

Abstract

A sudden eruption of hot mud and steam began on May 29th, 2006, near the Banjarpanji-1 exploration well in Sidoarjo, East Java, Indonesia. In the early stages, the general public opinion speculated that the mud flows were caused by an underground blowout on the Banjarpanji well. But as the data was studied and analyzed, it quickly became clear that the mud flow was not triggered by the well, that an underground blowout did not occur. Firstly, the well-bore fluid pressure was too low to fracture the well bore. Secondly, there was no sustained pressure to propagate fractures. Thirdly and most importantly, the wellbore was open and totally dead whilst mud was erupting at more than 300,000 bbl/day only 200 m away.

In the absence of the Underground Blowout, studies (e.g. Mazzini, et al. 2007) suggest that tectonically reactivated faults provide the conduit for the water and overpressured shale to erupt and form the LUSI mud volcano. The presence of overpressured zone due to rapid subsidence and burial in the East Java Basin is evident. The high sedimentation rate of its maturing organic rich sediments makes it an ideal setting for mud volcanism. Other mud volcanoes occur naturally in the area, and are aligned with the LUSI mud volcano on the NNE-SSW Watukosek fault zone.

Introduction

On May 29th, 2006 at around 05:00 hrs it was reported that Hot Water eruption intermittently with a maximum height of 25 ft and elapsed time of 5 minutes between the burst and occurred around 200 meters from the well. This burst was very dramatic with a distinct geyser-like cycle of active and passive periods. This marks the formation of a new mud volcano known as LUSI in East Java, Indonesia.

This new mud volcano adds to the many mud volcanoes existing in the area, such as the Porong collapse structure (NE of LUSI), Kalang Anyar & Pulungan (Sedati, Sidoarjo), Gunung Anyar (UPN campus, Surabaya), Bleduk Kuwu & Keradenan (Purwodadi), Wringin Anom / Pengangson (Gresik), Semolowaru (Unitomo campus, Surabaya), Dawar Blandong (Mojokerto), Sangiran (Central Java), Socah (Bangkalan, Madura) and others. LUSI however is special, as one can observe the ongoing geological processes from its controversial birth.

Three different hypotheses have been proposed as the trigger of LUSI, namely i). Underground Blowout (Davies et.al 2007 and Tingay et.al 2008), ii). Mud Volcanism due to remobilization of overpressured shale through a reactivated fault as the conduit (Mazzini et.al 2007) iii). Geothermal activities where superheated hydrothermal fluids at high temperature and pressure are released through fault zone or fracture network as the conduit.

The objective of this paper is to clearly and transparently set out the drilling engineering data and analysis to correct the technical record and to provide a platform for further analysis. It focuses on key drilling pressure measurements and drilling facts to investigate the early speculation that drilling was the trigger of LUSI.

Underground Blowout is a Hypothesis

Several writers suggested that an Underground blowout triggered LUSI (Davies et.al and Tingay et.al). However, the facts and pressure calculations clearly show that an underground blowout did not happen in the Banjarpanji-1 well. Several conditions must be met for an underground blowout to occur. The most important is that pressure in the wellbore must be sufficiently high to break the weakest formation (typically the casing shoe). Secondly, sustained fracture propagation pressure is required to extend the fracture to surface. Davies et.al suggested that the casing shoe was fractured and breached. However,

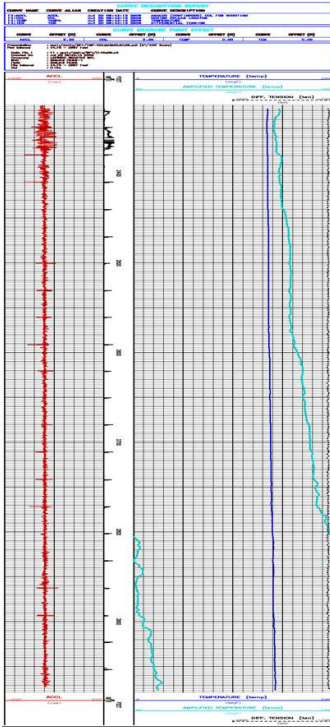


Figure 1 – Temperature log does not indicate any temperature anomaly

calculations based on proper data obtained from the well and related facts clearly show the opposite; the shoe was still intact and not breached.

An investigation was carried out to determine if there was a connection between the well and the mud eruption. If an underground blowout did occur, then it was expected that a temperature anomaly and noise would be recorded in the Banjarpanji-1 wellbore. Temperature and Sonan logging were carried out during the relief well campaign to determine if such phenomena occurred. The temperature logs did not record any anomaly within the Banjarpanji-1 well (Figure 1). The sonan log did not indicate any unusual noise, indicating there was no flow behind casing (Figure 2).

