PHYSICAL AND GEOMECHANICAL CHARACTERISTICS OF KEUTAPANG FORMATION IN ARUN GAS FIELD, NORTH SUMATRA, INDONESIA

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Abstract

Arun Field has been documented as one of the biggest gas field in the world. One of the unique formations in this giant field is the presence of Keutapang Formation which has an abnormal pressure zone. The presence of this zone is certainly correllated with Keutapang Formation characteristics. Well log data from three wells have been collected, processed, and analyzed to understand the physical and geomechanical characteristics of Keutapang Formation. The result of this study shows that Keutapang Formation consist interbedded three types of lithology (siltstone, shale, and sandstone). Sandstone has porosity 0.22 – 0.34, permeability 1 – 66.18 darcy, UCS 32.5-56.42 Mpa, static and dynamic Young's Moduly 2.48-4.03 GPa and 10.70-12.06 GPa. Interbedded siltstone and Shale has UCS 32.53-46.96 Mpa, static and dynamic Young's Moduly 2.48-3.35 GPa, and 10.70-11.47 GPa. All of these characteristics proved that the occurrence of abnormal pressure zone is affected on the lithological characteristics of Keutapang Formation itself.

Keywords: abnormal pressure, Arun Field, geomechanics, Keutapang Formation, petrophysics.

1. INTRODUCTION

On several decades, hydrocarbon industries are always becomes the most important industries of Indonesian economic society. Years in the 2 decades have witnessed drastic decline in Indonesia's national oil production. On the other hand, however, the same period is also characterized with encouraging development in natural gas production and reserves (Widarsono, 2013).

One of the potential gas fields to be studied and developed is the Arun Field. The Arun field has recorded as one of the world's giant retrograde gas reservoirs (Affidick, 1994). Approximately 45 years after production began, Arun gas field still has a lot of interesting phenomenon such as abnormal pressure and salt water sand zone in Keutapang Formation. The presence of this zone is certainly correllated with Keutapang Formation characteristics.

This paper aims to understand the physical and geomechanical characteristics of Keutapang Formation including litological characteristics, petrophisical characteristics, and geomechancal characteristics. The research parameters are including type and litological description, porosity and permeability, and the value of Unconfined Compressive Strength (UCS) and young's moduly. The results of this study are expected to be a reference in accordance of development in natural gas production and reserves.

2. LITERATURE REVIEW

Geology of Arun Field

The Arun Gas field is one of the hydrocarbon field in the North Sumatra Basin, Indonesia. The North Sumatra Basin is a back-arc basin of Tertiary age bounded to the east by onlap onto the Malacca Platform and to the southwest by the Barisan Mountains uplift. The North Sumatra basin had been an area of active marine sedimentation for most of Tertiary times, representing a full marine depositional cycle (Soeparjadi, 1983). Sedimentation began with a transgressive sequence of coarse clastics that rests on Pre-Tertiary basement. The North Sumatra Basin was initially subject to Late Eocene rifting that formed the north-south horsts and grabens. A quiescent phase of basin sag, with widespread carbonate deposition and reef growth during the Late Oligocene and Early Miocene, followed the rifting (Barber, 2005).

