CCOP – KIGAM Unconventional Oil and Gas Project:

Mapping of Black Shale Formations for the Prediction of Shale resources (UnCon or UC Project)

GEOLOGICAL SETTING OF SOUTH SUMATERA BASIN

(SHALE HIDROCARBON BASINS IN INDONESIA)

UCM7

Bangkok, Wednesday 29 Mach 2017.

RESEARCH AND DEVELOPMENT CENTER FOR OIL AND GAS TECHNOLOGY "LEMIGAS"

AGENCY OF RESEARCH AND DEVELOPMENT FOR ENERGY AND MINERAL RESOURCES

MINISTRY OF ENERGY AND MINERAL RESOURCES REPUBLIC OF INDONESIA

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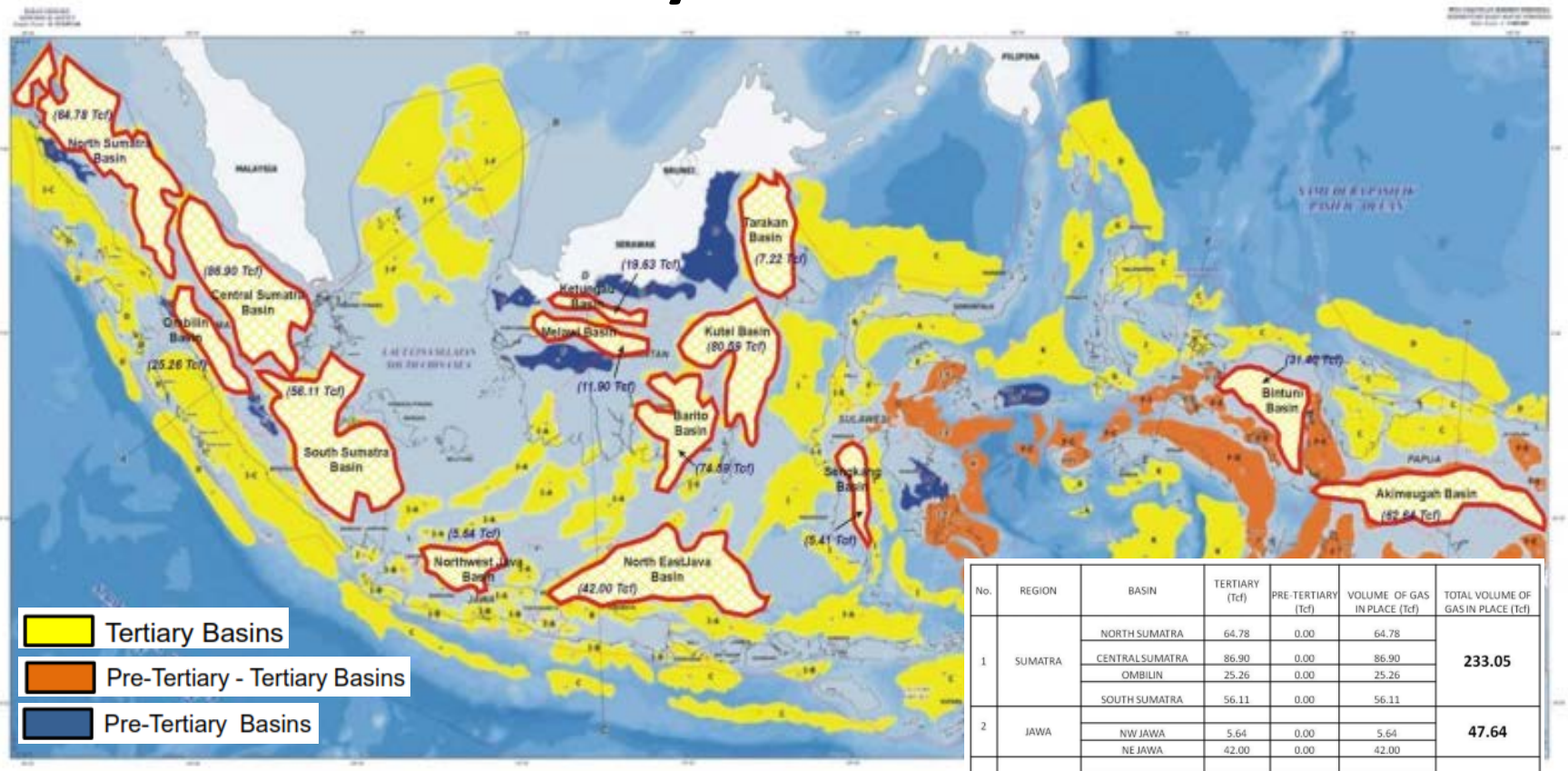
Outline

- Indonesia Shale Hydrocarbon Potential Basins
- South Sumatera Basin
  - Geological Setting
    - Tectonic
    - Stratigrafi
  - Major Structural Features
  - Exploration Activities
- Resume

Indonesia Sedimentary Basins and **Shale Hydrocarbon Potential Basin**.



No.	REGION	BASIN	TERTIARY (Tcf)	PRE-TERTIARY (Tcf)	VOLUME OF GAS IN PLACE (Tcf)	TOTAL VOLUME OF GAS IN PLACE (Tcf)
1	SUMATRA	NORTH SUMATRA	64.78	0.00	64.78	233.05
		CENTRAL SUMATRA	86.90	0.00	86.90	
		OMBILIN	25.26	0.00	25.26	
		SOUTH SUMATRA	56.11	0.00	56.11	
2	JAWA					47.64
		NW JAWA	5.64	0.00	5.64	
		NE JAWA	42.00	0.00	42.00	
3	KALIMANTAN					193.93
		BARITO	74.59	0.00	74.59	
		KUTEI	80.59	0.00	80.59	
		TARAKAN	7.22	0.00	7.22	
		MELAWI	11.90	0.00	11.90	
		KETUNGAU	19.63	0.00	19.63	
4	SULAWESI					5.41
		SENGKANG	5.41	0.00	5.41	
5	PAPUA					94.04
		AKIMEUGAH	5.50	57.14	62.64	
		BINTUNI	1.15	30.25	31.40	
	TOTAL SPECULATIVE RESOURCES OF SHALE GAS					574.07

The Promising Hydrocarbon Shale Resources in some Sedimentary Basin in Indonesia

Geological Agency (2011)

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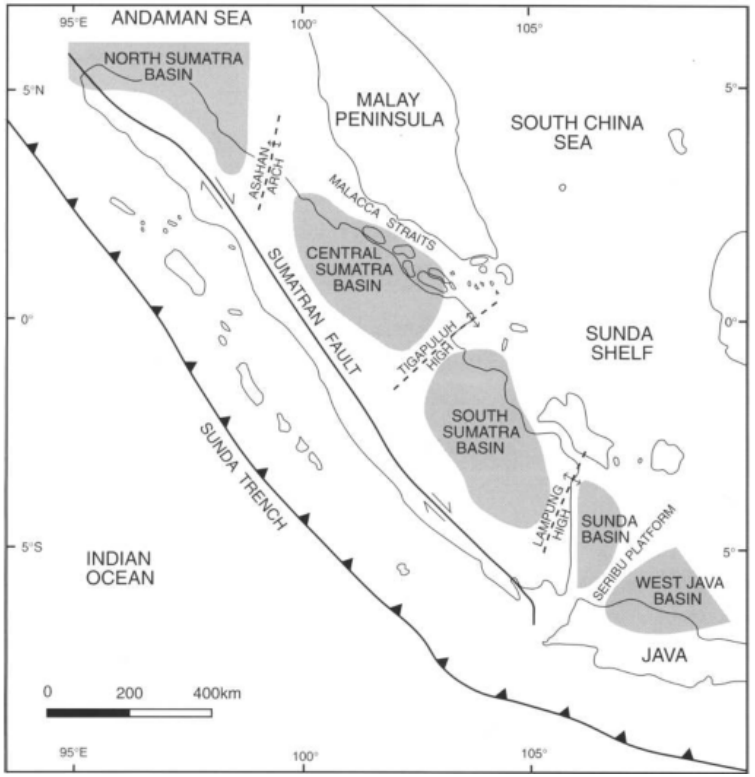
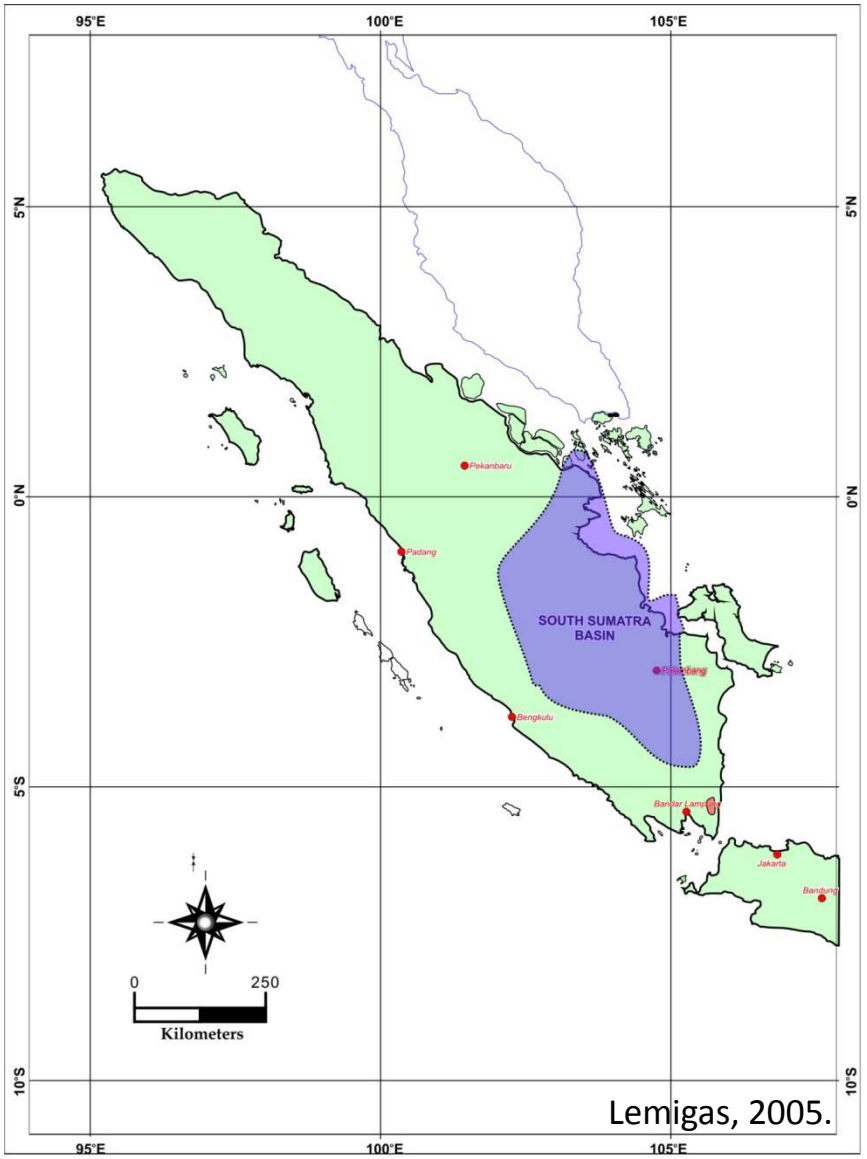
South Sumatera Basin

- Based on the classification and estimation of potential shale hydrocarbon mentioned above, not all the potential for shale basins hydrocarbons done detailed studies
- Lemigas study in South Sumatra Basin, Pertamina conduct exploration activities in North Sumatra Basin and Centre of Geological Survey in Central Sumatra Basin as has been shown in this CCOP forum (UCM1-UCM5)
- Already written a brief report of the 14 basins that have the potential to shale hydrocarbon regarding location, tectonic setting and stratigraphy.
- In this opportunity will be present the geological setting and exploration activities in the South Sumatra Basin.

