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Abstract
The subsurface configuration or stratigraphy of the Sidoarjo Hot Mudflow (Lumpur Sidoarjo/LUSI) is used to see what formations are transported out and how the material properties can be known from the well log data of Banjarpanji#1 or BJP#1 well. There is something unusual about the BJP#1 log, namely the presence of solid volcanic sandstone at a depth of 6000-9297 ft where drilling ended. This abnormality was investigated by reanalyzing volcanic sandstone by reading the well log data which is drilling data during the exploration of the Banjarpanji-1 well by PT. Lapindo Brantas, Inc. which consists of rock logs as a result of predictions (prognosis) and facts found (actual) were then compared with the interpretation of the results of the investigation team with BP MIGAS 2006 which was then confirmed by petrographic and paleontological analysis. The unusual occurrence is the LUSI stratigraphic arrangement changes based on findings in volcanic sandstone sequences that were once considered part of the Kalibeng Formation of Plio-Pliestocene age, then changed to solid volcanic sandstone units of Middle Miocene age with a depositional environment in the outer neritic-upper bathyal.

1. Introduction

The subsurface configuration of the Sidoarjo Hot Mudflow (Lumpur Sidoarjo/LUSI) or the stratigraphy is an important part of the occurrence of the LUSI eruption, especially to see what formations were transported out and how their material properties can be known from the well log data of Banjarpanji#1 or BJP#1 well. The location of the BJP#1 log is very close to the center of the LUSI eruption with coordinates X: 112° 42' 43.82" E and Y: 3° 31' 35.35" S (see Figure 1). There is something unusual about the BJP#1 log, it is the presence of solid volcanic sandstone at a depth of 6000-9297 ft where drilling ended. The presence of this volcanic sandstone is not commonly found in the stratigraphy of the Kendeng Basin, where beneath the Kalibeng Formation with a deep-sea environment suddenly found a sequence of volcanic rock products. This abnormality will be investigated using a petrographic and paleontological test approach. The big implications is if the type, age, and depositional environment of the rocks tested show different results from the previous one, this will have the impact of changing and creating new stratigraphic arrangements in the area around LUSI [1].

2. Methodology

This well log data is drilling data during the exploration of the Banjarpanji-1 well by PT. Lapindo Brantas, Inc. which consists of rock logs as a prediction results (prognosis), the facts found (actual) are then compared with the interpretation of the results of the investigation team with BP MIGAS 2006. Based on the results, it shows that the subsurface lithology as an assumption result is far from the real conditions below the surface. Based on BJP#1 well log analysis results, temporal changes of the cutting taken shows significant differences, especially the age of the previous stratigraphic arrangement compared to the results of the analysis in this study [2].

The method used is reanalysis the volcanic sandstone with log readings confirmed by petrographic and paleontological analysis. The initial data before being reanalyzed regarding rock stratigraphy, the oldest is the Volcanic Sandstone Unit which enters the Upper Kalibeng Formation at a depth of about 9297 feet to a depth of 6149 feet under the sea level with an Early Pleistocene age [3].

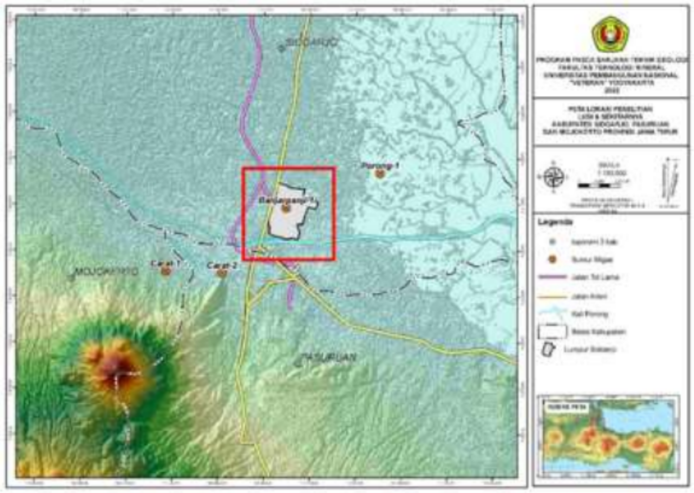

Figure 1. Banjarpanji -1 (BJP#1) well location (red square)

