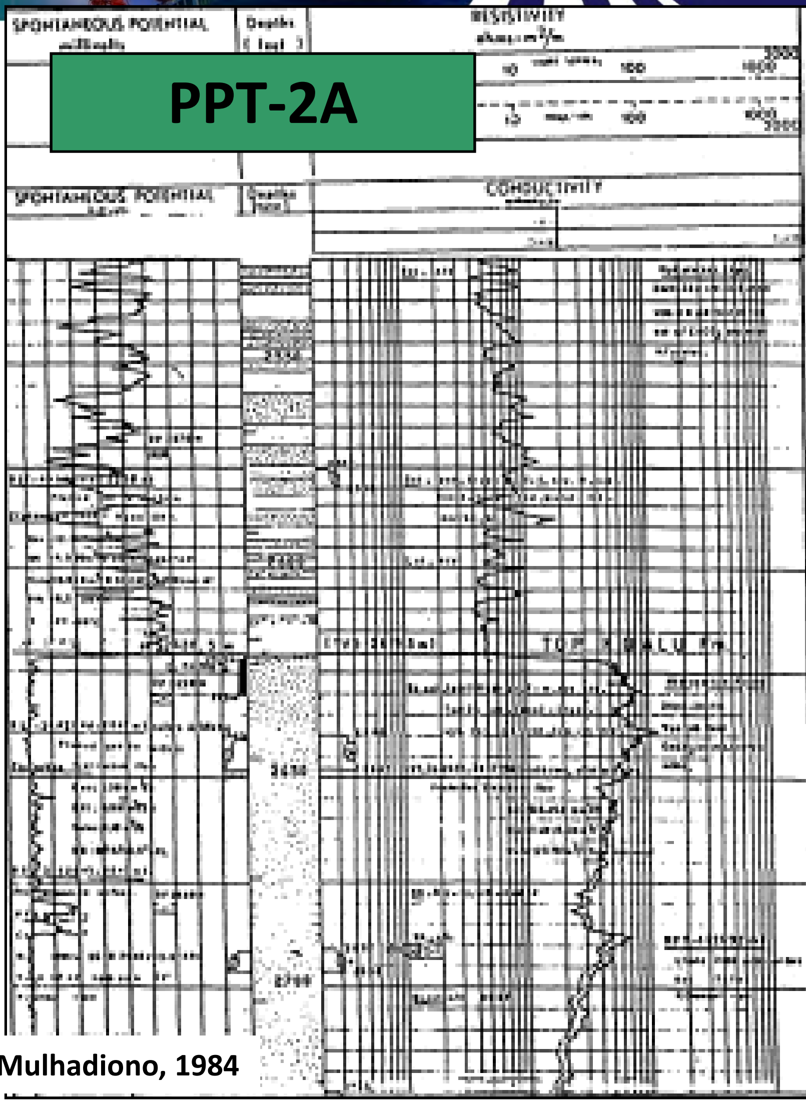
During the Mid – Late Triassic, the whole of Sumatra and Peninsular Malaya were subjected to NE- SW extension with the formation of several north - south and NW – SE graben structures, the Kualu and Tuhur basins in Sumatra and the Semantan and Semanggol Basin in Malaya, separated by intervening horst blocks.

Sample From POLONIA-1

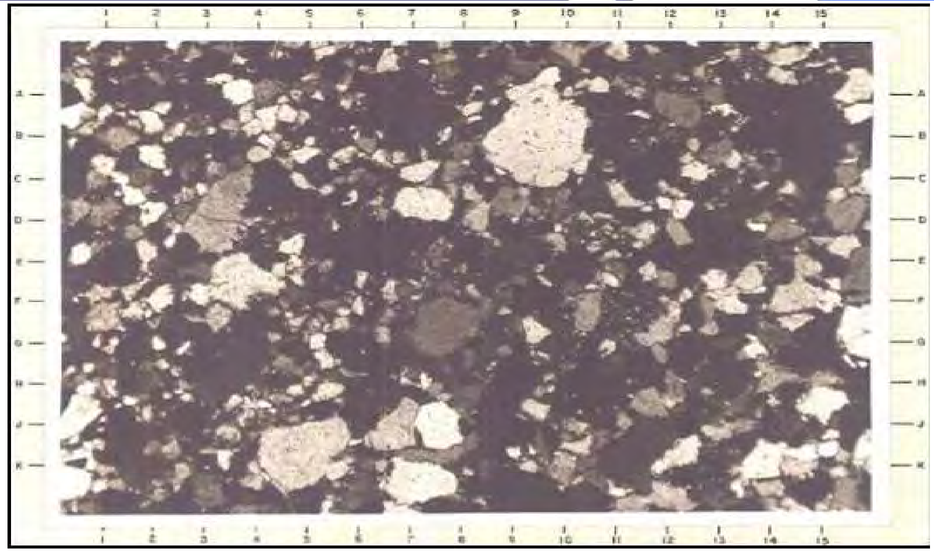


2741.64 – 2741.7m Argillaceous Sandstone (Kualu Fm.); the chief detrital grains of this sample are quartz; the grains have tangential and straight grain contacts withintergranular spaces infilled with authigenic clays and calcite cement.

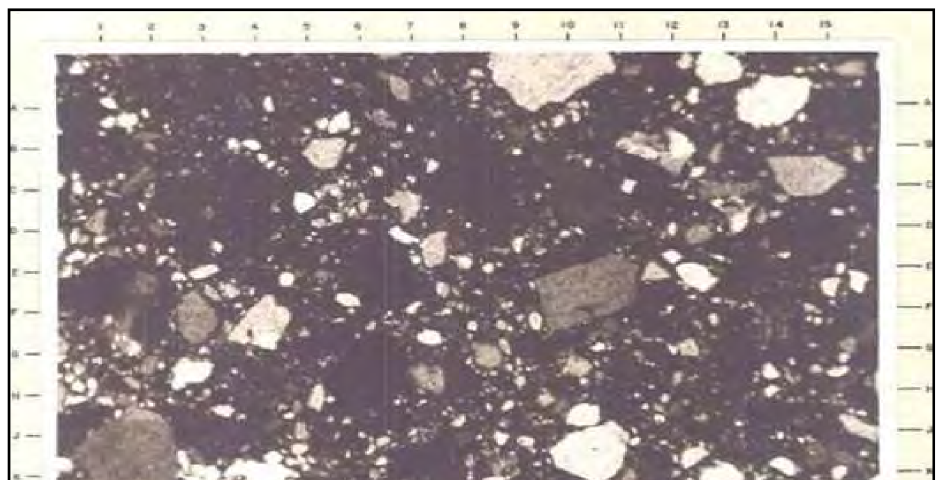




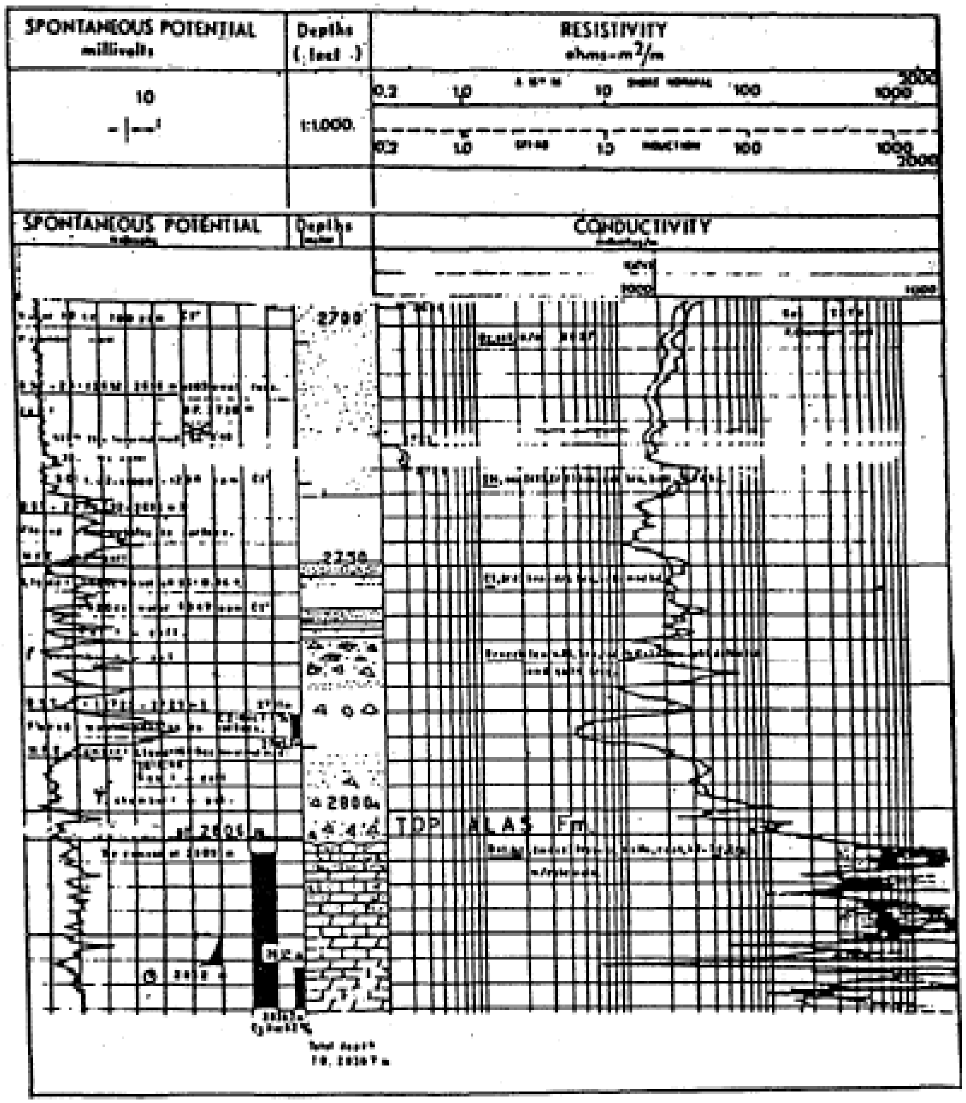
Kualu Fm.Eq. (2,525 -2,725m); Max.porosity is 12%, average 2-5%, Sw is about 85%, and K is <10mD, with very fresh water <1000ppm Cl.



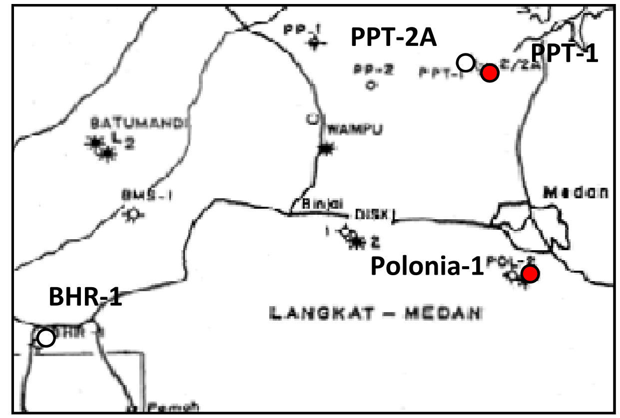
Sample PPT-1 Well, 2595m; fine SS; quartz grains, and chert rock fragments with slightly sutured grain contacts; visible porosity generaly 5%, locally increased to 10 – 15%.

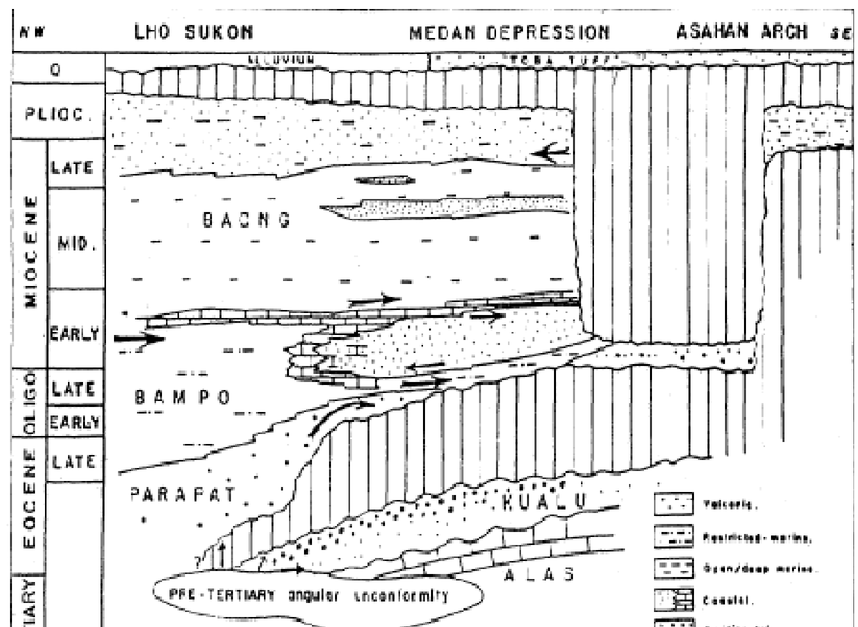


Sample PPT-2 Well, 2650.8 – 2650.86 m; lithic SS; quartz grains dominant, poorly sorted, and individual grains are– 15%.



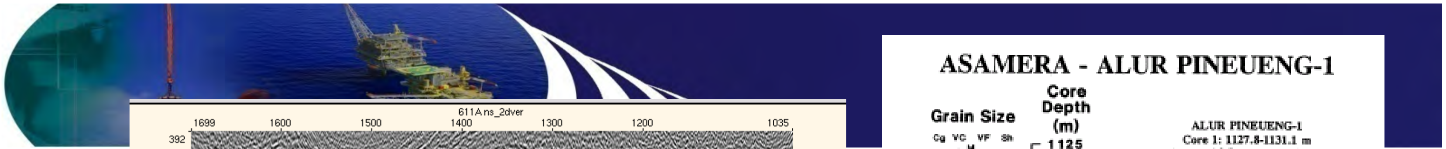
ELECTRIC LOG OF DOLOMITIC PRE-TERTIARY
PPT - 2A WELL : 2700-TD

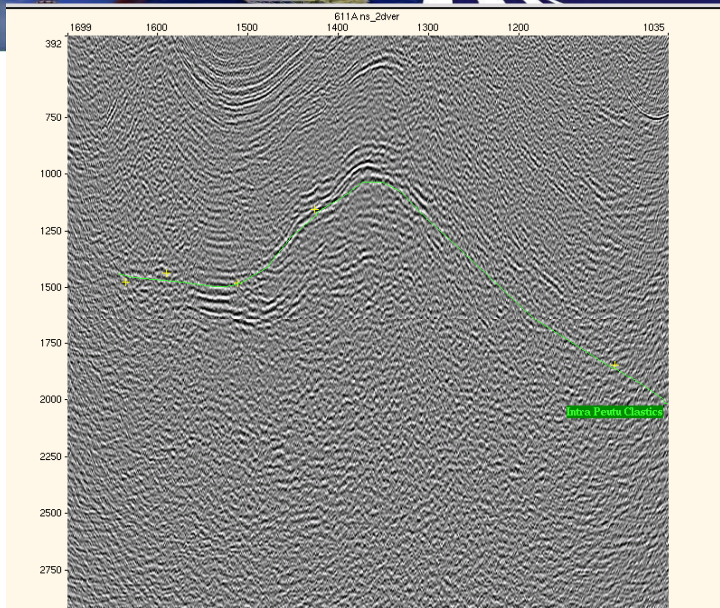


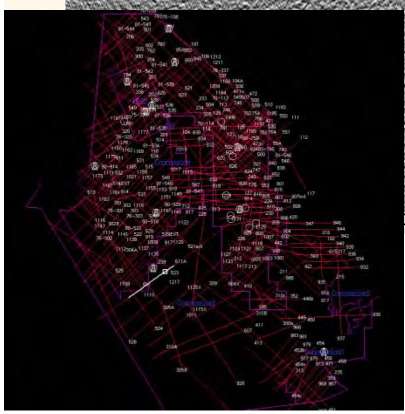


IDEALIZED STRATIGRAPHIC SECTION OF N.SUMATRA (NW - SE)

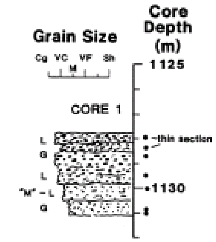
Mulhadiono, 1984







ASAMERA - ALUR PINEUENG-1



ALUR PINEUENG-1

Core 1: 1127.8-1131.1 m

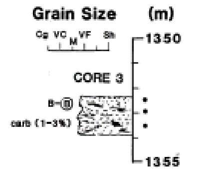
(recovered 3.5 m; preserved 2.6 m)

BAONG FM: Mudstone Clast, Very Coarse SANDSTONE to Fine-Pebble CONGLOMERATE; with Minor Interbedded, Muddy SKELETAL (Planktonic Foraminifer) PACKSTONE with Glauconite Pellets; medium gray (N4) with medium yellowish brown (10YR5/4) mudstone pebbles; poorly- to moderately-sorted; well-rounded clasts, locally up to 10 mm across; well-stratified with oriented elongate pebbles; composed mainly of reworked silty mudstone and sideritic mud matrix; with minor to common quartz sand/silt; minor to locally common greenish glauconite (intraskeletal and pellets); minor to locally common skeletal fragments (including planktonic and small benthonic foraminifers, molluscs and echinoid fragments); non-framework mainly detrital clay and quartz silt; well-compacted with interpenetration concavo/convex grain contacts and locally abundant calcite cement; no visible porosity.

Core 2: 1227.4-1230.4 m

(recovered 0.6 m; preserved 0 m)

NO CORE MATERIAL AVAILABLE



Core 3: 1352.4-1354.2 m

(recovered 1.5 m; preserved 1.2 m)

BELUMAI FM: SANDSTONE; medium dark to dark olive gray (N4-5Y3/1); clayey, moderately-sorted, fine-grained; burrowed to bioturbated with distinct *Helminthoidia* and probably *Teichichnus* structures; composed of mix of quartz and dolomite clast sand grains with minor chert and very minor glauconite; locally with minor coalified plant fragments; non-framework mainly brownish detrital clay matrix; minor visible porosity (1-4%), mainly isolated grain-dissolution secondary porosity.

Core 4: 1452.7-1454.8 m

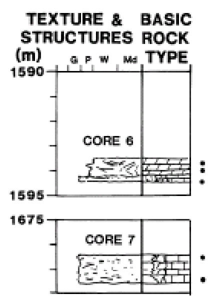
(recovered 0.3 m; preserved 0 m)

NO CORE MATERIAL AVAILABLE

Core 5: 1563.3-1566.3 m

(recovered 3 m; preserved 0 m)

NO CORE MATERIAL AVAILABLE



Core 6: 1593.5-1566.3 m

(recovered 0.9 m; preserved 0.8 m)

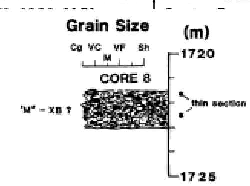
BELUMAI FM: (with Peutu Ls-like Composition); Poorly-Preserved Core Sequence with Sandy, Dolomitic, SKELETAL (Bivalve) GRAINSTONE/PACKSTONE and Dolomitic SKELETAL (Larger Foraminifer) GRAINSTONE/PACKSTONE; light olive to olive gray (5Y6/1-4/1); poorly-stratified(?); variable composition of various skeletal elements and minor to moderate amounts of crystalline dolomite matrix; well compacted with common small-amplitude stylolites; no visible porosity.

Core 7: 1676.4-1678.5 m

(recovered 1.2 m; preserved 0.5 m)

BELUMAI FM: (with Peutu Ls-like Composition); Poorly-Preserved Cored Sequence with Very Sandy, Dolomitic, SKELETAL (Bivalve/Larger Foraminifer) GRAINSTONE/PACKSTONE; light olive gray (5Y6/1); non-stratified(?); composed of variable amounts of bivalve and larger foraminifer and abundant quartz sand (very fine- to medium-sand size; with carbonate mud and crystalline dolomite "matrix"; well-compacted with common small-amplitude stylolites; no visible porosity.

