Fractures Identification and Reservoir Characterization of Gas Carbonate Reservoir at Merbau Field, South Palembang Basin, Sumatra, Indonesia*

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Abstract

Merbau gas field is situated on the southern part of South Palembang Basin at Sumatra Island, Indonesia. The field was discovered in 1975, but the delineation wells were drilled in 1980's. Recently, to support the high gas energy demand in vast growing economic area of Java and Sumatra, the South Sumatra Gas Project developed the field to fulfill commitment of 300 MMSCFD supply to energy demand of industry.

The gas project in the Merbau field has drilled 10 (ten) development wells already with a significant increase the calculated reserves. Application of borehole images data on two wells (MBU#6 and MBU#BA3) clearly show that fractures were developed and influenced the capacity of gas production of each well. The carbonate reservoirs in the field are heterogeneous laterally and vertically. Fault intensity also produced several fractures that enhanced the permeability and productivity of gas, such as at MBU-4A and MBU-8. A further detailed sedimentary and structural study of borehole image data is thus required, including detailed facies and secondary porosity identification and structural controls of carbonate reservoir layers in the field.

The determination of fractures density and orientation, porosity distribution of carbonate facies, altogether with seismic inversion and interpretation, were proved as the main tools to help the next development well locations and reservoir zones.

FRACTURES IDENTIFICATION AND RESERVOIR CHARACTERIZATION OF GAS CARBONATE RESERVOIR AT MERBAU FIELD, SOUTH PALEMBANG BASIN, SUMATRA, INDONESIA

Presented at AAPG San Antonio 2008

San Antonio, TX, USA

By

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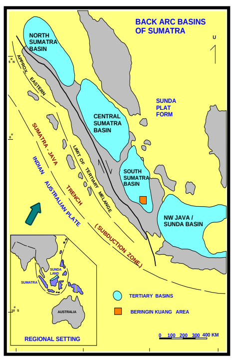
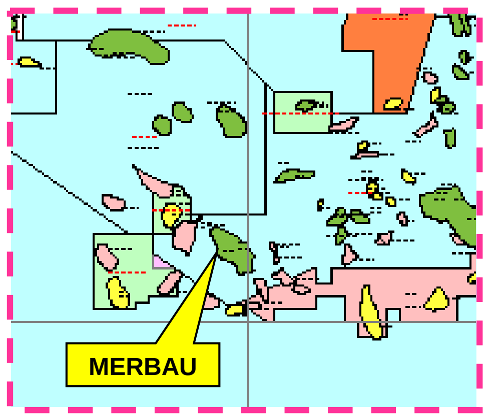
OUTLINE

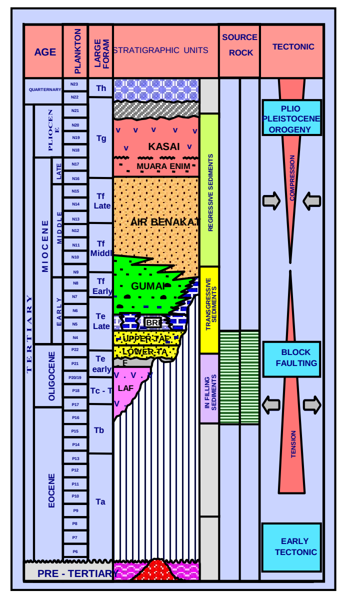
- INTRODUCTION
  - Regional Setting
  - Gas Project in South Sumatera
- THEORY
  - Borehole Images
  - Seismic Inversion
- RESERVOIR CHARACTERIZATON
  - Application
  - Results
- CONCLUSION

INTRODUCTION

- **STUDY AREA**
  - **SOUTH SUMATRA**
  - **MERBAU STRCTURE**







STRATIGRAPHY IS COMPRISED OF :

- **F. MUARA ENIM (MEF)**
- **F. AIR BENAKAT (ABF)**
- **F. GUMAI (GUF)**
- **F. BATU RAJA (BRF)**
- **F. TALANG AKAR (TAF)**
- **F. LAHAT (LAF)**
- **BASEMENT**

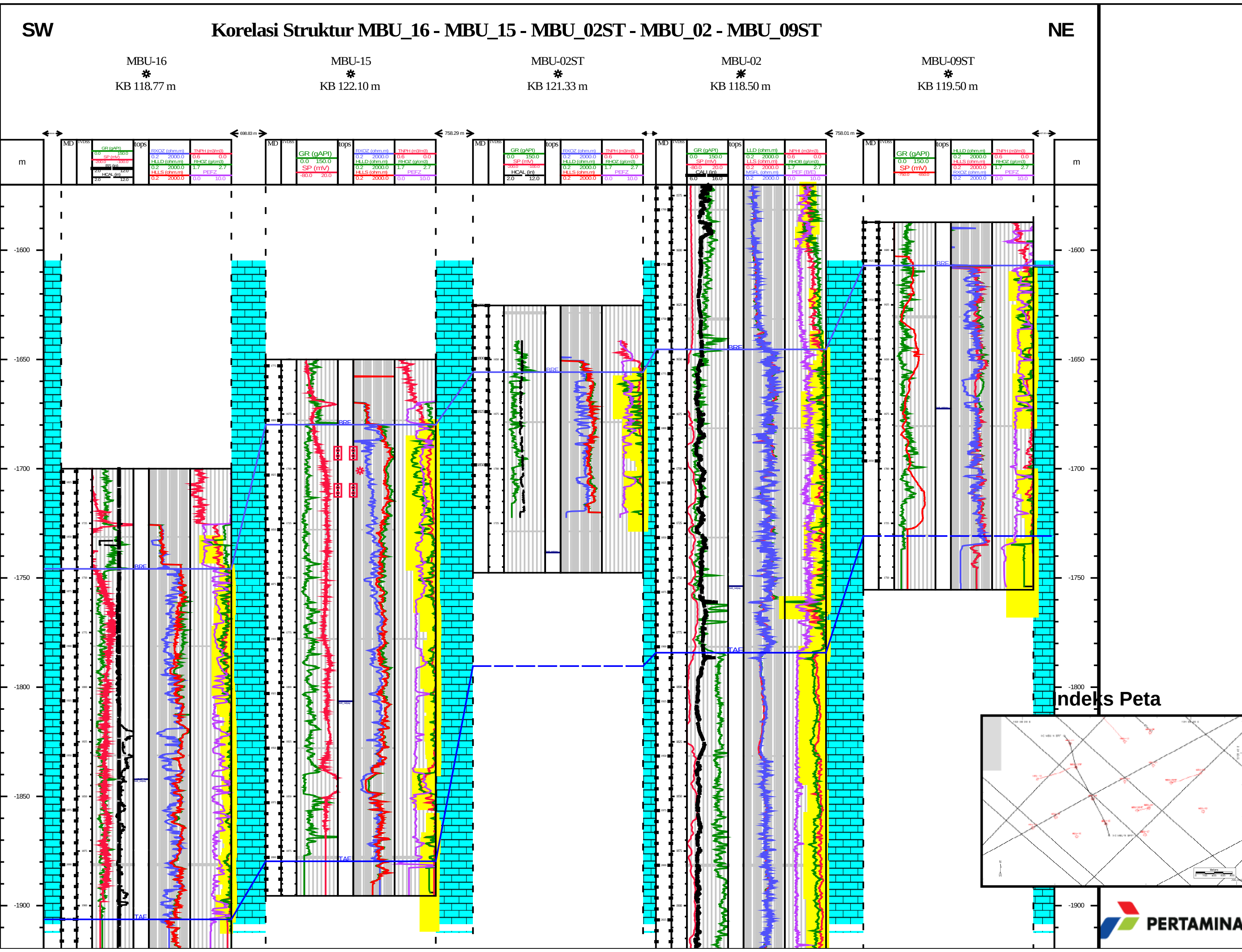
MAP LOCATION AND STRATIGRAPHY OF STUDY AREA IN SOUTH SUMATRA

SYSTEM		SERIES		STRATIGRAPHY	MAIN LITHOLOGY	DEP.ENVIRONMENT	TECTONIC SUMMARY
TERTIARY	NEOGENE	Plio-Pleis.		KASAI FORMATION	tuff	FLUVIAL	Primary traps formed
		Miocene	Late	MUARA ENIM FORMATION	shales, coal	DELTAIC-SHALLOW MARINE	Widespread compression
			Middle	AIR BENAKAT FORMATION	shales	MARGINAL-NEARSHORE	Basin sag stage
				GUMAI FORMATION	shales, calc. shales	DEEP MARINE	
			Early	**BATURAJA FORMATION**	**limestones**	**SHALLOW MARINE**	
				PENDOPO SHALE	shales	DELTAIC	
				TALANGAKAR FORMATION	shales, sandstones	DELTAIC	Late graben fill
	PALEOG.	Oligocene	Late	BENAKAT SHALE	shales	FLUVIAL-LACUSTRINE	Graben fill & localized uplift
			Early	LAHAT FORMATION	shales, volcanics	FLUVIAL-LACUSTRINE	Rifting begins
PRE-TERT.		Eocene		PRE TERTIARY BASEMENT	igneous rocks		