3. Results and discussions

3.1. Well Log Analysis of Well BJP#1

This solid volcanic sandstone has a fairly high density and is hard and compact, this can be seen from the density log which shows a large value and the very low ROP (Rate of Penetration) log indicates that the rock is hard and difficult to drill [4]. The high GR (gamma ray) log indicates that this sandstone comes from volcanic materials with high radioactive content such as Uranium (U), Thorium (Th) and Potassium (K) which were detected on the gamma ray log sensor. The DTC (Dynamic Transit-time Compressional wave) log from the sonic log also shows a low transit time value which indicates that the rock is compact and hard, because if the rock is compact and hard, the primary wave (compressional wave) will spread quickly and return to the sonic sensor with fast time, so the value of transit-time is low [5] (see Figure 2).

This solid volcanic sandstone has compact and hard physical properties because it is influenced by hydrothermal solutions that enter through the Watukosek Fault. This volcanic sandstone does not originally have a very high level of hardness [7], but because of the effect of silicification by hydrothermal solutions which makes this sandstone very hard and compact [8]. This is also evidenced by the alterations found in this volcanic sandstone caused by the heat from the hydrothermal solution [9].

Above the Volcanic Sandstone Unit is deposited unconformity with the greenish-gray Claystone Unit which is also the part of Upper Kalibeng Formation. This unit is composed by the dominance of claystone with several sandstone inserts, where the physical properties of this unit are very different from the physical properties of the Volcanic Sandstone Unit. The Claystone Unit is located at a depth of 6149 ft to 2950 ft under the sea level with a thickness of about 3199 ft. When viewed from the gamma ray log, this unit is still composed of volcanic material [10], which is characterized by a high gamma ray value indicating a high content of radioactive elements originating from volcanic materials.

The rock in this Claystone Unit is relatively soft, indicated by the high ROP log value where the drill bit can quickly penetrate this unit because the rock is relatively soft. The rock density changes gradually from a high density at the bottom to a lower density at the top of the unit, this is due to compaction factors that affect the rock density, where the rock at the bottom gets a greater overburden compaction pressure so that it becomes denser and larger the density [11]. The DTC sonic log also follows the trend of the density log, where the more compact and hard rock will have a lower transit-time than the softer rock.

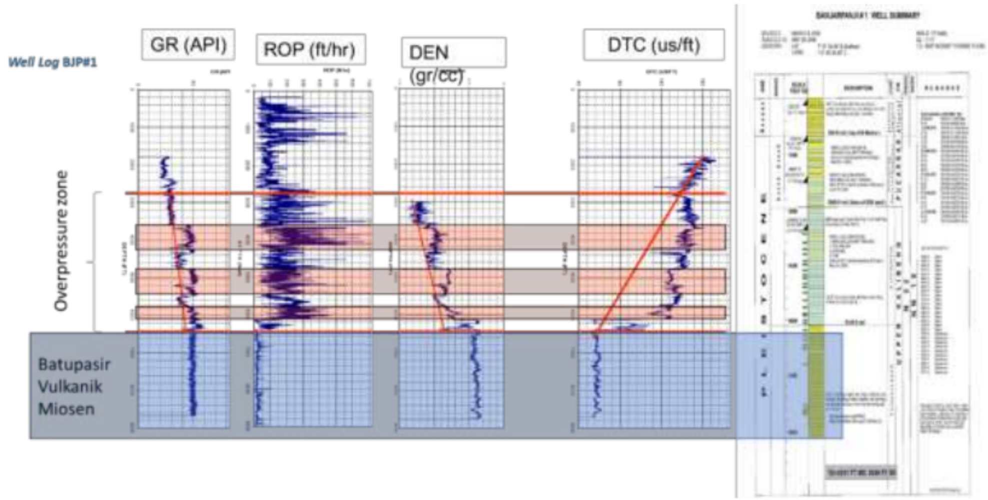

Figure 2. BanjarPanji#1 well log showing overpressure in the Kalibeng Formation deposited on a solid volcanic sandstone sequence