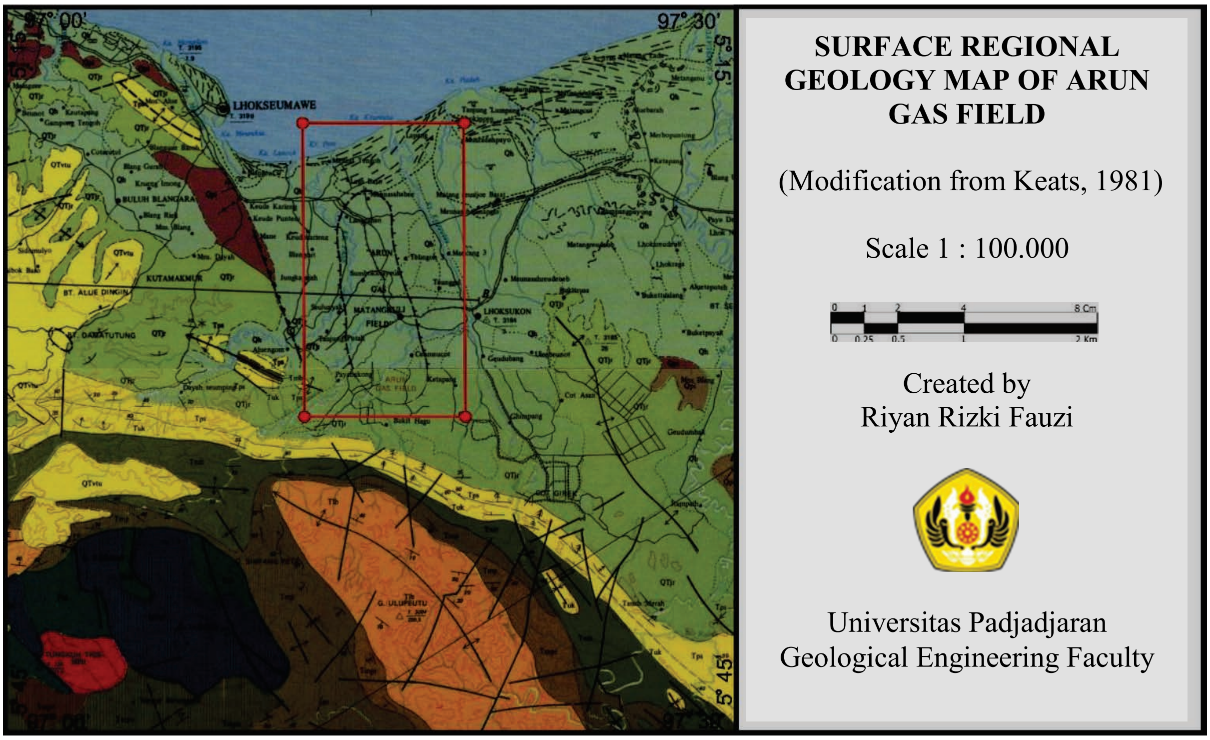


Figure 1. Regional Geology Map of Arun Gas Field

During Oligocene time a thick transgressive sequence of black claystone (Bampo formation) was deposited, particularly in the topographic lows. The Lower Miocene was a time of maximum marine ingression. However, rapid subsidence had ceased and rate of deposition was minimal. Marls and very calcareous shales, rich in planktonic foraminifera, became the dominant sediments (Peutu formation). Environmental conditions were also ideal for development of reefs and other biogenic limestones (Arun Limestone). The period of quiescence continued through the Middle Miocene with the deposition of shale (Baong formation). This shale became the seal of the Arun reef and contributed most, if not all, hydrocarbons found in this area. The remainder of the Tertiary section comprises the regressive clastics of the Keutapang, Seurula, and Julu Rayeu formations in ascending orner, completing the depositional cycle (Soeparjadi, 1983). based on Arun-A1 well data, the stratigraphy of Arun Field from the oldest to the youngest as follows:

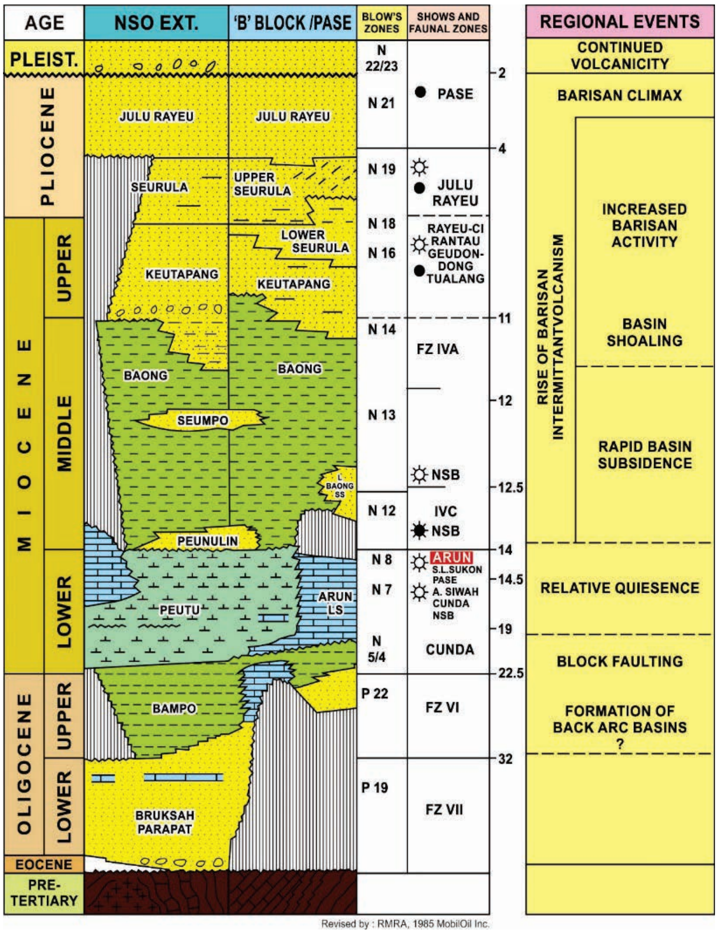


Figure 2. Stratigraphy of Arun Gas Field (Modification from Atmadibrata, 1993)

The object study of this research is Keutapang Formation. Keutapang Formation are were deposited in a rapidly shallowing basin, resulting from slowing sea level rise and the rapid influx of clastic sediment from the incipient Barisan uplift. The thickness of this Formation is about 404 – 1534 meter. The sediments are predominantly deltaic and shallow marine sandstones and shales. These litology has a highly content of quarzt, pyrite, mica, and carbon.

3. METHODOLOGY

The methodology of this research is analizing well log data. Well log in the term of oil and gas industris is a recording against depth of any characteristics of the rock formations traversed by a measuring apparatus in the well-bore. Well log constitute a fantastic source of information on subsurface geology with a vertical resolution that can even reach 1 cm. Well logging also has a represents cost generally between 5 and 10% of the drilling cost and that logs provide approximately 90% of the information extracted from a well (Serra, 2003).

The types of logging data that used in this research are gamma ray log, SP log (Spontanuous Potential), resistivity log, and sonic log. Gamma ray log responds to the natural gamma radiation in the formation. We shall first address the question of the origin of this natural radiation. The few isotopes which are responsible for it can be attributed to a small list of common minerals (Ellis, 2007). The SP log is a record of direct current (DC) voltage differences between the naturally occuring potential of a moveable electrode in the well bore, and the potential of a fixed electrode located at the surface (Doll, 1948 in Asquith, 1982). The SP log is used to identify impermeable zones such as shale, and permeable zones such as sand.

Resistivity log is a measurement of a formation's ressitivity, that is its resistance to the passage of an electric ccurrent. Electric log is used to determine hydrocarbon versus water bearing zones, indicate permeable zones, and determine resistivity porosity. The sonic log provides a formation's interval transit time, designated (Δt). It is a of the formation capacity varies with lithology and rock texture, notably porosity (Rider 2002).

McNally (1987) in Schon (2011) studied the correlation between the uniaxial compression strength (142 samples) and the compressional wave slowness (measured with a sonic logging tool) of fine to medium grained sandstone from the German Creek formation (Queensland, Australia). There is for this particular geological situation a good correlation that is probably controlled by variation of porosity and grain-contact quality. The resulting regression is originally as follows:

$$\sigma_c = 1277.\exp(-0.0367.\Delta\, t) \quad R^2 = 0.83$$

σ_c= UCS value in MPa dan Δt = interval transite time in μs ft^{-1}.

Horsrud (2001) in Schon (2011) gives a detailed analysis and derived the empirical correlation between compressional wave velocity (dynamic) and static Young's moduly Estat and static shear modulus μstat:

$$\sigma_c = 0.77 \cdot V_P^{2.93} \quad R^2 = 0.99$$ ………(for shale lithology)

$$E_{stat} = 0.076 \cdot V_P^{3.23} \quad \mu_{stat} = 0.03 \cdot V_P^{3.30} \quad R^2 = 0.99$$ ……..(for sand lithology)

4. RESULT AND DISCUSSION

Physical Characteristics of Keutapang Formation

Based on gamma ray log and SP log data from three wells in the research area, Keutapang Formation is composed of three types of lithology, there are sandstone, siltstone, and claystone. The result of electrofacies analysis shows that all of Keutapang Formation lithology makes a interbedded lithology which characterized by serrated cylinder shape of gamma ray log graphics. The sedimentation process in Keutapang Formation is influenced by sea water fluctuations (regression process). This regression is also characterized by serrated bell-shaped electrofacies which shows fining upward sequence.