Other facts that do not support the underground blowout hypothesis include:

- From after the well kick was killed on the 28th of May 2006 until the mud eruption, the Blow Out Preventer (BOP) was kept in the open position and numerous activities were conducted in the

wellbore such as fishing, cementing and circulating. If the well was fractured, in order to propagate the fracture

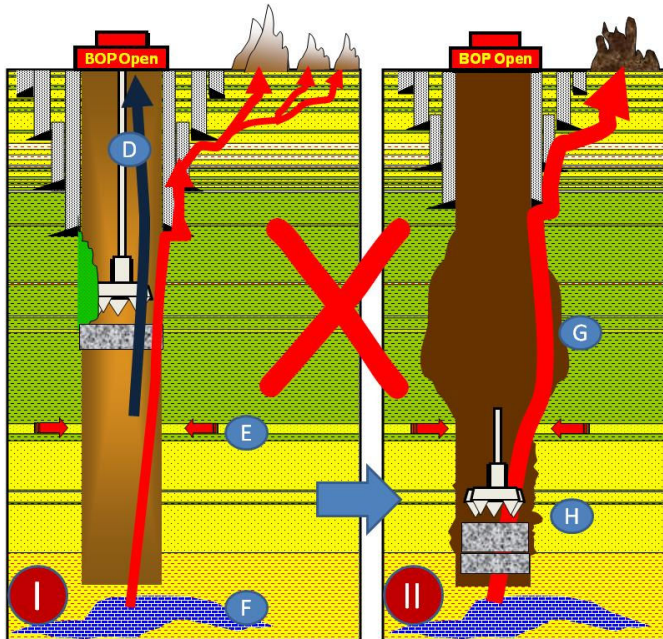


Figure 3 – Illustration of underground blowout scenario of what would be expected.

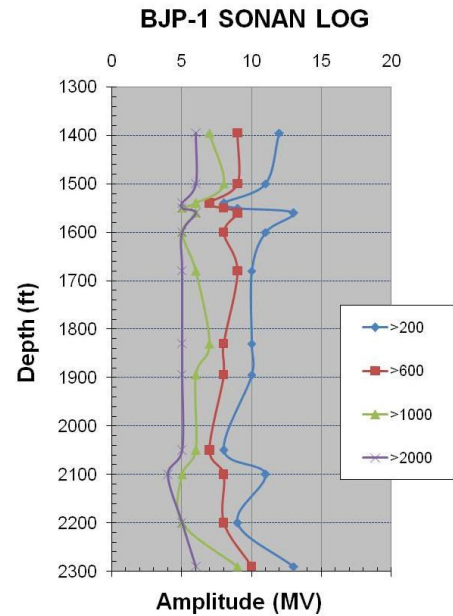


Figure 2 – Sonan Log taken during re-entry operations, 2 months after eruption did not show any noise indicating no flow behind casing

to surface, it would require sustained high pressure and for the BOP to be kept closed.

- No mud or gas or steam came out of the well despite the BOP being in the open position. It would have been easier for the mud to come out of the well instead of having to fracture the formation (Figure 3- I/D). If caused by drilling, the well should at the least be surging and flowing itself as the path of least resistance to surface and there would

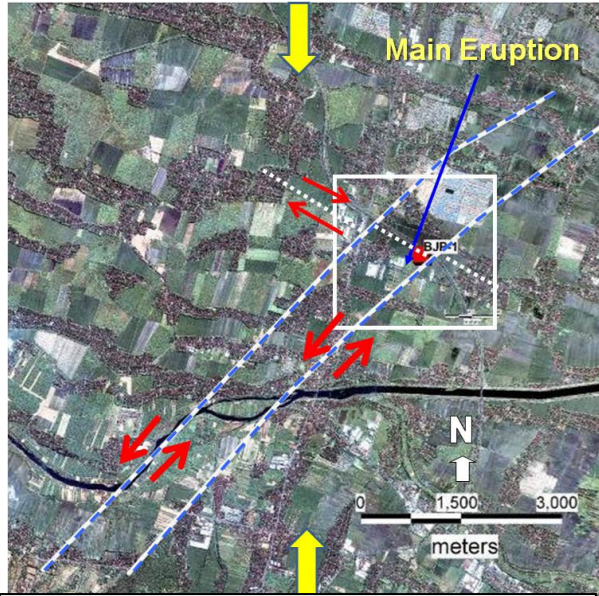


Figure 4 – Location of the mud eruption, major stress directions, fault zones and their relative movements.

enlarge due to erosion from the very high mud rates. Such erosion was expected to result in the dropping of the fish and cement (Figure 3-II/H), however this did not happen and the fish remained intact as reported in Daily Drilling Report on 16th July 2006, 1.5 months after the eruption.