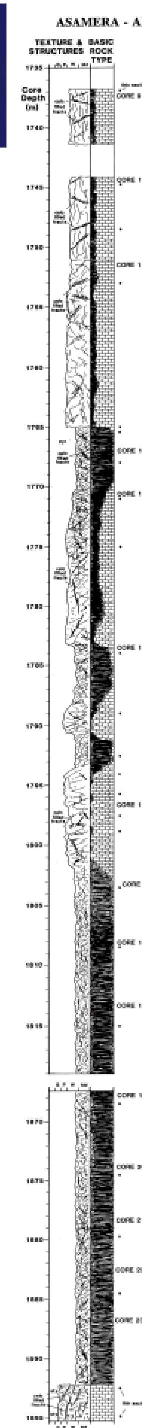
Alur Pineueng 1	1895	May 1972	Suspended	Slight Oil & weak gas show at 1340m.	Peutu Formation Sandstone	DST1 1338.7-1343.3m Week blow no gas to surface recovered 3m mud.	Peutu Formation Sandstone

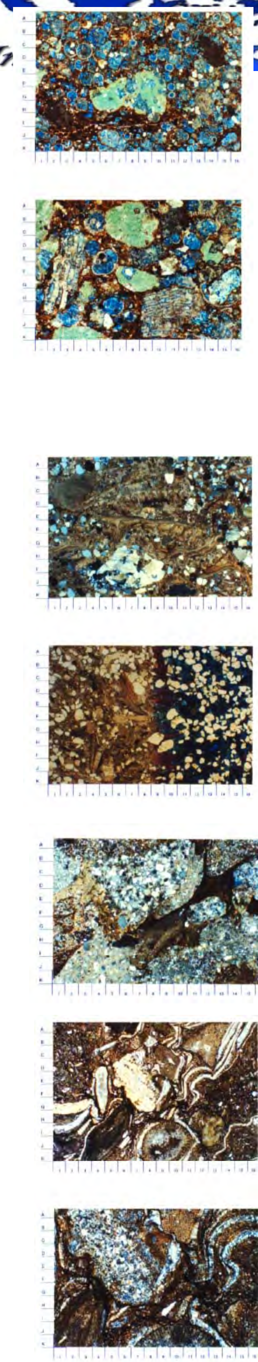


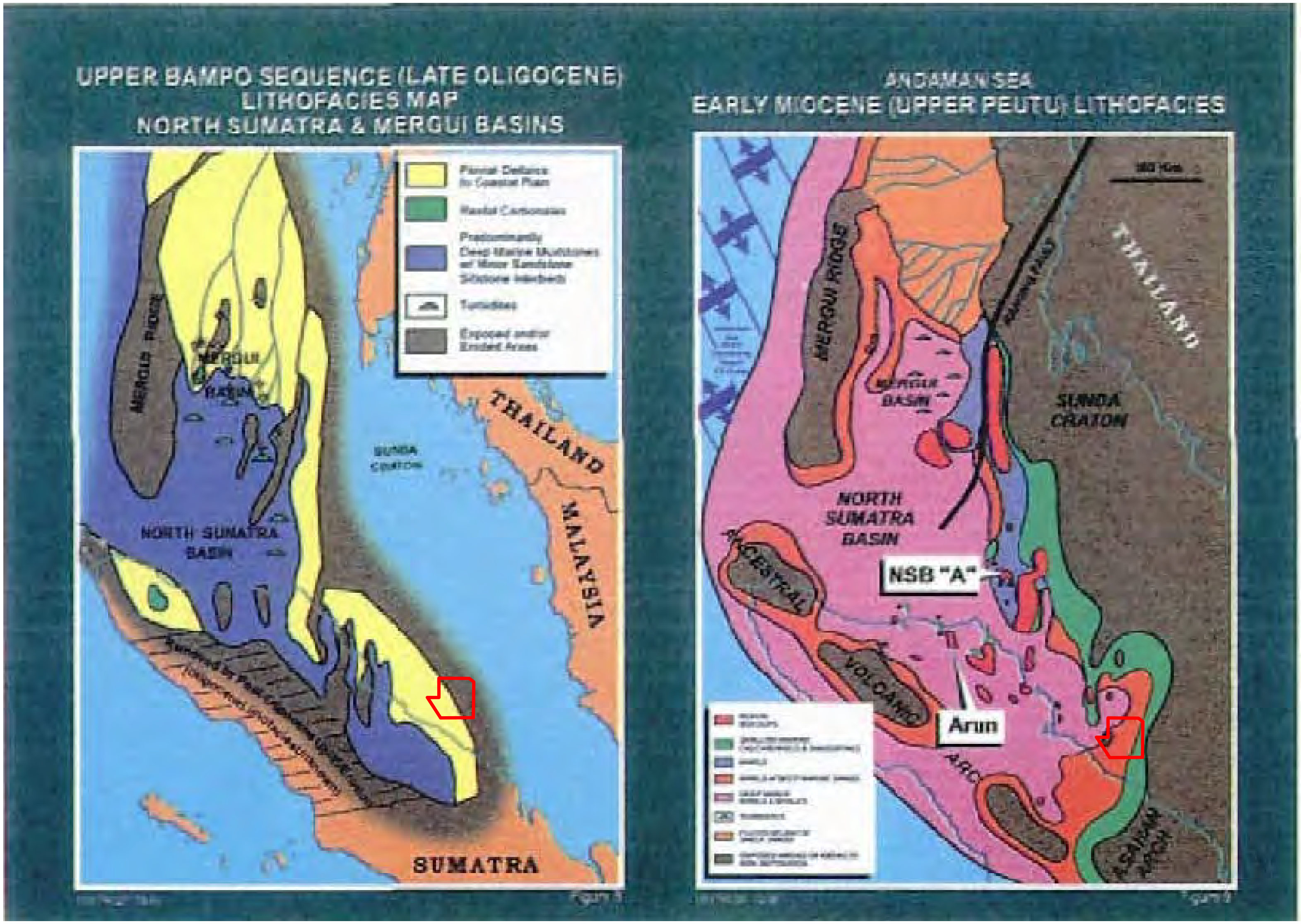
Core 8: 1721.5-1723.0 m

(recovered 1.5 m; preserved 0.3 m)

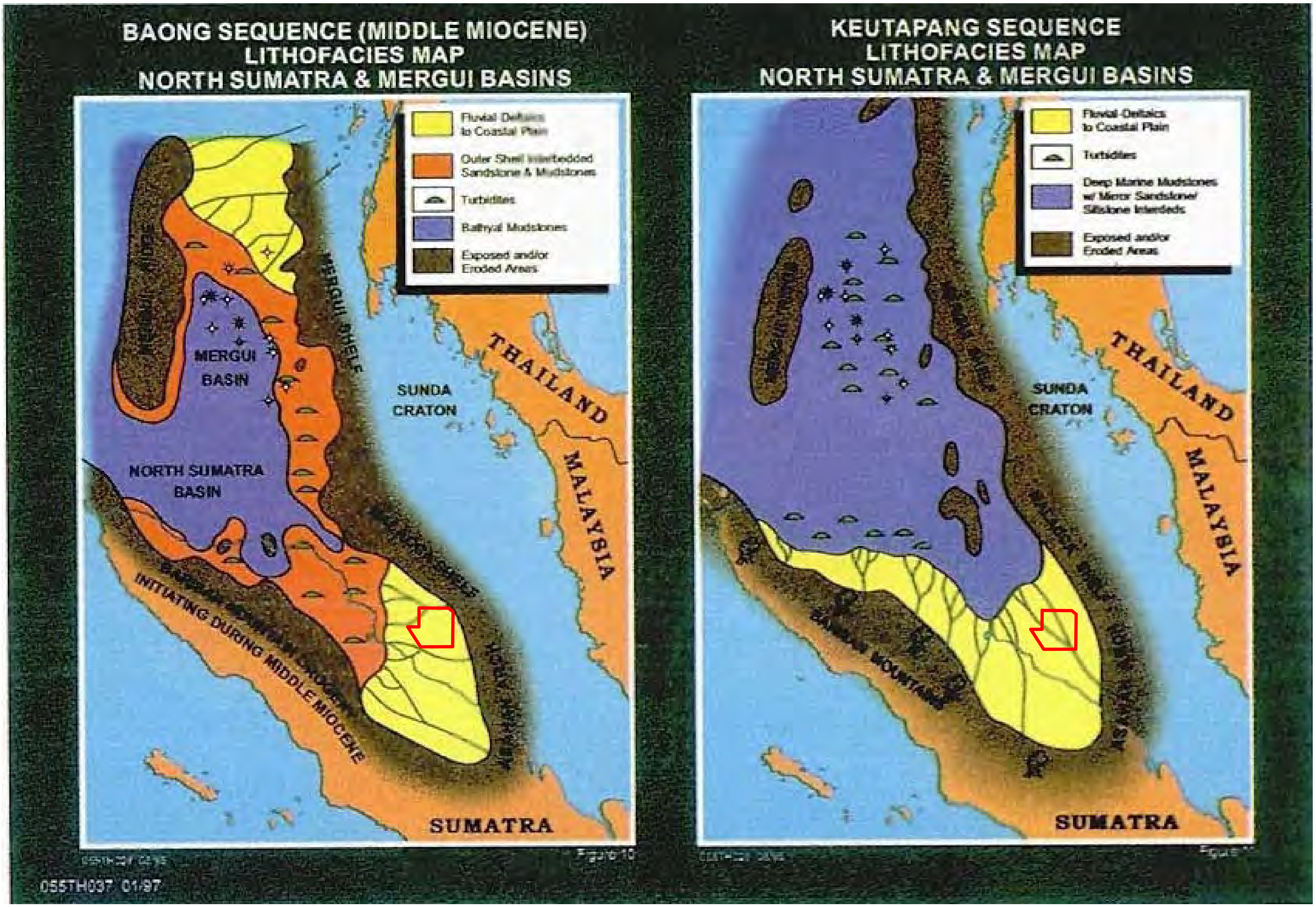
BRUKSAH FM: Metasediment PEBBLE CONGLOMERATE; medium to dark gray (N5-N3), very poorly-sorted, pebble conglomerate with well-rounded pebbles ranging up to greater than 5 cm across; vague stratification (cross-stratification?) with oriented elongate pebbles; composed mainly of metasedimentary pebble clasts (including silty to sandy, sheared mudstone, slate, clayey sandstone/quartzite, chert and muddy limestone); well-compacted rock displays little intergranular matrix; extensive grain interpenetration, concavo/convex and sutured grain contacts; no visible porosity.





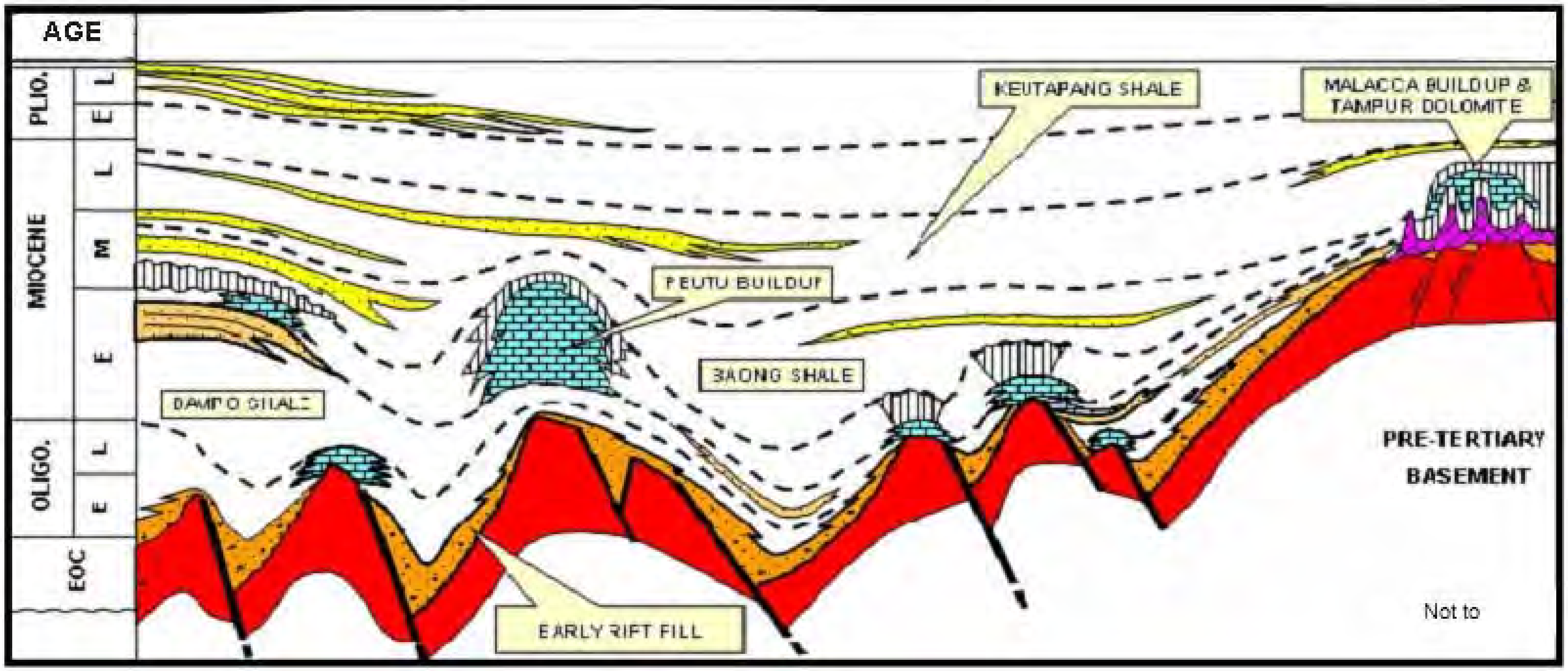


(Andreason et al., 1997)

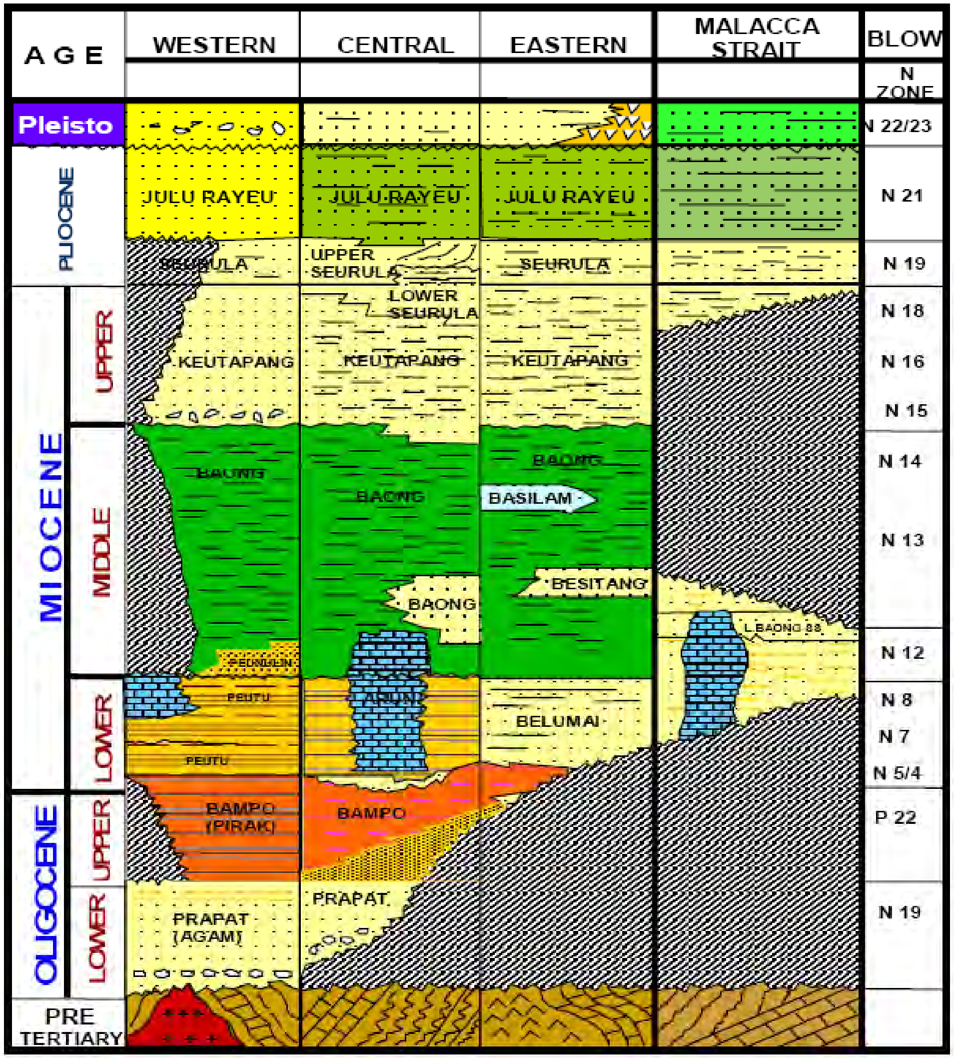


(Andreason et al., 1997)

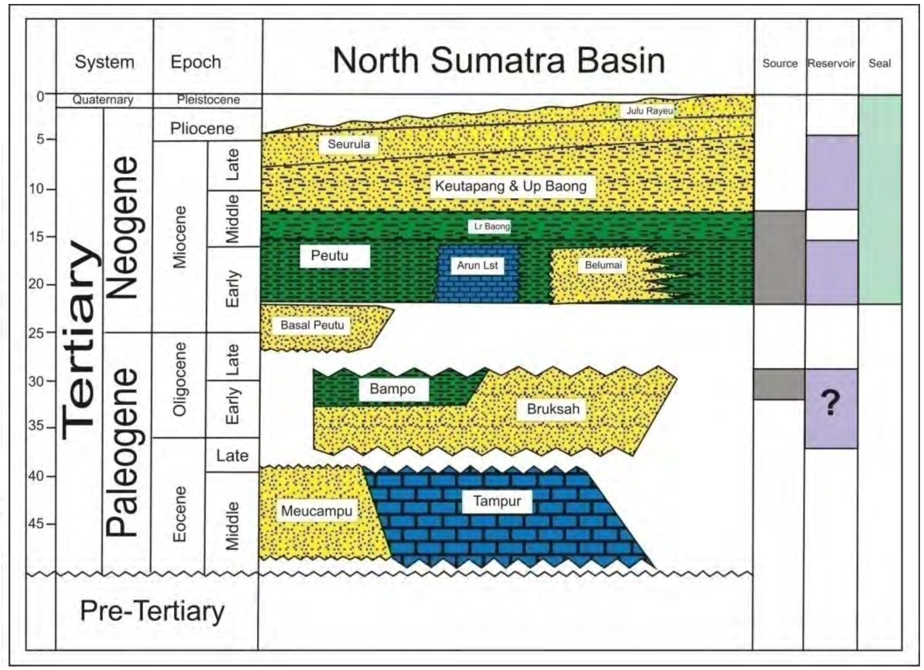
Schematic cross section showing geological model of N. Sumatra basin



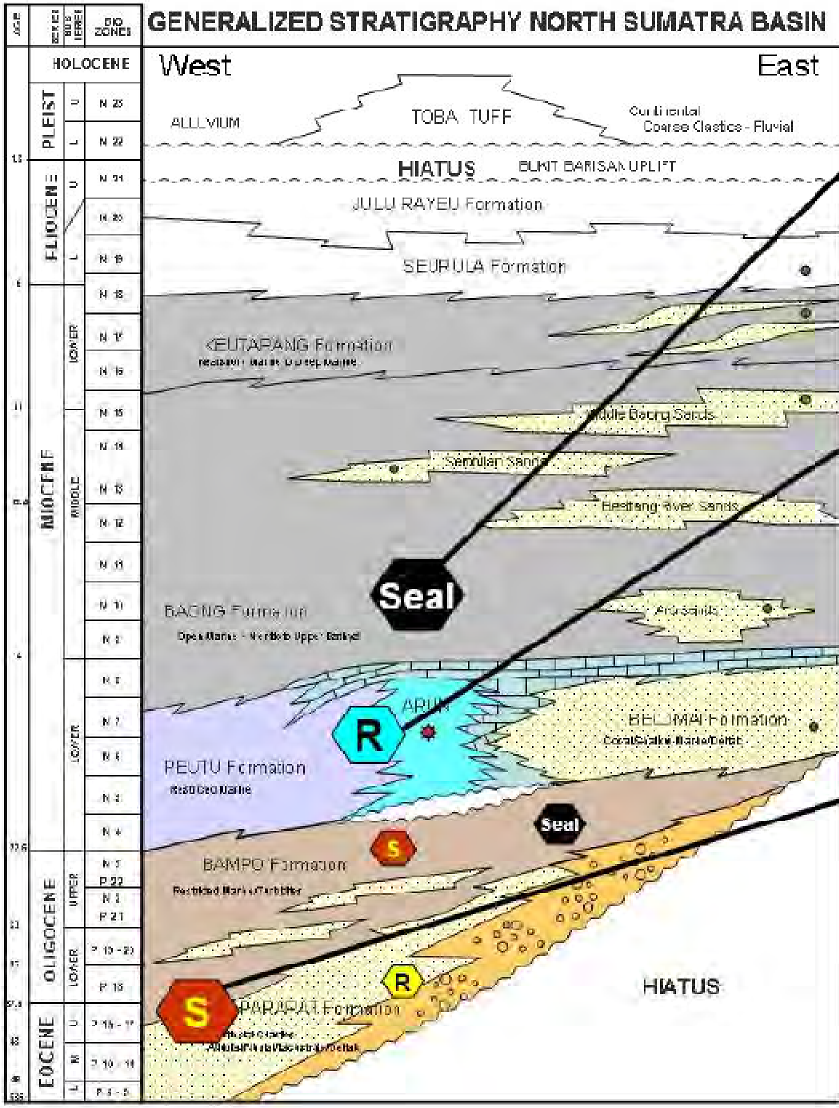
(Widarmayana, 2007)



(Hakim *et al*., 2007)



(Barber *et al*., 2005 modified)