Simplified stratigraphic column of the study area (modified from Sitompul, N, et al., 1992, and Rashid, H., et al., 199

GEOLOGY - STRATIGRAPHY

- **CLASTIC AND NONCLASTIC MID MIOCENE**
- **CUTTINGS FORMASI BATU RAJA (BRF)**
  - **TWO PARTS OF CARBONATE :**
    - **UPPER PART**
      - » WHITE, CHALKY, VUGGY, PERMEABLE
    - **LOWER PART**
      - » LT GREY, CRYSTALINE, INTERCRYSTALINE, TIGHT
  - **AVERAGE THICKNESS BRF :**
      - » MERBAU : 100 – 200 METER
      - » WEST MUSI : 45 – 100 METER
      - » POTENTIAL RESERVOIR 50 – 100 METER
- **DATA LOGGING OF BRF**
  - Rt of F. Batu Raja has > 100 Ohm m
  - GR 30 – 45 unit
  - High Density and Low Porosity in Lower Part (Espec. MERBAU)


SW
Korelasi Struktur MBU_16 - MBU_15 - MBU_02ST - MBU_02 - MBU_09ST
NE
MBU-16
KB 118.77 m
MBU-15
KB 122.10 m
MBU-02ST
KB 121.33 m
MBU-02
KB 118.50 m
MBU-09ST
KB 119.50 m
BRF
TAF
-1600
-1650
-1700
-1750
-1800
-1850
-1900
Indeks Peta
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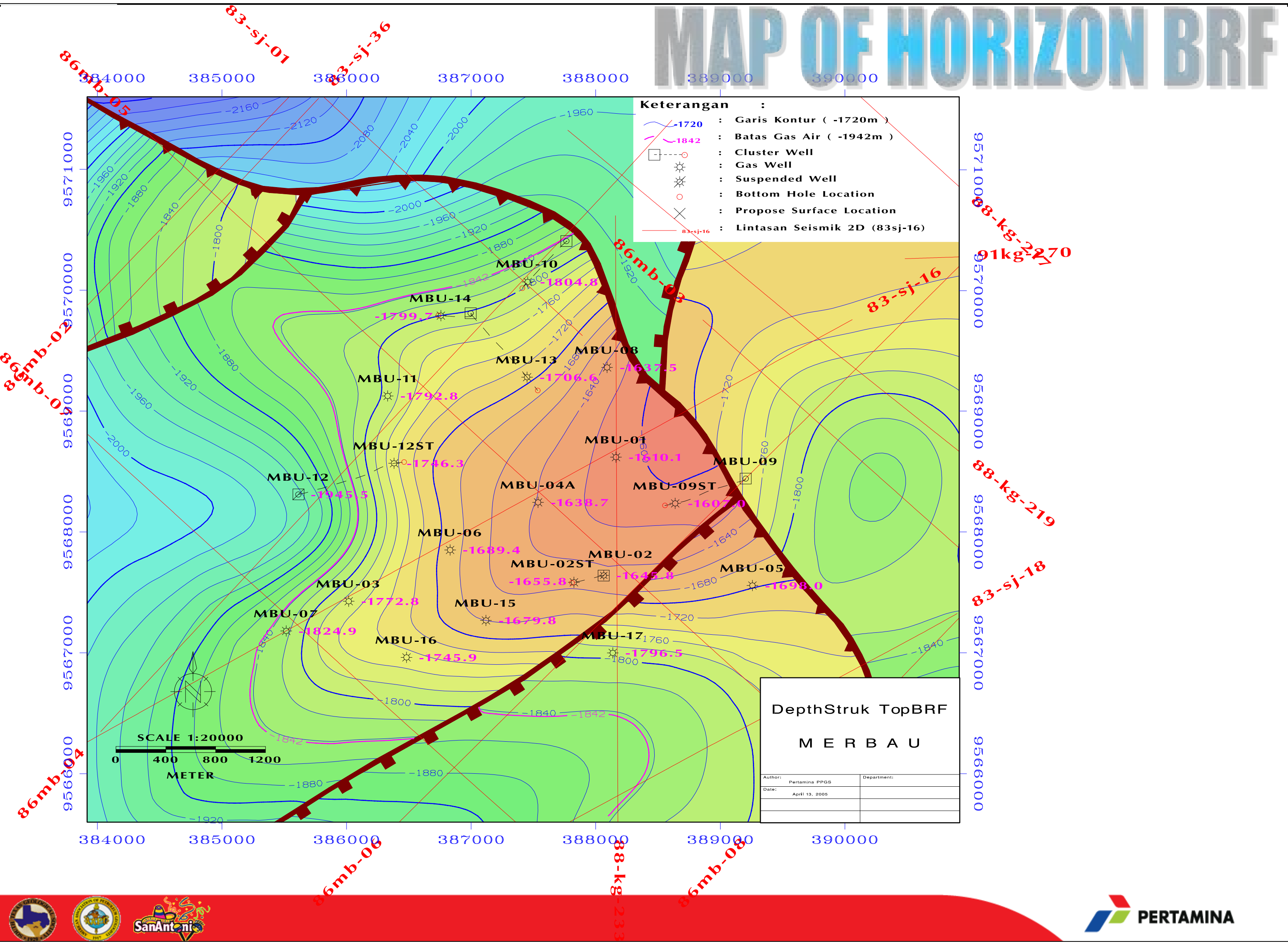
GEOLOGY - LITHOLOGY

- **GENERAL LATERAL DISTRIBUTION OF BATU RAJA FORMATION (BRF) MERBAU STRUCTURES**
    - **SOUTHEAST – NORTHWEST ANTICLINE ORIENTED (MERBAU FIELD)**