This Claystone Unit is estimated to be unconformity with the Volcanic Sandstone Unit because the Claystone Unit is not affected by the hydrothermal solution that hits the solid Volcanic Sandstone Unit so it is interpreted that the deposition of the Claystone Unit occurs after the hydrothermal solution enters the Volcanic Sandstone Unit through the Watukosek Fault [12]. Volcanic areas has a very fast depositional system with volcanic sedimentary material which is also very abundant causing a lot of fluid to be trapped in the rock pores, causing this Claystone Unit to become an overpressure zone due to fluid pressure trapped in the rock pores. The heat factor that may propagate through the Watukosek Fault also causes the existing fluid to expand in volume, thereby increasing the level of overpressure in this unit.

Above the Claystone Units were deposited conformity with the Interlude Sandstone-Claystone Units which entered the Pucangan Formation. This unit was deposited at a depth of 2950 ft to 990 ft under the sea level with a thickness of about 1960 ft. A low gamma ray value indicates the presence of non-volcanic material mixing in this unit. The density value is possibly low [13], seen from the higher sonic log DTC value [14], indicating that the rock in this unit is softer than the Claystone Unit due to the lack of compaction. The lower ROP log value compared to the Claystone Unit could be due to a collapsed wall or expanded claystone and tends to clamp the drill bit and pipe.

Table 1. Analysis of planktonic foraminifera on cutting BJP#1 in volcanic sandstone at a depth of 6000-8000 ft

RANGE CHART OF EOCENE TO RECENT PLANKTONIK FORAMINIFERA (Compiled from W.H. BLOW, 1969 and J.A. POSTUMA, 1974, BOLLI, 1985)																								
KAENOZOICUM																						ERA	SAMPEL	
TERTIARY																			KUARTER			PERIODS		
OLIGOCENE		MIOCENE														PLIOCENE			PLEISTOCENE	HOLOCENE		EPOCHS		
late		early					middle						late											
e.1-4		e.5					f.1		f.2		f.3		f.4	g		h						LETTER CODE FAR EAST		
N2 P21	N3 P22	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14	N15	N16	N17	N18	N19	N20	N21	N22	N23	CHART No. (BOLLI) 1989	NO	NAMA
																						Globigerinoides subquadratus	2	6180
																						Hastigerina siphonifera	4	
																						Globigerina venezuelana	15	
																								6280
																								6760
																						Globigerinoides quadrilobatus	1	7000
																						Orbulina universa	3	
																						Globorotalia praemenardii	4	
																						Globigerinoides trilobus immaturus	1	7620
																						Globigerinoides trilobus trilobus	2	
																								7860
																						Orbulina suturalis	1	8000
																						Orbulina universa	2	
																						Globoratalia fohsi peripheroacuata	5	

: Baren
A : Abundance (>50)
M : Medium (50 - 26)
R : Rare (1 - 25)
: Eksitu

Table 2. Benthic foraminifera analysis results on cutting BJP#1

PALEOBATHIMETRI FORAMINIFERA BENTHONIK (BARKER, 1960)													
Sampel	No	Bathimetri (Barker, 1960) / Spesies	fathom	Meter (ft*1.83m)	Jml	Neritik: Tepi	Neritik: Tengah	Neritik: Luar	Batial: Tepi	Batial: Luar	Abisal	Hadal	Kesimpulan
				1.83		20	100	200	500	2000	4000		
6180	13	*Uvigerina schwageri*	95-100	174-183	R								Neritik Luar
	14	*Streblus beccarii*	8	14.64	R								
6280	1	*Hoglundina elegans*	100-150	183-274.5	R								Neritik Luar-Batial Tepi
6760	1	*Bolivina cf. semicostata*	155	283.65	R								Batial Tepi
	2	*Saccamina sp.*	-	-	R								
	3	*Psammatodendron aborescens*	89-145	162-265.35	R								
	4	*Acervulina inhaerens*	18	32.94	R								
7000	-	-											
7620	-	-											
7860	-	-											
8000	-	-											

: Baren

A : Abundance (>50)
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The youngest unit is the Alluvial Sediment Unit which was unconformably deposited above the Interlude Sandstone-Claystone Unit at a depth of 990 ft to the surface. This unit is dominated by less compact sandstone with claystone inserts. No log data has been carried out in this zone so that the physical properties of the rock are not well known.