Location of South Sumatera Basin



The geographical and tectonic setting of the Sumatran backarc basins. The volcanic arc follows approximately the trace of the Sumatran Fault (Davies, 1984)



Lemigas, 2005.

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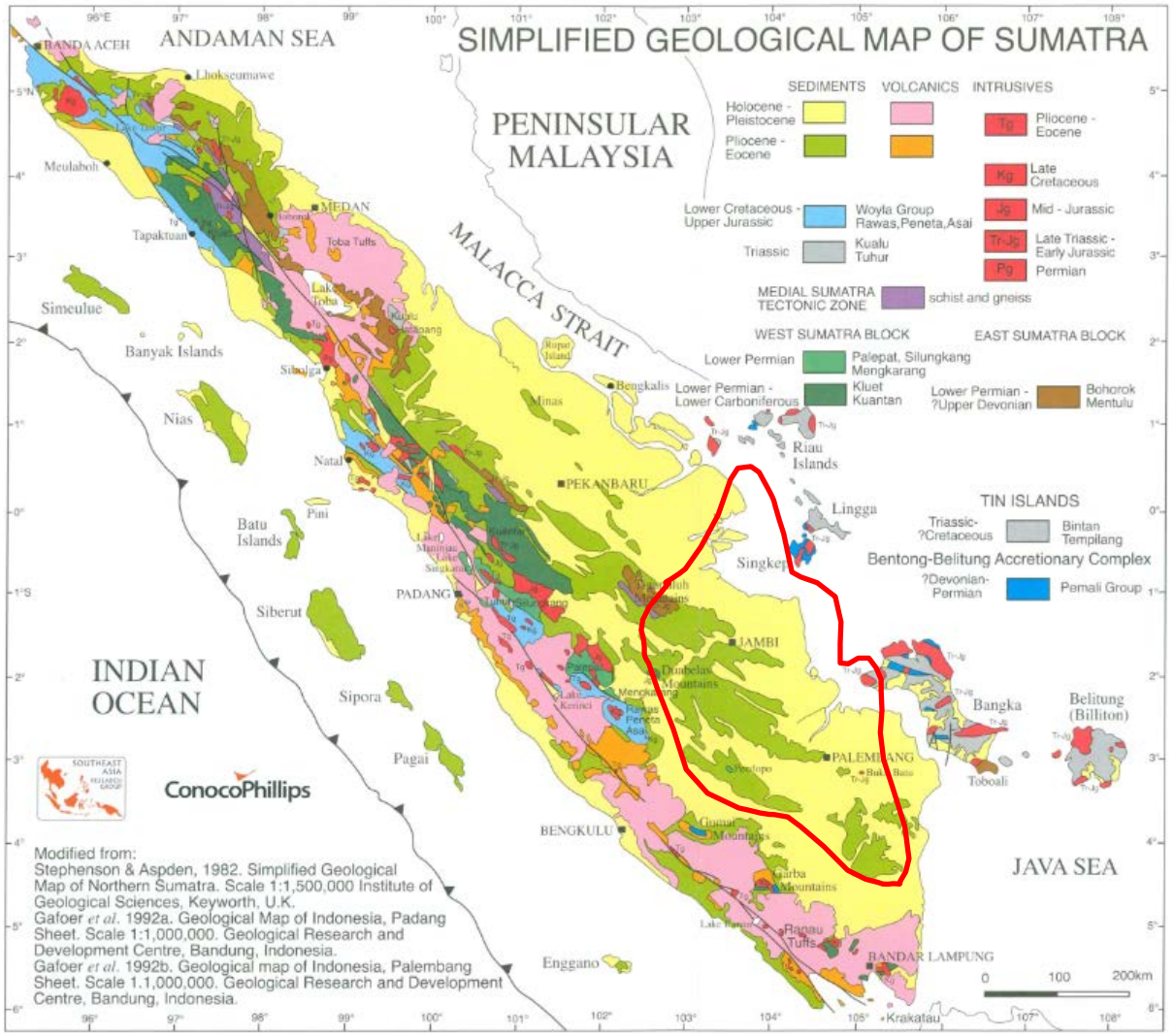
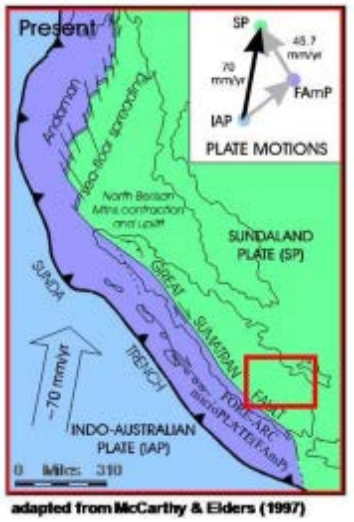
Geological Setting



(Barber, 2005)

- South Sumatra basin is a back arc basin.
- formed by the movement of Hindia-Australia Oceanic Crust and Asia Continental Crust that have occurred since the Late Cretaceous to Early Tertiary.
- Filled the basin formed by deposition of sediment aged Eocene-Pliocene



adapted from McCarthy & Elders (1997)

