MUDFLOW GEOLOGY AND GEOPHYSICS STUDIES IN PORONG, SIDOARJO, EAST JAVA Mudflow

Expert Team Indonesian Association of Geologist (IAGI) Recently more information and discussion of how the mudflow occurred in Sidoarjo, East Java is proving to be more thematic. Cumulative evidence is linked to scientific problemshow the mudflow has spread and the precise source has not been determined yet. The main questions are: How the mudflow happened? What is the driving mechanismfrom the fluid uprising? How does the feeding system function?Fluids that are progressively concentrated under the surface could be discharged at the surface if there is enough pressure / overpressure (in case there is geological seal), or if there is a big enough gap in pressure and temperature (in case of the releasing of hydrate gas). This condition can be fulfilled if there is pathway like a fracture or fault. Apart fromthat, another basic sign that it is important to acknowledge is the early character (deep signal) from the fluid and gas that are involved in the discharge. The fact that can be seen after the exploration in the Banjar Panji-1 well reached a depth of 9,297 ft, is that there is no indication of clay in the liquid phase. Soon after the well reached 9,297 ft, a total loss was experienced but this could be managed by LCM (Lost Circulation Material). After the loss was managed, drill bit was removed. However, after the bit reached 4,241 ft KB of depth, there was a kick that could be managed by volumetric method. In May 29, 2006 at 05.00 WIB people reported the mudflow started. The first broach was located 150-200 meter from the drilling location BJP-1 well that was followed by second and third extrusion / broach located 500 meters from the well. Three broach points are showing a linear pattern. Two other points showed parallel line, with three points showing linear pattern.

In the early extrusion, the mud material consisted of clay (30 percent) and salty water (70 percent) with average bulk density of 10.56 ppg (1.27 gr/cc), average water salinity of 14.151 ppm NaCl. The average of early extrusion height is 25 ft above land surface or 36 ft above sea surface. The Sidoarjo mud that has spewed-out on surface has the following physical characteristics: Chemical content of rocks and biota, suggest a provenance from volcanic rocks with no more than 4.9 million years of age that settled in marine environment. The X-ray analysis showed that the mud contained pyrite, albite, kaolinite, paragonite, and halite minerals. The mineral composition content showed that the mud came from rocks that have experienced hydrothermal alteration and the water that comes out together with mud has salty water characteristic. The salty water does not come from the mud. The analysis showed the mud water is dominated by elements like Sodium (Na), Magnesium (Mg) and Potassium (K), with average content above 8 mg/l and Chloride (Cl) of 1.8 mg/l in average. The mud comes from an over pressurized zone located at 4,000 – 6,100 feet of depth. The pressure at this depth is around 14.3 – 14.5 ppg, which is a condition higher than normal hydrostatic pressure of 8.3 ppg. The difference in pressure is the cause of the long-term mudflow. Regional tectonic activity in the East Java Basin cannot be separated from geologic history in the west part of Java and the overall tectonic activity in Southeast Asia. The East Java Basin is located in the southeast margin of Sunda platform where Mesozoic basic rock and mélange rock are found. The patterns from old structures of continental edge from Mesozoic time, which is basically oriented northeast – southwest direction, in line with a subduction that happened during that period and affected the current basin formation.

Many tectonic models have been proposed by several authors to explain the complexity of the East Java's basin geology. One model that is relevant as a background to regional geology is a model developed by Budiyani et.al (2003). The geologic map of Porong – Banjarpanji shows a well-defined surface structure called Watukosek fault zone. The interesting thing is that Watukosek fault is parallel and very close to the hot mudflow center point near the Banjarpanji-1 well. Similar patterns and directions from the fracture and mudflow center can be interpreted as the mudflow is related to the fracture zone. The distribution of potential of mud diapir and overpressured shale in Java island, especially in East Java, are established in one stretched zone and is located in anticline. In Central Java, it is reported that several regions including Bleduk Kuwu, Purwodadi and also Sangiran Dome are included in the zone. In East Java, several regions including Kalang Anyar, Pulungan, G. Anyar and Bangkalan (Madura) also located in a linear pattern of NE-SW.The hot mudflow in Sidoarjo shows that the mud broached from a layer below the surface that is quite thick and contain clay (shale) that has a higher pressure due to hydrostatical pressure (overpressured), a very plastic characteristics and it might be in mobile condition. On the surface, the mud is a mixture of fluid and solid elements in the form of salty water, sand, gas as well as steam that reach 100 degree Celsius. The process of mud volcanism through several mechanisms; the rapid sedimentation process and burial process that causes the rocks not to compact perfectly yet. In the plastic condition, over burdened by the upper layer, the rock layer will have dynamic characteristics and able to spew out to the surface through fractures or fault zones. The Sidoarjo mudflow is a geological process (the establishment of mud volcano). These materials were coming from the earth. The extrusion process is caused by the establishment of new fracture, or the reactivation of an old fracture, which then functions as a conduit. In certain tectonic settings, the phenomenon of mud diapir that has the potential to become a mud volcano can be well observed based on seismic data. In the Banjarpanji structure, the geometry that shows mounded pattern can be observed in seismic track b-96-504 that is directed to northeast – southeast and through the north of BJP-1 well at around 1,800 – 2,100 msec of depth. However, the pattern can be interpreted as several geological phenomenons such as the appearance of carbonate and an inverted channel, so that there is not enough justification to interpret the pattern as being part of a shale diapir. A seismic reflection pattern that shows a low amplitude zone can be observed and divided vertically from the reflection pattern of high amplitude. The pattern can be interpreted as rocks with low acoustic impedance, such as shale. According to a correlating result with the Porong-1 well, a zone with low amplitude is an over-pressurized zone. Based on well data, litology interpretation and the anomaly of interval velocity, several phenomenons have been identified. However, more detail investigation using seismic section is needed, especially to find out the lateral extension pattern. Apart from that, the interpretation of seismic reflection patterns that show geological events both structural and stratigraphic is also needed. Seismic section b-91-124 directed to North – South that is through Banjarpanji-1 well, it can be seen that structurally the south part is higher and gently slopes to the north. It is quite hard to observe the structure and stratigraphic events using seismic sections considering its low quality. However, the faults that cross the section can be observed. This pattern can be also observed in seismic section b-91-197 that is located parallel to the east of the b-91-124 section. The intensity of the fractures can be observed involving low shallow and deep layers. Paleo-highs can be observed through onlapping sediments on these structures.