- **LANDWARD PROGRADING EASTWARD**

MAP OF HORIZON BRF



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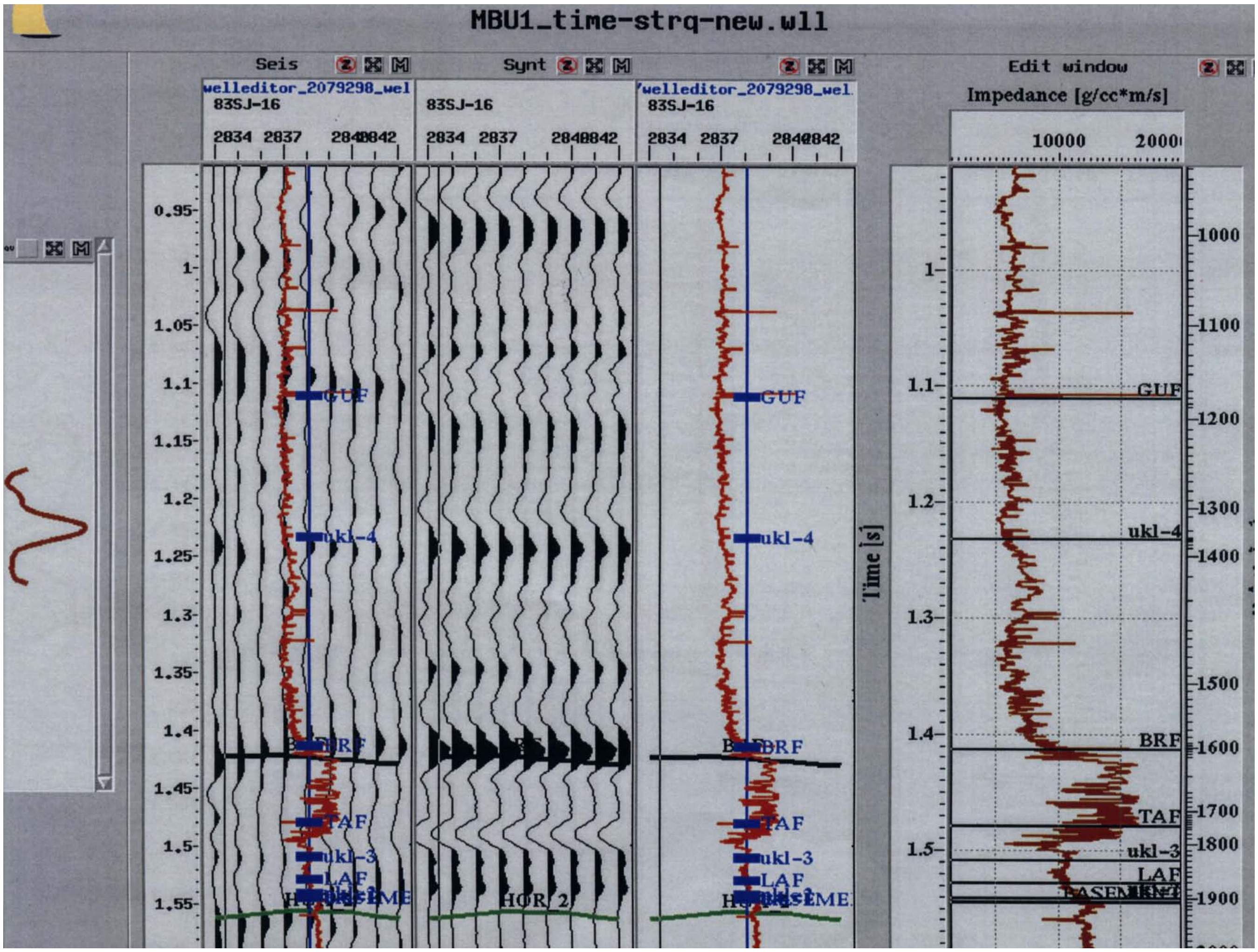
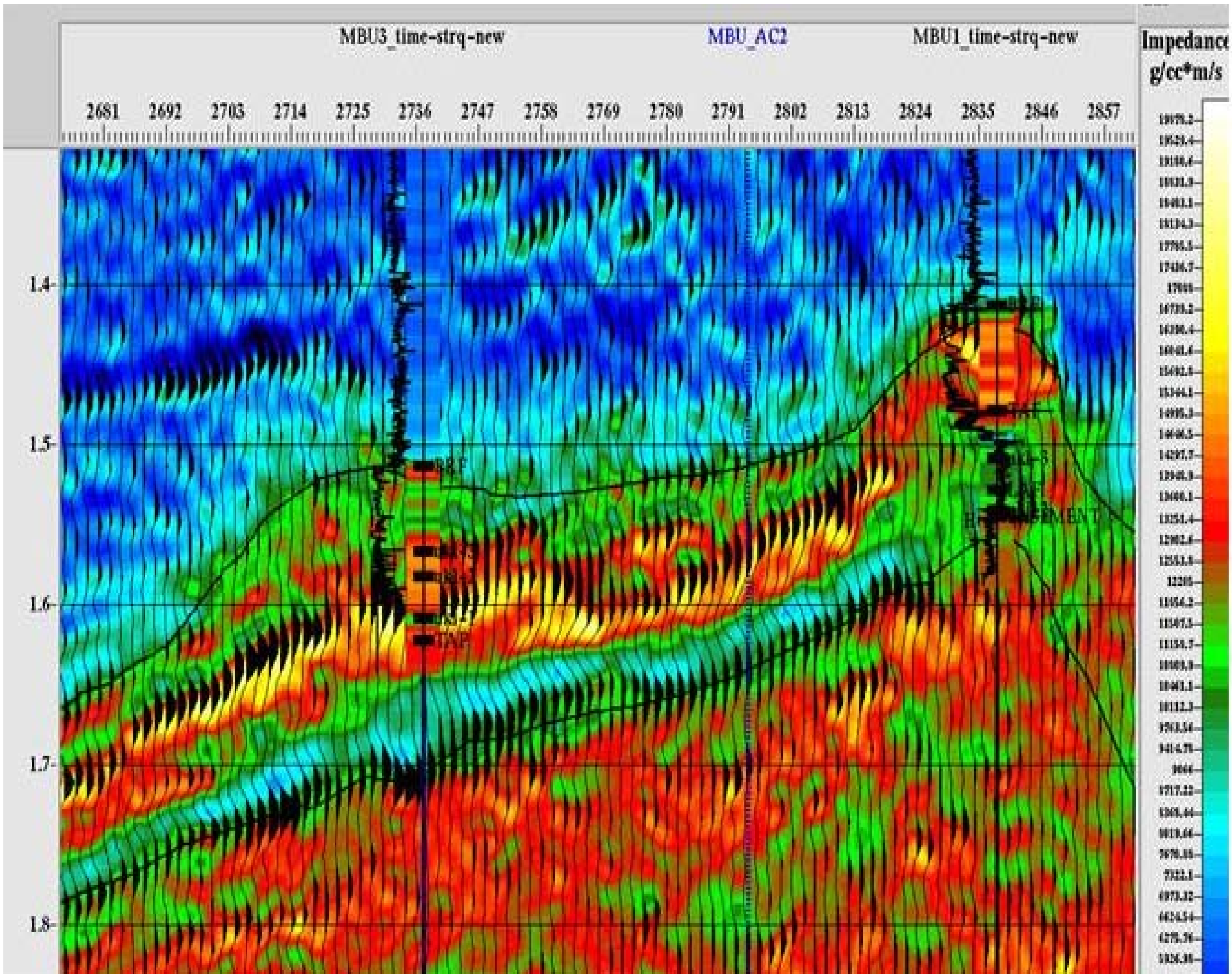


Well seismic tie through the objective of Baturaja Fm

Notes by Presenter

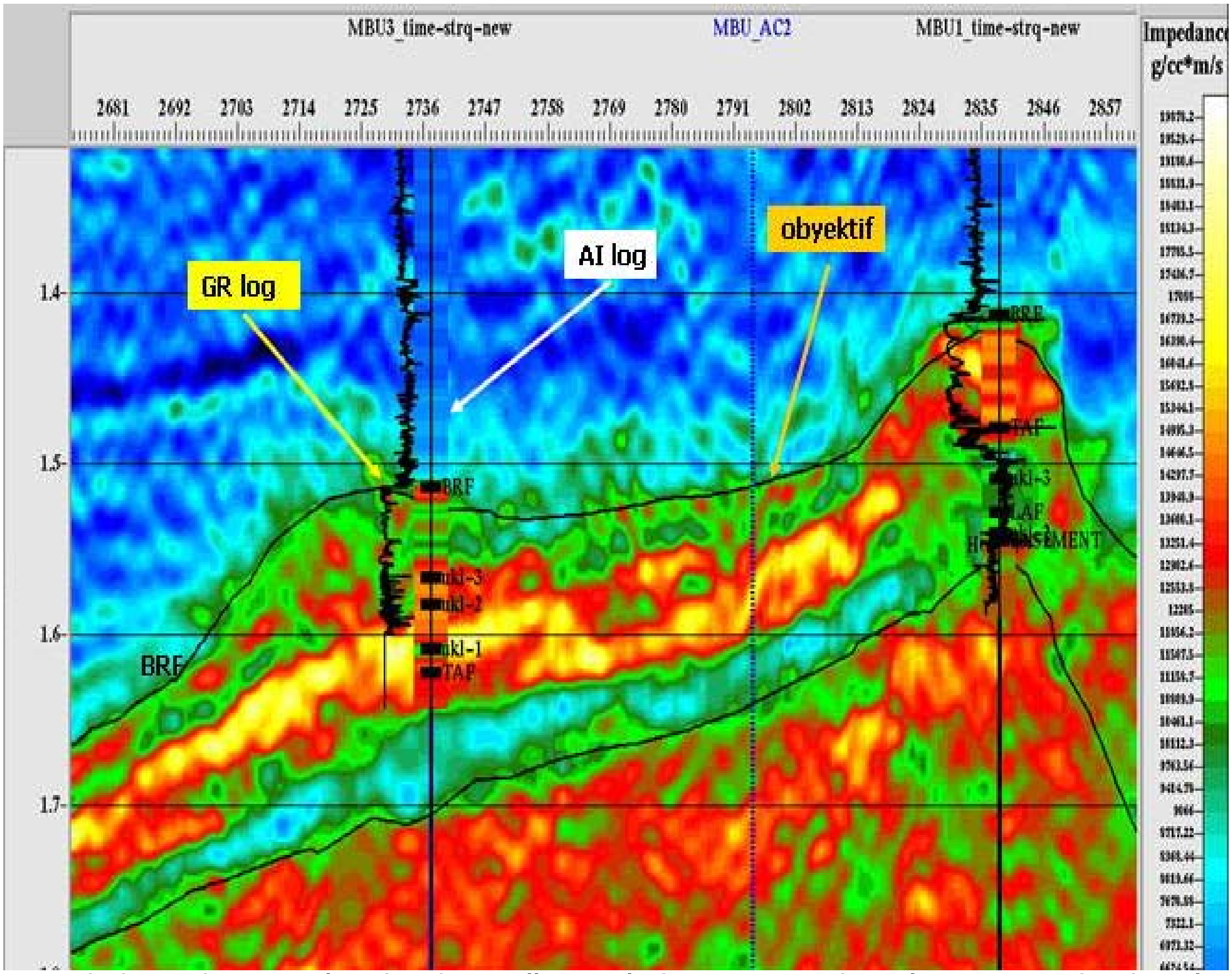
Shown is match between real data (second panel from the left) and synthetic seismic (third from left) using wavelet (first panel) from line 83SJ-16 through well MBU-01. Gas zone found in carbonate reservoir, Baturaja Formation.