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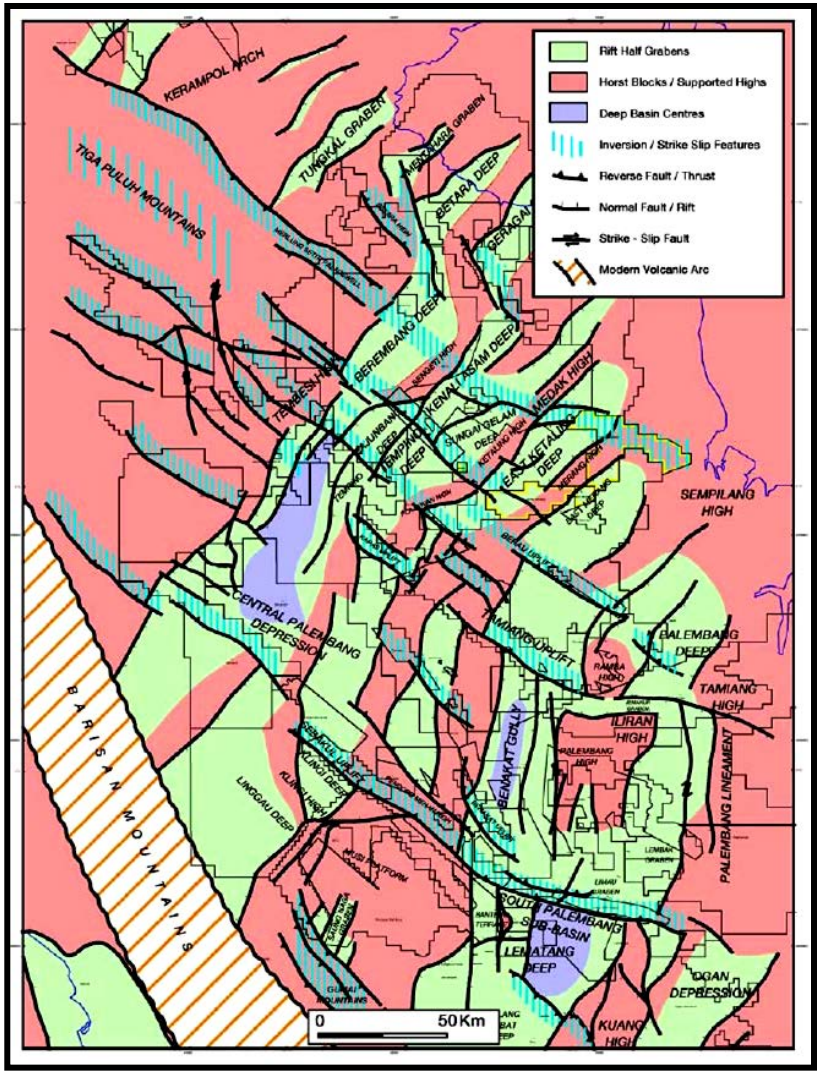
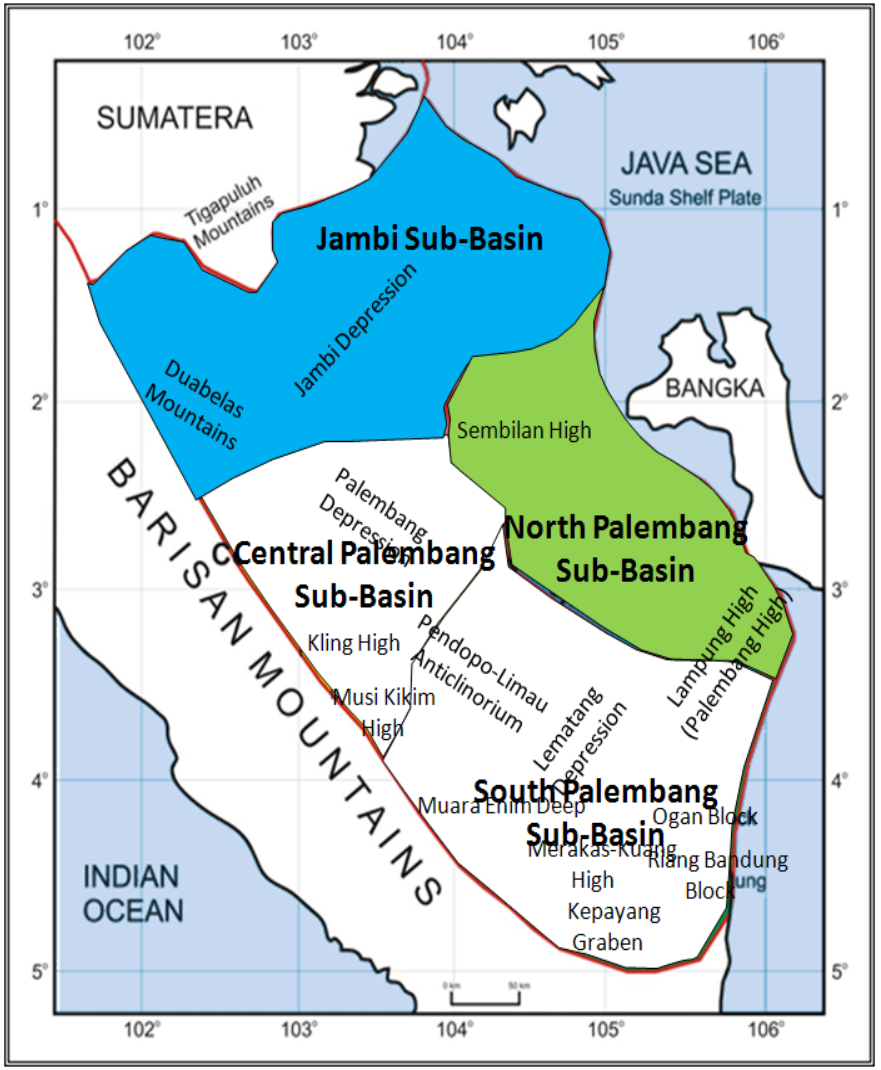
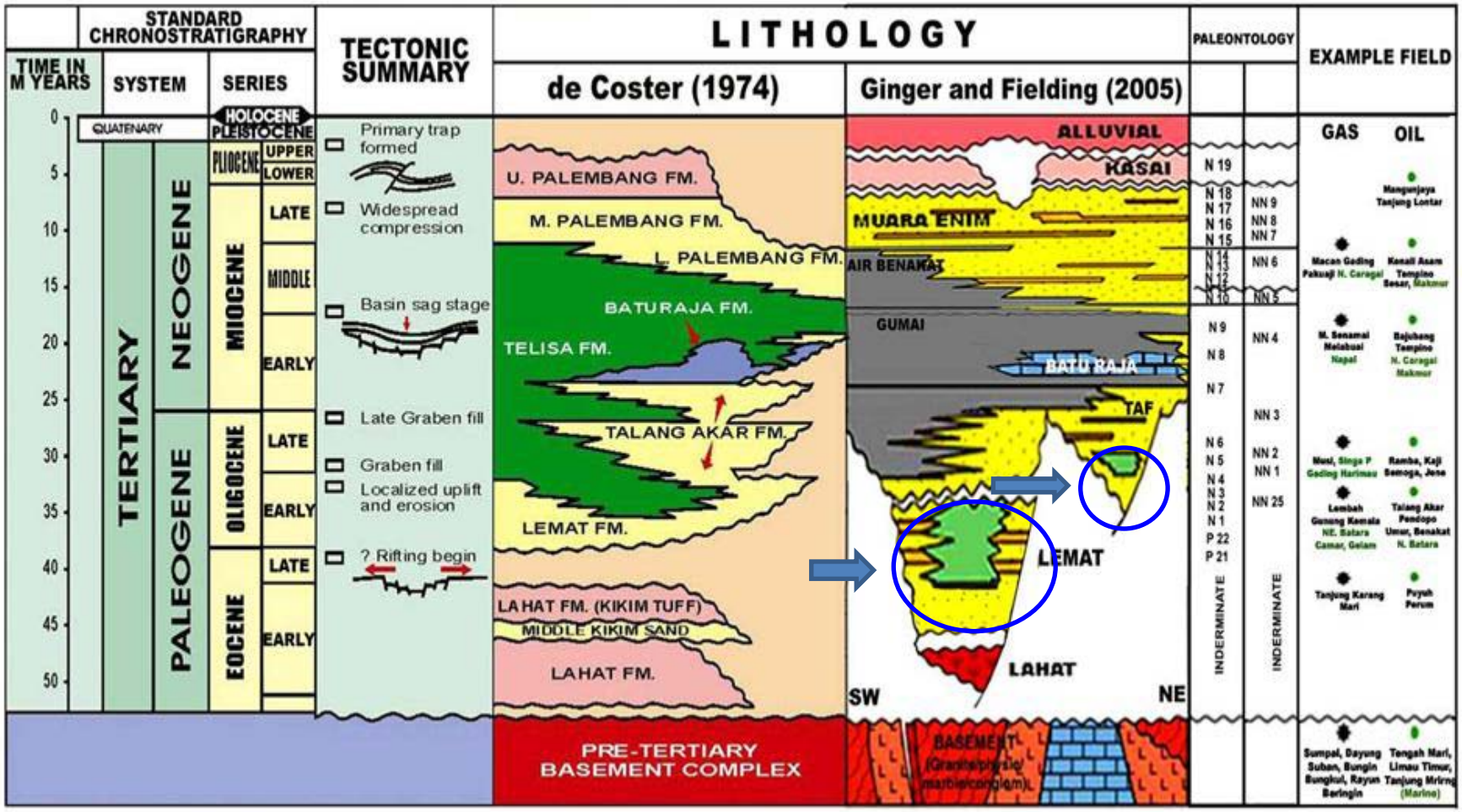
Structural Element





(Ginger and Fielding, 2005).

Regional Stratigraphy



TARGET SHALE PLAY, Lahat/Lemat Formation and Talangakar Formation
(rift/synrift phase)

There are three tectonic mega sequences in South Sumatera Basin which, Syn-Ryft, Post-Rift, dan Syn-orogenic-Inversi (Ginger and Fielding, 2005).

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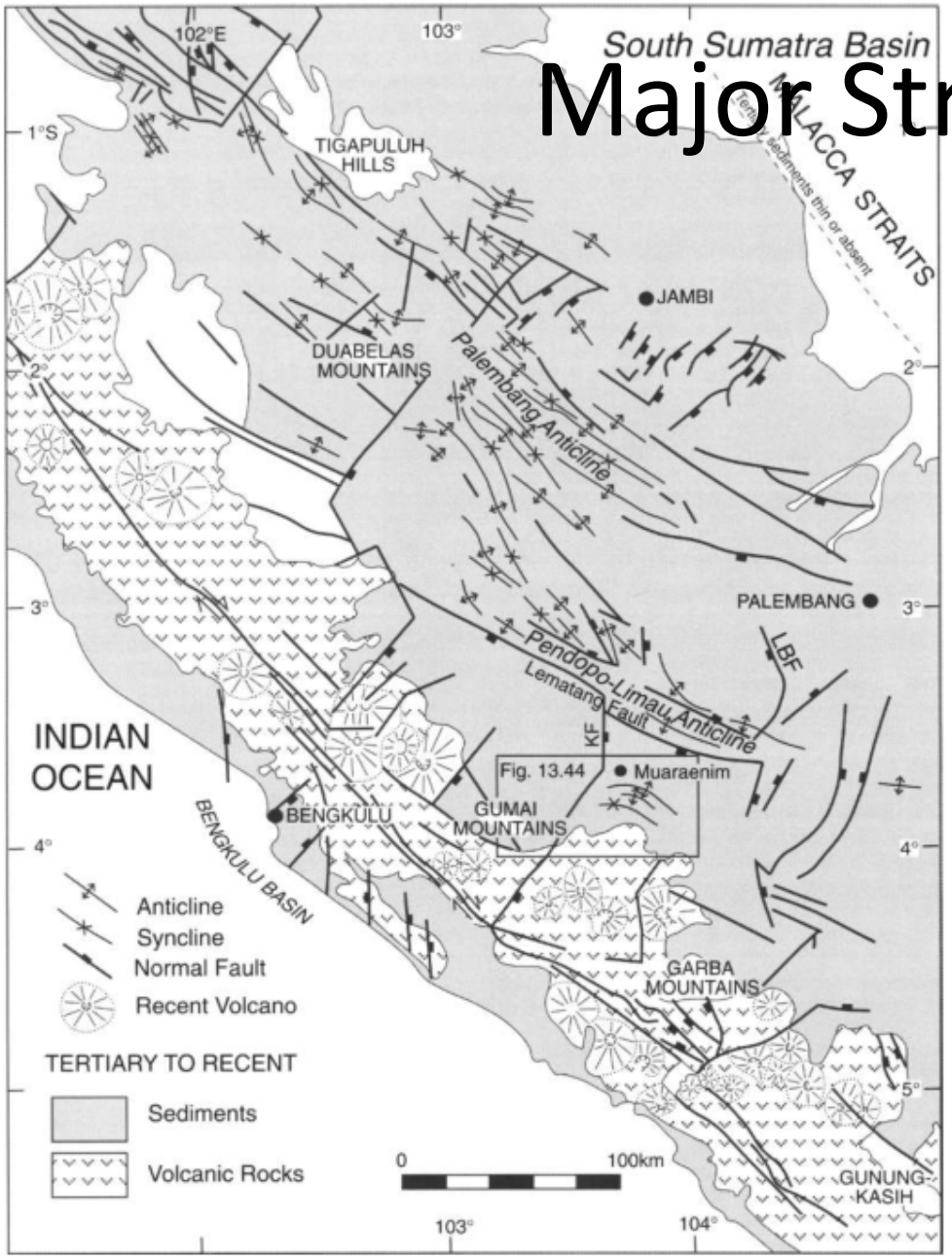
Major Structural Feature



Barber, 2005.

Structure of the South Sumatra Basin showing the distribution of folds and faults, based on data from GRDC map sheets, De Coster (1974), Pulunggono (1986) Pulunggono *et al.* (1992) and Kamal (1999). LBF, Lebak Fault; KF, Kikim Fault, in Barber, 2005.

during the Plio-Pleistocene strong compressional tectonics associated with uplifting of the volcanic arc to the west reactivated earlier structural feature and created northwest-southeast trending reverse faults and basement uplift.