3.2. Paleontology of BJP#1 Cutting Volcanic Sandstone

The results of paleontological analysis (see Table 1 & Table 2) show that rocks at number 1, 2, 3 at a depth of 7860-8000 ft, found 3 planktonic foraminifera fossils, namely *Orbulina suturalis*, *Orbulina universa* and *Globorotalia periperoacuta*. The existence of these three fossils indicates an age range of N10-N13 (Middle Miocene) [1]. Rock samples number 1,3,4 at a depth (7000 ft) and sample number 1, 2, at a depth of 7620 ft, planktonic foraminifera fossils were found in the form of *Globigerinoides quadrilobatus, Orbulina universa, Globorotalia praemenardii, Globigerinoides immaturus, Globigerinoides trilobus trilobus* which show the age range N10-N13 (Middle Miocene) [1]. In samples number 2, 4, 15 at a depth of 6180 ft, *Globigerinoides subquadratus* fossils, *Hastigerina shiporifera, Globigerina venezuelana*, showed an age range of N13 (Middle Miocene) [1]. From all rock samples that have been analyzed, it can be concluded that the age of these rocks has a range of N10-N13 (Middle Miocene).

3.3. Petrography of BPJ#1 Cutting Volcanic Sandstone

From the petrographic observations of the cutting of the BJP #1 well at a depth of 6800 to 7000 ft, it was found that volcanic sandstone rocks with mineral sizes of 0.1-1mm with a degree of rounding are subrounded, matrix supported, which is dominated by hornblende minerals which are converted into clay mineral, pyroxene, lithic igneous rocks, glass, quartz, plagioclase, and opaque minerals (see Figure 3). From the mineral composition, the volcanism of the rock source can be estimated to be intermediate [7-10].

3.4. Prognosis and Actual Comparison of BJP#1 well

The subsurface stratigraphy of the research area, especially for the area around the LUSI area, can be seen from the well log data. This well log data is drilling data during the exploration of the Banjarpanji-1 well by PT. Lapindo Brantas, Inc. which consists of rock logs as a result of predictions (prognosis), the facts found (actual) are then compared with the interpretation of the results of the investigation team with BP MIGAS 2006 (see Figure 4). Based on the comparison results, it appears that the subsurface lithology as a result of the assumption is far from the real subsurface conditions [3-6].

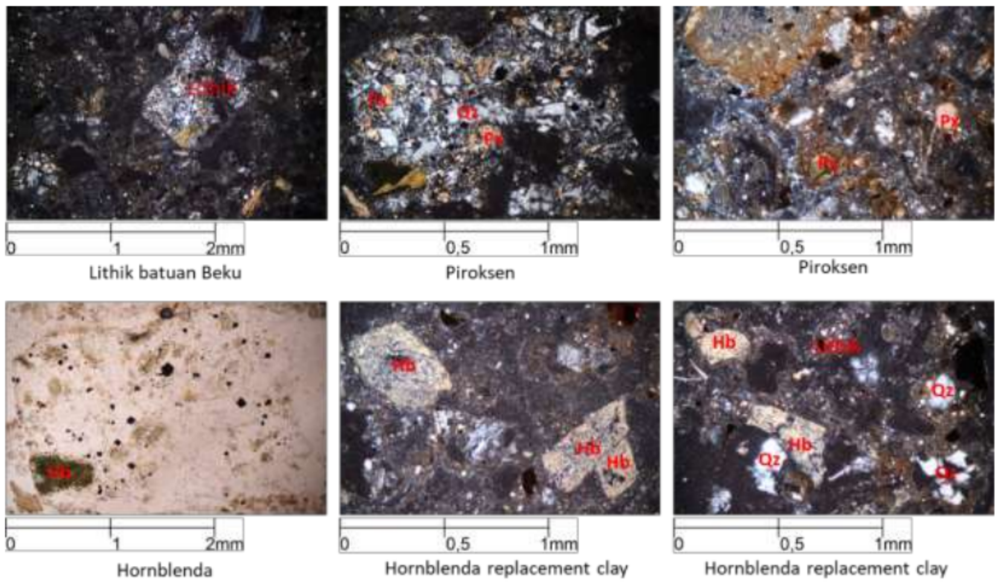

Figure 3. Petrographic photo of BJP#1 well cutting at a depth of 6800 – 7000 ft showing the structure and texture of the mineral constituents of the rock derived from volcanic products such as the presence of igneous lithic, pyroxene and hornblende replaced by clay minerals