Seal: Baong/Keutapang Fm:

- Excellent Regional seal
- Post-rift deposition – continuous and thick
- Proven top seal for majority of hydrocarbon accumulations
- Sandy facies are aerially restricted

- Bampo Fm sub-regional seal
- Deep marine, bathyl shales
- Syn-rift timing, therefore absent on basement highs

Reservoir: Peutu/Belumai Fm

- Major reservoir in basin accounting for ~75% of reserves
- Carbonate build-ups on basement highs or shelfal position
- Giant field Arun, also NSO-A and Kuala Langsa Fields
- Excellent reservoir quality but can be variable

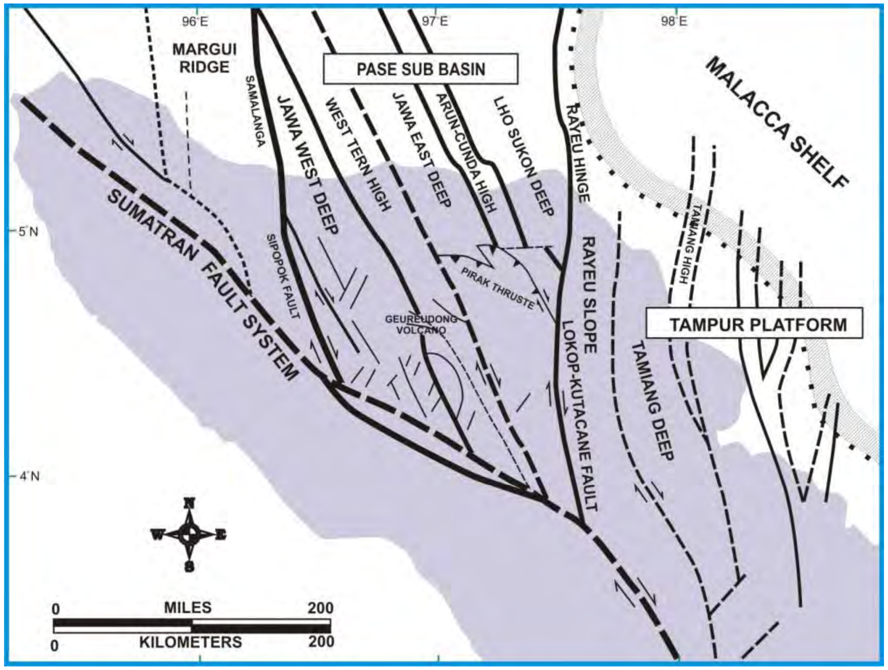
- Parapat Fm Secondary Reservoir – syn-rift clastics
- No accumulations but consistently good reservoir quality
- Present in rift basins as fluvial to alluvial fan facies

Source: Parapat Formation

- Proven source interval in Indonesian back-arc basins
- Lacustrine facies developed in rift graben axis
- Syn-Rift organic richness increases away from highs
- Thermally mature in most parts of the Andaman blocks

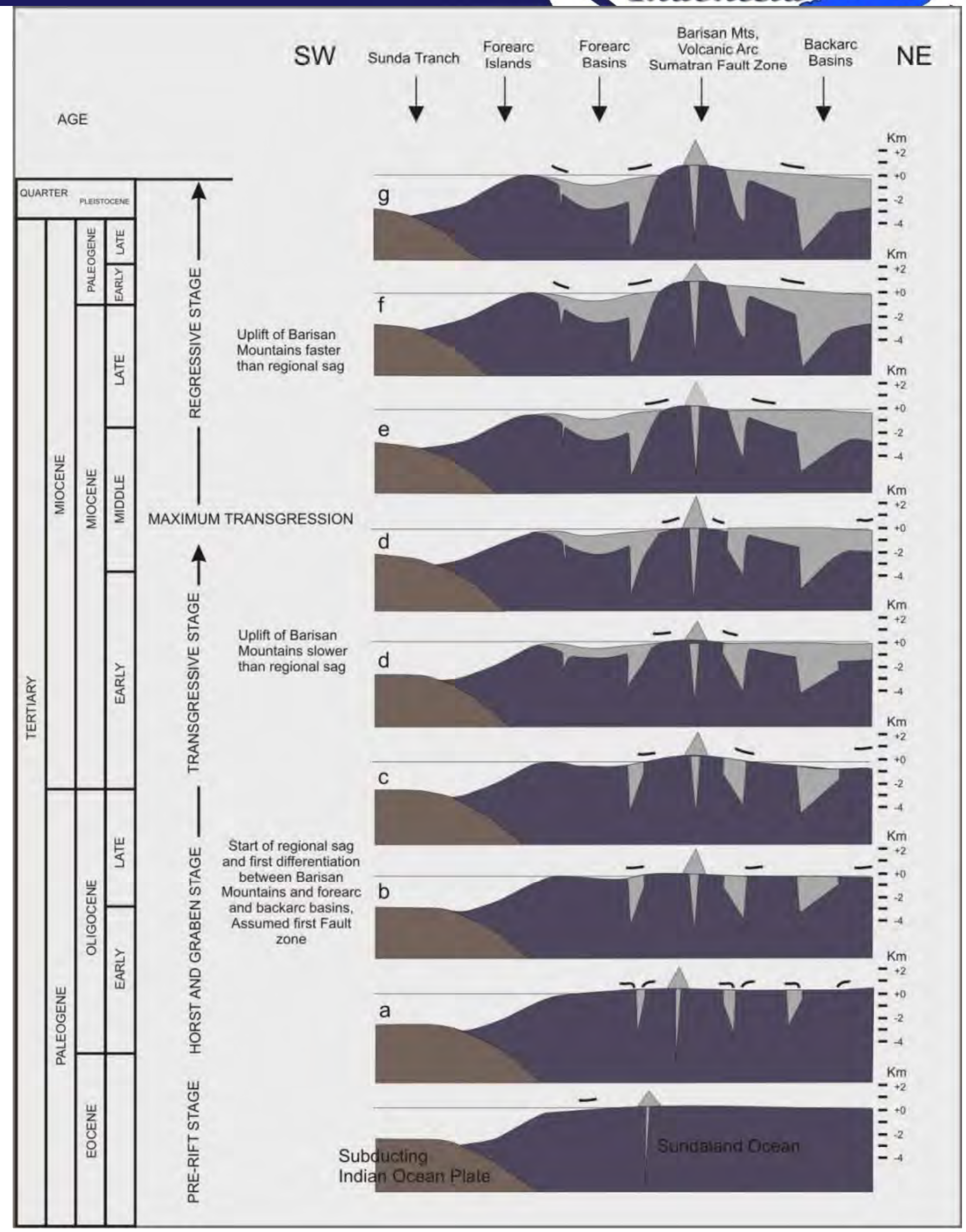
- Bampo Fm secondary source – marine syn-rift
- Important source interval in basin – sourced Arun Field
- Not thermally mature in Andaman 1 and 3 block

North Sumatra Tectonic Elements (Present day)

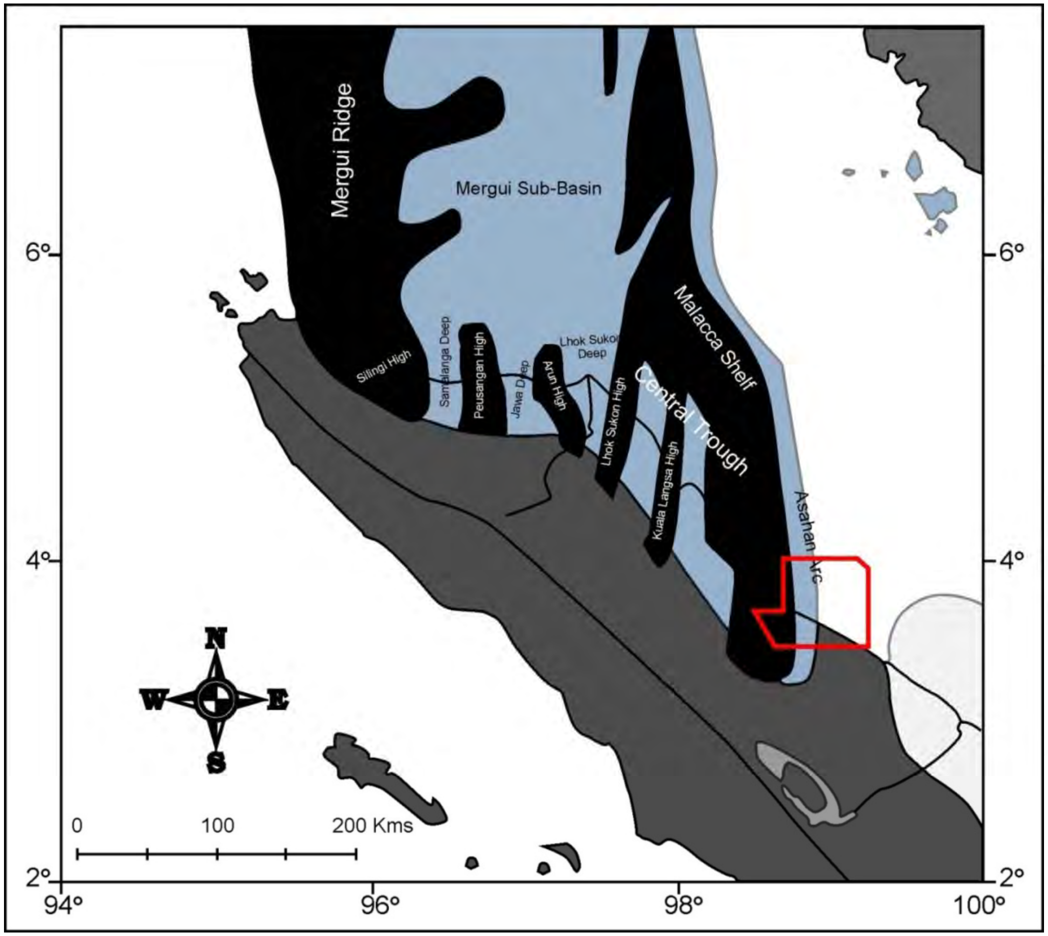


(Sosromihardjo, 1999)

Tertiary structural and basin evolution of Sumatra



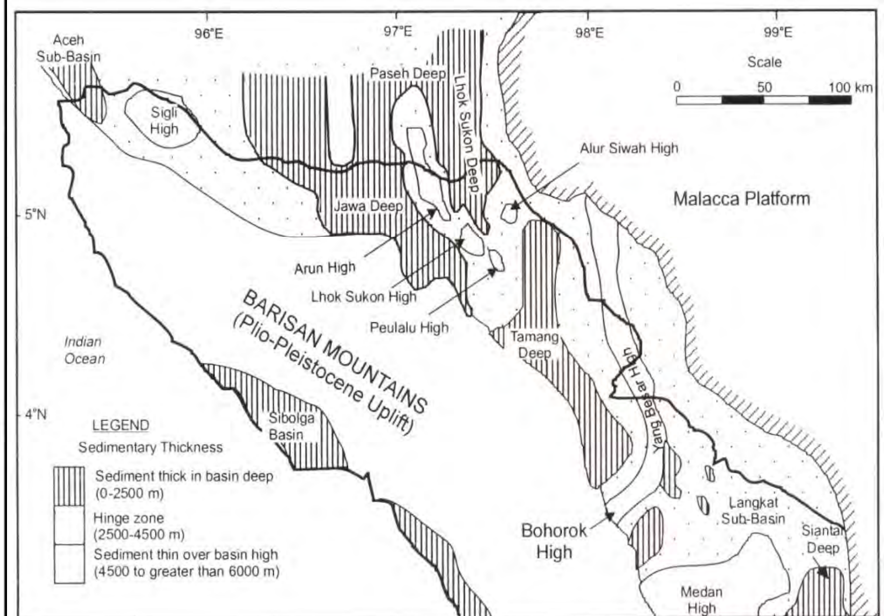
(Barber *et al.*, 2005)



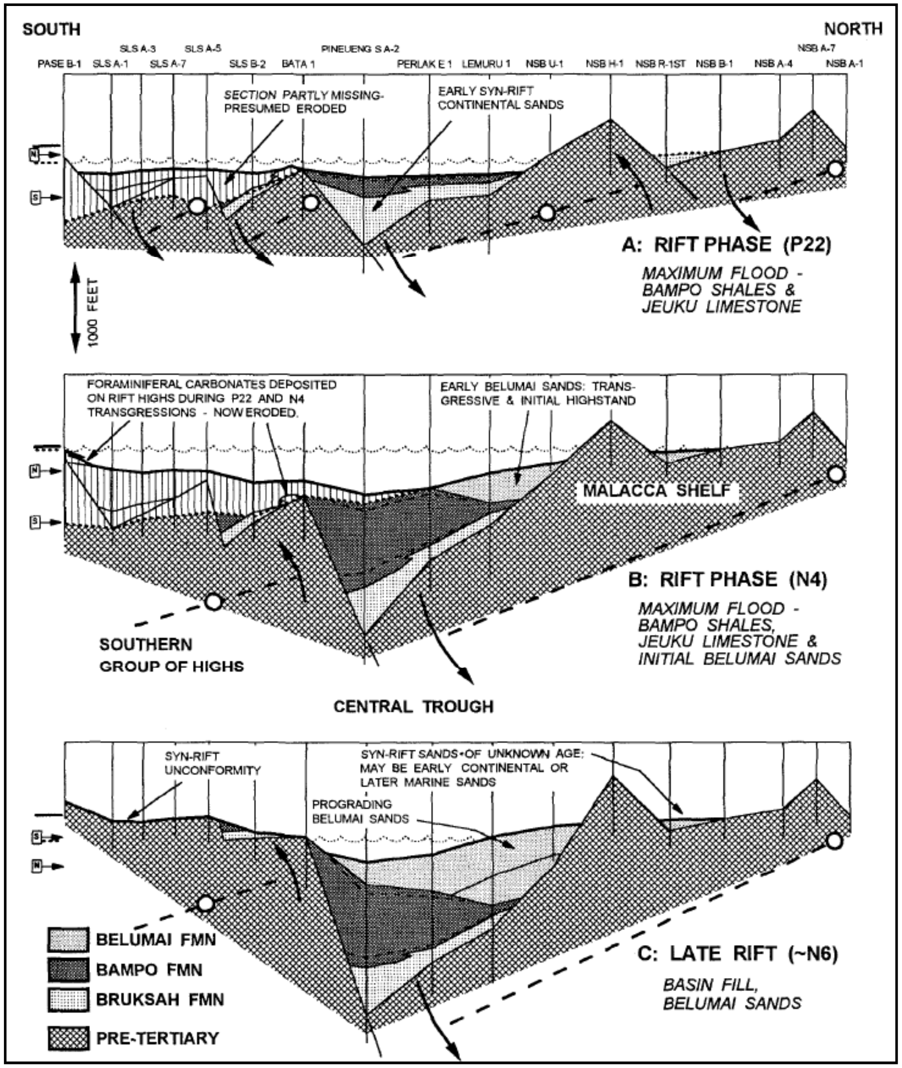
STRUCTURAL FRAMEWORK OF N.SUMATRA BASIN

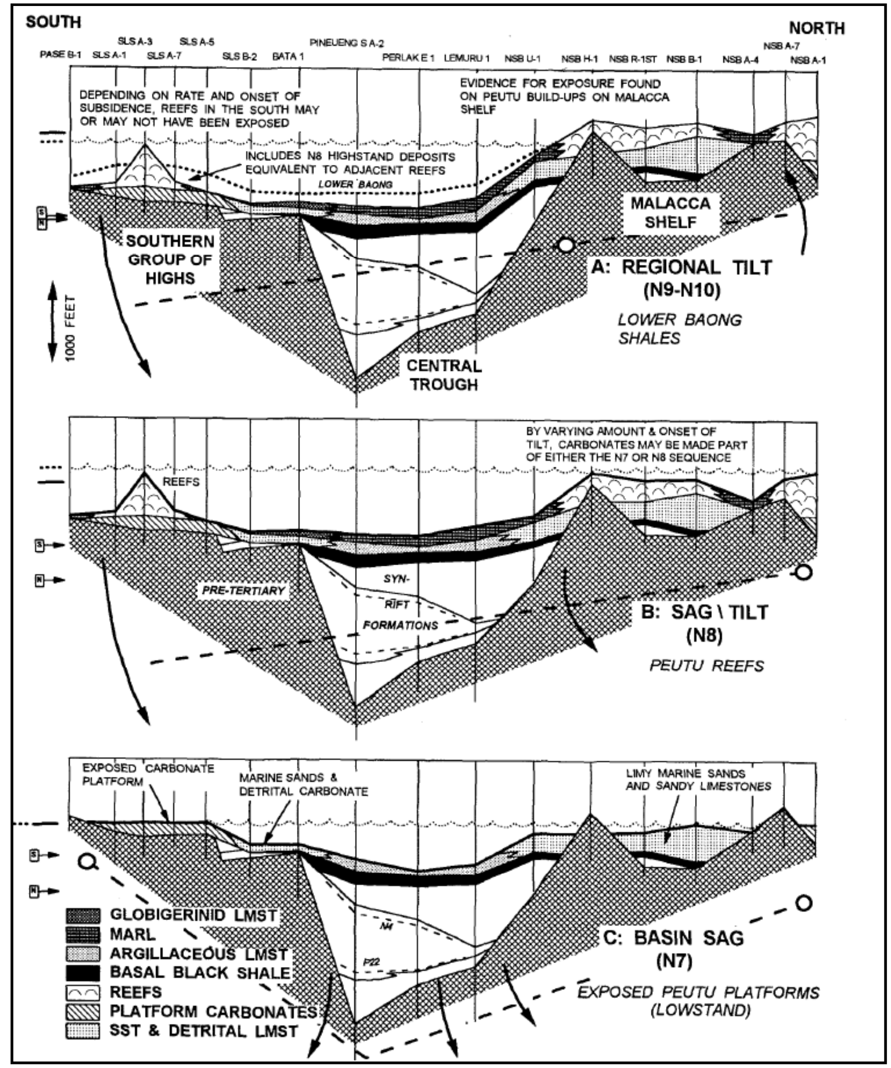
(Clure, 2005)

Present day internal framework of the North Sumatra Basin



(modified after Kamili *et al*., 1976)