The spread of geologic events made from “traverse” seismic section passing the Tanggulangin and Porong-IX wells, which is seismic section b-96-504, can be interpreted structurally and the depth of the layer is deeper towards the east. Another phenomenon that can be observed is that there is a quite significant “collapse structure” around the Porong-1X well. This is generally correlated with mud volcano formation and mud diapir existence. Based on the reflector, it was predicted that there was subsidence in this area at around 900 ms or more or less 900 m. Several stratigraphic and structural events could be observed in more detail through seismic section b-96-504. From the section, two geology events can be interpreted. The shape of a “mounded” geometry can be clustered as stratigraphic phenomenon while the number of reflector discontinuity, especially in shallow section, can be interpreted as a fracture or fault planes and structural phenomenon. The “mounded”/”buildup” geometry in seismic section is an indicator of the presence of carbonate rocks if the reflectors that are lapping on to it can be observed. Besides being associated with carbonat rocks, this geometry can be interpreted as mud diapir. However, based on drilling data, this is not limestone rock or shale diaper, but volcanoclastic rocks. In the shallow interval, we can observe intensive reflector discontinuity that shows the active fractures involving young sedimentary rocks. Many weak zones, interpreted to be associated with fracture, near the surface can not be mapped in detail considering the quality and data limitation (only data 2D). The understanding of what truly happened is that there is mud movement below the surface, flowing to the surface and establishing a mud volcano that is hard to stop. This broach will stop or extrude less if hydrostatic pressure condition is achieved. This condition will be depend on several subsurface condition. The broach can be stopped in months, years or even hundred of years. Generally, the broach will stop if hydrostatic equilibrium is achieved. In geological terms, the process of Sidoarjo mudflow is a geologcal phenomenon called mud volcano.

Page 6

According to the calculation of seismic and gravitation combination, the mud volume has the potential to spew out to the surface of 1,155,000,000 m3. This calculation shows the mud rate over the last four months at between 50,000 m3-120,000 m3 per day. If we assume that average mud debt is around 100,000 m3/day, the mud will stop spewing in more or less than 31 years. However, it depends on how long the hydrostatic equilibriumis achieved. Subsidence has occurred as the geological impact due to the mudflow over the last four months. GPS measurements result is showing the subsidence is fluctuating (not linear). The subsidence that happened during June-July is averaging around 5cm. In the measurement of July and August, there is an significant subsidence by 3cm to 91 cm. Meanwhile, for August to September in Siring, the rebound reached 30 cm. The result of GPS measurement also shows a horizontal movement, where the movement from fifteen points to center points is in a concentric form. The subsidence happened in quite a wide area, and more than the area flooded by mud. The most interesting thing is there is an observation showing recent tectonic movement. The movement indication is shown by the railway tracks that curves to the right. The location where the railway tracks are curving is crossing with the location of the Watukosek fault zone. This shows the reactivation of faults. The Banjarpanji-1 well, located on the East Java Basin which has been proven as one of the major oil and gas source in Indonesia, is an exploration well intended to prove the oil and gas deposits in the Kujung formation. This well is located between two original oil and gas structures, Tanggulangin and Wunut. Unlike those two, which have been proven as a source of oil and gas on shallow horizons (volkanoclastic Plio-Pleistocene), Banjarpanji-1 Well is intended to prove oil and gas deposits in a deeper horizon, the Miocene-aged Kujung carbonate formation.

Regionally, Banjarpanji-1 is located in a region with “Petroleum System” where it has been proven that aspects of source rock, migration, reservoir rock and trap are found. This fact is supported by the seismic mapping results around the Banjarpanji-1 well and drilling data. Source Rock analysis on the Wunut well showed the accumulated gas in this structure is a biogenic product on the shallow horizon and a thermogenic product on the deeper section. On the other hand, the accumulated gas in Tanggulangin well is mostly a thermogenic product, which can be interpreted as coming from the Ngimbang formation. The presence of gas deposits detected from the mud eruption near Banjarpanji-1 well showed that hydrocarbon accumulation had migrated from the main rocks to reservoir layers in this well. The intensive fault pattern with the potential of migration path can beidentified from the seismic section.Based on to Banjarpanji-1’s log data, the presence of layer with the potential of becoming reservoir rocks can be identified, which is volkanoclastic sand rocks at a depth of 6360 – 6385 ft and the Kujung formation’s limestone rock which has been proven as a loss zone. Mapping results of some seismic horizons around Banjarpanji-1 showed that by structure, this well is located at the peak of anticline which is transected by faults on its north and south edges and is a “4 way dip” closure. Based on the “petroleum system” discussion aspect around Banjarpanji-1, it can be summarized that finding the point to prove the oil and gas potential in this structure is relevant. The find of oil and gas in Wunut and Tanggulangin structures showed that the chance of exploration to find economic hydrocarbon accumulation in this region is still high.