

Mud Extrusion at Banjarpaji Areas, Sidoarjo, East Java

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Adjacent to exploration well Banjarpanji (BJP-1), Sidoarjo, East Java, Indonesia at least on three separate locations, mud, water, and gas are ejected into the surface in the early stage at the end of May 2006. However, after 6 months of the occurrences found more than 50 locations, with one big hole. The study of ejected material yields useful information about source of sedimentary deposits, and water at particular depths.

The research results of field works consists of several field works such as aerial photography, gravity, resistivity, micro-earthquake and GPS monitoring. All field works were based on two premises. The first, mud extrusion was set off either by large earthquake or drilling activities. The second, mud extrusion was triggered by both large earthquake or drilling activities.

Late Pliocene shale sequence is a major source of the mud. It is composed of 45% clay mineral (smectite, illite, kaolinite and chlorite), 45% quartz and 10 % others. Vitrinite reflectance data (R_o 0.64%) suggested the depth of mud source is equivalent to 4000-6000 ft. Log analyses of Banjarpanji-1 well, such as GR, Density and Sonic log, exhibit an anomaly within rock strata and indicated an under-compacted environment. This zone, located between 2800 and 6200 ft depth, is Late Pliocene in age and is dominated by thick shale layer. Moreover, the under-compacted zone is segmented into three depth interval of overpressure zones, 3652-4400 ft (OP-1 interval), 4800-5400 ft (OP-2 interval) and 5800-6200 ft (OP-3 interval). Only two intervals (OP-1 and OP-2) have maximum water saturation, as indicated by resistivity in these zones. Resistivity of uninvaded zone is as high as resistivity of water (0.32 ohm-m).

Two separated fault zones exist within the under-compacted zones. They are at 4400-4800 ft and 5500-5800 ft interval. OP-1 and OP-2 interval zones are separated by a fault zone that consists of cataclastic material. This fault zone is characterized by lower GR reading, lower density, and slower compressional velocity, compared to the other fault zone on adjacent strata. The first fault zone has the highest water saturation compared to other fault zone and it is acted as conduit and escape route for mud and water, from the over-pressured zone.

Gravity survey has been carried out in August, September, and October 2006. Each survey is separated by approximately three weeks period. From those three gravity survey, two microgravity time-lapse are derived. Using August as a reference, the first anomaly is between September - August 2006 interval and second anomaly is between October - August 2006 interval.

Microgravity time-lapse anomaly value in the surface has straight relationship and reflects the changes in subsurface density and changes in surface elevation. In the case of Sidoarjo area, where there is mud flow movement in the subsurface at certain depth:

- ☑ Negative anomaly is related to mass (mud) loss, caused by mud flow movement to the surface.
- ☑ Positive anomaly is related to mass (mud) addition, caused by mud flow movement to near surface and/or caused by elevation decrease (subsidence).

Both microgravity time-lapse anomaly maps for Sidoarjo area in two periods show that the whole area is dominated by a negative anomaly related with mass (mud) loss at average depth (mass centre) of 1,700 m and it is located right in the central portion of study area. Mass has been loss continually from August to October 2006 since the negative anomaly values of October – August 2006 are greater ($> -200 \mu\text{Gal}$) than negative anomaly values of September – August 2006 (about $-150 \mu\text{Gal}$).

Positive anomalies are distributed regularly in the NE–SW direction. This direction conforms to fault lineament in this area. Those anomalies are related with mud flow movement to the surface through fault planes. At the mud extrusion location (around BJP-1 Well), there is no positive anomaly identified. This is interpreted as no additional mud and pressure along the fault planes which could gave positive response on microgravity time-lapse. Evidences from the anomaly's magnitude, time interval, and distribution pattern leave very small possibility that the positive anomaly is a reflection of subsidence phenomena.

Positive anomaly is also identified in the southwest area. This anomaly is probably related to fluid movement from volcanic area in the southern part of study area to mud extrusion location. This fluid may function as the water source of mud extrusion for a long period of time, until a balance between mass and pressure in the subsurface is achieved. The volume of this fluid movement is quite significant since the anomaly has a wide coverage and reaches $80 \mu\text{Gal}$.

Microgravity time-lapse anomaly map of September - August 2006 and October - August 2006 have similar pattern. This consistent pattern and a fact that large quantity of mud extrusion has been expelled to the surface, gave strong indication that the anomalies came from the same source and it happened continually during those periods. The positive anomaly in September - August 2006 is relatively higher than October - August 2006. It indicated larger quantity of mud extrusion in September to October 2006 period than in August to September 2006 period. This is confirmed by field fact that mud extrusion average volume in August to September 2006 interval period was $50,000 \text{ m}^3$ per day, while in September to October 2006 interval period was about $100,000 \text{ m}^3$ per day.

Based on analysis of the phenomena which show the mechanism of mud flow movement to the surface, mud extrusion location, and large quantity of mud it was expelled, it lead to a conclusion of a 'mud-volcano' formation. This leaves tiny possibility to stop the mud extrusion process, as long as a balance between mass and pressure in the subsurface has not been achieved. If mud extrusion is stopped in one location, it will re-emerge in another location along the fault planes where mud flow to the surface. This was confirmed by field fact that another mud extrusion emerged in southern part of fault plane, during the second period of microgravity survey (September to October 2006).