- The mud eruption occurred along lines of weakness aligned with the Watukosek fault zones, which is not typical of underground blowouts. The crack that formed at the rig site on 2nd June 2006 was not followed by extrusion of fluid nor mud, suggesting they were not due to hydro-fracturing. Other fractures parallel with the Watukosek fault were observed at the same time as the initial mud eruption. The movements suggest sinistral reactivation of the faults. Second order dextral movements were observed several times in the railway line movements in September 2006 (Figure 4).

Banjarpanji-1 Casing Shoe Strength Analysis

The following data is used to calculate the pressure at the casing shoe and determine if an underground blowout occurred in the well.

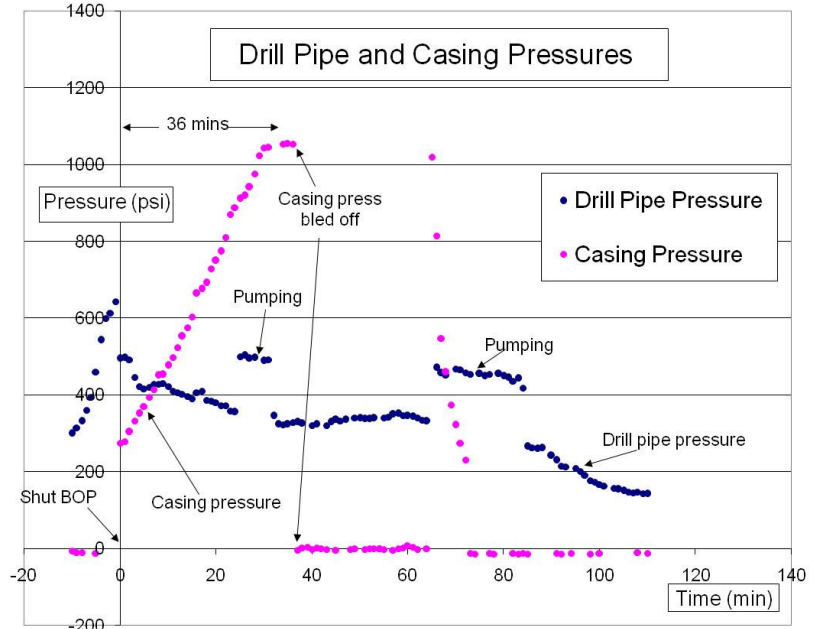


Figure 5– BJP-1 Real time data dated May 28th, 2006. The max casing pressure was 1,054 psi, pressure reading 30 mins after shut in. Well was dead and BOP was opened at 10:00 hrs, May 28th, 2006.

definitely be some gas and steam coming from the wellhead. It seems totally impossible for 300,000 bbl/day of mud and steam and gas at the beginning to flow through a well that is totally dead at surface.

- Noting this nearby eruption, the first information required was evidence for any connection or channel between the eruption and the well. This assessment was done by closing the well and pumping into it on the 29th May 2006. After pumping two batches of mud the well did not experience any losses and the pressure was holding at 900 psi. Another injection test was done on 30th May 2006 prior to placing the cement plug with an injection pressure at 370 psi with a

rate of 2.5 bbl/minute. Pumping into the well confirmed no connection between the well and the mud eruption.

- The unprotected wellbore was expected to

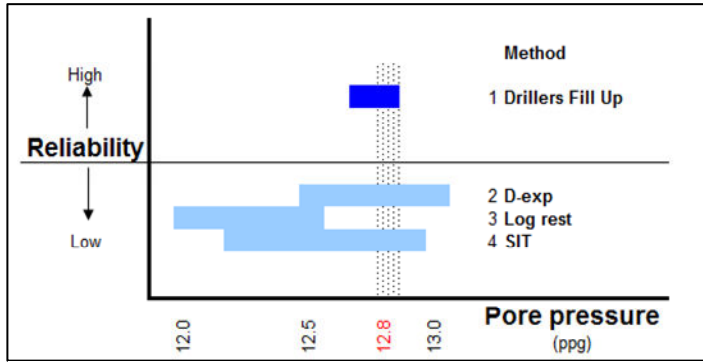


Figure 8—Range of bottom hole pore pressures. The pore pressures are derived from a number of pressure prediction methods with different reliability. The ‘Fill Up’ method is considered the most reliable and widely used in drilling.