Overlaying seismic data with Acoustic Impedance section which proved that inversion modeling can be a powerful tool to refine the horizon interpretation

Notes by Presenter

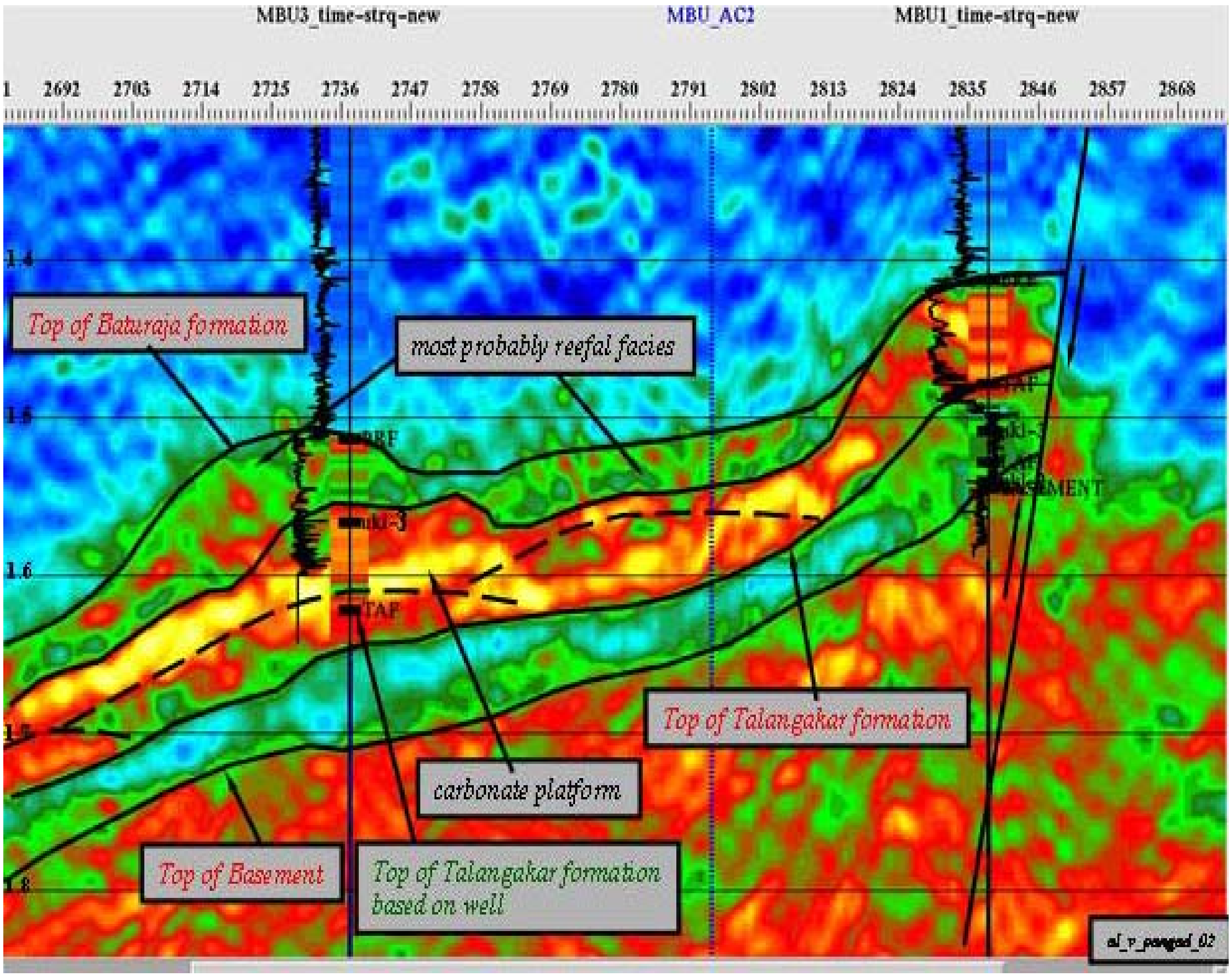
Top of Baturaja Formation does not appear to be significant using the seismic amplitude itself, but it is more clear when the final AI data is incorporated.



High acoustic impedance value (red to yellow color) corresponds to lower porosity than low acoustic impedance (light blue to green)

Notes by Presenter

From Acoustic Impedance section (Final AI) through key line 83SJ-16 and constrained by MBU-03 and MBU-01 well for Baturaja carbonate reservoir. Those reservoirs can be distinguished using inversion modeling.

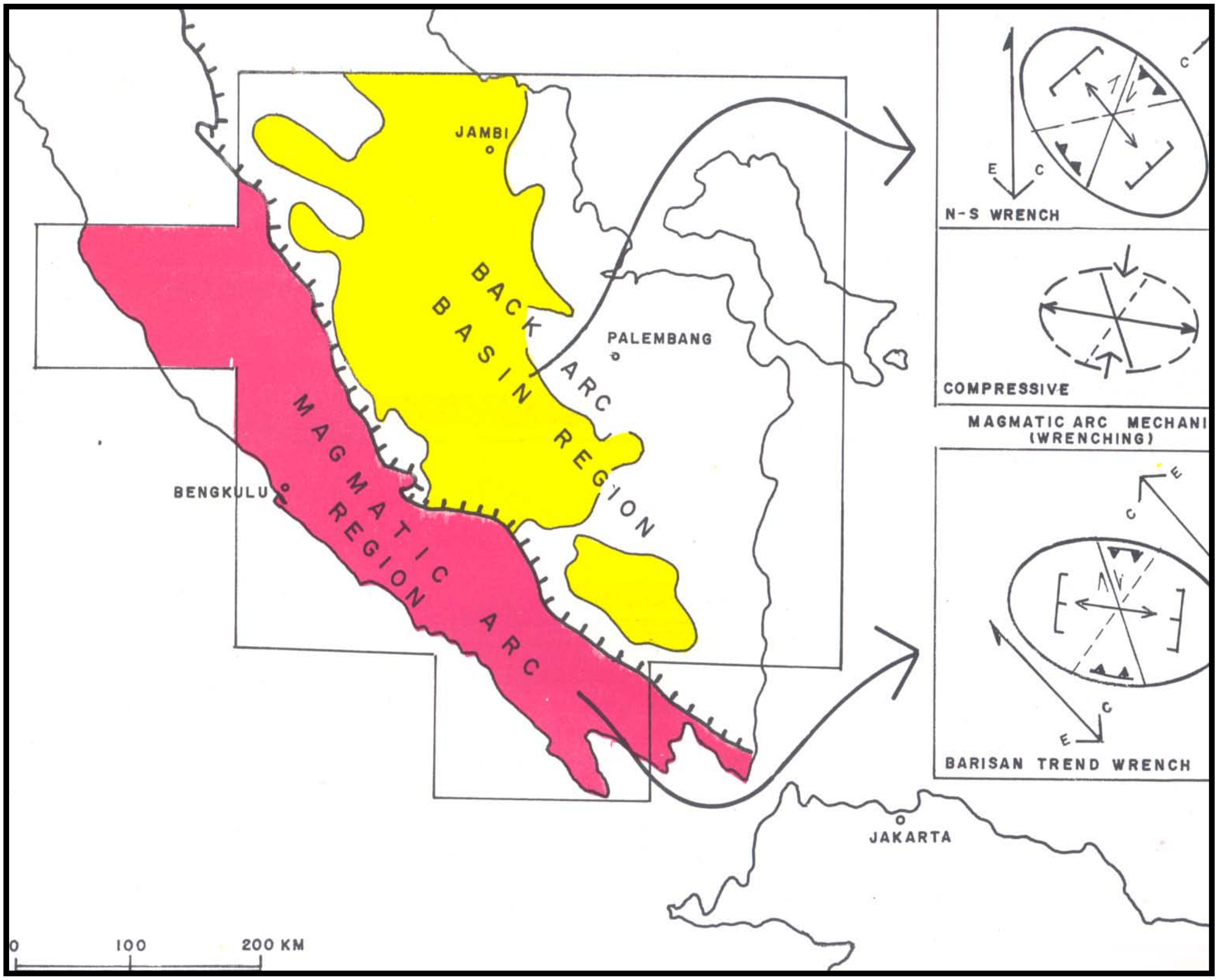


Interpretation of facies change in Baturaja carbonate reservoir can be distinguished by acoustic impedance data

Notes by Presenter

Reefal facies at the upper part is represented by low acoustic impedance value (light blue to green color) and carbonate platform at the lower part is identified by lateral distribution of high acoustic impedance value (red to yellow color).

