SIDOARJO MUD PHENOMENON AS A PERMANENT MUD-VULCANO FOR PRELIMINARY HYPHOTHESIS

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Abstrak

Penelitian ini adalah pengembangan penelitian sebelumnya yang berjudul Interpretasi Seismik terhadap Fenomena Lumpur Sidoarjo. Penelitian tersebut mengestimasi: 1) Volume cadangan lumpur yang tersedia, 2) Potensial energi yang membangkitkan power untuk menyemburkan, 3) Potensi semburan baru di lokasi sekitar semburan utama. Pengembangan penelitian pada paper ini adalah membuat dugaan atau hepotesa awal bahwa mud volcano adalah fenomena alam biasa dan akan bersifat permanent. Dugaan ini utamanya berdasarkan analisa geologi struktur. Struktur lapisan batuan sumber lumpur adalah layered dan memiliki kemiringan yang cukup terjal, sehingga beda ketinggiannya menyebabkan adanya potensial energi gravitasi untuk menyemburkan lumpur. Apabila diasumsikan bahwa lapisan sumber lumpur terus terisi oleh air tanah akibat ilfiltrasi pada setiap musim hujan, maka semburan tidak akan berhenti. Penelitian yang sedang berjalan memberikan konfirmasi bahwa data debit semburan selama 18 bulan memberikan kecenderungan demikian, yakni pada musim hujan membesar dan menurun pada musim kemarau. Area rentan sesar (collapsed area) di atas lapisan batuan sumber lumpur juga memberikan kontribusi tentang kerentanan munculnya semburan baru. Kerangka analisa yang digunakan sebagai referensi dalam penelitian ini adalah komparasi terhadap kejadian mud volcano yang wajarnya ada di dunia.

***Kata Kunci**: mud volcano, interpretasi seismic, Sidoarjo, struktur geologi*

1. Introduction

In the beginning of Sidoarjo mud phenomenon, the local people have been surprised by this accident. This is caused by no indication at all before accident or around people has not available to detect kind of signs. All communities suppose to stop the blowout especially in the commencement term. It is a look like no obsession to stop the blowout after the people cannot bring to a close them during more than four years. This is due to the lack of analysis of geological condition and geophysical aspect. This paper describes the result of seismic interpretation in order to estimate the mud phenomenon as a permanent mud-volcano.

The focused matter is not clear what is the logical reason of the geological characteristic? This phenomenon is leading to the conclusion of perception as the permanent mud-volcano. Therefore, the aim of this research is to decide the background reason of Sidoarjo mud phenomenon as permanent mud-volcano.

The methodology is the critical analysis of geological structure, the mud sources, and potential energy as what the mud available to flow up. The result has been validated to the natural phenomenon as mention in the reference. The special characteristic of the structure has been compared to the criteria of the mud-volcano.

2. Literature Review and Methodology

2.1 Literature Review

Mud-volcano is the geological phenomenon. It has some distinguishes when to be compared to the normal volcano. Volcano confuses the magma while the mud-volcano brings-out mud as an eruption product. Normally, volcano is conducted due to tectonic subduction activities as part of plate tectonic processes. It always produces the magma what usually be erupted. On the other hand, mud volcano (figure 1) is happened due to three conditions of structural geology there are; 1) Source rock that has mud filled possible porosity, 2) Potential energy as the power to push up the mud, and 3)