- The well lost mud twice on May 27th, 2006 indicating that the BHP is less than the mud weight of 14.7 ppg. (Figure 11).
- The Static Influx Test conducted at 9010 ft on 27th May 2006 was used to check the Bottom Hole Pressure. This test was negative with no increase in gas reading meaning that the pore pressure was less than the Mud Weight used, which was 14.7 ppg.

• **Leak Off Test.**

The leak off test done at the 13 3/8” casing shoe is shown in Figure 9. The LOT was 16.4 ppg at a depth of 3580 ft. The LOT result is consistent with the LOT of Wunut 2, an offset well approximately 2 km away which had a LOT of 16.6 ppg at a shallower depth of 3,160 ft. It should be noted that the shallow section of Banjarpanji-1 is within the Wunut anticlinal structure.

• **Pressure analysis at the casing shoe showed that it is intact.**

Using the basic data above, the pressure analysis is as follows:

1. Maximum Casing Pressure = 1,054 psi
2. Fluid in the upper part of the hole = 8.9 ppg. Maximum mud weight = 14.7 ppg
3. Bottom Hole Pressure = 12.8 ppg
4. Leak Off Test at the casing shoe (3,580’) = 16.4 ppg

The resulting graph is shown in Figure 10. The pressure at the shoe exerted by the fluid is 2710 psi which is lower than the strength of the rock (LOT) of 3053 psi. This proves that the weakest point in the well, which is the shoe, was still intact and was not fractured.

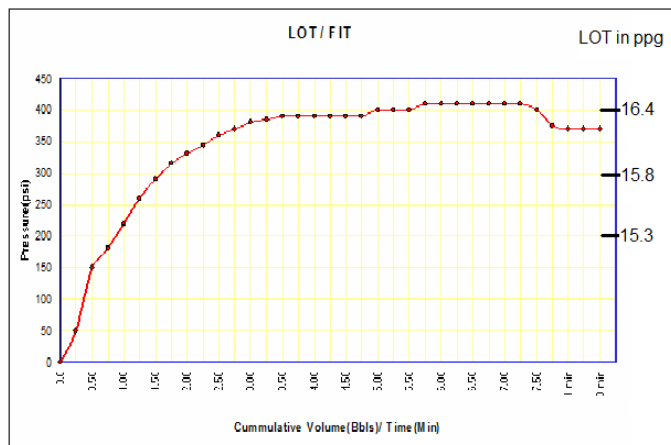


Figure 9 – Banjarpanji-1 Leak off test result of 16.4 ppg at the 13-3/8” casing shoe at a depth of 3580 ft. The result is consistent with the nearest offset Wunut-2 well which had 16.6 ppg LOT from a shallower depth of 3160 ft.