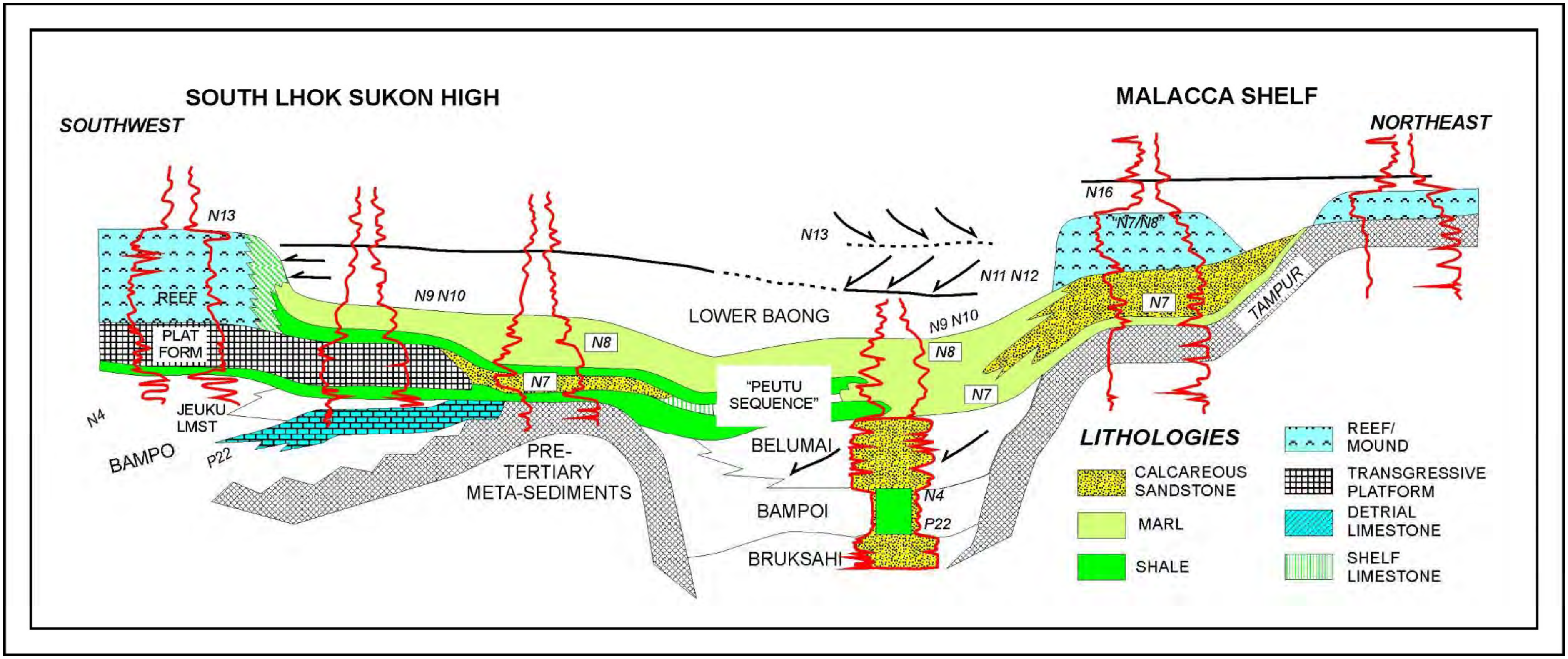


Basin development : Syn rift period

Basin development : Late rift & Sag periods

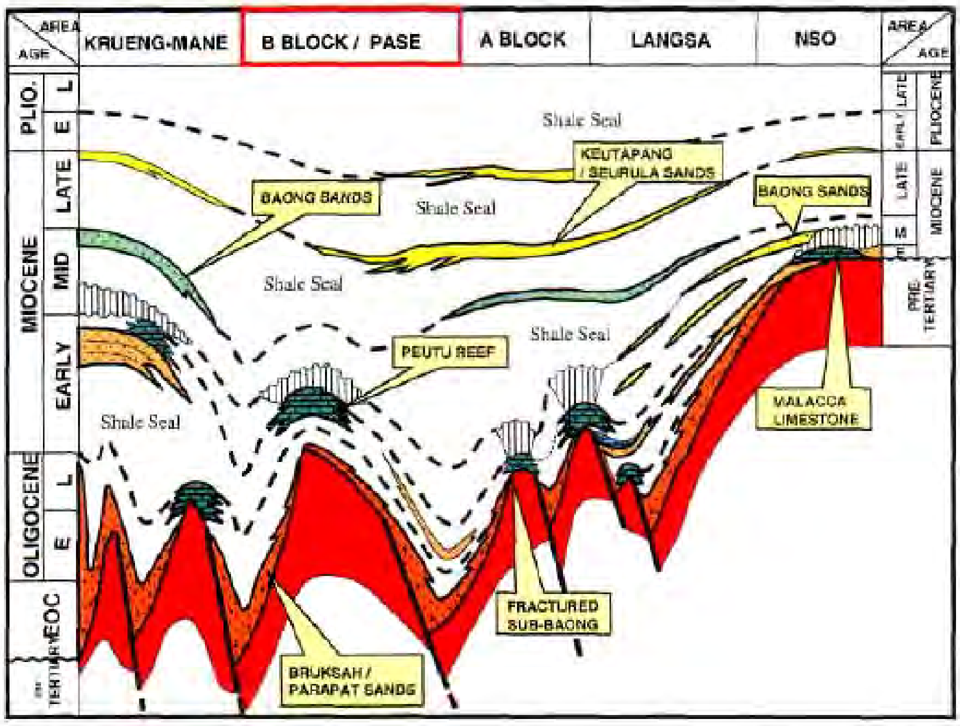
(Collins et al., 1996)

Schematic cross section showing geological model of N. Sumatra basin



(Collins *et al.*, 1996)

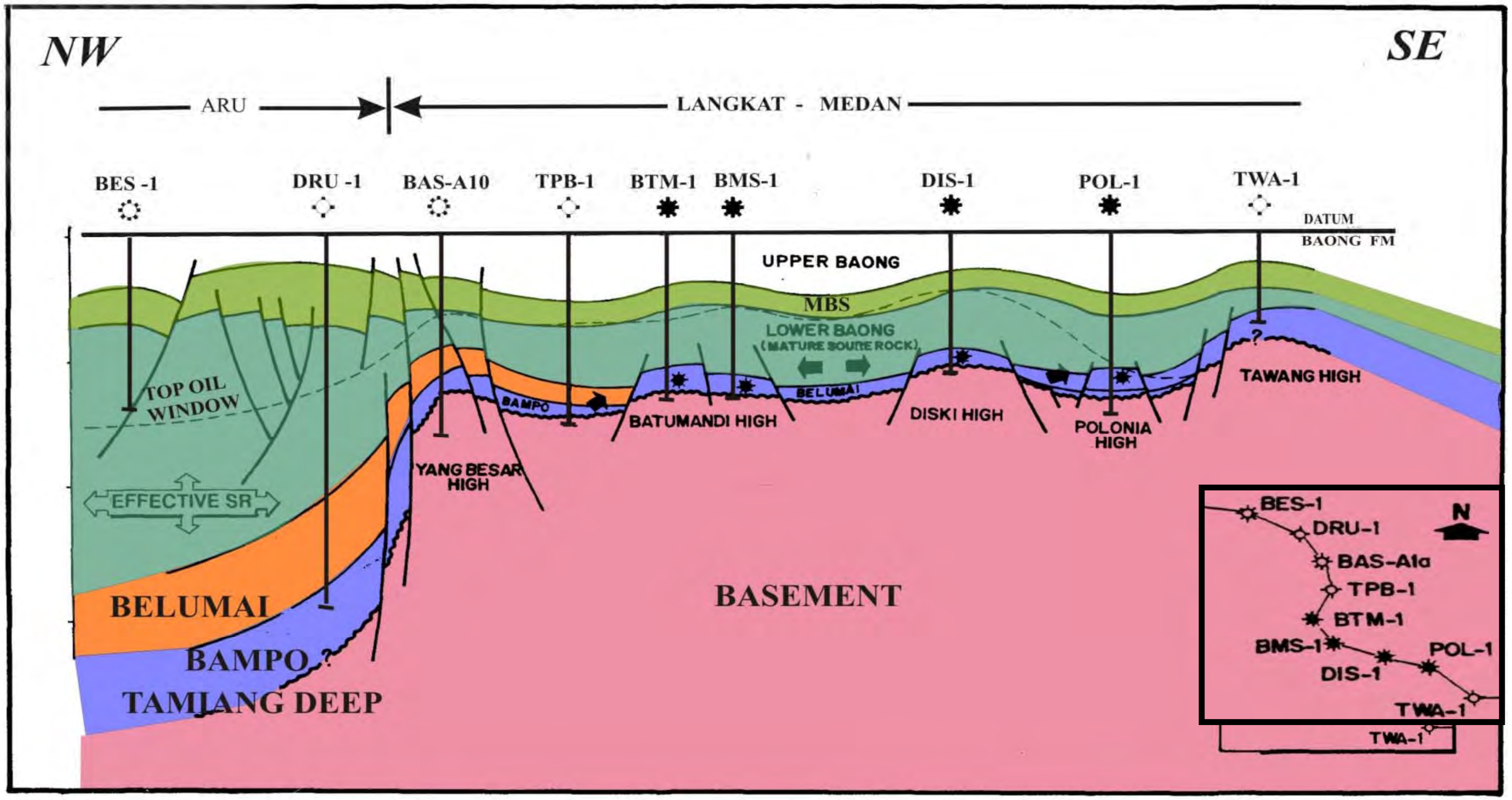
Play Concept and Risk



- **Fracture/Sub-Thrust Play**
  - Complex reservoirs, difficult to image
  - *Relatively high success rate onshore (in Pase area)*
  - High productivity, but difficult to estimate GIP
  - Matrix contribution essential
  - Disappointing reservoir *performance*

- **Buildup Plays - Eocene/ Middle Miocene Peutu/Arun/Malacca/Tampur**
  - Lower technical risk in reefs but remaining opportunities are small & mainly offshore

- **Clastic Plays - Eocene/Oligocene, Miocene/Pliocene**
  - High technical risk for trap, source/migration, seal & reservoir quality


NW
SE
ARU
LANGKAT - MEDAN
BES -1
DRU -1
BAS-A10
TPB-1
BTM-1
BMS-1
DIS-1
POL-1
TWA-1
DATUM
BAONG FM
UPPER BAONG
MBS
LOWER BAONG
(MATURE SOURE ROCK)
TOP OIL WINDOW
EFFECTIVE SR
BAMPO
BELUMAI
BATUMANDI HIGH
DISKI HIGH
POLONIA HIGH
TAWANG HIGH
YANG BESAR HIGH
BASEMENT
BELUMAI
BAMPO ?
TAMIANG DEEP
N
BES-1
DRU-1
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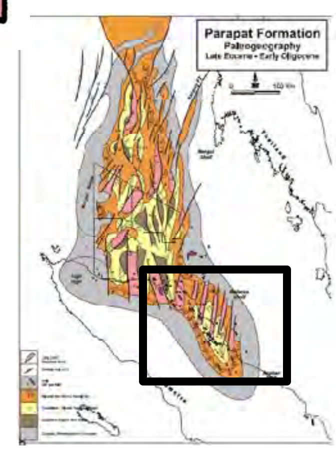
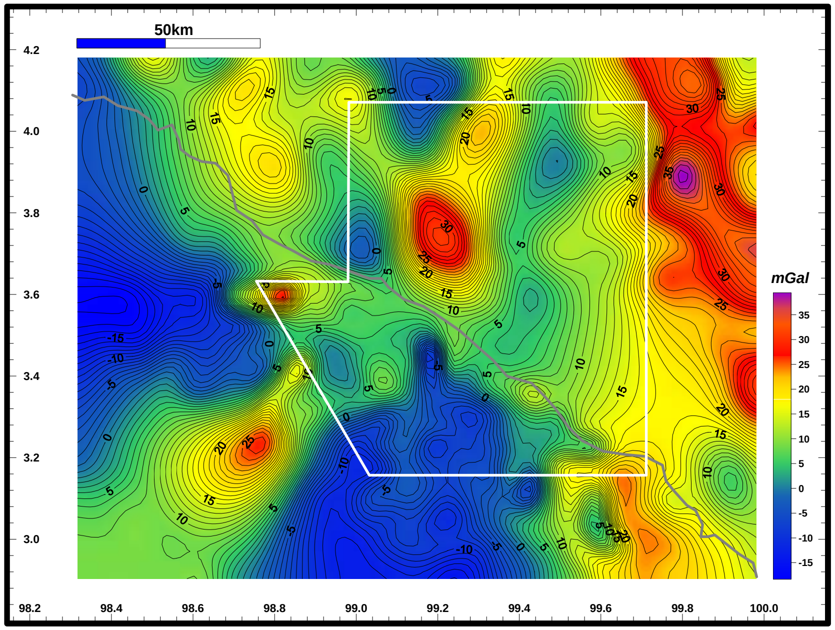
TPB-1
BTM-1
BMS-1
POL-1
DIS-1
TWA-1
TWA-1

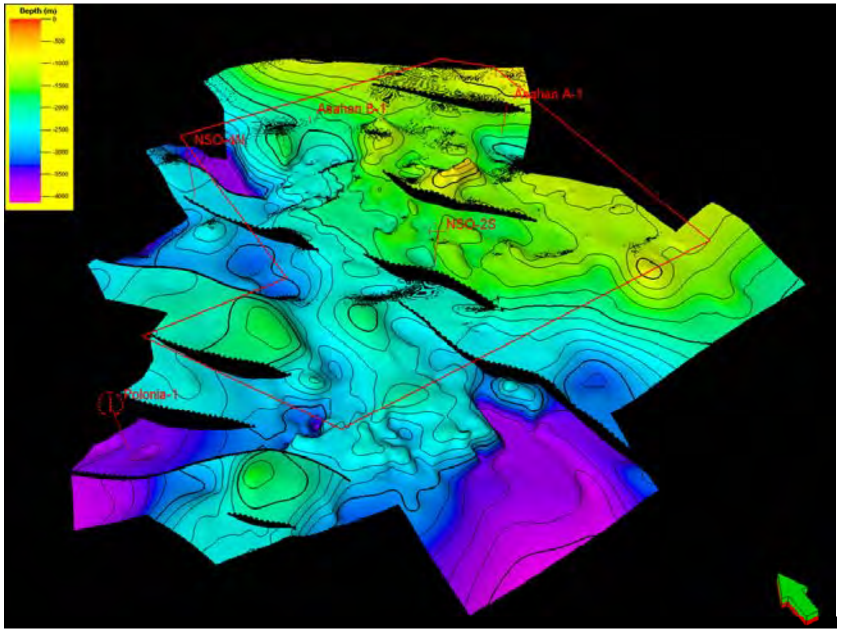

Parapat Formation
Paleogeography
Late Eocene - Early Oligocene

BOUGUER GRAVITY IMAGES AND CONTOUR LINES MAP



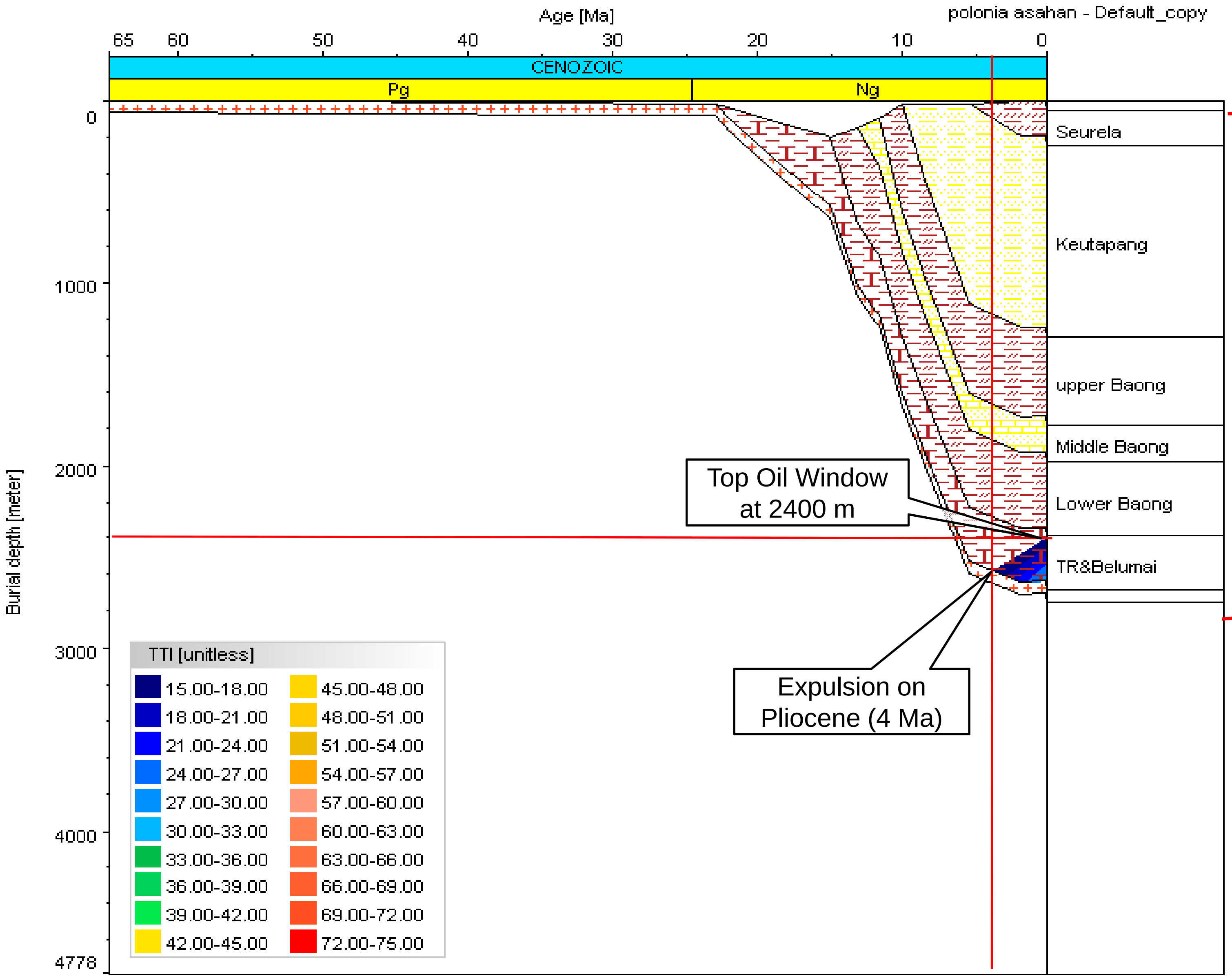
(Geo Prima Energi, 2009)

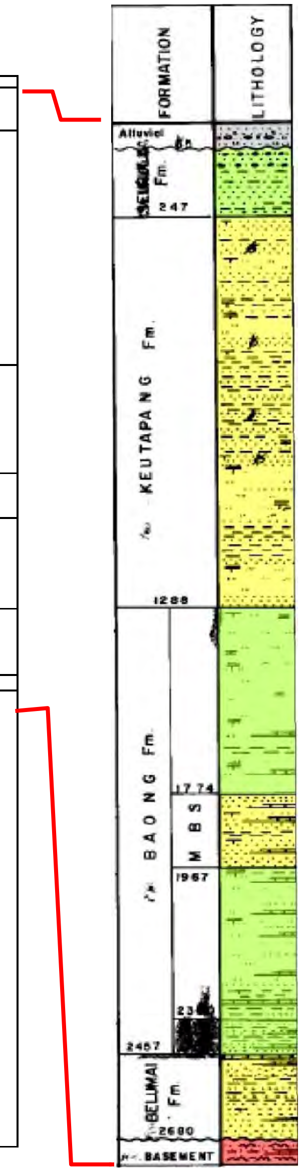
gravity in mGal, contour intervals 1 mGal



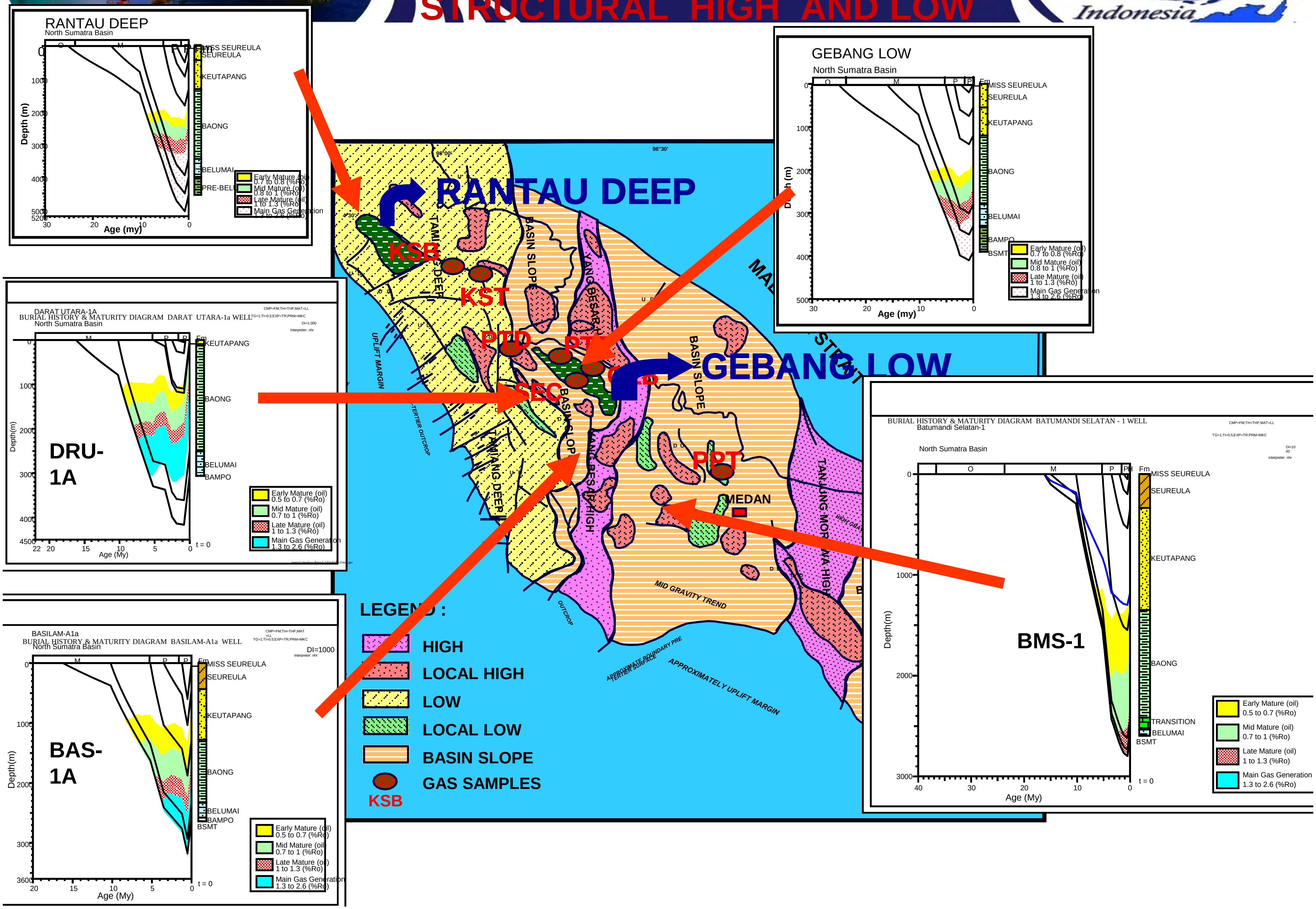
BASEMENT CONFIGURATION (BASED ON SEISMIC MAPPING & GUIDED BY GRAVITY DATA)