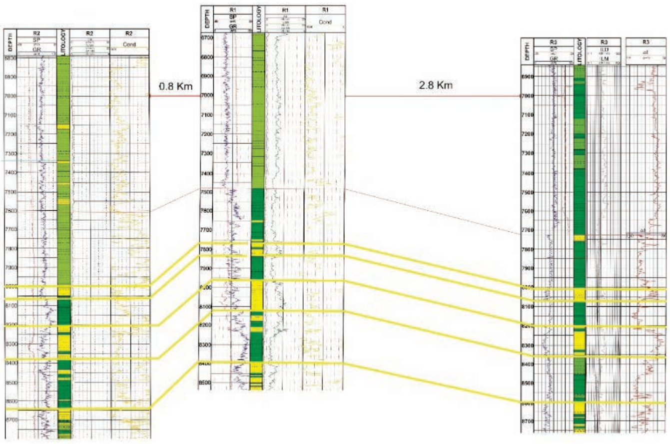


Figure 3. Gamma Ray Log Correlation From 3

The result of quantitative measurements shows that Keutapang Formation Sandstone has characteristics of gamma ray 20-35 API, shale volume Vsh 0.00-0.54, dan radioactive heat generation A 0.30-0.75 µWm^{-3}. Keutapang Formation Siltstone has characteristics of gamma ray 35-50 API, Vsh 0.54-0.67, dan A 0.75-0.78 µWm^{-3}. Keutapang Formation Claystone has characteristics of gamma ray 50-100 API, Vsh 0.67-1.00, dan A 0.78-1.57 µWm-^{3}.

Table 1. Physical Characteristics From Gamma Ray Log

Lithology	Depth (ft)		Thickness (feet)	GR (API)	Vsh	A (µW/m3)
	Upper	Lower				
Interbedded BLn & BLp	6850	6900	50	40-55	0.44-0.78	0.62-0.86
Interbedded BLp & BLn	6900	7000	100	45-60	0.56-0.89	0.70-0.94
Interbedded BLp & BLn	7000	7115	115	48-60	0.62-0.89	0.75-0.94
Interbedded BLn & BLp	7115	7170	55	45-50	0.56-0.67	0.70-0.78
Interbedded BLp & BLn	7170	7225	55	40-60	0.44-0.89	0.62-0.94
Interbedded BLn & BLp	7225	7265	40	48-50	0.62-0.67	0.75-0.78
Siltstone (BLn)	7265	7275	10	40	0.44	0.62
Interbedded BLp & BLn	7275	7325	50	55	0.56-0.78	0.70-0.86
Interbedded BLn & BLp	7325	7390	65	45-55	0.56-0.78	0.70-0.86
Interbedded BLp & BLn	7390	7560	170	48-60	0.62-0.89	0.75-0.94
Interbedded BLp & BLn	7560	7660	100	45-65	0.56-1.00	0.70-1.01
Interbedded BLp & BLn	7660	7680	20	50-60	0.67-0.89	0.78-0.94
Claystone (BLp)	7680	7725	45	45	0.56	0.7
Interbedded BLp & BLn	7725	7750	25	30-40	0.22-0.44	0.46-0.62
Interbedded BLn & BLp	7750	8000	250	40-50	0.44-0.67	0.62-0.78
Sandstone	8000	8060	60	25-45	0.11-0.56	0.38-0.70
Claystone (BLp)	8060	8150	90	45-35	0.56-0.33	0.70-0.54
Sandstone	8150	8290	140	45-20	0.56-0.00	0.70-0.30
Sandstone	8290	8340	50	20-40	0.00-0.44	0.30-0.62
Interbedded BLp & BLn	8340	8355	15	25-35	0.11-0.33	0.38-0.54
Interbedded BLn & BLp	8355	8450	95	30-40	0.22-0.44	0.46-0.62
Interbedded BLp & BLn	8450	8555	105	40-50	0.44-0.67	0.62-0.78
Interbedded BLn & BLp	8555	8580	25	30-35	0.22-0.33	0.46-0.54
Interbedded BLp & BLn	8580	8600	20	40-50	0.44-0.67	0.62-0.78
Sandstone	8600	8660	60	20-40	0.00-0.44	0.30-0.62
Claystone (BLp)	8660	8680	20	30-45	0.22-0.56	0.46-0.70
Interbedded BLp & BLn	8680	8710	30	30-40	0.22-0.44	0.46-0.62
Claystone (BLp)	8710	8730	20	40	0.44	0.62
Sandstone	8730	8760	30	25	0.11	0.38

Based on sonic log data from well R3, The lower Keutapang Formation Sandstone has a good – excelent porosity (22% – 34%). This porosity value is used to determining the permeability value. The permeability of Lower Keutapang Formation Sandstone is k 1 – 66.18 darcy (Table 2).