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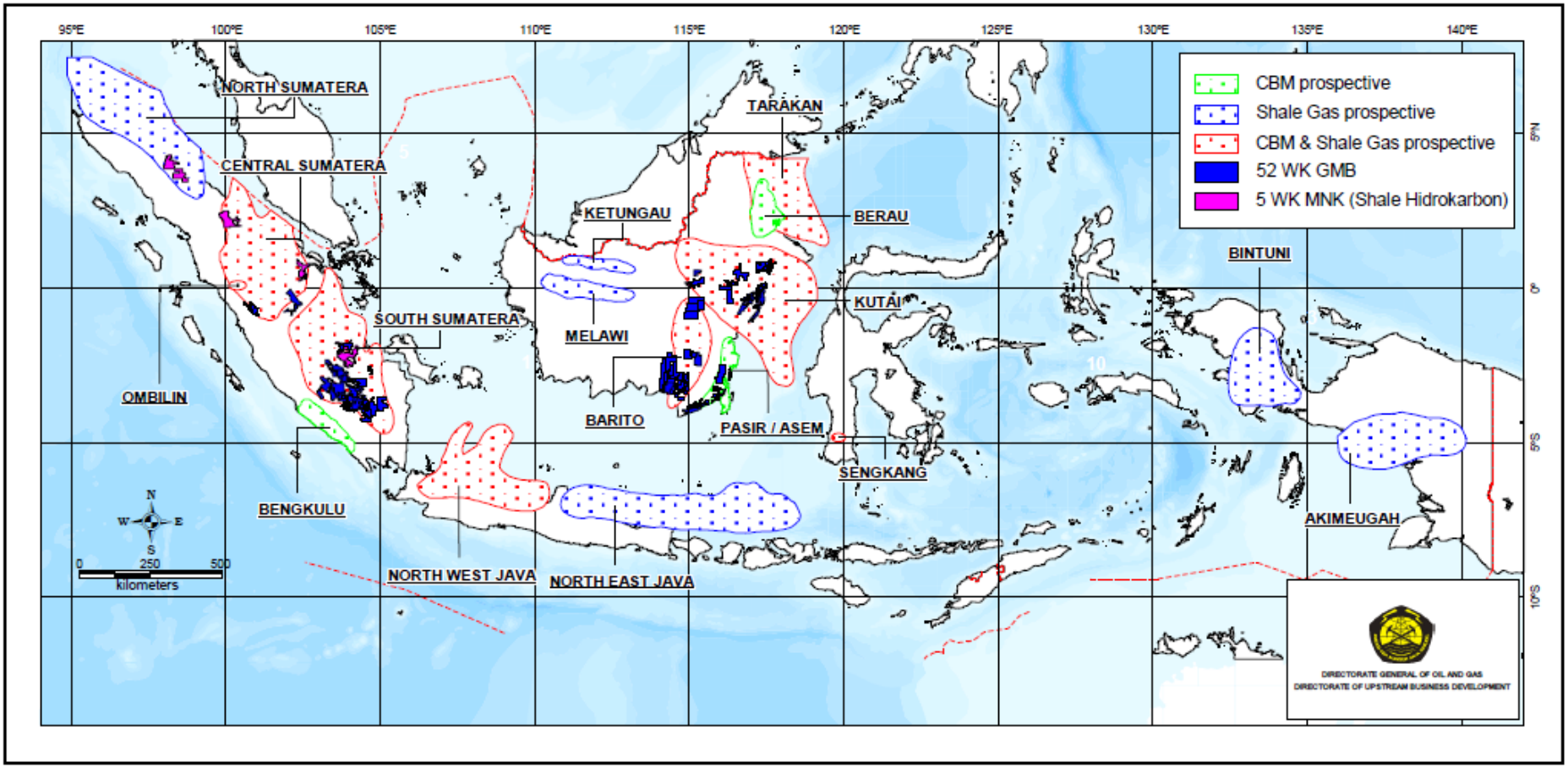
Exploration Activities

- **Exploration History**
  - Oil was first reported in the South Sumatra Basin near Muara Enim, to the east of Karangradja by Granberg in 1866.
  - Since oil and gas field discoveries in the South Sumatera Basin, more than a hundred of oil and gas production fields recorded, about sixty of them still on production.
  - Total oil proven reserve is 3.1 BBO and cumulative production is 2.3 BBO, while gas proven reserve is 6 TCF and cumulative production is 22 TCF.
  - Since discovery of Kampung Minyak oil field in 1896, there are four peaks of activities
    - 1928-1940 : Shell-led BPM begun seismic exploration and drilling.
    - 1968-1975 : Implementation of PSC system in south Sumatera , and followed by foreign oil company.
    - 1984-1988 : Release of the best Pertamina reserved acreage to the industry
    - 1994- now : Recent success Res related to the switch from solely oil exploration to an emphasis on gas
- **Exploration Activities**
  - Exploration activities for non-conventional oil and gas started around the year 2011 by conducting a study in North Sumatra Basin and continued in the South Sumatra Basin in 2014.
  - Until now there are 5 blocks WK MNK (non-conventional oil and gas) operated by national private and only at the exploration stage with locations in North Sumatra Basin, central Sumatra and South Sumatra. Blocks of non-conventional oil and gas was acquired since 2015.

Oil and Gas Non Conventional Working Area Status 2016



Block	Year	Basin	Status
MNK SUMBAGUT	17 MAY 2013	North Sumatera	Explorasi
MNK KISARAN	22 MAY 2015	North Sumatera	Explorasi
MNK SAKAKEMANG	22 MAY 2015	South Sumatera	Explorasi
MNK SELAT PANJANG	22 MAY 2015	Central Sumatera	Explorasi
MNK PALMERAH	22 MAY 2015	South Sumatera	Explorasi

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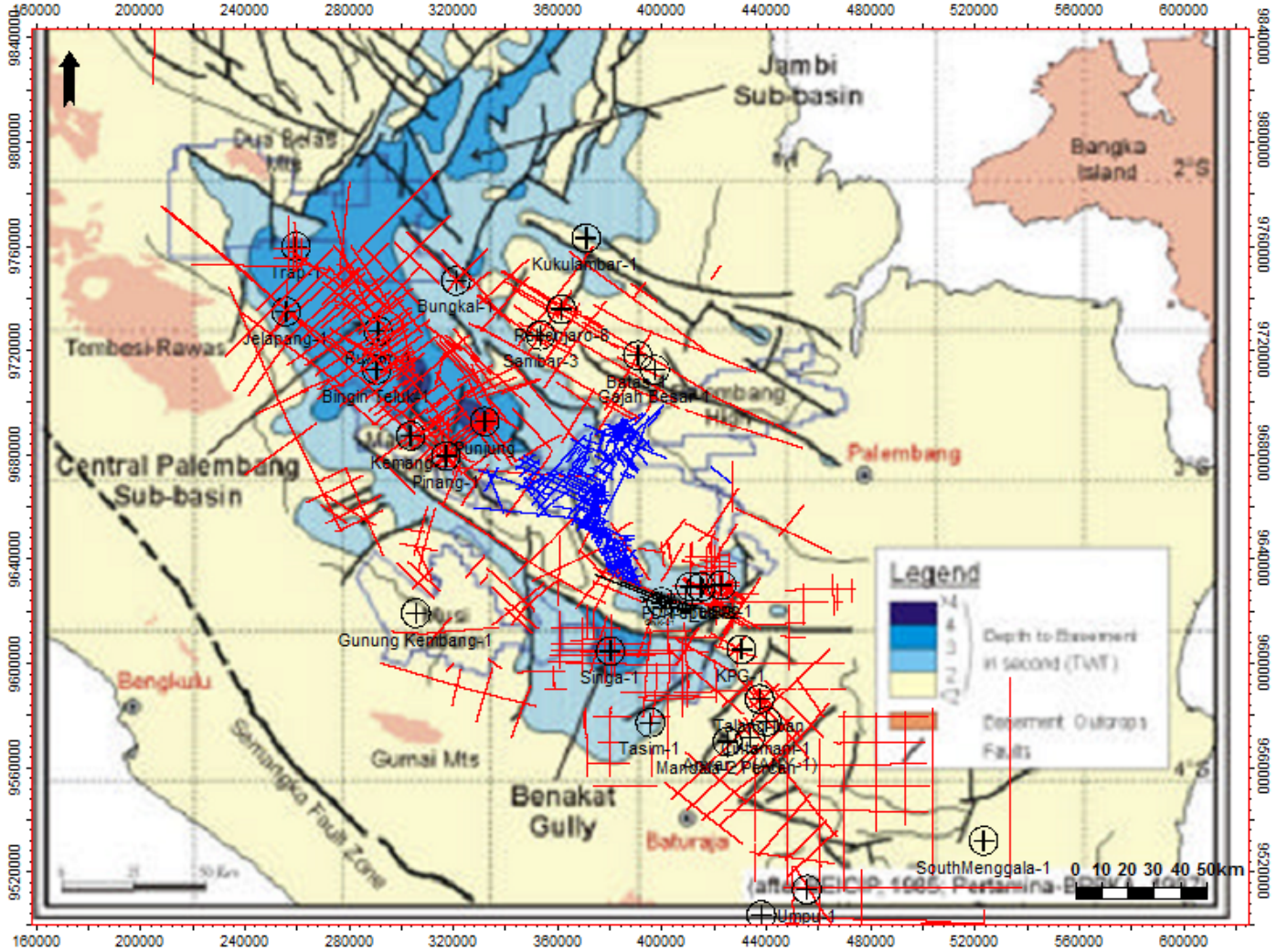
Data Aviability of South Sumatera Basin



521 Seismic Line (red line)
175 Seismic Line (blue line)
(696 line) and
26 Well

LEMIGAS used to study shale Hydrocarbon

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Resume

- The South Sumatera Basin is considered as one of Mature back arc basin in western Indonesia. Laterally an area of approximately 119,000 km2 and filled sediments with an average thickness reaches 4000-7000 meters (De Coster, 1974).
- The Tertiary half- graben and major faults of the South Sumatera Basin are oriented NE-SW, N-S and NW-SE.
- The South Sumatera Basin dynamic can be differentiated into 3 (three) tectonic mega sequences.
  - Syn-rift Megasequence (40 – 29 Ma) Lahat/Lemat Fm
  - Post Rift Megasequence (29 - 5 Ma) Talang Akar Fm
  - Syn-orogenic & Inversion Megasequence (5 Ma – Present)
- As for shale hydrocarbon exploration target is Lahat/Lemat Formation, and Talangakar Formation.
- During the Plio-Pleistocene strong compressional tectonics associated with uplifting of the volcanic arc to the west reactivated earlier structural feature and created northwest-southeast (NW-SE) trending reverse faults and basement uplift.
- Based on exploration activity, the South Sumatra Basin is most active basin. The present-day play concept in Sumatra basins has resulted in exploration of deeper, older targets and shale hydrocarbon potential in this basin is promising.