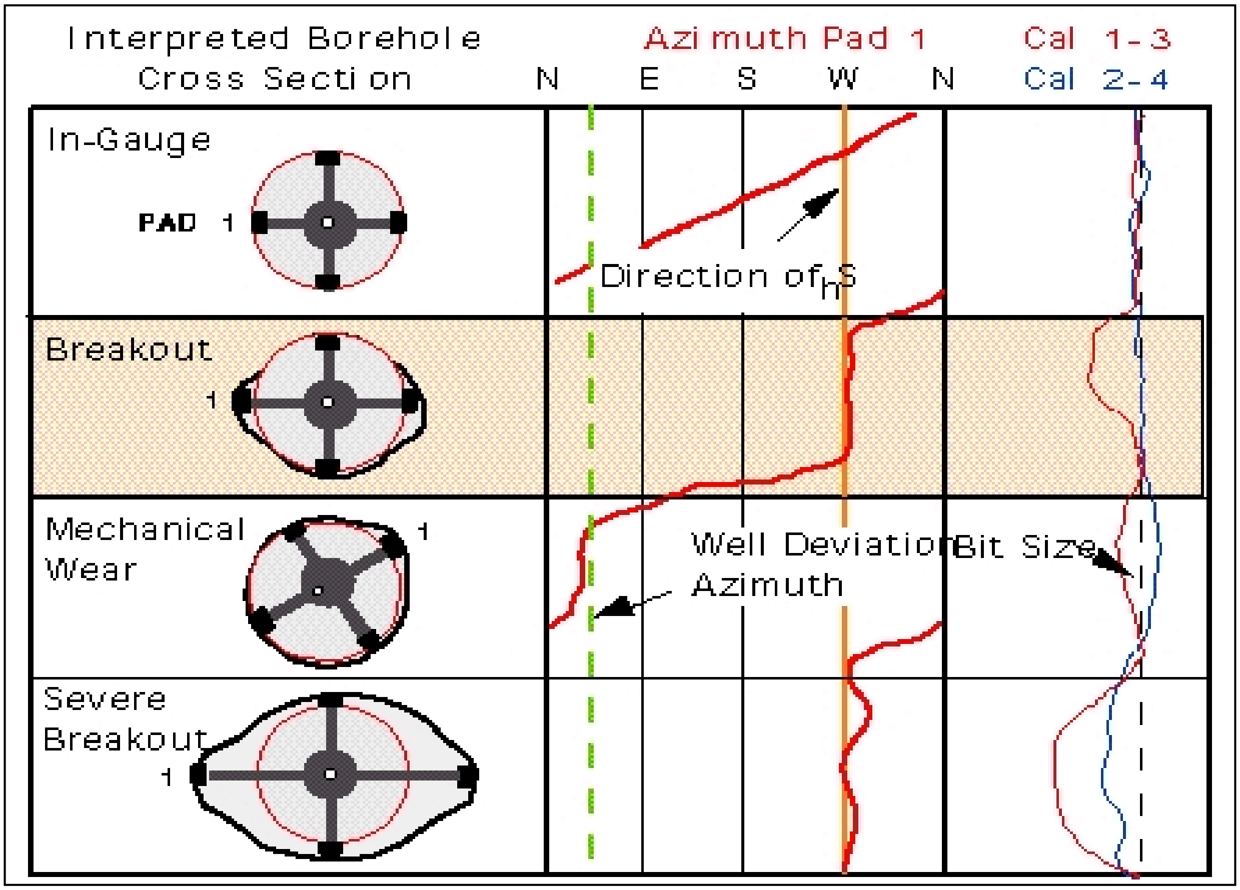
1



Structural regime and style in the back arc and magmatic arc in South Sumatra basin

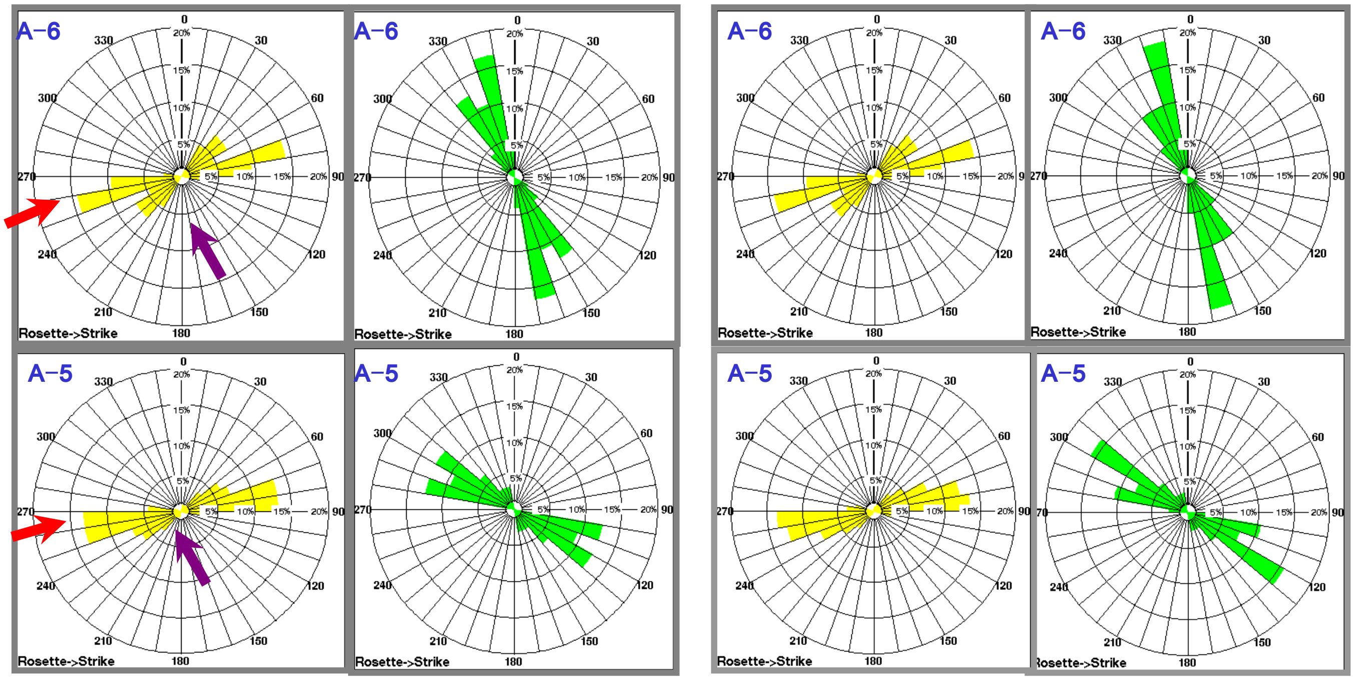
Notes by Presenter

The study area is within the back arc basin in which two ellipsoid models apply in this region (A and B) for Mid-Miocene up to Recent (after Pulonggono, et al., 1992).



Cross sectional schematics of possible wellbore conditions and their appearance on the four dipmeter caliper log

Notes by Presenter
The Caliban computation is based on these conditions.