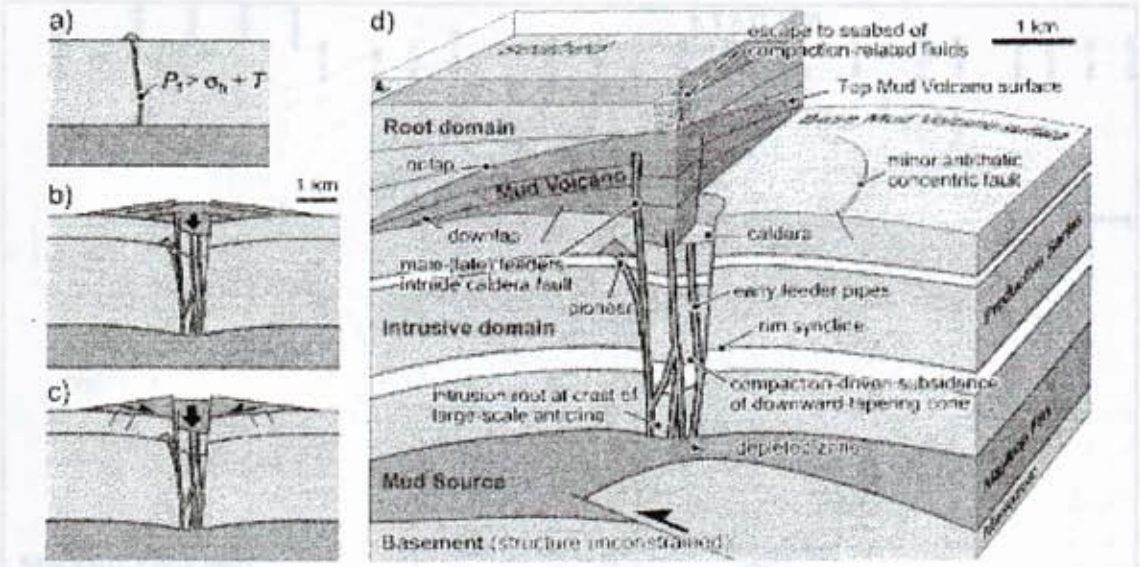

Figure 1. Illustration of mud volcano processes, fold as supported structure, mud source rock, and strong pressure such as potential gravity or/and oil and gas blowout, a) b) c) and d) is a simple sequence of process (Stewart *et al*, 2006)

Availability access to go out such as the faults (Stewart and Davies, 2006; Yusifoy, 2004).

A mud volcano phenomenon in the world is in around 800 places, more than half are in Azerbaijan and Caspian Sea (Volcano.com, 2006). Figure 2 shows the locations of mud-volcano in the Middle–East Java.

2.2 Geological Structure of Sidoarjo Mud-Volcano

The well of Porong-1 has been drilled based upon evaluation of 2D seismic method since 1993 by Lapindo Brantas Inc. (Kusumastuti *et al*, 2002). Kusumastuti *et al* (2002) made analysis the sequences of carbonate platform formation and reservoir potential in Madura trough. Specially, they

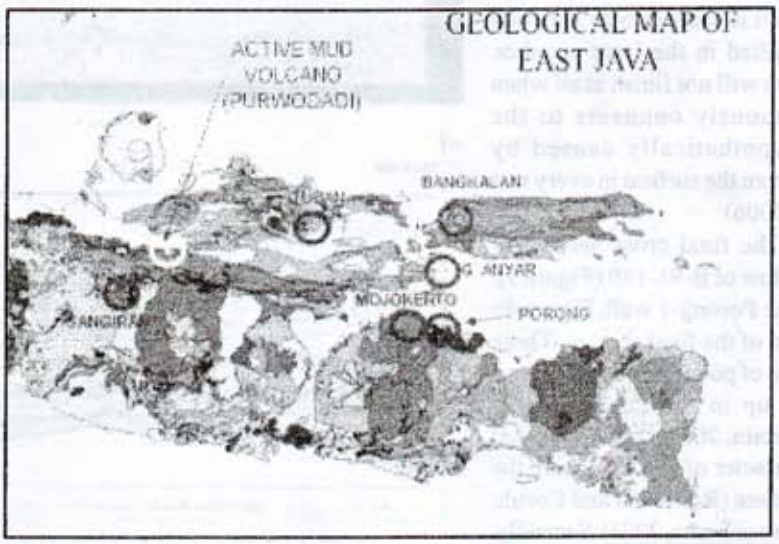

Figure 2. Six locations of mud volcano in the Middle-East Java (Putrohari, 2006)