Thank You

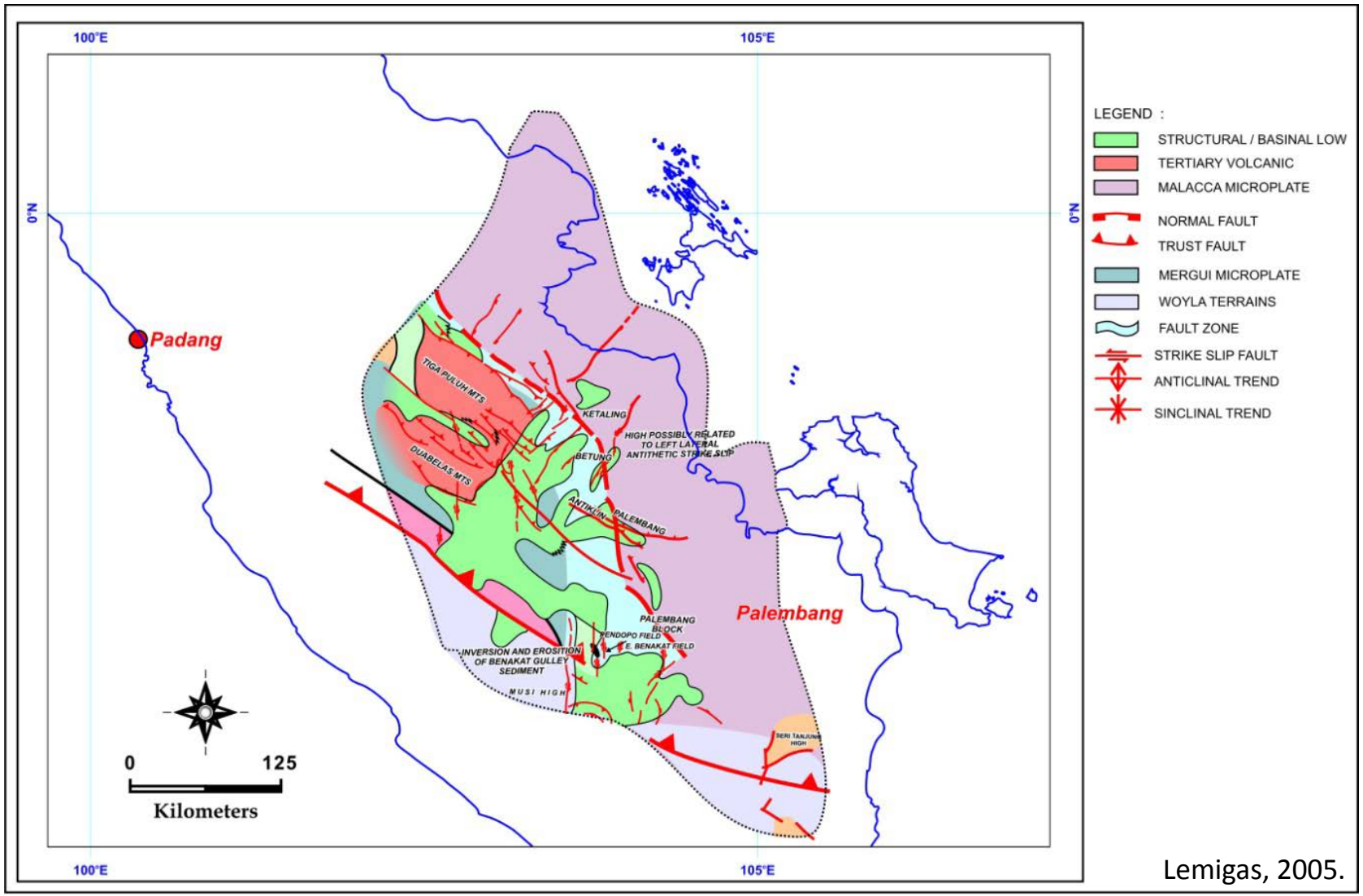
www.lemigas.esdm.go.id

BACK UP SLIDE

Indonesia Shale Hydrocarbon Potential Basin

No	Code		Basin Name	Basin Age	Tectonic/Basin Type	Area (Sq Km)	Basin Status	Formation Target SH
1	1	I-A	North Sumatera	Tertiary Basin	Rift Valley – Back Arc	118,251.040	Production Basin	Bampo, Belumai, Baong Fm.
2	11	I-A	Ombilin	Tertiary Basin	Rift Valley – Intra Mountain	27,209.670	Drilled Basin, No discovery	Sangkarewang Fm.
3	12	I-B	Central Sumatera	Tertiary Basin	Rift Valley – Back Arc	10,3256.23	Production Basin	Pematang, Telisa Fm.
4	16	I-A	South Sumetera	Tertiary Basin	Rift Valley – Back Arc	124,444.64	Production Basin	Lemat/Lahat, Talangakar Fm.
5	22	I-A	Northwest Java	Tertiary Basin	Rift Valley – Back Arc	30,351.55	Production Basin	Lower Cibulakan/ Talangakar Fm.
6	29	I-A	Northeast Java	Tertiary Basin	Rift Valley – Back Arc	116,300.24	Production Basin	Ngimbang Fm. (Eocene)
7	41	I-E	Ketungau-Mandai	Tertiary Basin	Rift Valley – Foreland	11,603.84	Undrilled Basin	Kantu Fm.
8	42	I-E	Melawi	Tertiary Basin	Rift Valley – Foreland	26,277.53	Drilled Basin, No discovery	Pendawan, Selangkai, Silat Fm.
9	46	F-H	Kutei	Tertiary Basin	Pasif Margin – Deltaic	70,596.4	Production Basin	Pamaluan, Pulubalang Fm.
10	47	F-H	Tarakan	Tertiary Basin	Pasif Margin – Deltaic	54,141.18	Production Basin	Sembakung, Meliat, Tabul Fm
11	48	I-E	Barito	Tertiary Basin	Rift Valley – Foreland	51,497.52	Production Basin	Tanjung Fm.
12	69	I	Sengkang	Tertiary Basin	Rift Valley	16,121.86	Production Basin	Toraja/Malawa Fm.
13	110	F-E	Bintuni	Pratertiary - Tertiary Basin	Rift Valley – Foreland	66,831.13	Production Basin	Ainim, Tipuma Fm.
14	122	F-E	Akimeugah	Pratertiary - Tertiary Basin	Rift Valley – Foreland	82,546.31	Drilled Basin, No discovery	Aiduna, Tipuma, Kembelangan Fm.

Regional Tectonic Element



Lemigas, 2005.