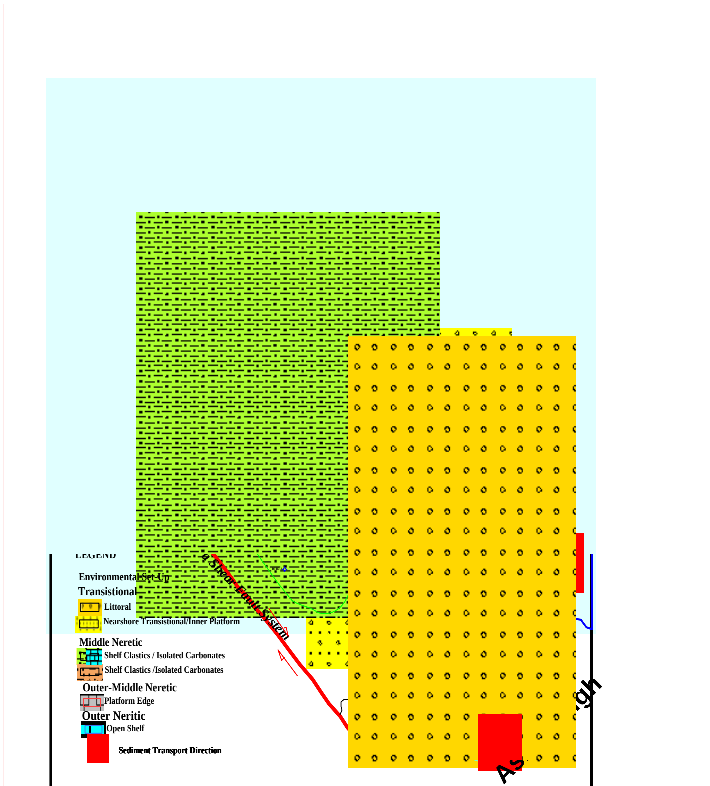
BURIAL HISTORY BASED ON POLONIA-1 WELL



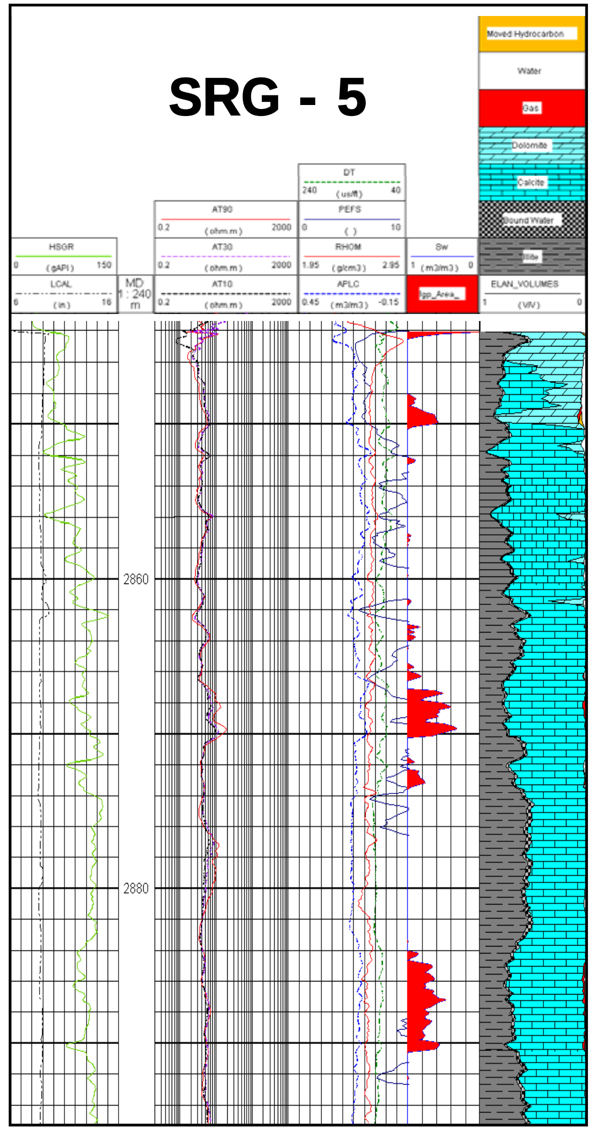


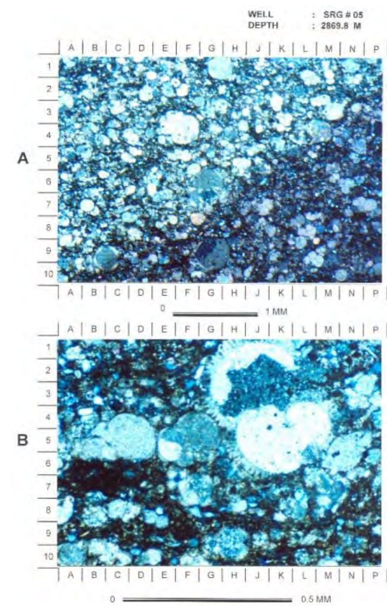
MATURATION MODELLING ON STRUCTURAL HIGH AND LOW

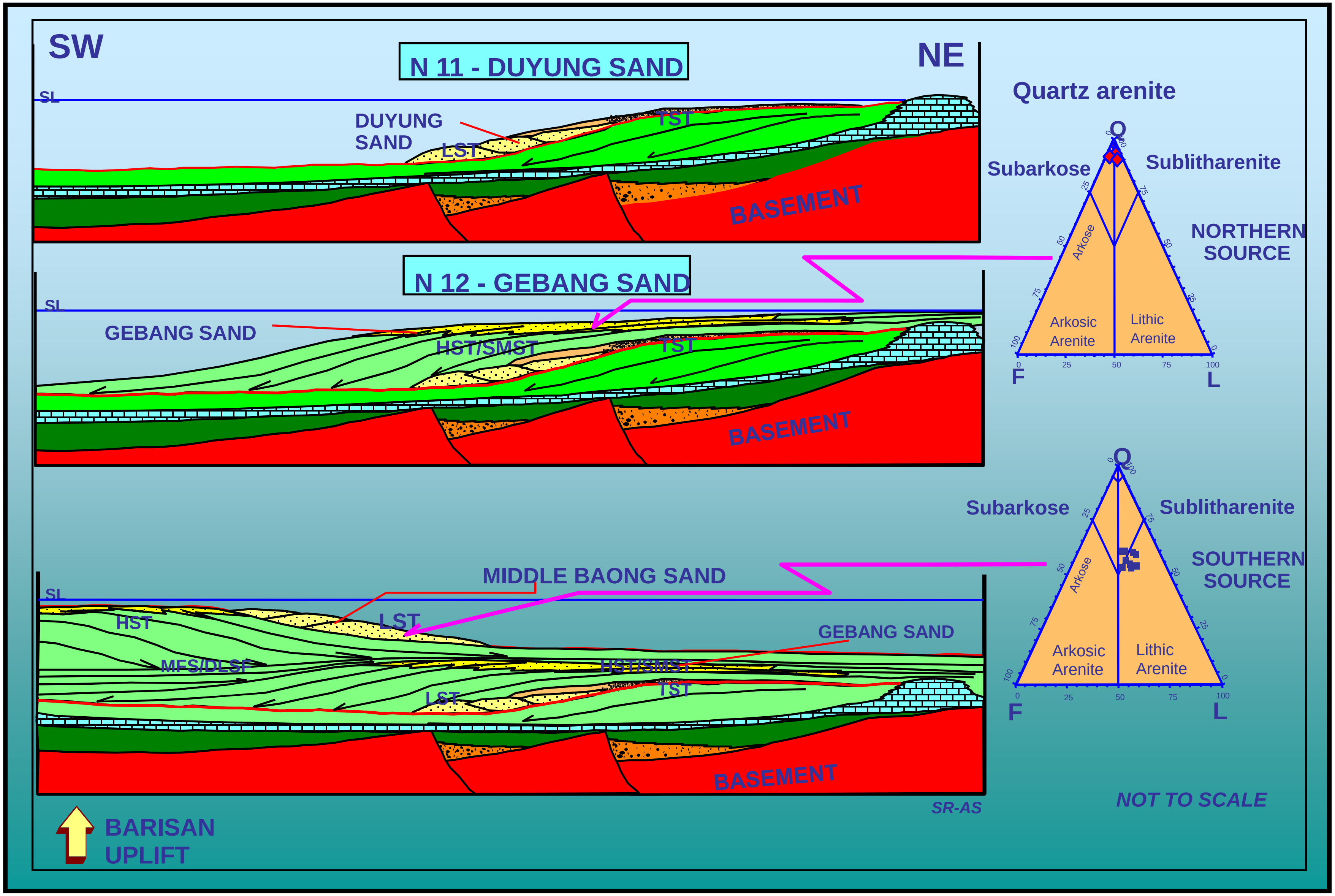


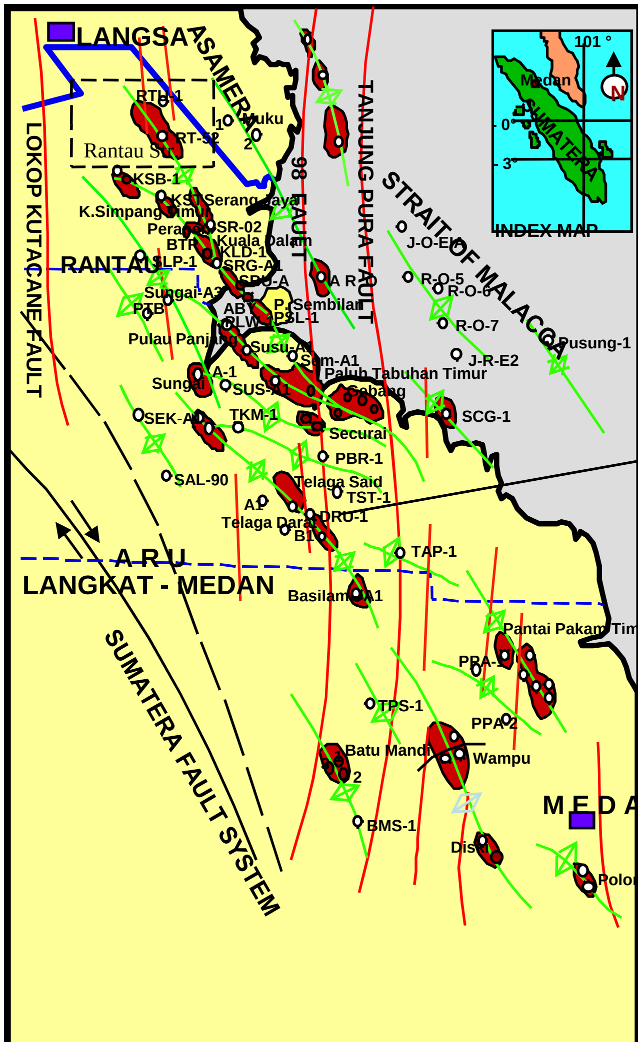


DEPOSITIONAL FACIES MAP : BELUMAI-PEUTU FM.

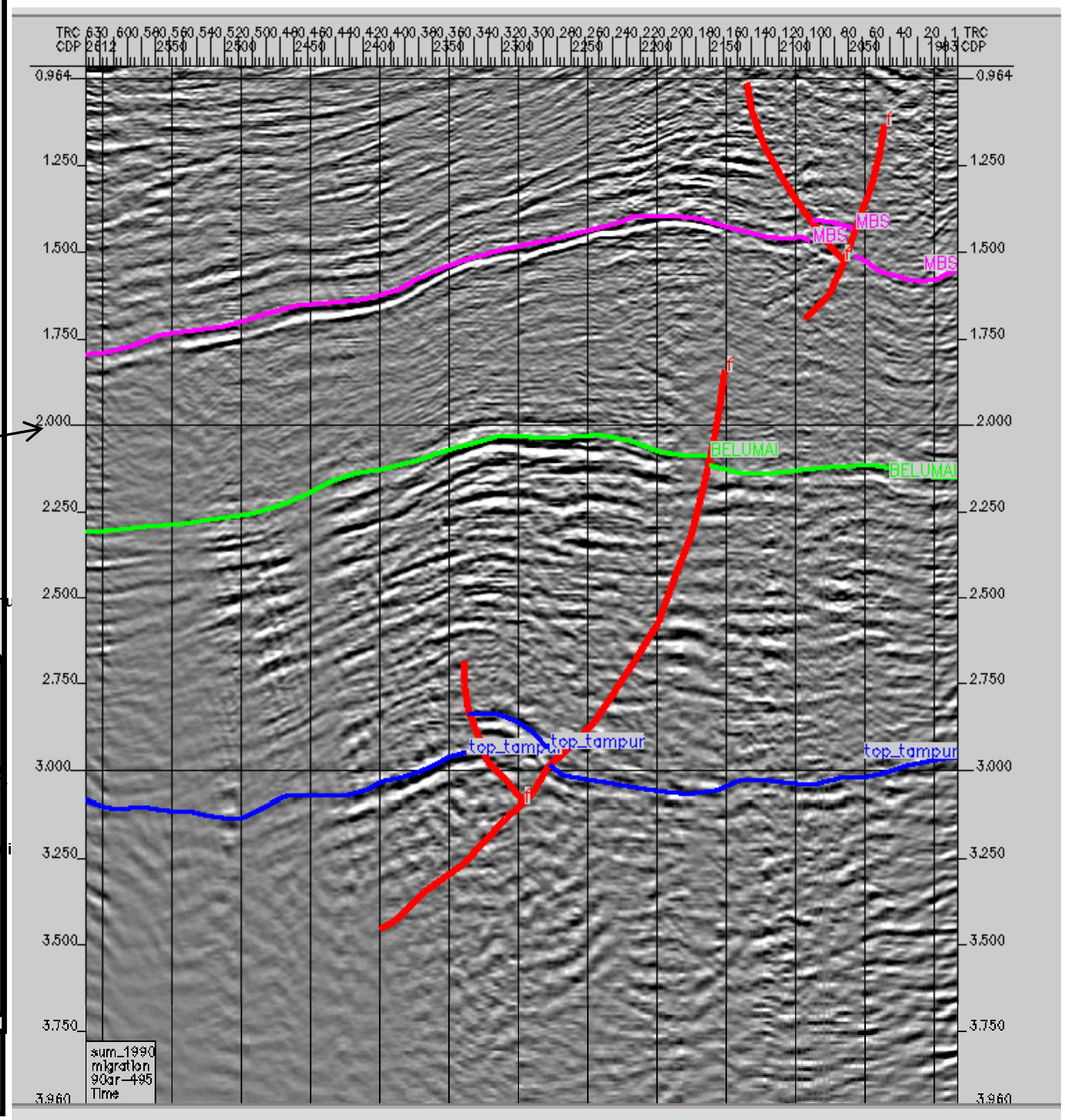




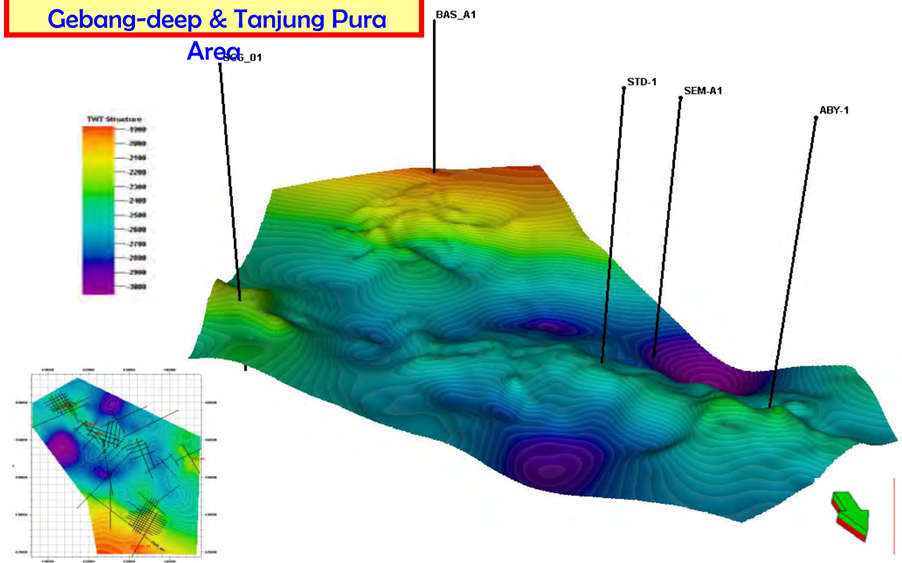

SW
NE
N 11 - DUYUNG SAND
SL
DUYUNG SAND
LST
TST
BASEMENT
N 12 - GEBANG SAND
SL
GEBANG SAND
HST/SMST
TST
BASEMENT
MIDDLE BAONG SAND
SL
HST
LST
MFS/DLSF
GEBANG SAND
HST/SMST
TST
LST
BASEMENT
SR-AS
BARISAN UPLIFT
Quartz arenite
Q
Subarkose
Sublitharenite
NORTHERN SOURCE
Arkose
Arkosic Arenite
Lithic Arenite
F
L
Q
Subarkose
Sublitharenite
SOUTHERN SOURCE
Arkose
Arkosic Arenite
Lithic Arenite
F
L
NOT TO SCALE



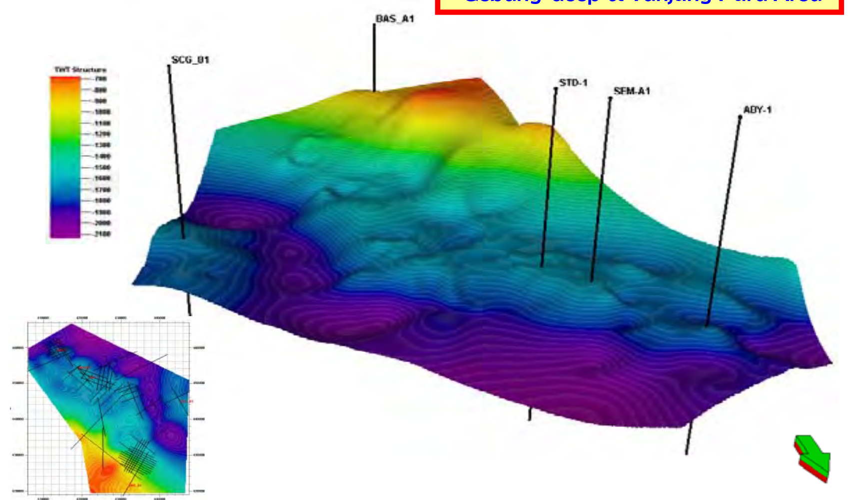
DISTRIBUTION MAP OF PROVEN STRUCTURE (Mod. DOH Nad 2005)



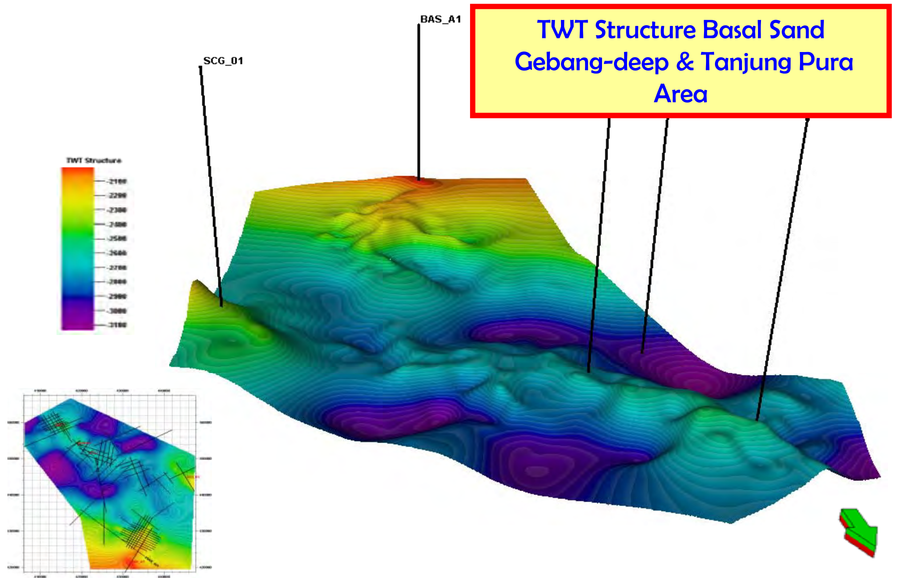
TWT Structure Belumai Gebang-deep & Tanjung Pura Area