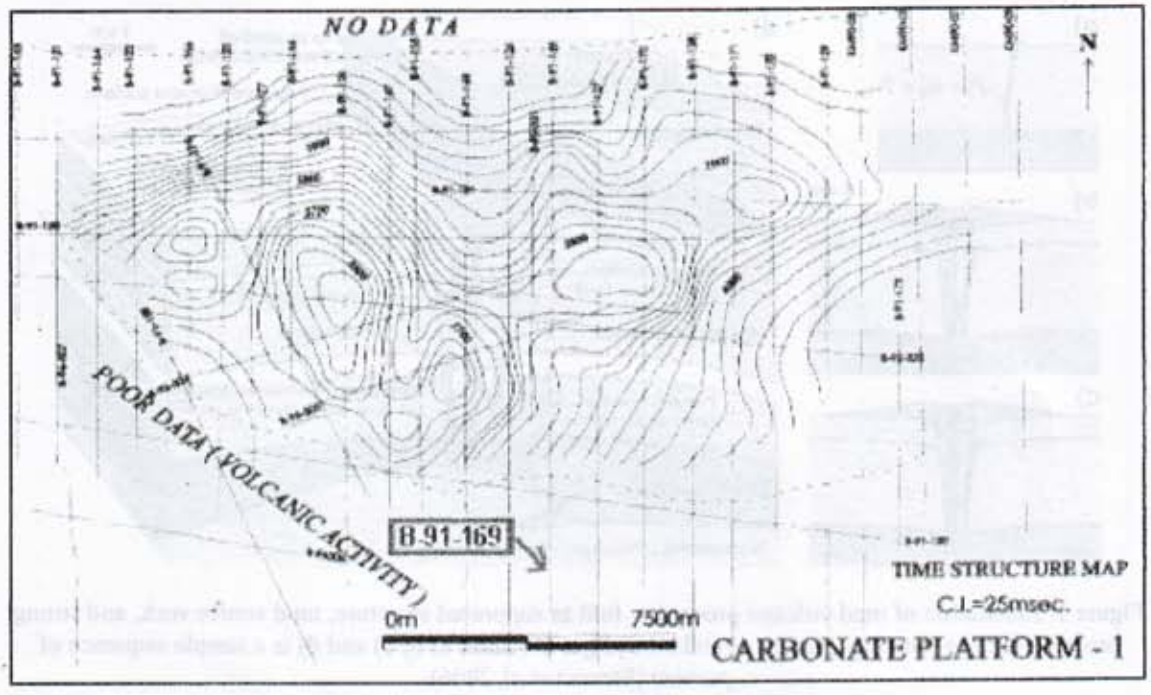

Figure 3. Position of seismic section line of B-91-169 in Porong-1 (after Kusumastuti *et al*, 2002)

constructed the map of reservoir structure of Porong-1. They made this from integrated seismic data as the time structure map. The carbonates reservoir is a porous layer (average of 15 % porosity) of clay. The layer overlays above the Porong-1 well areas. The thickness of sediment above this reservoirs is 1,2 to 1,5 km. This dimension illustrates how the mud sources were supplied in the large number. The material source will not finish at all when the layer continuously connects to the surface. It is hypothetically caused by infiltration water from the surface in every wet season (Mustain, 2006).

Figure 4a is the final cross section of seismic record for line of B-91-169 (Figure 3). The line crossed the Porong-1 well. Figure 4b is the interpretation of the final section. There are two possibilities of potential energy to give a power to flow up in the mud Sidoarjo phenomenon (Mustain, 2006). Firstly, oil and gas are normal character of move up from the oil basin to the surface (Robinson and Coruh, 1988; Petroleum Geosciences, 2008). Secondly, the potential energy is potential gravity due to the difference elevation of depth source

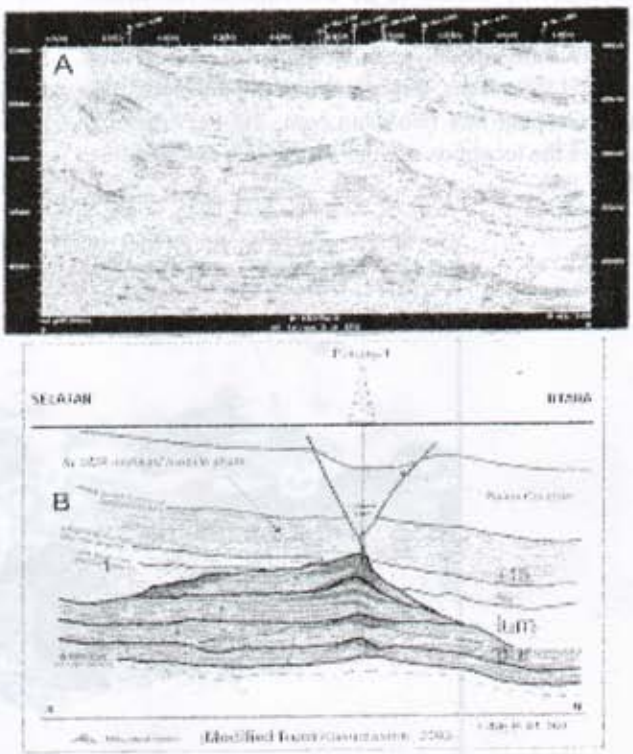

Figure 4. a) Seismic record in North-South line to cross Porong-1. and b) the interpretation (after Putrohari, 2006)

layer that has a positive slop to the south direction (Figure 6). This difference depth causes the potential gravity power or known as overburden pressures.