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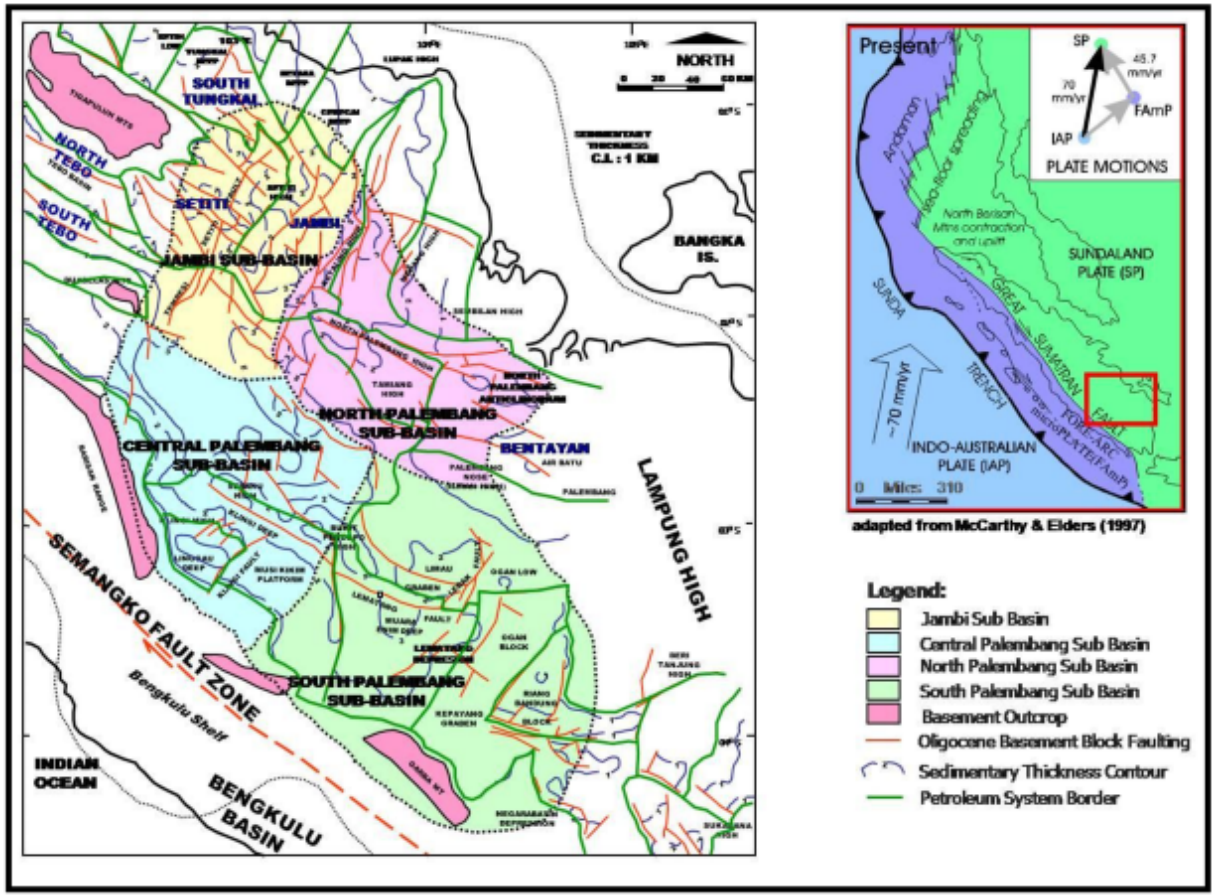
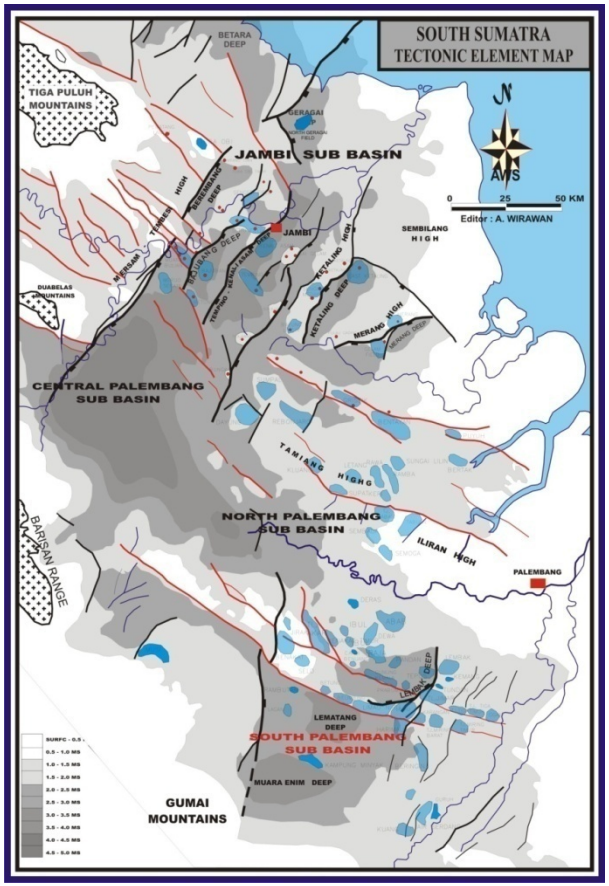
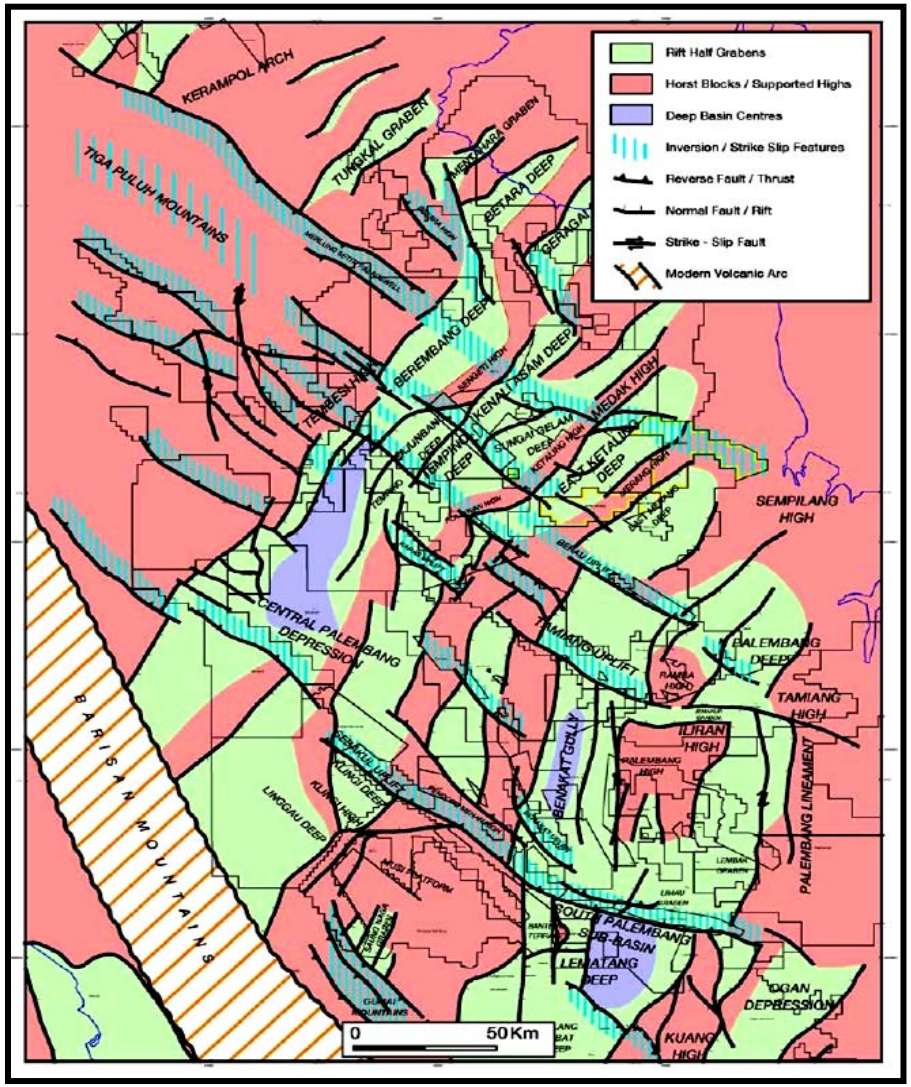
Regional Tectonic





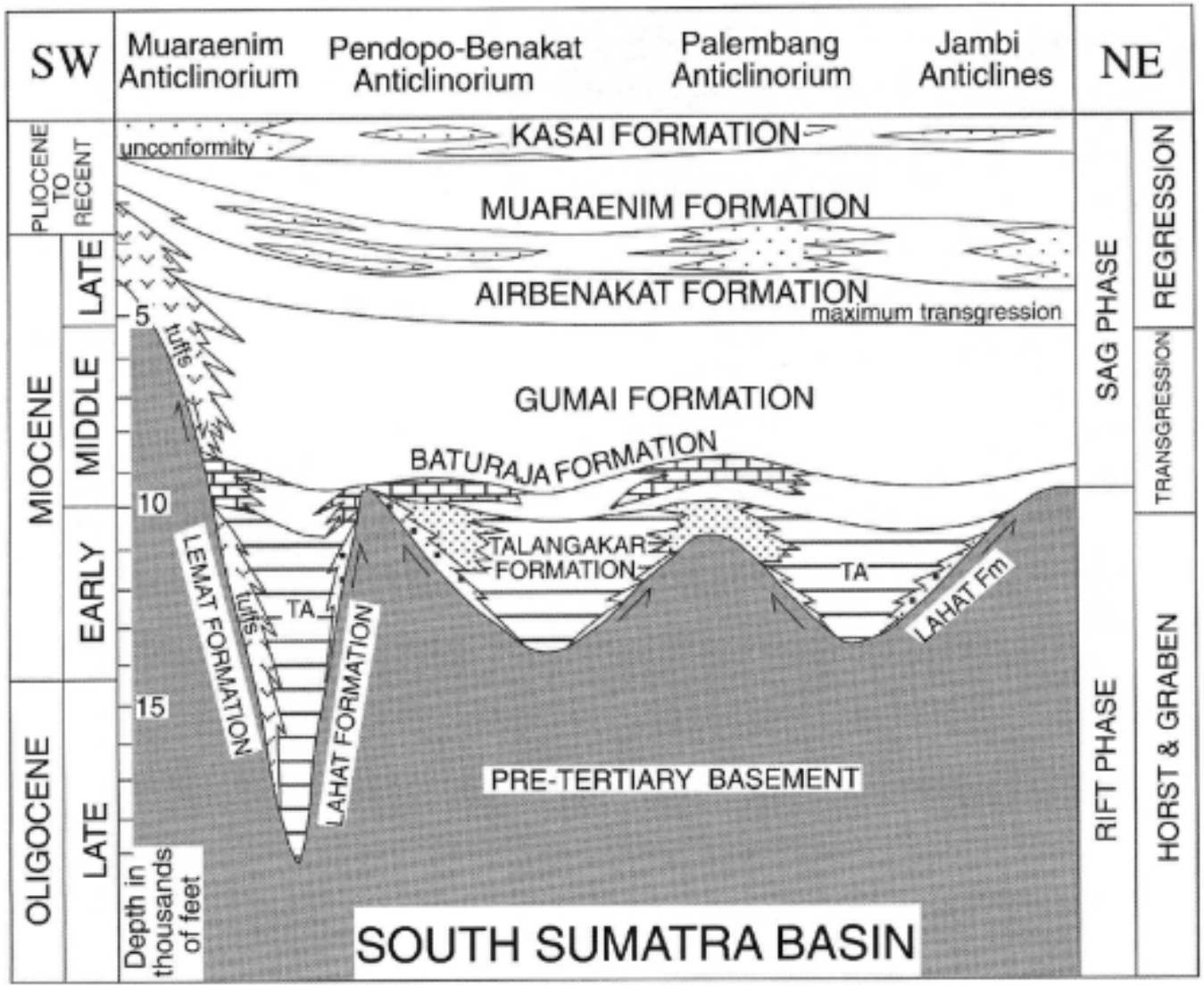
Structural Element



- The Tertiary half- graben and major faults of the South Sumatera Basin are oriented NW-SE, SE-NW and N-S
- Numerous depocentre bounded by major faults
- Lahat/Lemat lacustrine shale and Talangakar shallow marine and deltaic coaly shale are the mature source rock
- Oil and gas are produced from the onshore South Sumatera Basin province.
- Shale from Lahat and Talangakar Formation were widely accepted as general source rock within province
- Lahat/Lemat and Talangakar source rock reservoir therefore are the main target.

(David G., 2005)

Stratigraphy



Diagrammatic cross-section to illustrate the tectonostratigraphic development of the South Sumatra Basin modified after Kingston (1988)..

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SHALE FORMATION

Lemat-Lahat Formation

The Lemat Formation was formed during rifting phase and associated to extension tectonic, while Lahat Formation was formed in Pre-rift phase. The Lemat Formation (Benakat Shale) is composed of a series fining upward clastic sediments. They consist of multi fragments conglomerate, sandstones and shales which are deposited in land (alluvial) as fluvial to deltaic.

De Coster (1974) in Gafoer, Cobrie dan Purnomo (1986) called the Lahat Formation as Lemat Formation and divided into two parts, they are granite wash at the lower part, and Benakat Member to the upper part.

The Lemat Formation is unconformable overlays the Kikim Formation, and exposed in Cawang and Saling rivers. It consists of interbedded conglomeratic sandstones, sandstones, and intercalation of blackish claystones. These sequence showing fining and thinning upward succession. The Lemat Formation in Gumai Mountain can be differentiates into two rock units, that are tuffaceous shale unit and conglomeratic sandstone unit.

The tuffaceous shale unit represents lower part of Lemat Formation as crop out in Cawang River. This unit consists of interbedded reddish claystones, dark claystones, tuffaceous shales with intercalation of thin parallel laminated of fine sandstones. It measuring thickness is 320 m. The reddish clay at some places was indicating the unconformity to above succession.

The black claystones in Cawang River lies below red claystone with 10 – 30 m thick, while sandy claystones (shale) has 0.5 – 2 m thick.

The conglomeratic sandstones unit that crop out in Saling River shows fining upward. The lower part of this unit is consists of sandy conglomerates, massive sandstones, and 2 – 8 m thick of claystone intercalation.