induced fracture

breakout

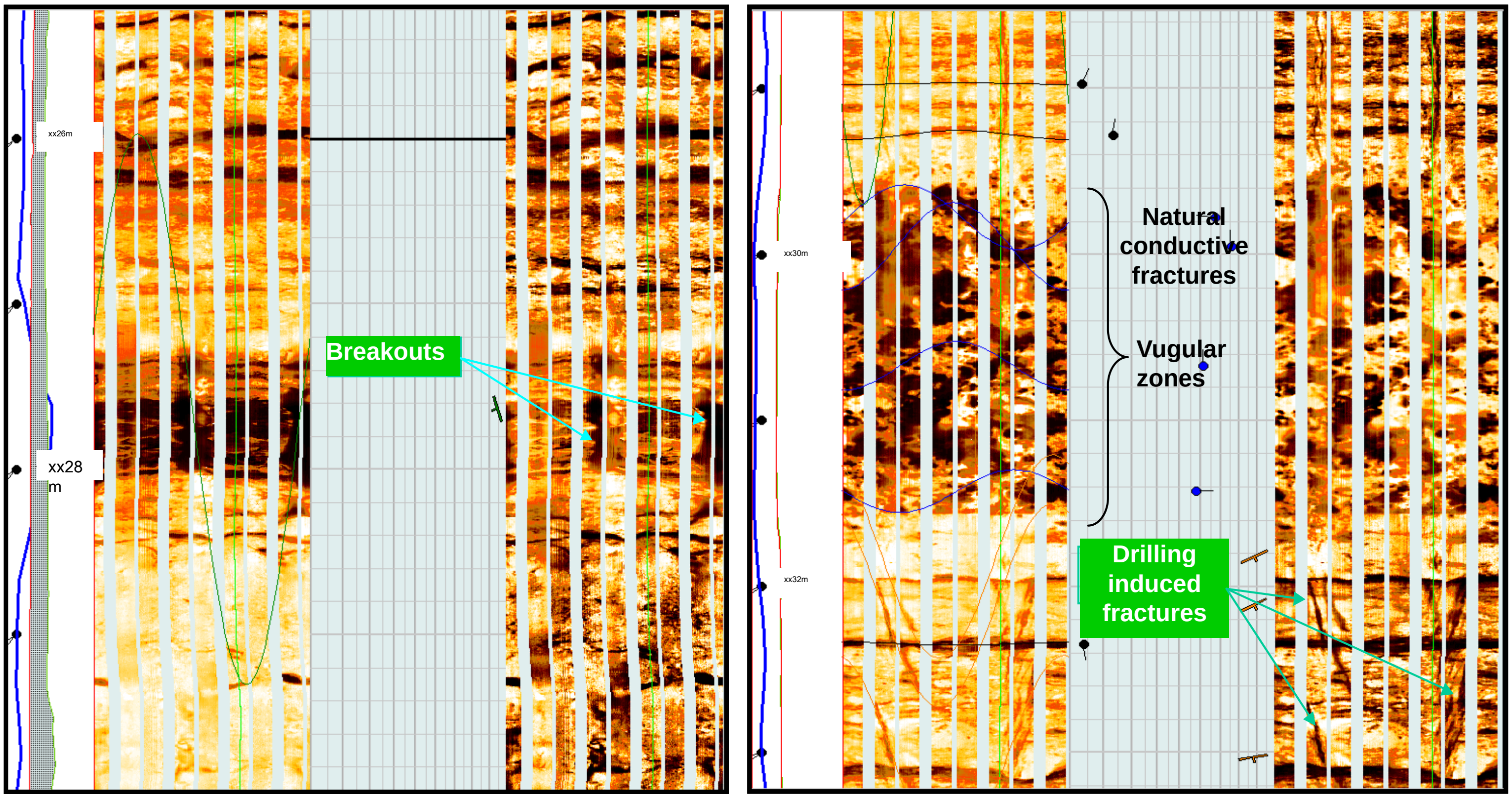
max. horizontal stress

min. horizontal stress

The dominant orientations of breakouts and drilling induced fractures determined from FMI images in the carbonate interval (wells A-6 and A-5) indicate the maximum and minimum principal stresses (red and violet arrows, respectively).

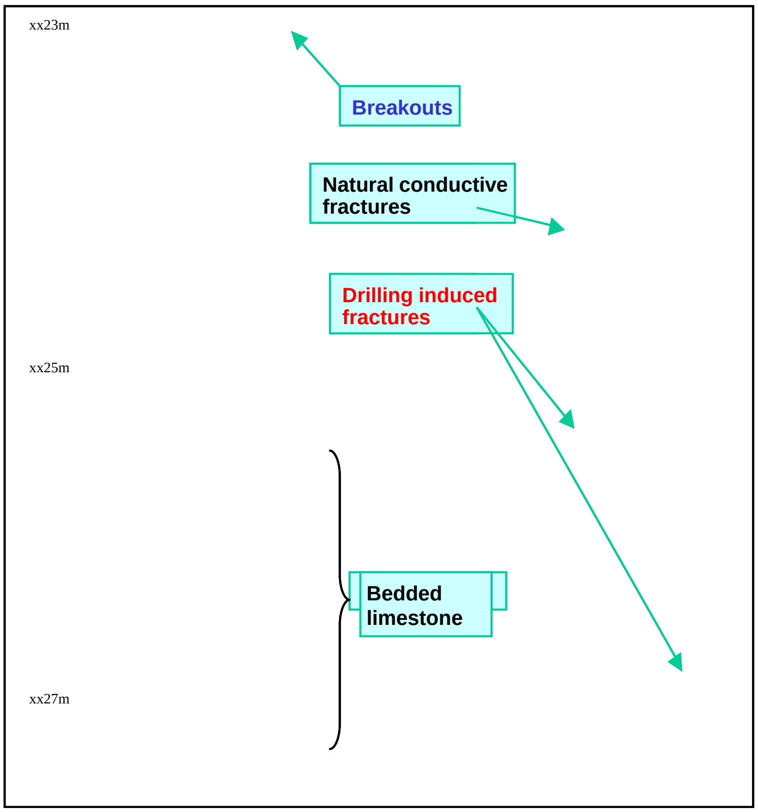
Notes by Presenter
Breakout orientations observed in both wells for entire logged intervals show no significant changes.

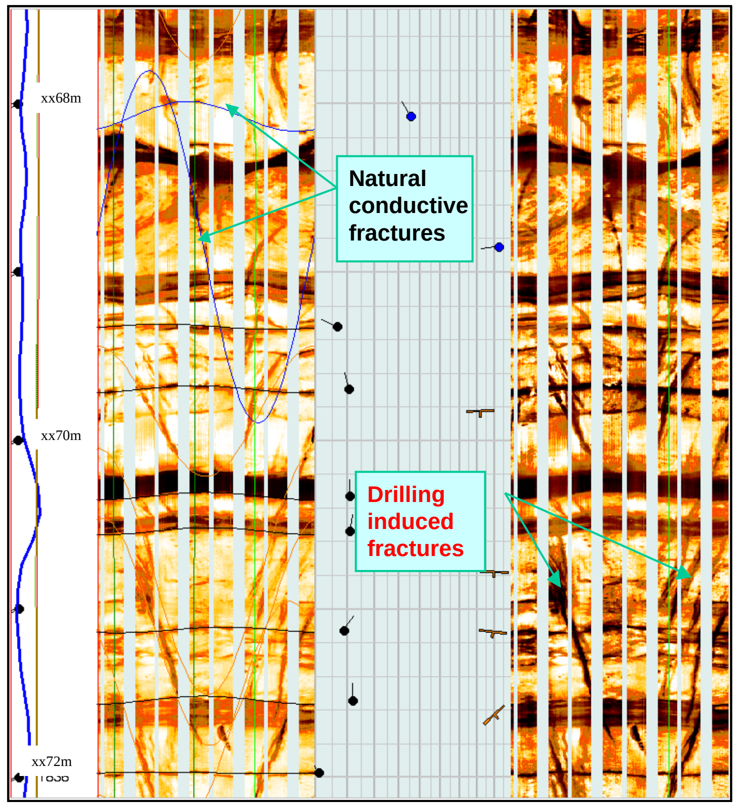
1



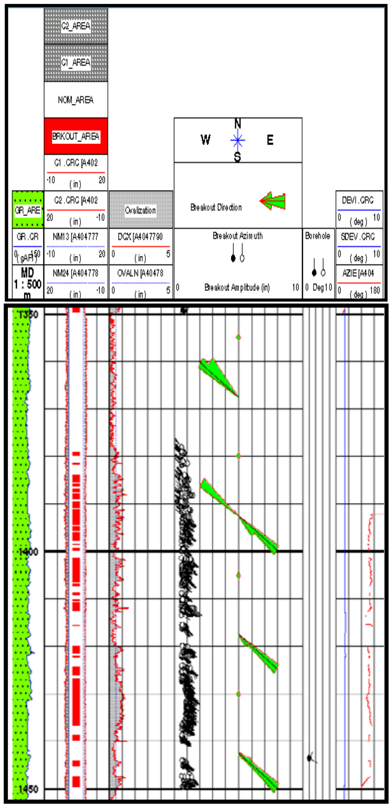
FMI images showing breakouts and drilling induced fractures in well A-5, Merbau field. The direction of breakouts is to NNW, while the direction of drilling induced fractures is NE.

Notes by Presenter
The lithology is predominantly limestone which is generally poorly bedded with localized vugular, porous zones.