The indication of collapsed zone is very clear. Bright circle in figure 4a is located area of collapsed zone. There are same discontinuity seismic reflections as the faulted area. It is localized by red line in Figure 4b as interpreted illustration (Putrohari, 2006). This is explicitly clear that the point of Porong-1 is exactly in the middle of collapsed zone. Similar interpretation has also done by Kusumastuti *et al.* (2002), there are some indication fault lines in the collapsed zone (Figure 5).

These all information gives us understanding that the area is a sensitive zone of mud blow out then become mud-volcano phenomenon. This is based on the references (such as Sheriff and Geldart, 1995) and the further description of Mustain, 2008. This becomes relevant reason of third condition of mud-volcano phenomenon i.e. the available way or axes to blow out through the fault line.

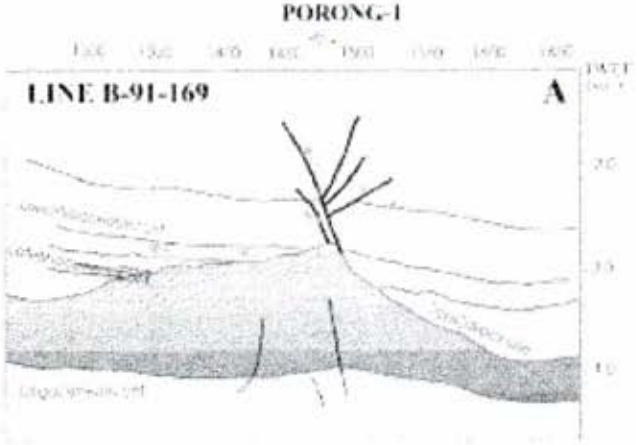

Figure 5. Interpretation of fault lines for the collapsed area (Kusumastuti *et al,* 2002)

Without concerning to the mud filled of material soft rock that has a high potential energy to blow up, the oil company has to make an extra careful due to collapsed zone. Theoretically, seismic exploration activity in this area is very danger and sensitively accident such as blowout. Therefore, the activity is only available if it has been done by an extra and more careful than the others. Logically, when the bore attach the cap rock then the pipe pressure become extremely high due to stress from oil basin. This is the relevant conception and principle of oil reservoir in the references (Telford *et al*, 1990; McQuillin and Barclay, 1979).

3. Result

3.1 Mud Volume Estimation

Mustain (2006) had made roughly calculation to the volume of mud source. Porosity average 15 % (bore hole data for Line B91-169, SP 1485, 1993; Kusumastuti *et al,* 2002), is have been used to calculate the each extrapolation seismic line of both South-North and East-West direction. It is assumed that here used a total line as the sum of extrapolation of 2.5 time of seismic line length i.e. 17 km. Therefore, the number of mud volume is calculated as $3.25\ 10^{11}$ m^3. This number will finish in the period of 8.907 years when the debit of blowout is 10^5 m^3/day (Table 1). This is roughly calculation but logically, due to poorly data except line B-91-169 from Kusumastuti et al, 2002. The next consideration for normally mud explosion that is also depend on the balance between subsurface pressure (overburden) and the height to flow upward (lithostatic force) as the pressure equilibrium. Therefore, the potential energy will be discussed below.

Figure 6 illustrates the average slope of mud source layer as Pliocene (yellow or bright) in the range of 0.059 to 0.088. This is had been calculated from different depth of 1000 to 1500 m. for seismic section of 17 km length. Here is had been assumed that distance between the surface (position of BJP-1) to the Top-Carbonate layer is 3000 m. or 1500 ms. TWT (Two Ways Travel Time) seismic record. The velocity of seismic wave is assumed in rms (Root Mean Square) and around 4000 m/s. Then the slope is a significant number for different depth of 500 m. to obviously create the potential gravity force in order to push up the mud. Therefore, when we assume that the specific weight (γ) is the constant, then the simple hydrostatics formulation of $p_1 - p_2 = \gamma(z_2 - z_1)$ gives the different pressure as large as different depth due to the slope of the layer. This figure clearly illustrates for us if the available of potential energy is large enough doe to potential gravity of geological structure. This assuming is only using the Hydrostatic Force no other forces.