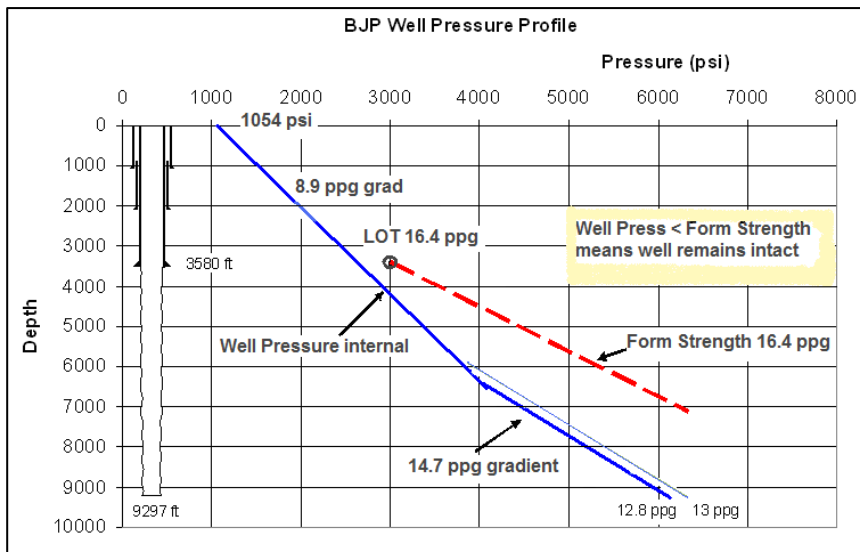
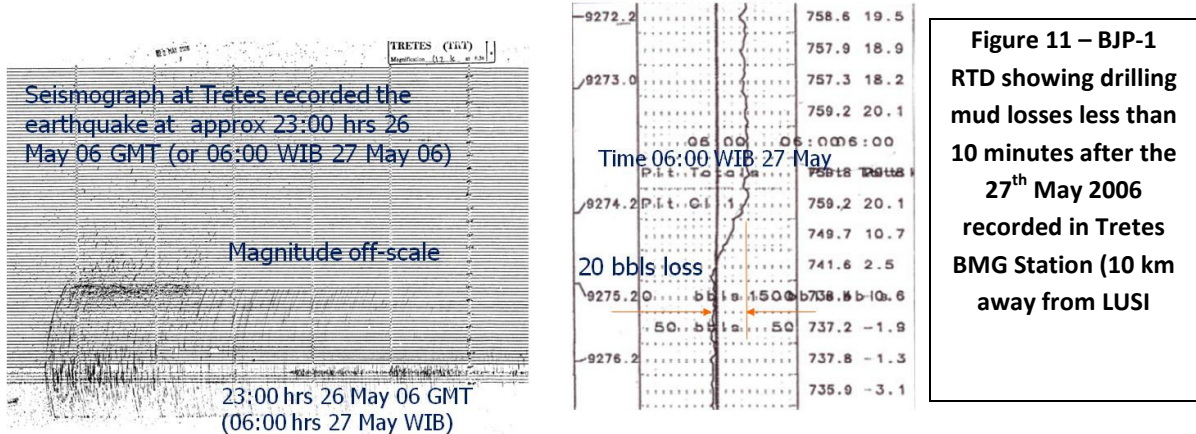


Figure 10 – BJP-1 Pressure Profile shows that the pressure within the wellbore is still lower than the strength of the rock at its weakest point, ie. Lower than the LOT.

Underground Blowout Arguments

Observers were quick to assume that the mud eruption was caused by an Underground Blowout because of its proximity to the well. Arguments on Underground Blowout however, are not supported by facts. These include:

1. Davies et.al 2007, showed the bottom hole pressure of 48 MPa (14.4 ppg) and proposed a kick occurred while drilling into the Kujung Formation. But in fact well had a loss, not a kick, when drilling using 14.7 ppg drilling mud on May 27th, 2006. The well suffered a partial loss of 20 bbls of drilling mud less than 10 minutes after the 27th May 2006 earthquake recorded at the Tretes BMG Station (Figure 11). The total loss of circulation of 130 bbls occurred in the well after 2 major aftershocks around midday of the same day.



2. Tingay et.al 2008, (Figure 3) quoted pore pressures which are unrealistically high. Pore pressure in BJP-1 was reported as 17.84 MPa/km (15.2 ppg) at 2130 m depth and 17.1 MPa/km (14.5 ppg) at 2800 m depth. These pressures are higher than the mud weight and the Static Influx Test that shows the actual pore pressure to be much lower than 14.7 ppg.
3. Claims made by Davies et.al. 2007 that hydrofracturing occurred and Tingay et.al. 2008 where the fluid pressures inside the well exceeded 19.5 MPa/km (16.4 ppg) shortly after the blowout preventer was closed. Contrary to claims, as shown on Figure 10 and calculations below indicate that the pressure at the casing shoe, which is the weakest point of the wellbore, was lower than the fracture pressure.

Pressure at casing shoe = Maximum casing pressure + hydrostatic pressure of fluid

$$\begin{aligned}
 P_{@3580} &= 1054 + (0.052 \times 8.9 \times 3580) \\
 &= 2710 \text{ psi} < 3053 \text{ psi (fracture pressure)}
 \end{aligned}$$

Conclusion

A number of papers hypothesized that the birth of the LUSI mud volcano was related to drilling of the Banjarpanji-1 well.

This paper presents drilling data, facts, analysis, and investigation during the re-entry and relief well campaign, which show that the well casing shoe did not breach. The well bore pressure was too low to fracture the well. Supporting this conclusion, field data demonstrated that the well was still intact and indicated no communication between the well and the mud eruption. Therefore it is concluded that an Underground Blowout as a trigger of the LUSI mud volcano is a hypothesis not supported by drilling data and facts.

In the absence of any evidence supporting an underground blow out hypothesis, reactivation of the Watukosek Fault is seen as the most likely and natural trigger for the mud volcano, as there was a clear connection between the timing of earthquake and after-shocks, and mud losses in the well.