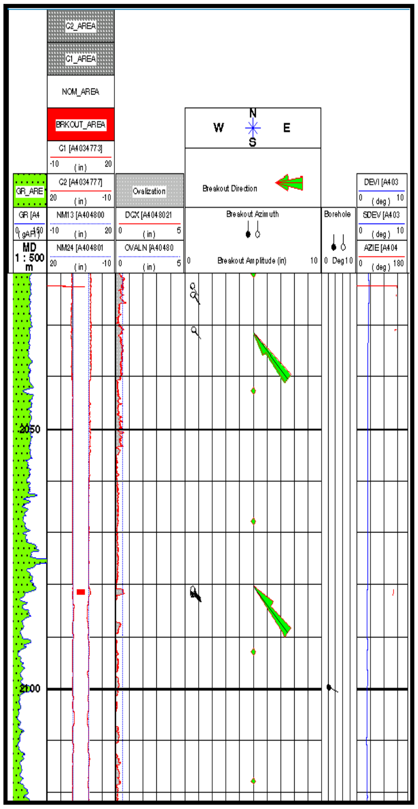




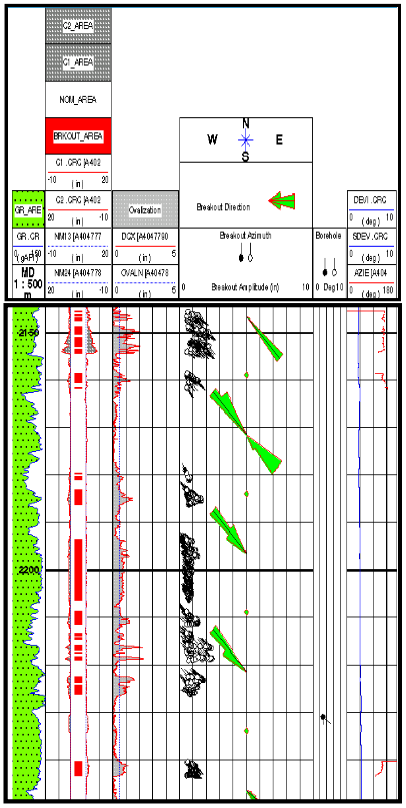
FMI images showing breakouts and drilling induced fractures in well A-6, Merbau field. Breakouts are oriented NNW, while most drilling induced fractures are oriented NE



Well: AA-2



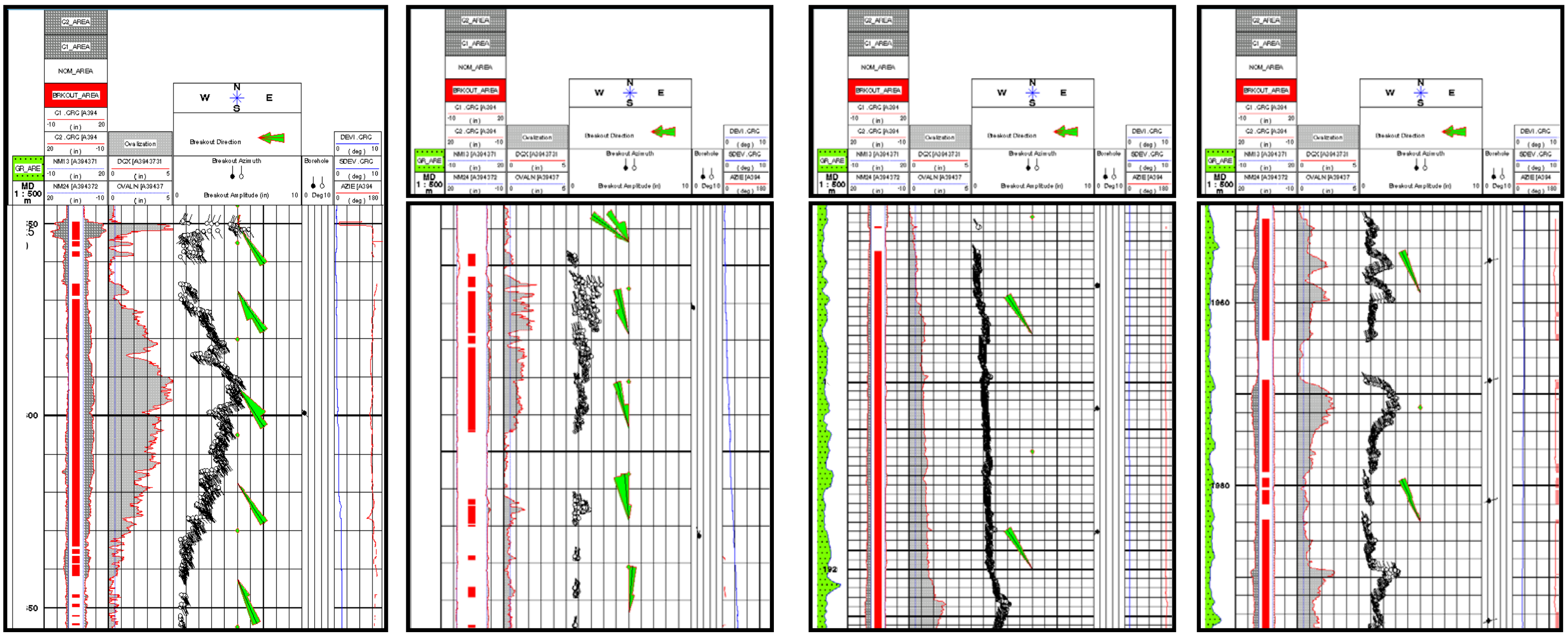
Well: BA-15



Well: BA-16

Breakout orientation determined from caliper data. The breakouts are constantly aligned NW-SE in these three wells, indicating the orientation of minimum principal stress to the northwest-southeast (N3100W-S1300E).

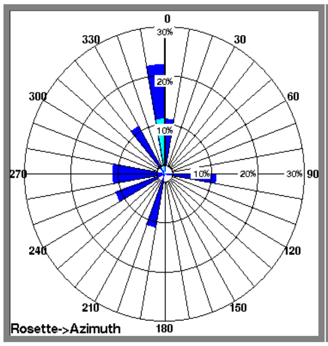
Well: A-1 | Well: A-2 | Well: A-3 | Well: A-6



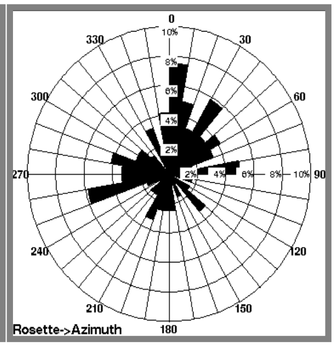
Breakout orientation determined from caliper data of selected intervals in the Merbau wells

Notes by Presenter

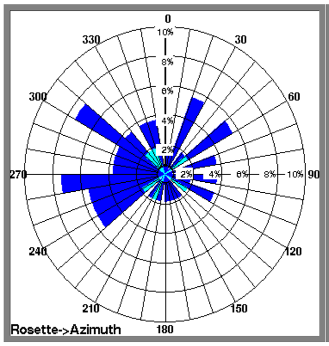
The breakouts are constantly aligned NW-SE in wells A-1, A-3, A-6 indicating minimum principal stress orientation (approximately N3100W-S1300E). However, in well A-2 the breakout orientations differ slightly and are aligned NNW-SSW (N3400W-S1600E). due probably to the existence of the thrust fault normal to the well (see Fig. 16).



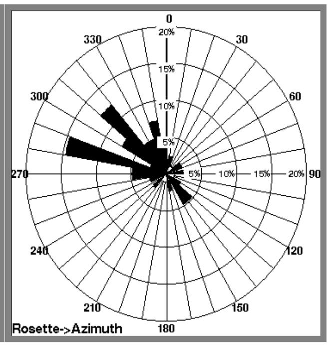
Natural fractures



Bedding dips (mostly shale dips)



Natural fractures



Bedding dips (mostly shale dips)

Azimuth rosette diagrams of natural fractures and bedding dip in wells A-5 (left) and well A-6 (right).