The quantity potential energy is in between

Table 1. The calculation of the mud source volume (Mustain, 2006)

PERHITUNGAN ESTIMASI VOLUME LUMPUR PANAS SIDOARJO

		Panjang (m)	Lebar (m)
Panjang line B-91-169 (m)	17000		
Faktor pengali panjang	2.5	42500	
Faktor pengali lebar	2.5		42500

Panjang lapisan (m)	Lebar lapisan (m)	Tebal lapisan (m)	volume batuan (m^3)	porositas batuan %	volume lumpur (m^3)	semburan perhari (m^3)	waktu sembur (hari)	waktu sembur (tahun)
42500	42500	1200	2.17E+12	0.15	3.25E+11	100000	3251250	8907.53

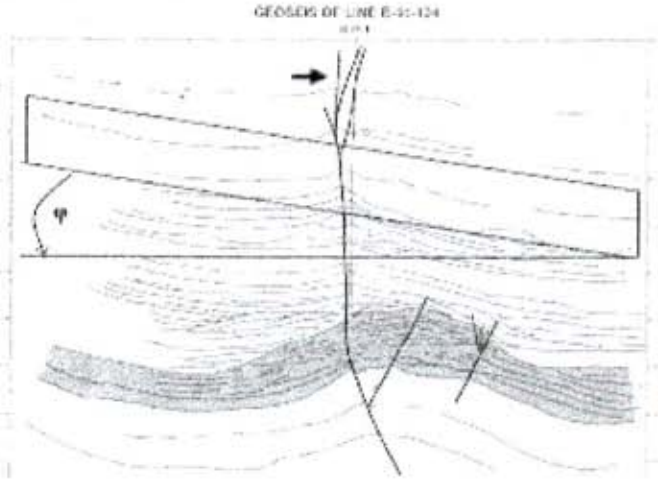

Figure 6. Interpretation of average depth of mud-source (After Istadi, 2006)

depth of 1000 to 1500 m. The potential energy from the calculation is 8500 kN/m^2 for the density of mud of 1.726 gr/cc. This quantity will be released by the water volume that available in the reservoir (Table 1) with debit of blowout of 100000 m^3/day. Therefore, the result of calculation of the timing of eruption is 8.908 years.

3.2 The Potentially Other Blowout

Figure 7 gives clearly illustration of collapsed zone. It was had been interpreted that the collapsed zone (slumps) is a fault zone as still active and productive faults in around BP-1 location. The positions of faults are in the depth of; 1703', 2617', 4030', and a zone of 4610'-5520'. All these positions (as slumped area) are above the source layer. This was had been supported by Kusumastuti *et al* (2002) interpretation in figure 5 of both fold zone and fault zone. Qualitatively, the moved faults and folds are to up direction. Figure 4B also supports this interpretation, Paleo collapse and subsidence or surface settlement structure. The length of 5 km along line of seismic line B-91-169 and exactly below BJP-1 is as collapsed zone. The other indication is a surface settlement due to incompact layers along 5 km.

The next significant point in geological structure is very-very sensitive zone for the other blowouts or the bubbles. This was also had been supported by the present of large potential gravity energy that have been discussed before. The active fold is interpreted as still move, while the productive fold is as continuous fold to produce the new folds and faults around BJP-1. This is caused by strong pressure of potential gravity energy to push up the materials.

3.3 Discussion

The calculation of mud sources volume is very roughly. But it is very importance for the beginning estimation (Mustain, 2006). So we available to estimate the next period of blowout related to geological structure and the availability of potential energy. When we need to calculate more accurately than here, we must find the seismic sections as much