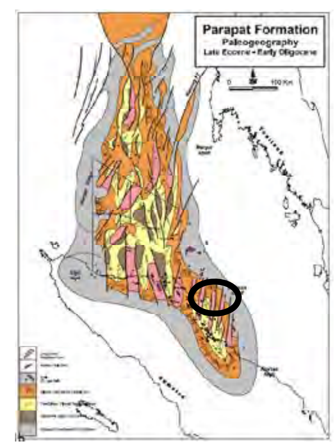


TWT Structure Middle Baong Gebang-deep & Tanjung Pura Area



TWT Structure Basal Sand Gebang-deep & Tanjung Pura Area

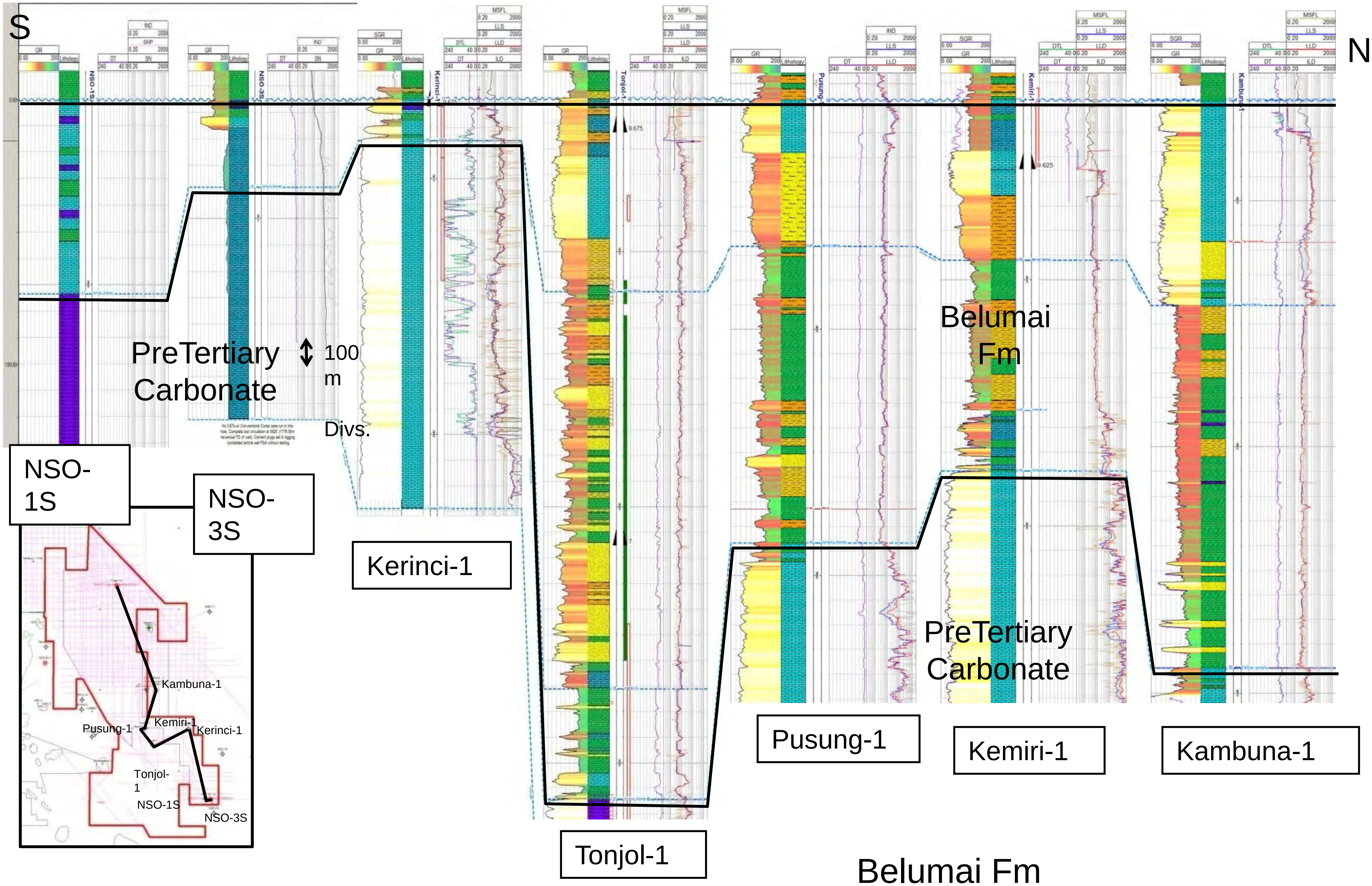


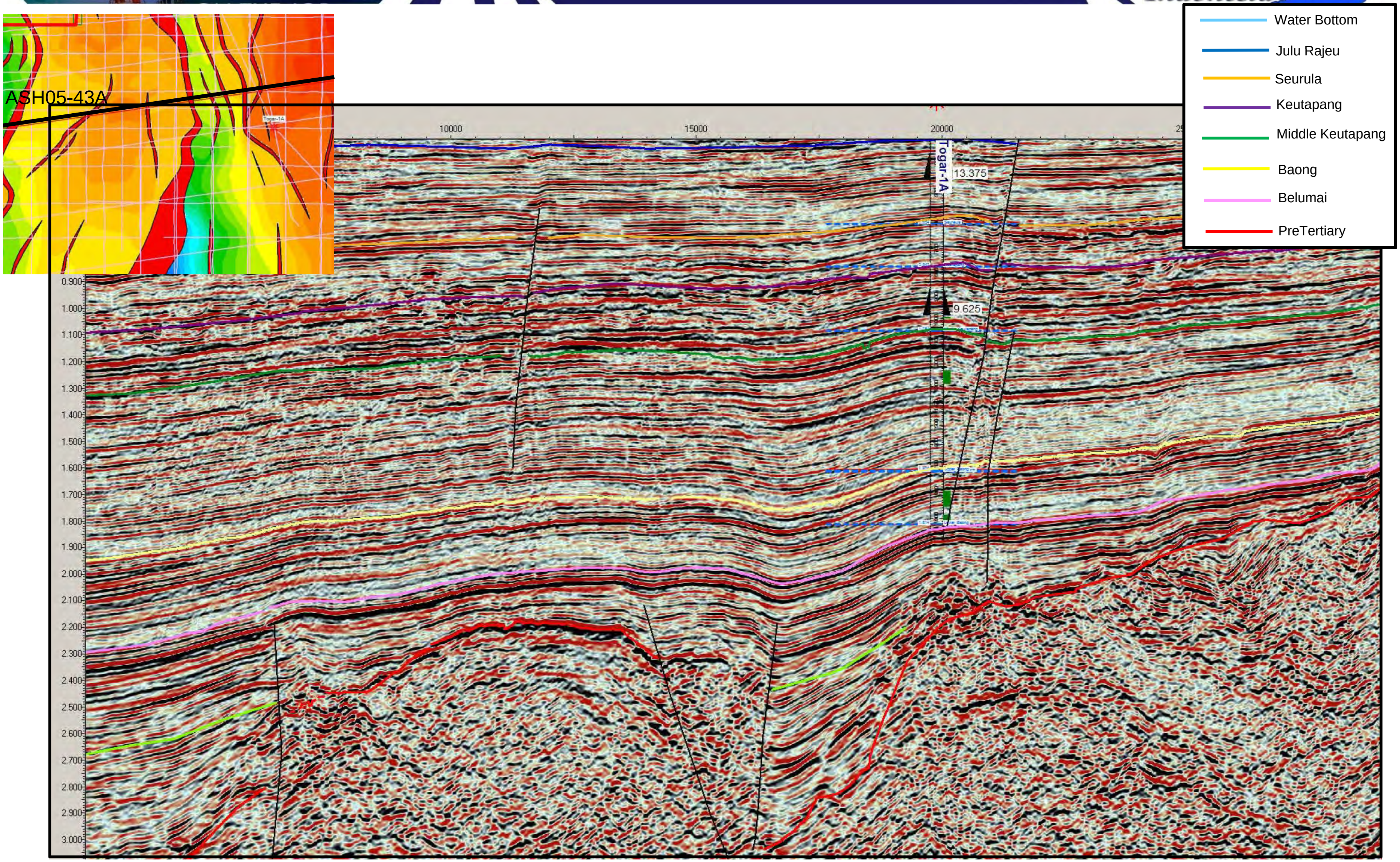


Reservoir Thickness and Quality

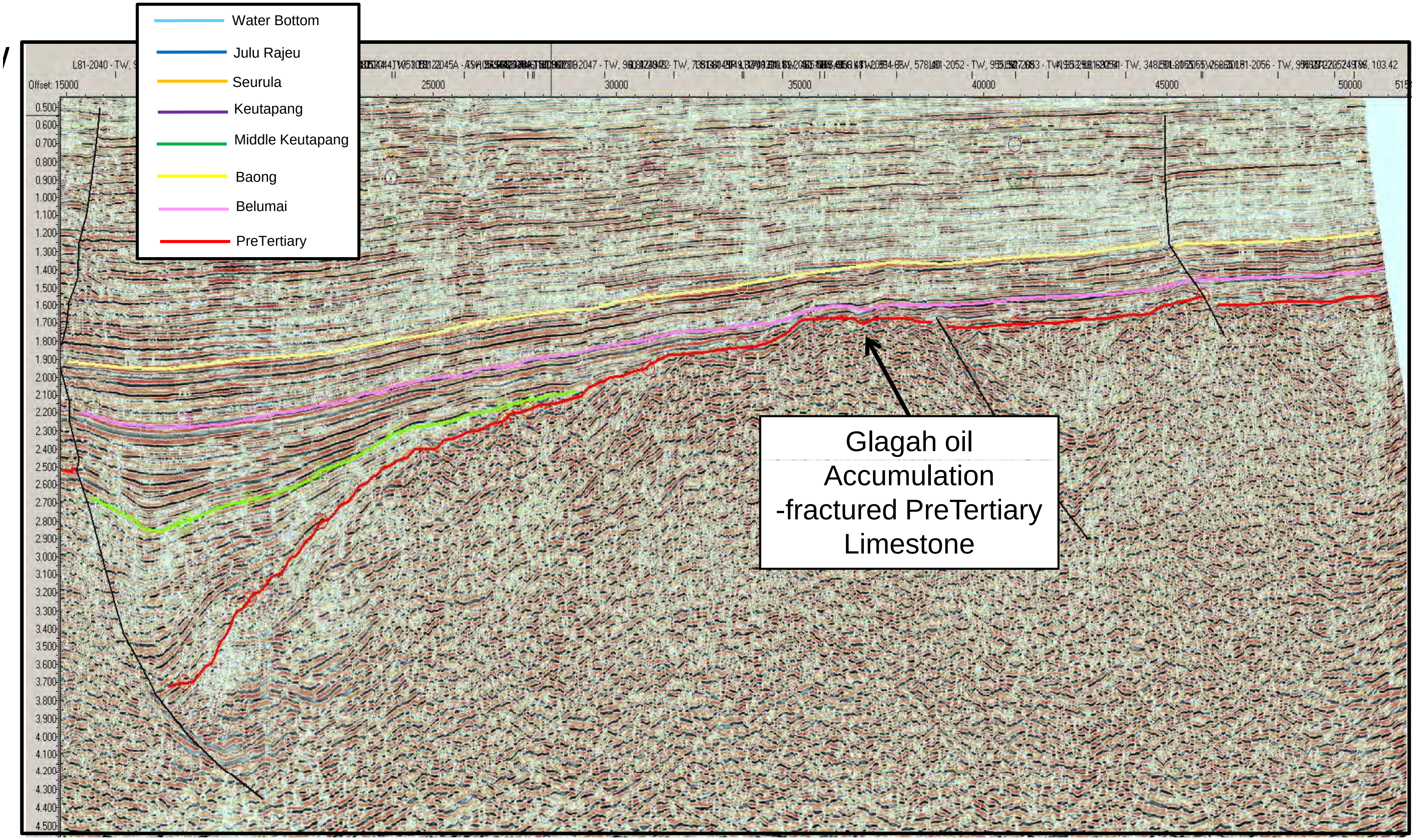
FORMASI	SUMUR	TIPE RESERVOAR	TOP m-MD	BOT. m-MD	GROSS SAND m	NET SAND m	N/G	Vsh %	POR %	K mD	Sw %	NOTES
BASAL SAND	SCG-1	Fluvial Channel Sand	2756	2928	171.5	49.8	0.29	25.5	16.3	4.27	57.5	DST-1 (26.486 mmscfd)
	ARO-1	Dist. Chanelel Sand	3234	3442	184	71.9	0.39	4.9	11.3	64.04	29.8	DST-2 (9.07 mmscfd)
	STD-1	Deltaik – Bar Sand	2963	3077	296	40	0.14	20-40	5-12		50-70	UKL-2 TG=240 unit
BELUMAI	SCG-1	Limestone	2640	2689	49	25	0.51	16.2	15.8	0.82	50.3	DST-4 (0.353 mmscfd)
	ARO-1	Sandy Limestone	2975	3097	122	34.3	0.28	10.9	8.7	2.33	46.5	DST-5 (0.6 bwpd)
	STD-1	Sandy Limestone	2819	2935	166	57	0.39	25	8		50-80	UKL-3 TG=1000 unit
MBS	SEC-1	Turbidite Sand	1749	2000	138	66	0.48	23.1	12		63.3	
	SEC-2	Turbidite Sand	1799	1995	141	95	0.67	44.1	15.7		85	
	STD-1	Turbidite Sand	1800	1892	92	66	0.72	24.9	13	5.0	66	
	SEM-A1	Turbidite Sand	1877	1935	58	45	0.77	32.8	5.9	6.0	70	
	ABY-1	Turbidite Sand	1906	1951	45	14	0.31	43.7	6.8	4.2	79	

N-S wells correlation



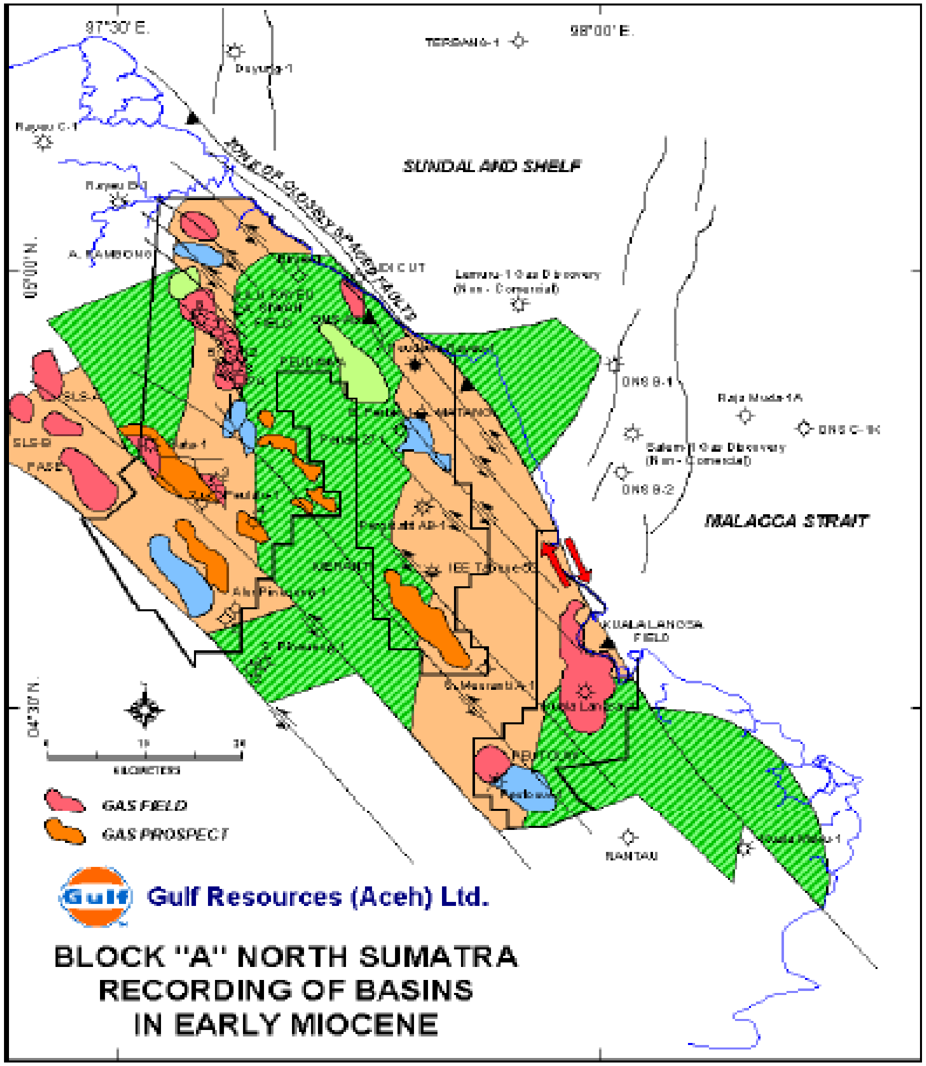


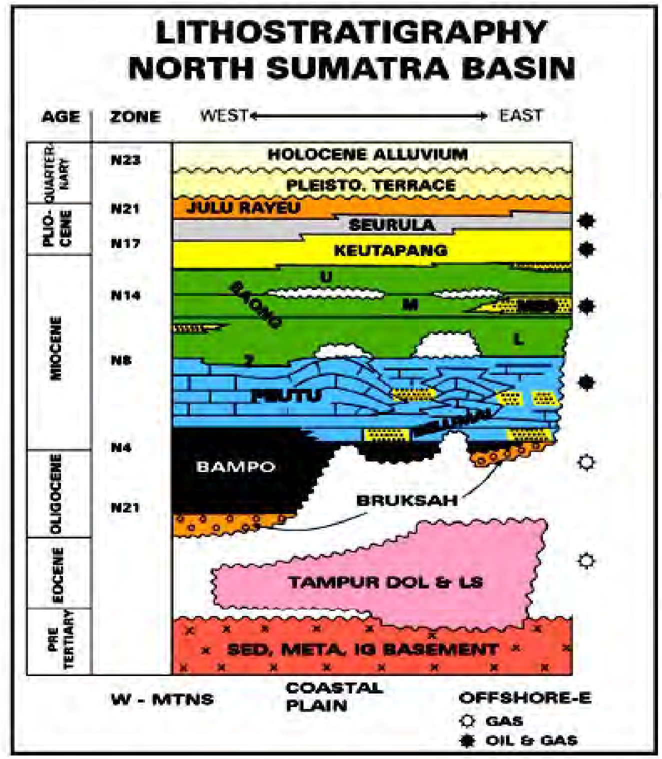
Series of Half Graben System

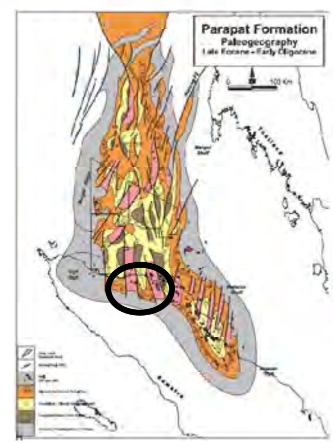


Untested Play in West Glagah

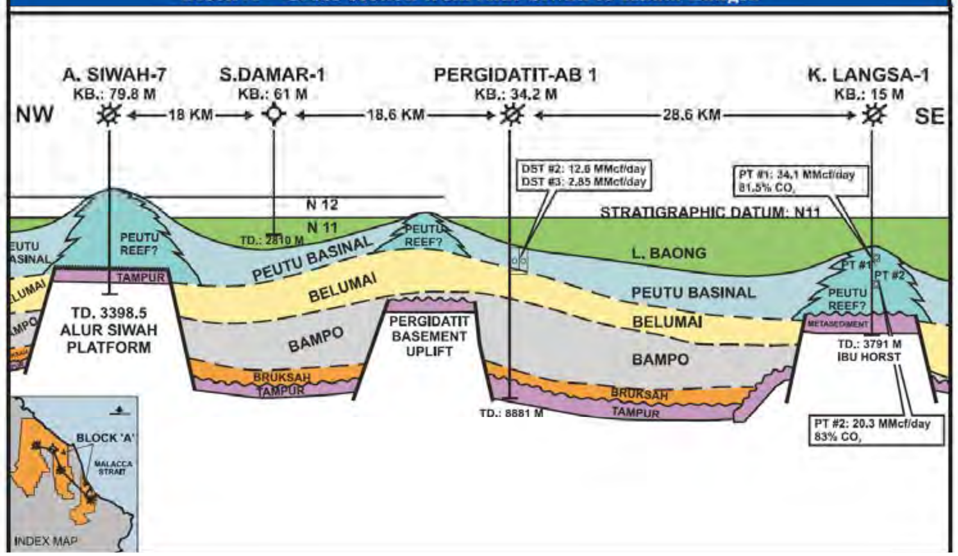

Indonesia

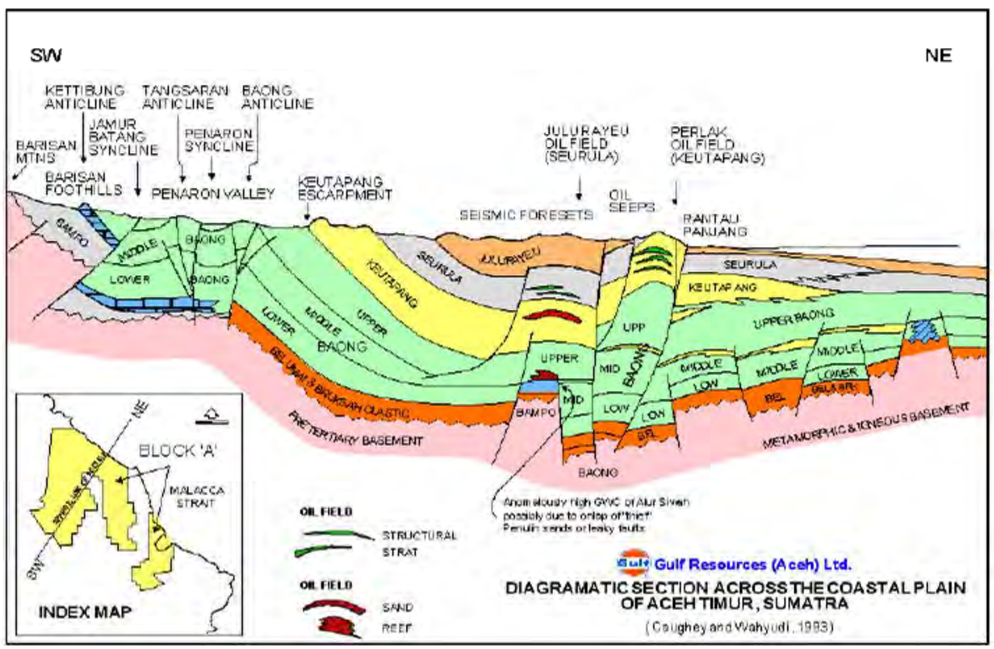

97°30' E.
98°00' E.
05°00' N.
04°30' N.
SUNDALAND SHELF
MALACCA STRAIT
TERDANG-1
Rayeu C-1
Lamuru-1 Gas Discovery (Non - Comercial)
Raja Muda-1A
ONS C-1K
ONS B-1
ONS B-2
Salem-1 Gas Discovery (Non - Comercial)
KUALA LANGSA FIELD
RANTAU
KILOMETERS
GAS FIELD
GAS PROSPECT
Gulf Resources (Aceh) Ltd.
BLOCK "A" NORTH SUMATRA
RECORDING OF BASINS
IN EARLY MIOCENE