The results of the well log analysis of the BJP#1 well (see Figure 5) combined with petrographic and paleontological data resulted in significant differences, especially the age of the rocks that made up the previous stratigraphy compared to the results of the analysis in this dissertation study. Based on preliminary data before reanalysis regarding the stratigraphy of rocks from old to young age are as follows: the oldest is the Volcanic Sandstone Unit at a depth of about 9297 ft to a depth of 6149 ft under the sea level with an Early Pleistocene age. After being reanalyzed with petrographic and fossil approaches, the volcanic sandstone changed its age to Middle to Late Miocene [15].

The physical properties of Miocene volcanic sandstones found at LUSI are compact and hard because they are influenced by hydrothermal solutions that enter through the fault line. This volcanic sandstone has been altered where the origin of the rock does not have a very high level of hardness, but because of the influence of silicification by hydrothermal solutions, it makes this sandstone very hard and compact [16].

Above the Volcanic Sandstone Unit, a soft green claystone unit is deposited which is still unconformity into the Upper Kalibeng Formation of Mio-Pliocene age. This unit is composed by the dominance of claystone with several sandstone inserts, where the physical properties of this unit are very different from the physical properties of the Volcanic Sandstone Unit. The Claystone Unit is located at a depth of 6149 ft to 2950 ft under the sea level with a thickness of about 3199 ft.

The rock density changes gradually from a high density at the bottom to a lower density at the top of the unit, this is due to compaction factors that affect the rock density, where the rock at the bottom gets a greater overburden compaction pressure so that it becomes denser and larger. the density.

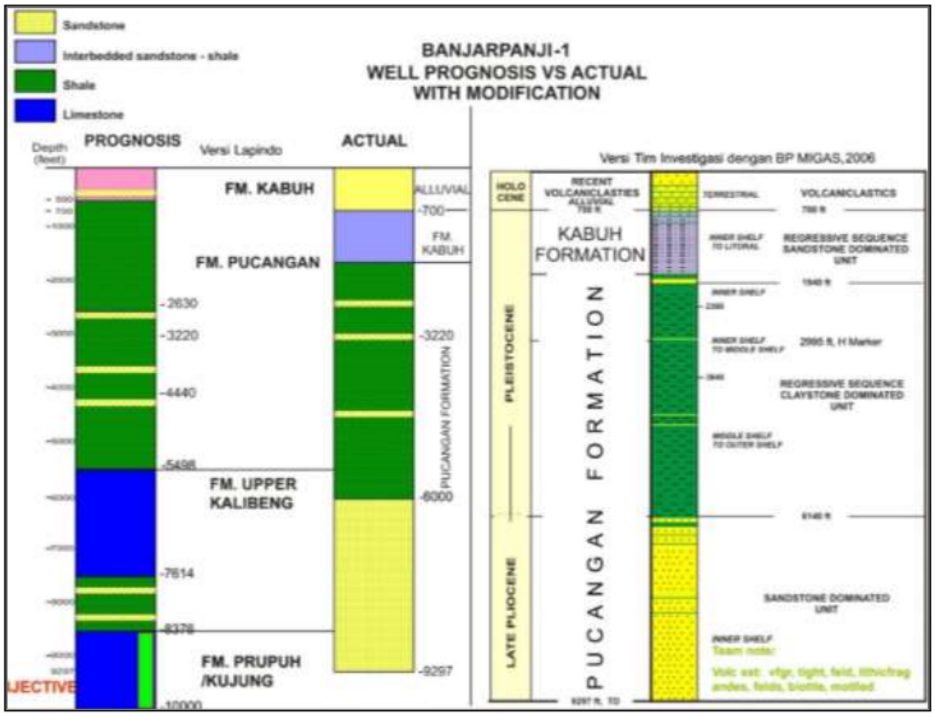

Figure 4. Comparison of BP-1 well rock log results between prognosis and actual drilling (Investigation Team, BP MIGAS 2006).