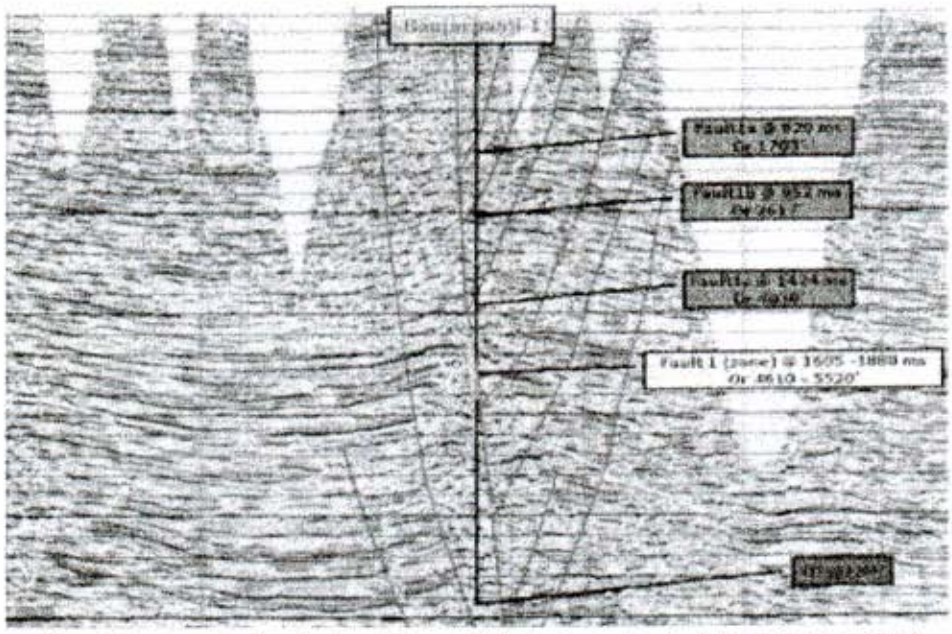

Figure 7. Interpretation of seismic line with faults indication in BJP1 (Andrew, 2004)

as the line in the figure 4. Then, we have availability to map all side area of fulfilled porous layer in depth between 1500 to 3000 m. or 2400 to 3400 TWT (two way travel time). Therefore, we could produce 3D model of the layer. Finally, we would like to calculate the volume of mud source more accurately. So, the key factor of the accuracy is the availability data for all the lines in the side area.

The sub-surface structure and the chemical structure (no hydrocarbon contain) of Sidoarjo mud indicate the character of potential gravity energy. This is caused by the different depth from the slope of layer that has been discussed before. There are no hydrocarbon in the chemical contain data that based on the result of Kusumastuti research (2002). Therefore, the potential gravity energy plays the role of blowout.

The potential gravity will finish for half of the total volume when we assume the blowout location in the middle of the line. This is caused by no pressure in the same depth. Consequently, the total time to finish is also the half i.e. 4.454 years. This calculation assumes no ground water infiltration to the mud sources layer (Mustain, 2002; Mustain, 2005). On the other hand, when the source layer is filled by ground water infiltration every wet season period, then the blowout never stops running. The recent research (The Dirgen Dikti as the research funding of *Hibah Bersaing 2010 and 2011*) confirms that trend, from the analysis of 18 months debit of blowout. It increases for the wet session. In contras, it decreases for the dry season. This is the preliminary information which much useful for the correlation season period. The next research will be investigated deeply both qualitatively and quantitatively.

This is interested indication that there are strong correlations between potential energy with the seasons. It gives us beginning information qualitatively about groundwater infiltration to the source layer. This is very importance because same relevancy to the amount of volume of mud source characteristic. The end of the day, we will say that the mud source never finish due to ground water infiltration in every wet season. In the same word, the blow out is never stop bubble and blowing, event there was the idea of new bubble as caused by settlement due to erosion subsurface by mud flow. The result of calculation of mud sources volume, the estimation of potential energy, and the analysis of sub surface geological structure become key factors. These are useful to decide the solution of social problem due to mud phenomenon. Finally, the human as ***Cholifah*** (such as a manager) in the world are always to solve every problem include Sidoarjo mud phenomenon. Once more time, the importance point in this research is to give learning to the people

especially around the location. Therefore, the people will increase concentration and give a more wear to this phenomenon. In the same meaning that the people could move to make more distance from the location.

4. Conclusion

a. The amount of volume estimation of mud sources is 3.25 10^{11} m^3 for blowing debit of 10^5 m^3/day and will finish in 8.908 years (very long lime).
b. The estimation of the energy is potential gravity due to difference depth.
c. The analysis of sub surface geological structure gives strong indication of available of new bubbles around location.
d. There is possible correlation between the source layer and ground water infiltration. The volume of mud source nearly constant and due to ground water infiltration in every wet season. The end of the day, as preliminary hypothesis, the mud phenomenon will be stated as a permanent mud volcano.

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