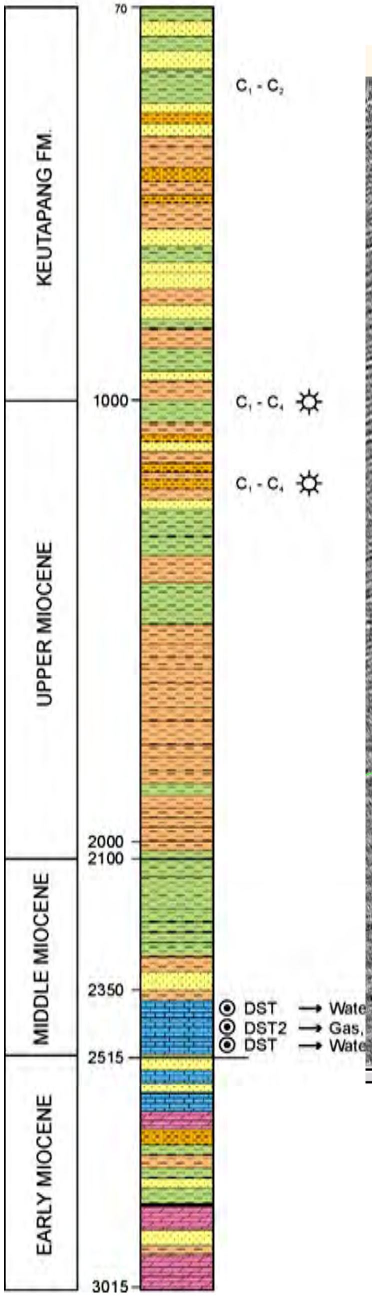

LITHOSTRATIGRAPHY
NORTH SUMATRA BASIN
AGE
ZONE
WEST
EAST
QUARTER-NARY
PLIO-CENE
MIOCENE
OLIGOCENE
EOCENE
PRE TERTIARY
N23
N21
N17
N14
N8
N4
N21
HOLOCENE ALLUVIUM
PLEISTO. TERRACE
JULU RAYEU
SEURULA
KEUTAPANG
U
M
L
PEUTU
BAMPO
BRUKSAH
TAMPUR DOL & LS
SED, META, IG BASEMENT
W - MTNS
COASTAL PLAIN
OFFSHORE-E
GAS
OIL & GAS

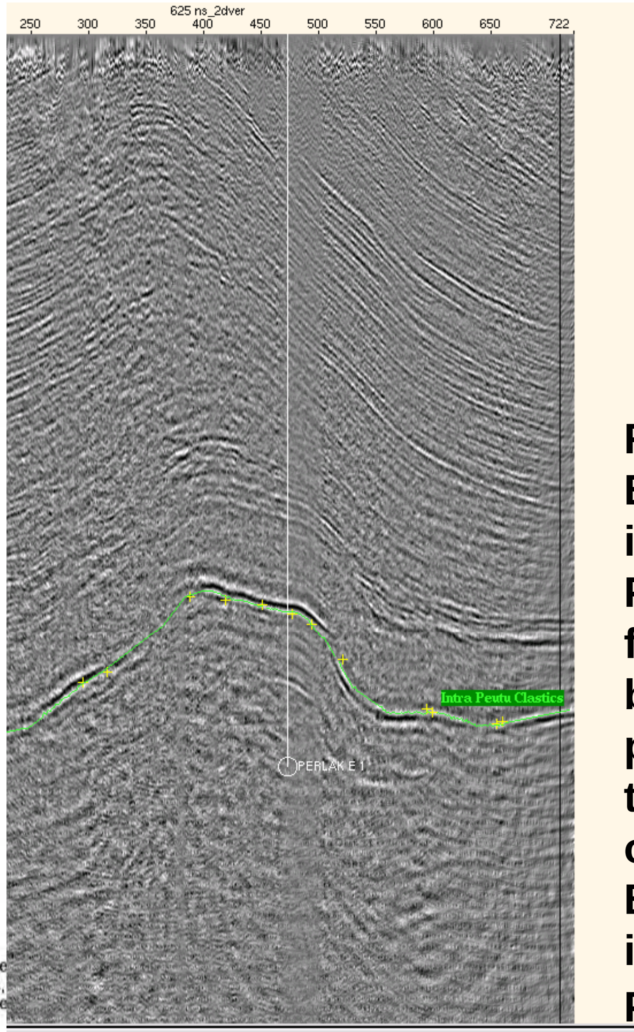

Parapat Formation
Paleogeography

Block A – Cross-section from Alur Siwah to Kuala Langsa









East Perlak-1

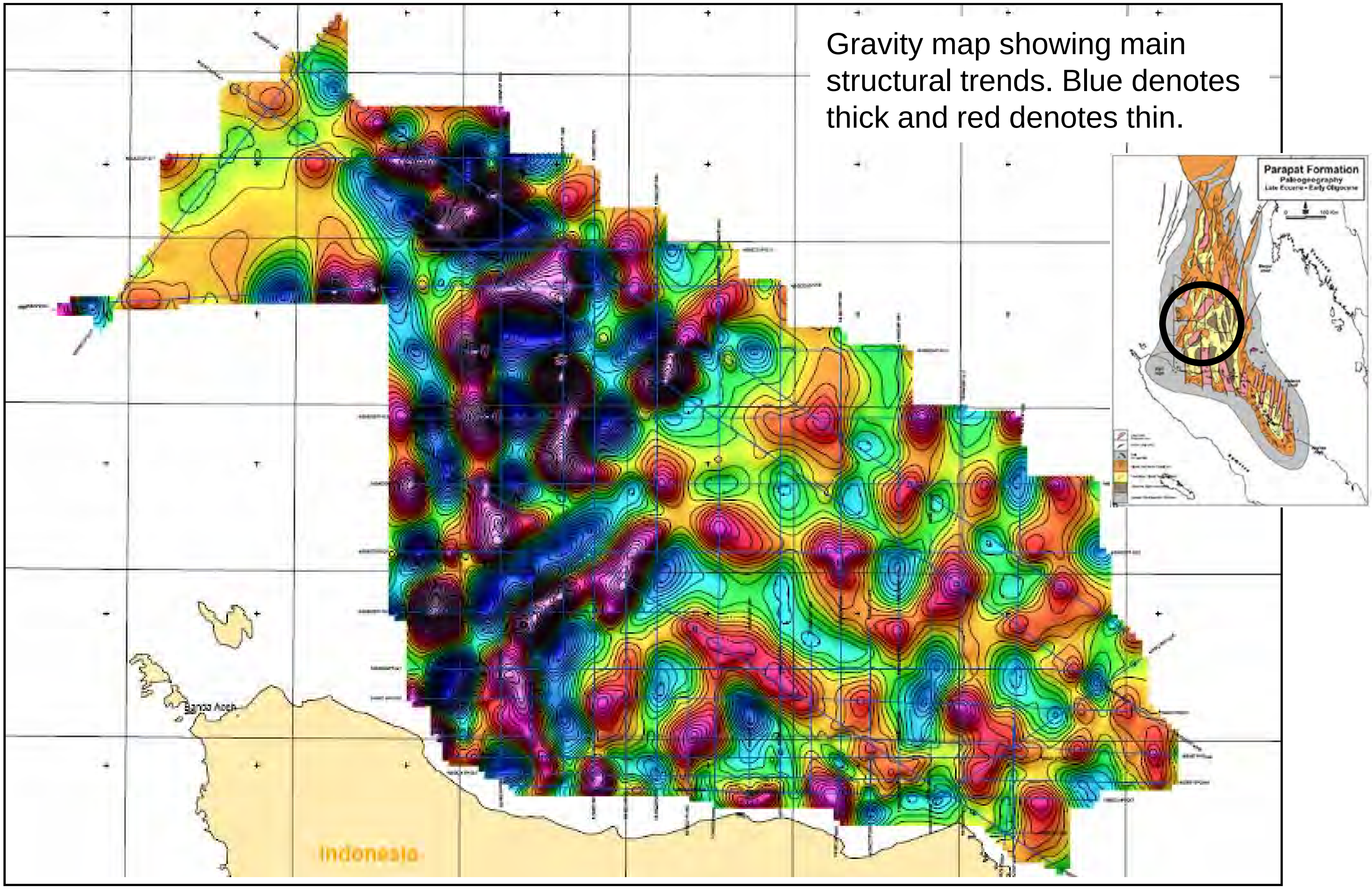
Spud date: oct.1981

Objective: Turbidite sandstone Baong Formation, carbonate Peutu Formation and sandstone of Brukash Formation.

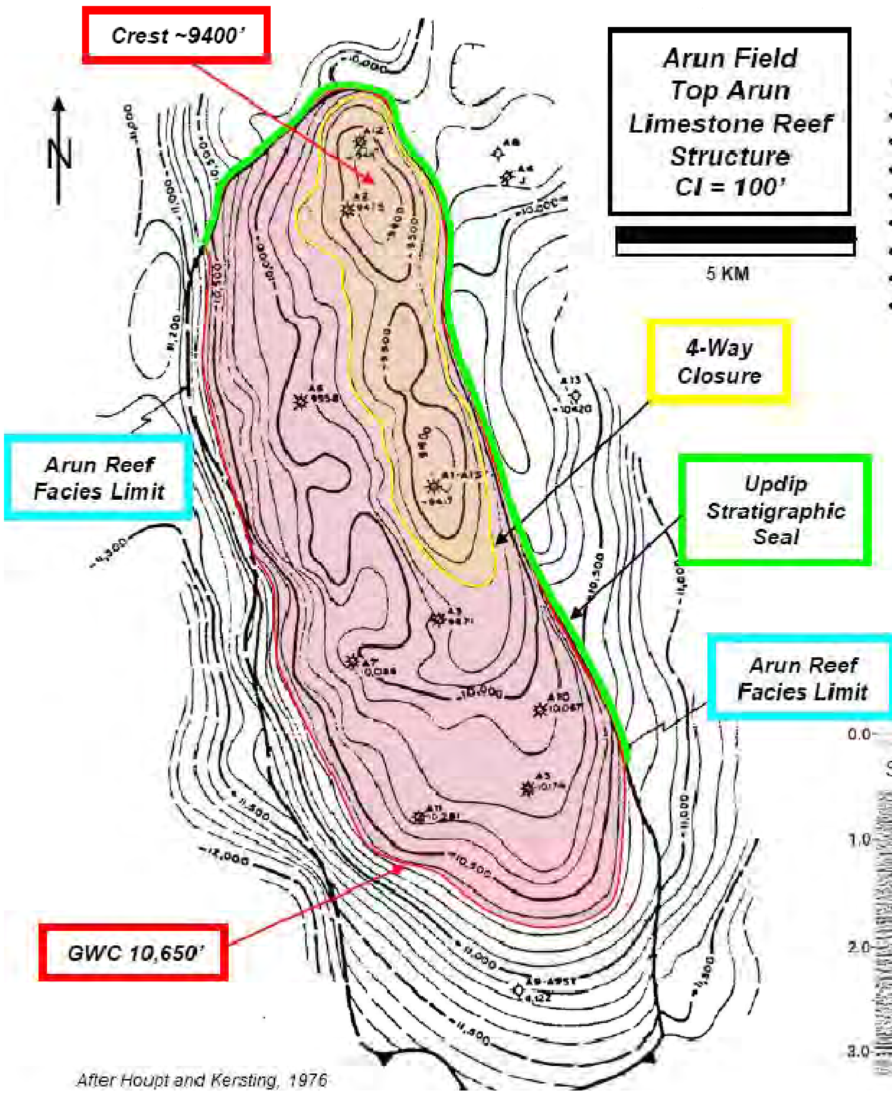
Deep well drilled in Perlak Platform

Result of East Perlak-1
Baong Formation consists mainly of interbedded fine sandstone and shale
Peutu Carbonate consists of interbedded fine sandstone and planktonic foram bioclastic wackestone in the upper part and planktonic foram bioclastic wackestone in the lower part. Depositional environment is open marine condition.
Brukash Formation composed of interbedded fine sandstone and shale. TD at Pre-Tertiary Dolomite?

Bouguer Gravity Map

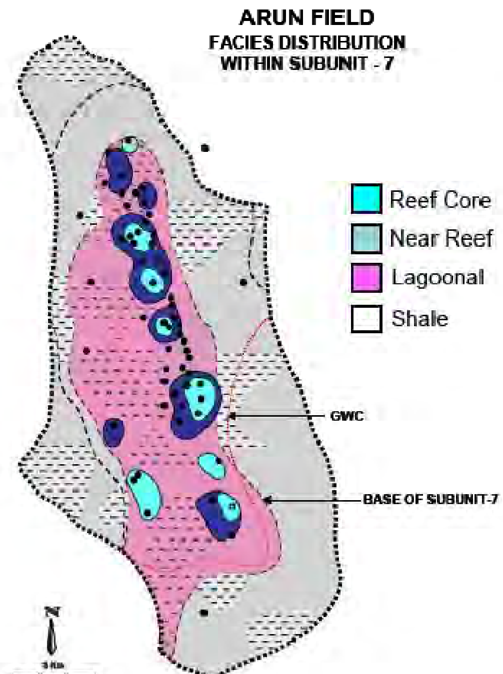


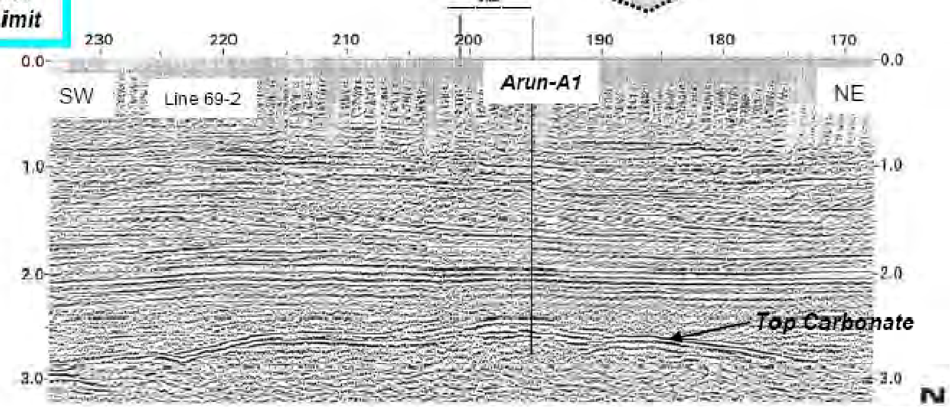
Gravity map showing main structural trends. Blue denotes thick and red denotes thin.

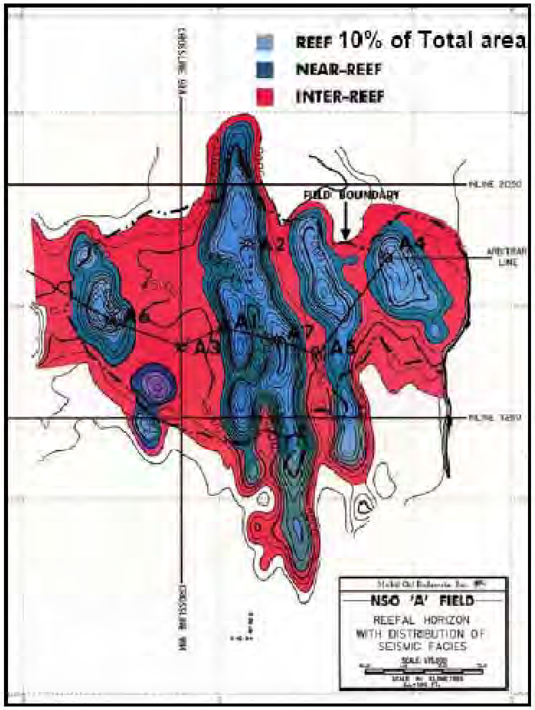


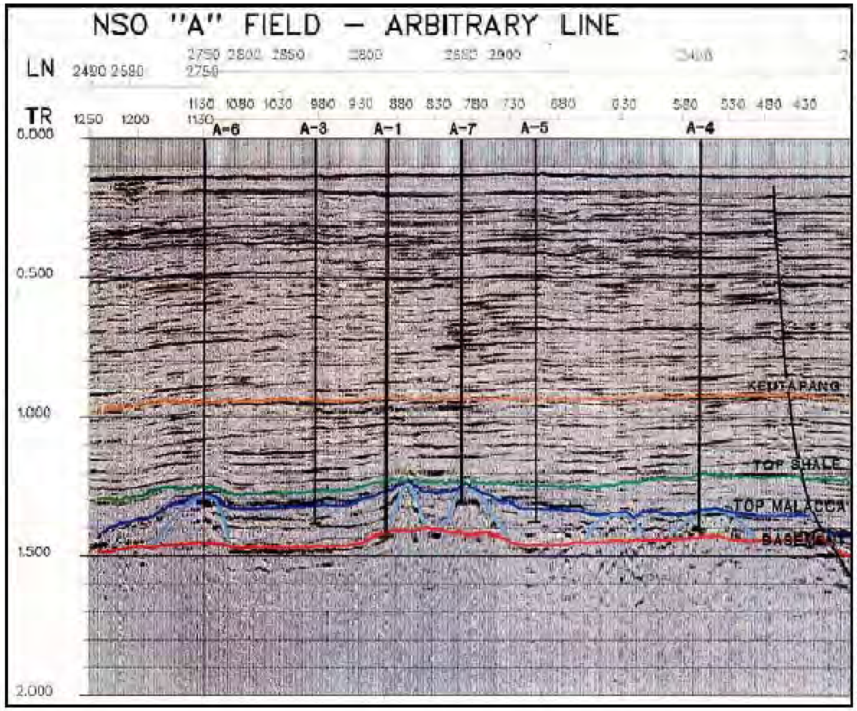
Arun Field (Esso 1971)

- Gas & Cond (75%/25%)
- 2,954 MMBOE Recoverable
- Belumai Fm – Carbonate Reef
- Top Reservoir: 9550'
- Column Height: 1050'
- Avg Porosity: 16.2%
- CO_2: 15%
- Area: 94 km2 or 23,300 acres



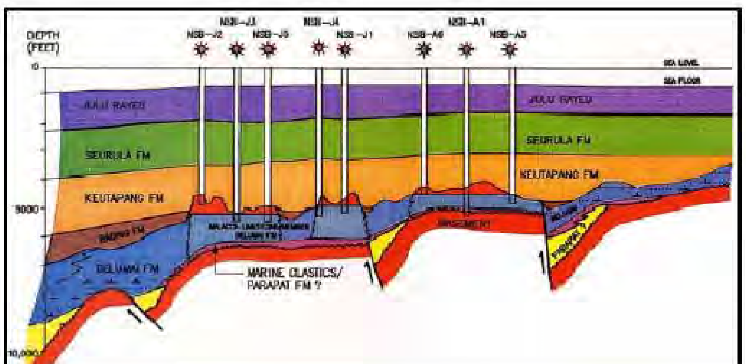






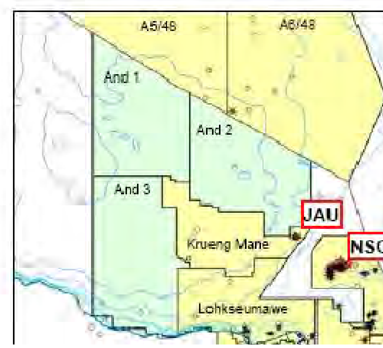
Core photo of typical inter-reef facies from A3 well. Packstone consisting of large recrystallized skelatal fragments with a micritic matrix fill (white)