This Claystone Unit is estimated to be unconformity with the Volcanic Sandstone Unit because the Claystone Unit is not affected by the hydrothermal solution hitting the Volcanic Sandstone Unit so it is interpreted that the deposition of the Claystone Unit occurs after the hydrothermal solution enters the Volcanic Sandstone Unit through the Watukosek fault line. The depositional system in volcanic areas has a very fast depositional character with volcanic sedimentary material which is also very abundant causing a lot of fluid to be trapped in the rock pores, causing this Claystone Unit to become an overpressure zone due to fluid pressure trapped in the rock pores. The heat factor that may propagate through the Watukosek fault also causes the existing fluid to expand in volume, thereby increasing the level of overpressure in this unit.

Above the Claystone Units, the Interlude of Sandstone-Claystone Units were deposited conformity with the Plio-Pliestocene age Pucangan Formation. This unit was deposited at a depth of 2950 ft to 990 ft under the sea level with a thickness of about 1960 ft. The youngest unit is the Alluvial Sediment Unit which was unconformably deposited above the Sandstone-Claystone Interlude Unit at a depth of 990 ft to the surface. This unit is dominated by less compact sandstone with claystone inserts.

4. Conclusion

Unusual occurrence when the drill tip touches solid volcanic sandstone at a depth of 6000 to 9297 ft. Considered part of the Kalibeng Formation of the Plio-Pleistocene age, then changed to solid volcanic sandstone units of the Middle Miocene age with a depositional environment in the outer neritic-upper bathyal [1-6]. This sequence is probable to change the stratigraphic of the LUSI area and possibly a regional scale because this sandstone sequence is a product of Miocene magmatism. The implications of this finding for the existence of older formations such as the Kujung and Ngimbang Formations are extinct because they will not be found because they do not grow and develop in this area due to the instability of the depositional environment [7-12].

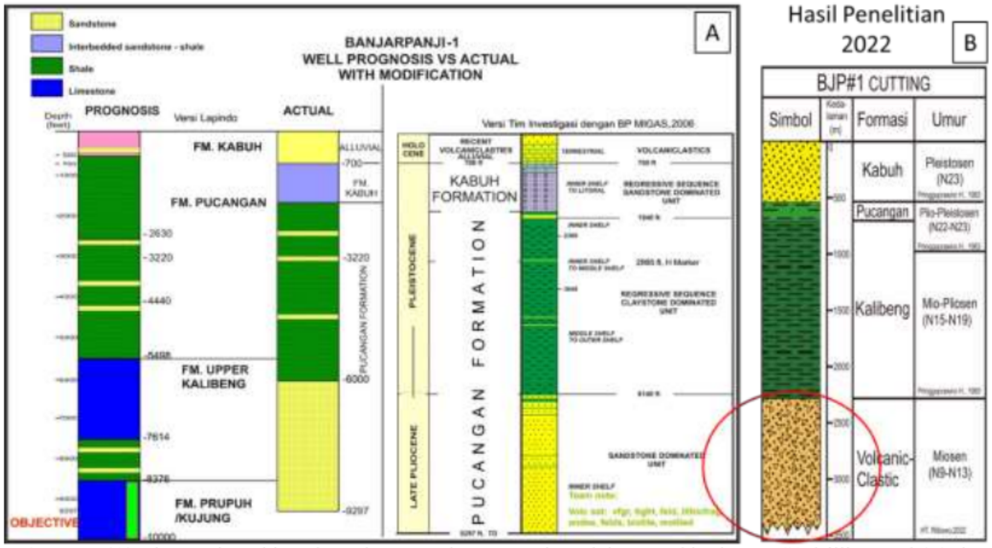

Figure 5. (A) The stratigraphic column between the prognosis and the actual in the BJP#1 drilling, and (B) the change in the LUSI stratigraphic order based on findings in the volcanic sandstone sequence which was previously considered to be part of the Plio-Pliestocene Kalibeng Formation members, then changed to a solid volcanic sandstone unit (red circle) of Middle Miocene age with a depositional environment in the outer neritic-upper bathyal.

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