Geochemical analysis of some hand specimens indicates TOC (0.5 – 1.02) % with T Max 442o C (mature source rock).

SHALE FORMATION

Talang Akar Formation

The Talangakar Formation consists of conglomeratic sandstone, fine – coarse sandstone, siltstone, claystone, and shale, with some coals intercalation. This unit was deposited during late period of syn-rift and early post-rift which was part of tectonic evolution of South Sumatera Basin. The lithologies of lower part of Talangakar Formation associated to fluvio-deltaic - shallow marine environment. While in the lower part of early Miocene, the environment and facies were changes to deltaic, shallow to deep marine indicating transgression event in South Sumatera Basin. The deposition of the upper part of Talangakar Formation followed by volcanic activity, and extensive marine environment. Those indicated by volcanic clastic and calcareous clastic sediments as exposed in Lahat area. Based on lithology composition, the Talangakar Formation can be divided into two members:

Gritsand Member (GRM): consist of coarse clastic sediments as conglomeratic sandstones, quartz sandstones, and shales with coals intercalation. Sedimentary structures are bedded, cross bedded and parallel lamination.

Transitional Member (TRM): consist of fine to medium clastic sediments as interbedded sandstones, shales, and dark grey silts with intercalation of coals and bituminous clay, glauconite minerals are abundance. It was deposited in transition to shallow marine during early Miocene.

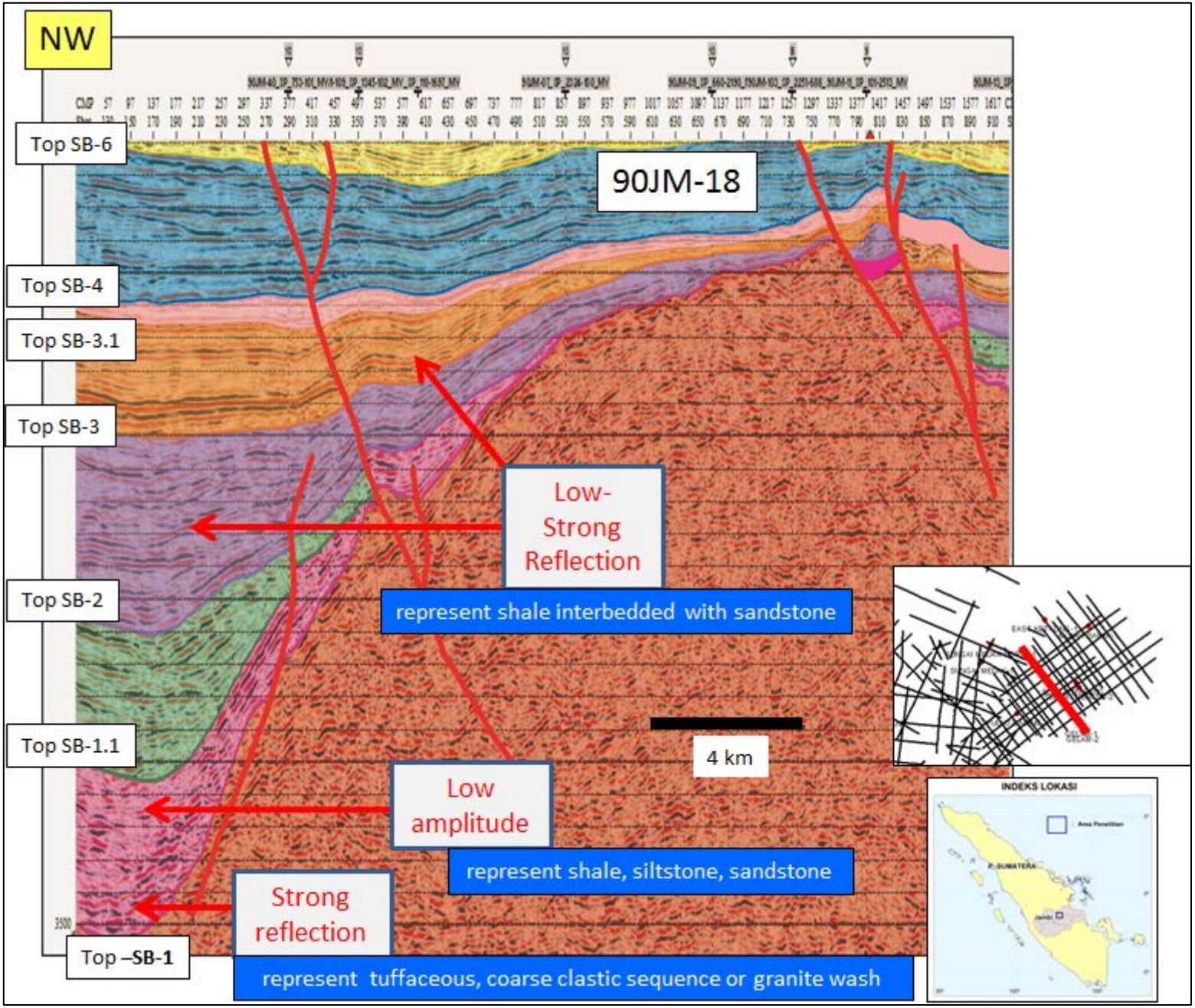
The Talangakar Formation is gradually overlain by reef limestone and sandy limestone of Baturaja Formation as open marine environment.

Shale Unit

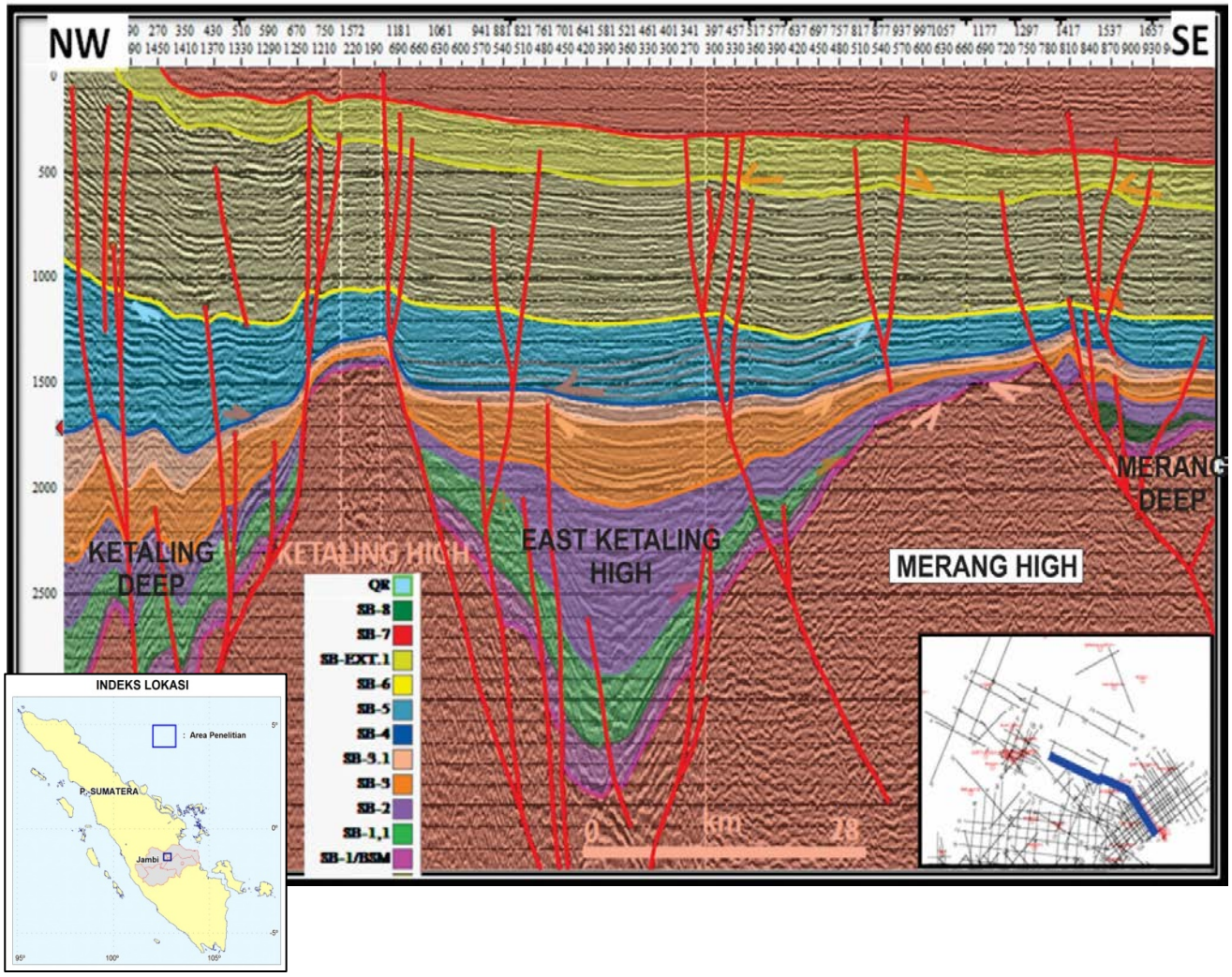
Shale Unit represents upper Talangakar Formation, and called as Transitional Mamber (TRM) 150 – 590 m thick, which was deposited in marine environment. This unit is exposed in Gumai Mountain consist of interbedded thin claystones, sandy claystones, and fine sandstones with calcareous sandstone nodules, and thin calcarenite limestone intercalation. It shows fining upward sequence with bed thickness (15 – 40) cm, parallel lamination, burrowed, and lenses/ lenticular sand.

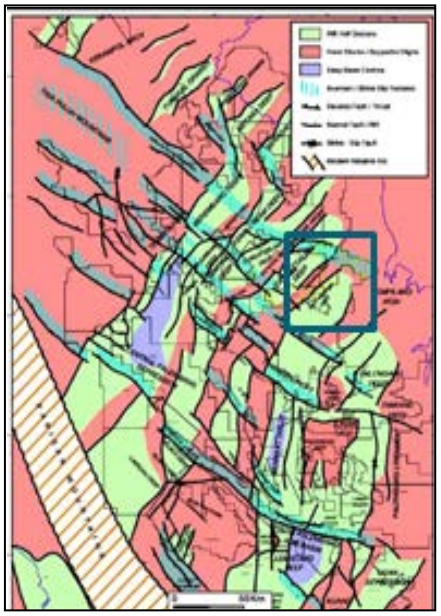
The claystone is dark grey-black in color, calcareous, massive, often containing molusc fragments, thinning upward with thickness (15 – 50) meters. The sandstone (10 – 15) cm, greenish grey, fine to medium grain, calcareous within calcareous sandstone nodules, massive, well sorted, containing molusc fragments, and has parallel lamination. Calcarenite (10 – 15 cm, brownish white, massive, rich of molusc fossil as intercalation in claystone,.