Core photo of typical reef facies from A7 well. Large skelatal and coral allochems are in a grainstone matrix

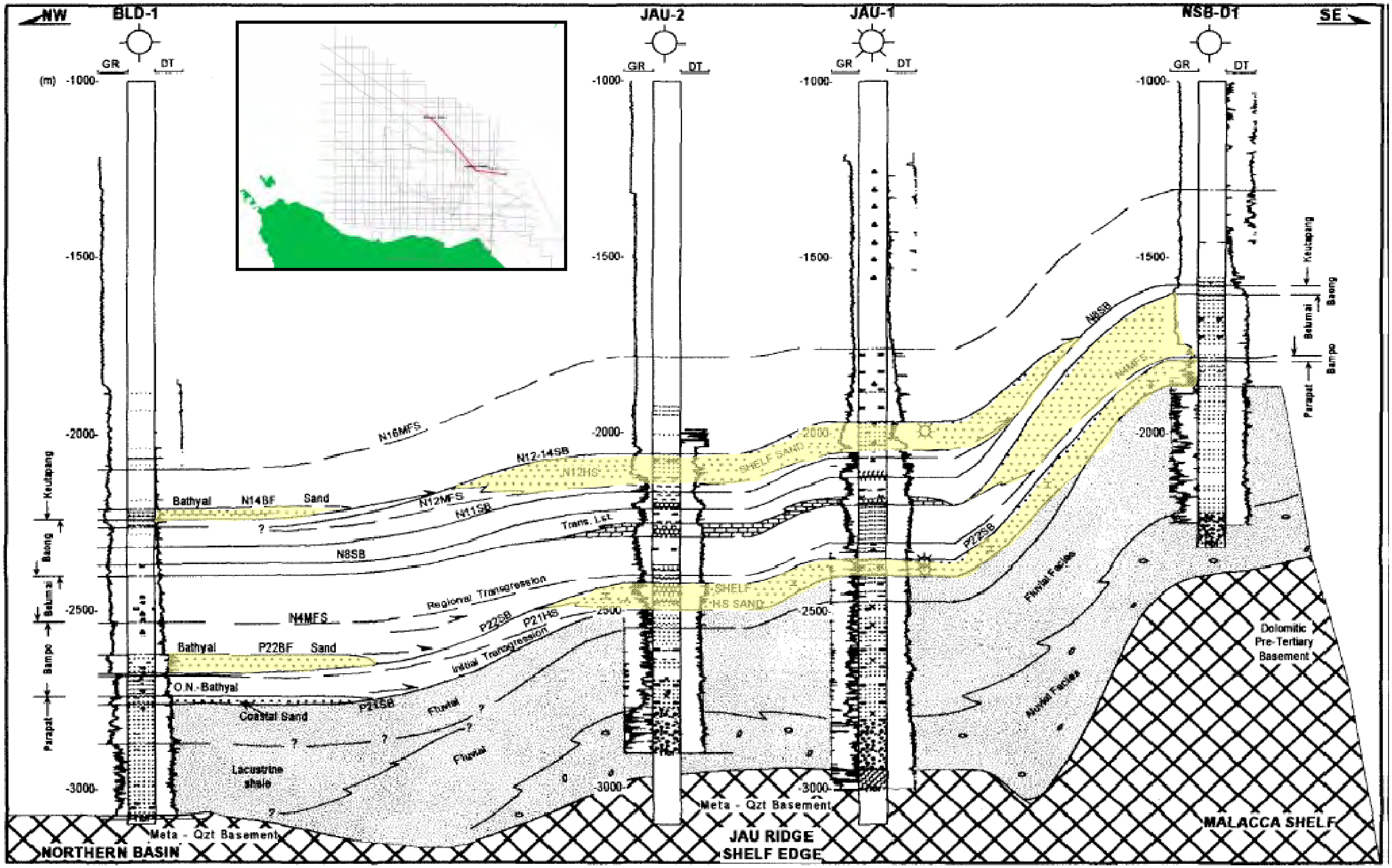


NSO Field (Esso 1972)

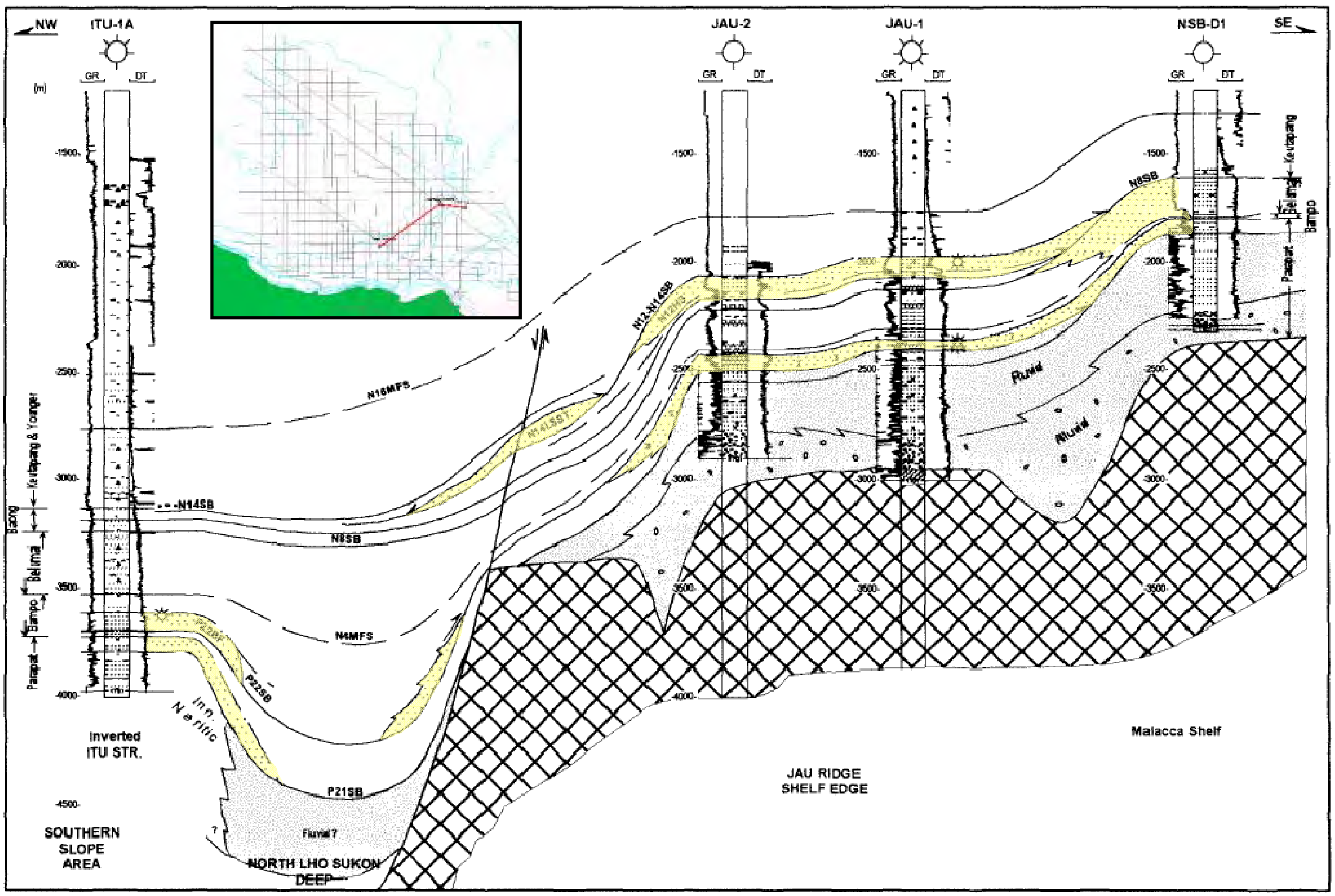
- Gas & Cond (93/7)
- 191 MMBOE Recoverable
- Belumai Fm – Carbonate Reef
- Top Reservoir: 3800'
- Column Height: 576'
- Avg Porosity: 23%
- Avg Sw: 8%
- Avg Perm: 200 md (10-3,700md)
- Normally pressured and 267 F Temp
- Area: 45 km2 or 11,000 acres
- Porosity enhancement from CO_2



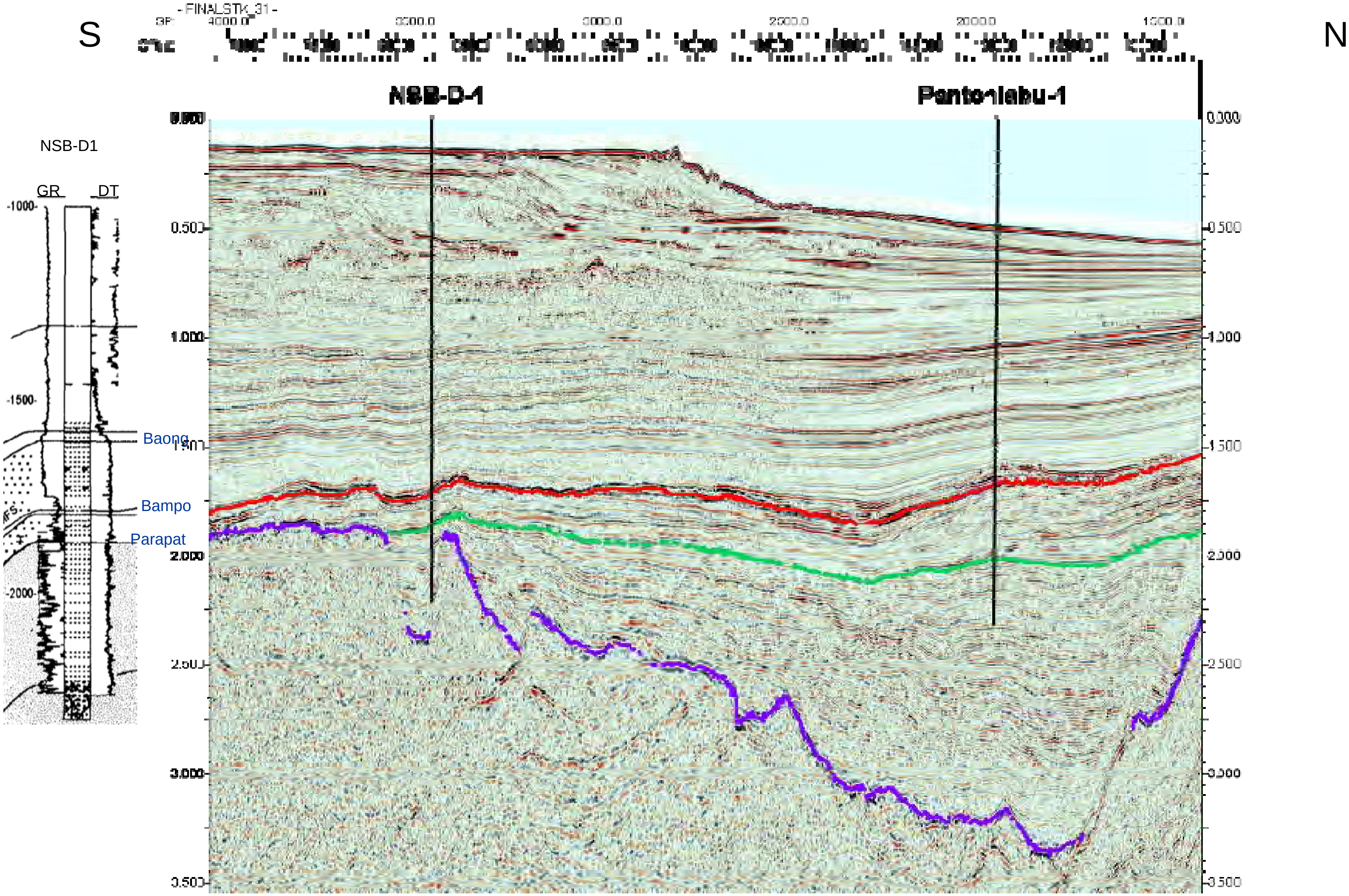
Correlations – Northern Basin

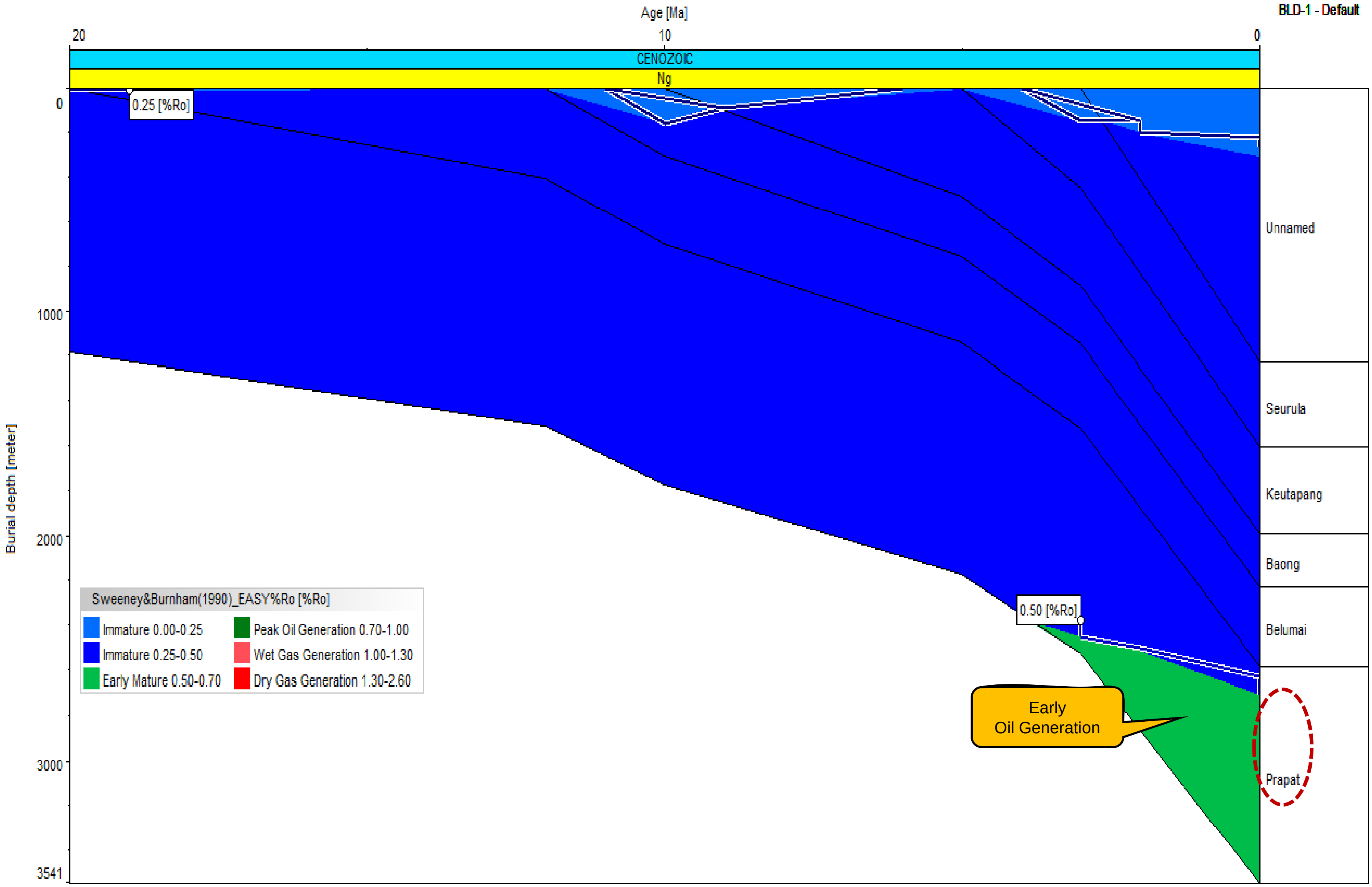


Correlations – Southern Slope Area



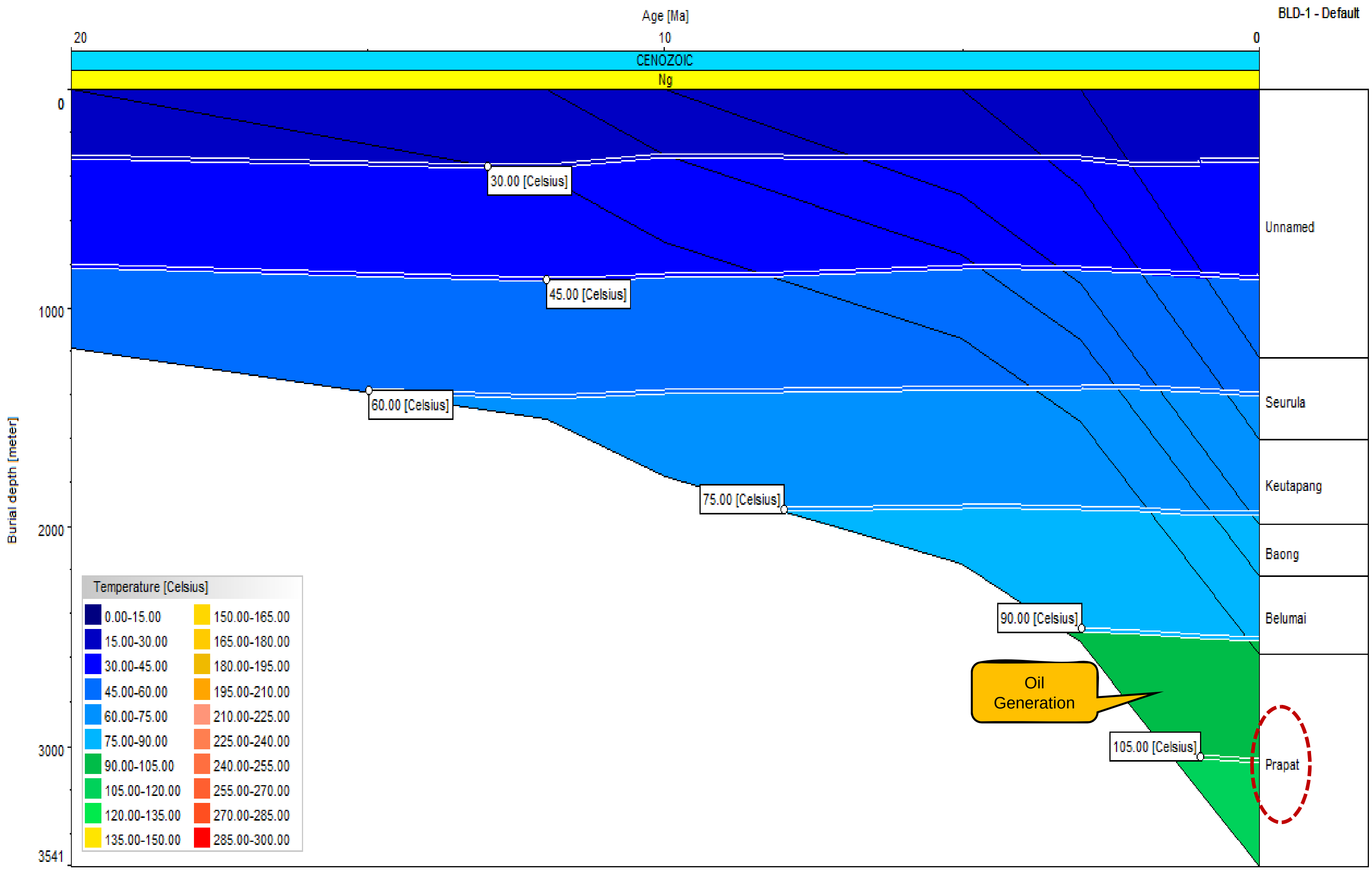
Well data with results





In *BLD-1* Well at the time < 4 million year ago estimated had happened early stages of the oil generation in the upper part of *Prapat Formation*

Thermal Geohistory



Estimated the formation of hydrocarbons in the BLD-1 Well happened on the *upper part of Prapat Formation* at temperature 105° - 120° C and occurred in 2 million years ago

Conclusion

- There are potential for pre-Tertiray play in North Sumatra Basin (NSB)
- Oligo-Miocene carbonate still the main target for exploration in NSB.
- Finding prolific basin like Java and Lho Sukon Deeps is a must in NSB for high impact exploration target (Arun/NSO size).
- Distribution of Middle Baong sandstone still poorly understood especially in Andaman area.
- For sandstone play need to have a good trap since tectonic is relatively intense during Plio-Pleistocene.
- Despite all the risk, NSB still have a potential for exploration to finding big hydrocarbon resources.
- Gas shortage to LNG/PIM/DMO need to fulfilled by explore the NSB