Well A-5

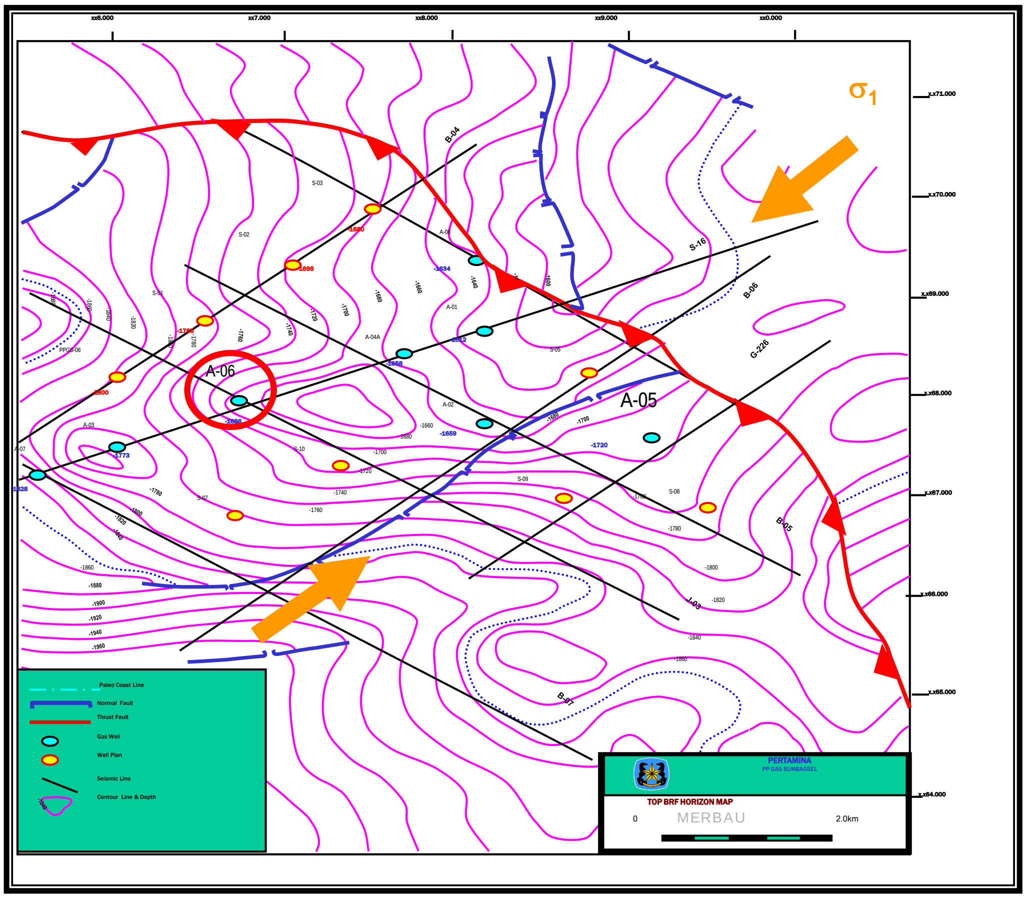
FEATURES	Interval	DIP		
		Number	Magnitude (Mean) Degree From North	Azimuth (Mean) Degree From North
CONDUCTIVE FRACTURE	Carbonate Interval	8	52	350
	Entire Interval	14	64	238
RESISTIVE FRACTURE	Carbonate Interval	1	45	350
	Entire Interval	3	76	6
BEDDING	Carbonate Interval	120	1.4	348
	Entire Interval	158	6.4	18
FAULT	Carbonate Interval	1	45	285
	Entire Interval	-	-	-
INDUCED FRACTURE	Carbonate Interval	57	81	163
	Entire Interval	82	81	164
BREAKOUT	Carbonate Interval	16	86	215
	Entire Interval	23	86	214

Well A-6

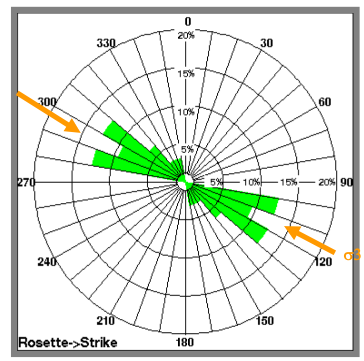
FEATURES	Interval	DIP		
		Number	Magnitude (Mean) Degree From North	Azimuth (Mean) Degree From North
CONDUCTIVE FRACTURE	Carbonate Interval	47	35	279
	Entire Interval	54	31	274
RESISTIVE FRACTURE	Carbonate Interval	7	40	320
	Entire Interval	-	-	-
BEDDING	Carbonate Interval	89	12	302
	Entire Interval	111	13	300
FAULT	Carbonate Interval	-	-	-
	Entire Interval	1	75	280
INDUCED FRACTURE	Carbonate Interval	15	84	153
	Entire Interval	20	84	155
BREAKOUT	Carbonate Interval	24	84	64
	Entire Interval	30	85	65

Summary table of natural and drilling-induced features from wells A-5 (left) and A-6 (right).

A



B



Breakout oriented N300W−S120E (minimum stress direction) in well A−6, that differ slightly from other breakouts and orientations in other Merbau wells.

Direction of the regional maximum principal stress (in brown arrow) in the Merbau area based on the regional structural elements. For determination of stress orientation in the Merbau field, breakouts (NNW) and drilling induced fractures (NE) are observed in FMI log of well A−5 located adjacent to the thrust fault.

PRODUCTION CAPABILITY ON MERBAU GAS FIELD
PERTAMINA - PPGS 2003 - 2004

Status : 30-Apr-05

	Sumur	Test Rate @ Ch. 32/64" (MMSCFD)	Est. Gas Rate (MMSCFD)	Max. WH Del. (MMSCFD)	AOFP (MMSCFD)	Date of Test	Remarks
			@ 800 psi				
1	MBU-07 (AWS.1)	1.19	1.19	1.19	1.19	6 - 8 Juli 2003	
		5.97	8.67	9.84	18.30	19-22 Mar 2005	Ex. Nitrified Acid
2	MBU-06 (CA.2)						Tbg 2-7/8"
	- BRF-1 (Lower)	6.85	9.28	10.37	15.54	15 - 18 Juli 2003	
	- BRF-2 (Upper)	6.68	9.08	10.04	13.25	10 - 14 Juli 2003	
	- BRF-1,2	6.96	10.04	11.26	16.46	18 - 20 Juli 2003	
	(Ren. dual compl.)	13.53	18.36	20.41	28.79		Ren. Dual Comp.
3	MBU-05 (BA.3)	0.06	0.07	0.07	0.07	21-24 Juli 2003	Ex. Nitrified Acid
4	MBU-08 (PPG.4)						
	- BRF-1 (Lower)	5.15	6.01	6.55	6.55	17-19 Sep. 2003	
	- BRF-2 (Upper)	5.61	6.36	6.94	6.55	23-24 Sep. 2004	
	- BRF-1,2						
	(Run. dual compl.)	10.76	12.37	13.49	13.09		Ren. Dual Comp.
5	MBU-4A (AC2.S)	8.20	15.48	17.59	20.79	30 Sep - 3 Okt. 2003	Tbg 3-1/2"
6	MBU-03	6.56	9.31	10.51	11.15	12 - 15 Nop. 2003	Tbg 3-1/2"
7	MBU-10 (PPG.3)	3.70	3.71	4.19	4.32	29 Jan - 2 Peb. 2004	Tbg 3-1/2"
8	MBU-01	7.47	15.56	17.27	19.11	8 - 11 Peb. 2004	Tbg 3-1/2"
9	MBU-11 (PPG.1)	4.71	5.11	5.70	5.86	5 - 8 Mar 2004	Tbg 3-1/2"
10	MBU-13 (PPG.2DE)	1.89	1.80	2.04	2.07	18 - 21 Juni 2004	Tbg 3-1/2"
11	MBU-14 (PPG.2DW)	0.93	0.80	0.93	0.93	15 - 17 Juni 2004	Tbg 3-1/2"
12	MBU-15 (PPG.10)	8.72	21.44	32.54	47.46	23 - 26 Juni 2004	Tbg 3-1/2"
13	MBU-16 (PPG.09)	5.96	8.66	9.73	10.61	10 - 13 Ags. 2004	Tbg 3-1/2"
14	MBU-17 (PPG.07)	0.07	0.07	0.07	0.07	15 - 17 Ags. 2004	Tbg 3-1/2"
15	MBU-12ST	7.64	15.79	16.79	25.06	10 - 13 Sep. 2004	Tbg 3-1/2"
16	MBU-09ST	8.33	21.03	22.61	135.03	24 - 27 Nop. 2004	Tbg 3-1/2"
17	MBU-02ST	8.32	22.25	24.75	32.65	30 Nop - 3 Des. 2004	Tbg 3-1/2"
	Sub total MBU	86.30	166.14	184.18	339.37		
	TOTAL TEST	86.30	166.14	184.18	339.37		

C:PPGS/MSB/DataSumur/Rekap_WT&FlowLine_Mar-2005.xls

Note : Sub total MBU Merbau

CONCLUSIONS

- The existence and orientation of wellbore failure features (breakouts, drilling-induced fractures) are easily recognized in FMI logs of study wells due to the overall good quality of electrical images. Combined with caliper data, these images can provide accurate maximum and minimum horizontal stress directions
-
- Maximum horizontal stress determined in both wells generally strikes NE-SW, which corresponds to the regional NE-SW compressive stress direction. Slight differences in maximum horizontal stress are observed, and they are due to the local structural influences (faulting).

- When the fields are intended for future development and production, directional wells oriented SSW or NNE are advised in order to intersect the maximum numbers of productive fractured zones of reservoir.

- Based on acoustic Impedance modeling and facies analysis, Batu Raja carbonate reservoir can be identified as two major facies: Reefal facies which is characterized by low acoustic impedance value; Carbonate platform facies with laterally distribution of high acoustic impedance value.

- The carbonate reservoir of Baturaja Formation in Merbau Field is commonly characterized by two onlapping,landward-prograding facies on top of the Sunda platform that is distributed from west to east of the north south potential closure.

- The BRF hydrocarbon reservoir has only gas hydrocarbons within its central area of the block, although the distribution of BRF carbonate extends beyond its GWC.

- .The development wells drilled based on the result of reservoir characterization and fracture determination have good results for the prospect development.

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THANK YOU