Biostratigraphy analysis of CR-19 and SR-22 samples, indicate not older than early Miocene (not older than NN1) and deposited in terresterial environment, transition to shallow marine.

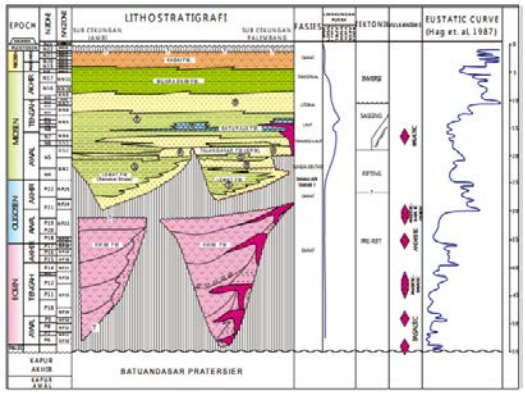

NW
90JM-18
Top SB-6
Top SB-4
Top SB-3.1
Top SB-3
Top SB-2
Top SB-1.1
Top –SB-1
Low-Strong Reflection
represent shale interbedded with sandstone
Low amplitude
represent shale, siltstone, sandstone
Strong reflection
represent tuffaceous, coarse clastic sequence or granite wash
4 km
INDEKS LOKASI
P. SUMATERA

COMPOSITE SEISMIC LINE PAST THROUGH DEEP AREA (*MERANG DEEP, EAST KETALING DAN KETALING*)





Structural Element Map of South Sumatera Basin



Stratigraphy Column South Sumatera Basin

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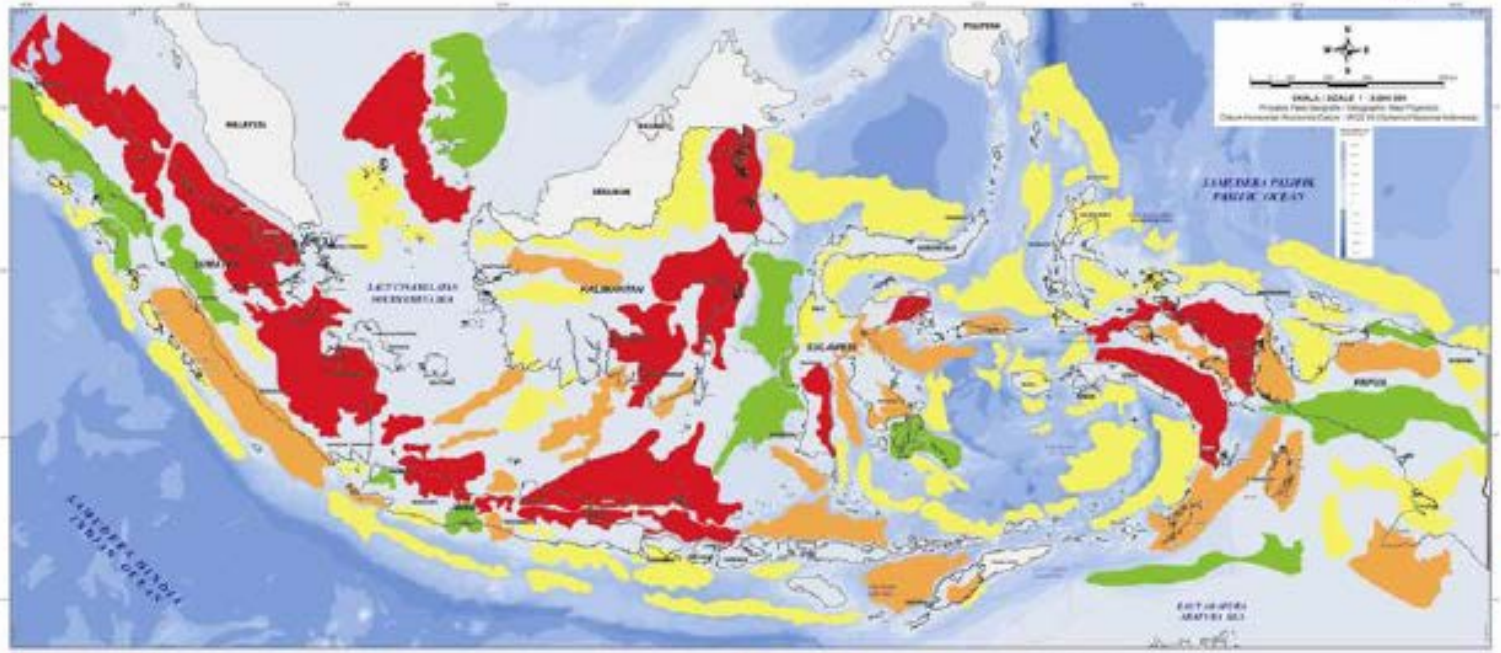
PETA CEKUNGAN SEDIMEN INDONESIA
BERDASARKAN DATA GAYA BERAT DAN GEOLOGI
SEDIMENTARY BASIN MAP OF INDONESIA
BASED ON GRAVITY AND GEOLOGICAL DATA



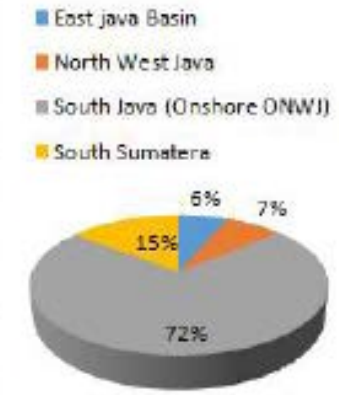
A. CEKUNGAN BERPRODUKSI MINYAK/GAS

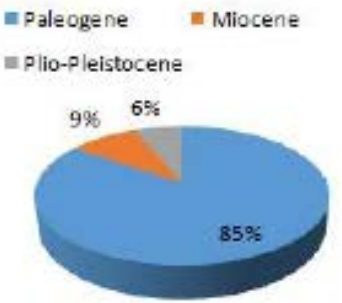
B. CEKUNGAN SUDAH DIBOR ADA PENEMUAN MINYAK/GAS

C. CEKUNGAN SUDAH DIBOR BELUM ADA PENEMUAN MINYAK/GAS

D. CEKUNGAN BELUM DIBOR

4,7%
110 / 2353
(WM, 2013)





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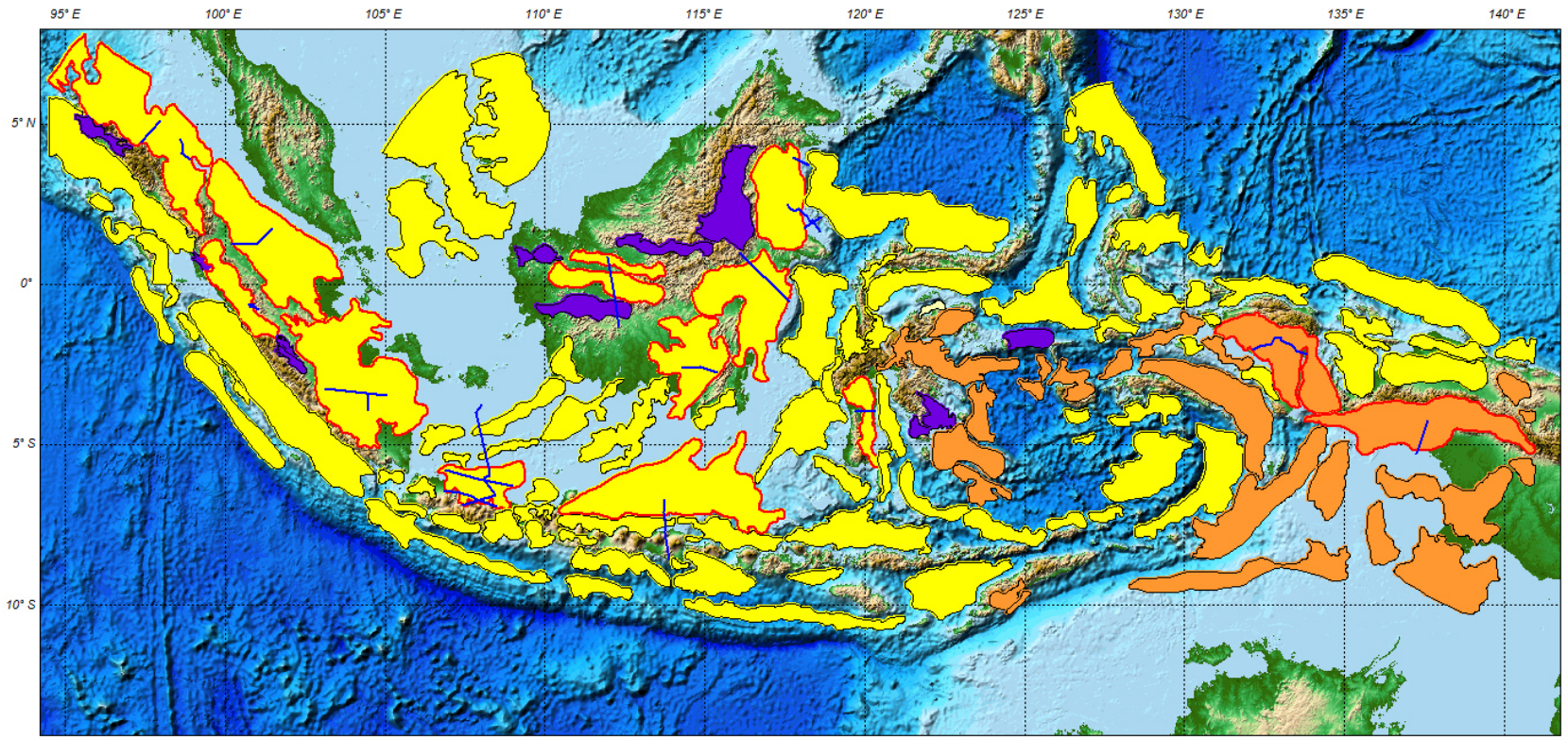
INDONESIA SEDIMENTARY BASIN AND SHALE HYDROCARBON POTENTIAL BASIN



LEGENDA:

- : Tertiary Basin
- : Tertiary - Pre-Tertiary Basin
- : Pre-Tertiary Basin
- : Shale Hydrocarbon Potentian Basin
- : Geology Cross Section Line

SHALE OUTCROP PHOTO