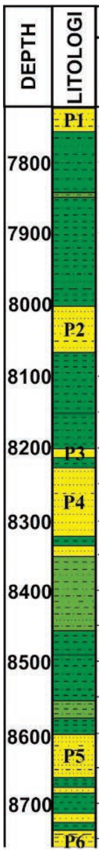
Table 2. Porosity and Permeability of Keutapang Formation Sandstone

Sandstone	Depth (feet)		Δt_{log}	ϕ	Permeability (k)	
	Upper	Lower	Average	Average	milidarcy	darcy
P1	7225	7750	95	30	1636.55	16.37
P2	8000	8060	85	22	100.06	1.00
P3	8200	8210	85	22	100.06	1.00
P4	8220	8460	90	26	404.67	4.05
P5	8610	8650	100	34	6618.40	66.18
P6	8740	8760	100	34	6618.40	66.18

Geomechanical Characteristics of Keutapang Formation

The geomechanical characteristics of Keutapang Formation are explained by UCS and young moduly value. Keutapang Formation Sandstone has UCS 32.5-56.42 MPa, E_{static} 2.48-4.03 GPa, and $E_{dinamic}$ 10.70-12.06 GPa. Siltstone and Claystone of Keutapang Formation has UCS 32.53-46.96 MPa, E_{static} 2.48-3.35 GPa, and $E_{dinamic}$ 10.70-11.47 GPa. Based on Carmichael UCS Clasification (1989), the strength of Keutapang Formation Sandstone is low – medium and the strength of Keutapang Formation Siltstone and Claystone is low. The rock strength (UCS) of Keutapang Formation is match with the cutting and side wall core description.

Table 3. Geomechanical Characteristics of Keutapang Formation Sandstone and Interbedded Claystone-Siltstone



Sandstone	Depth (feet)		Δt_{log}	σ_c	Vp		Young Moduly	
	Upper	Lower	Average	MPa	m/s	km/s	Estatic (Gpa)	Edinamic (Gpa)
P1	7225	7750	95	39.09	3071.72	3.07	2.85	11.03
P2	8000	8060	85	56.42	3418.34	3.42	4.03	12.06
P3	8200	8210	85	56.42	3418.34	3.42	4.03	12.06
P4	8220	8460	90	46.96	3229.17	3.23	3.35	11.47
P5	8610	8650	100	32.53	2940.67	2.94	2.48	10.70
P6	8740	8760	100	32.53	2940.67	2.94	2.48	10.70

Lithology	Depth (feet) (feet)		Δt_{log}	σ_c	Vp		Young Moduly	
	Upper	Lower	Average	MPa	m/s	km/s	Estatic (Gpa)	Edinamic (Gpa)
Interbedded Claystone and Siltstone	6840	6910	100	32.53	2940.67	2.94	2.48	10.70
	6910	7200	95	39.09	3071.72	3.07	2.85	11.03
	7200	7225	100	32.53	2940.67	2.94	2.48	10.70
	7225	7375	90	46.96	3229.17	3.23	3.35	11.47
	7375	7640	90	46.96	3229.17	3.23	3.35	11.47

5. CONCLUSION

Keutapang Formation consists of interbedded three types of lithology (siltstone, shale, and sandstone). Sandstone has porosity 0.22 – 0.34, permeability 1 – 66.18 darcy, UCS 32.5-56.42 Mpa, static and dynamic Young's Moduly 2.48-4.03 GPa and 10.70-12.06 GPa. Interbedded siltstone and Shale has UCS 32.53-46.96 Mpa, static and dynamic Young's Moduly 2.48-3.35 GPa, and 10.70-11.47 GPa. All of these characteristics proved that the occurrence of abnormal pressure zone is effected on the lithological characteristics of Keutapang Formation itself.

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