Geological Structure Analysis of Satellit Gravity Data in Oil and Gas Prospect Area of West Aceh-Indonesia

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Estimation of the subsurface geological structures in oil and gas prospect area of West Aceh has been done by utilizing gravity field anomaly of satellite gravity data. This research aim to analyze satellite gravity data in order to get geological features which is include deep and shallow structure or fault around oil and gas prospect area in West Aceh. The satellite gravity data is originally provided as Free Air Anomaly and should be corrected to get Complete Bouguer Anomaly (CBA). Furthermore, CBA was transformed into a horizontal plane and corrected from regional anomalous effects to obtain residual anomaly, horizontal and vertical derivative. From CBA, the gravity anomaly show good correlation with geological boundaries on different rock formation and the anomaly is decrease from NE-SW. Residual anomaly also gives same information with CBA but this anomaly focus on shallow structure. Furthermore, horizontal derivative and vertical derivative also show good correlation with geological structure or fault but in some areas the anomaly related with deep structure cannot be seen on the surface or geological map. Despite the result cannot correlate directly with oil and gas prospect area, satellite gravity can be used to identify gravity anomaly and also fault that related with hydrocarbon anomaly area.

Keywords: satellite gravity, geological structure, oil and gas

Introduction

Indonesia has a diversity of geological basins which continue to offer sizeable oil and gas potential. Indonesia has 60 sedimentary basins including 36 in Western Indonesia that have already been thoroughly explored. Fourteen of these are producing oil and gas (Directorate General Oil and Gas, 2017). In underexplored Eastern Indonesia, 39 tertiary and pretertiary basins show rich promise in hydrocarbons. About 75% of exploration and production is located in Western Indonesia. The four oil-producing regions are Sumatra, Java Sea, East Kalimantan and Natuna. The main gas-producing regions are East Kalimantan, West Papua, South Sumatra, Sulawesi and Natuna (PwC, 2016). Besides Indonesia has big reserve for oil and gas, demand for the energy recently still increases that cause an unbalanced condition between demand and production and it is predicted that will be continuing for 25 years from now (Satyana, 2013). This condition is mainly due to by some technical disturbances and unplanned shutdown of several fields of oil and gas and also primarily influenced by the old fields that have run since 1971, so that the activity of hydrocarbon, as crude oil, exploration should be done to fulfil the domestic needs (Karno, 2012). One of the exploration method that can be used is using satellite gravity data analysis. This method advances in recent years has helped earth science researchers to identify and map the distribution of target minerals on the Earth's surface. Besides of low cost, satellite gravity analysis also very helpful in the primary exploration especially to study geological condition in extend and or remote area (Kurniawan and Sehah 2012; Sadeghi, et al. 2013; Zeinelabbdein, et al. 2014). Aceh is one of the provinces in Indonesia having oil and gas reserves that feasible to be developed (Asrillah, et al. 2016). There are some fields that are in production, namely Alur Rambong, Julu Rayeue, Alur Siwah, Bata, Peulalu, Tualang, Iee Tabeue, Kuala Langsa, and Peutouw for oil fields; Julu Rayeu, Perlak, Tualang and Ie Tabeue for gas fields; and some prospects area that located around West Aceh region (Figure 1). These fields then can be used as references in order to test the viability of satellite gravity data with limited field work for regional geological mapping located in West Aceh.

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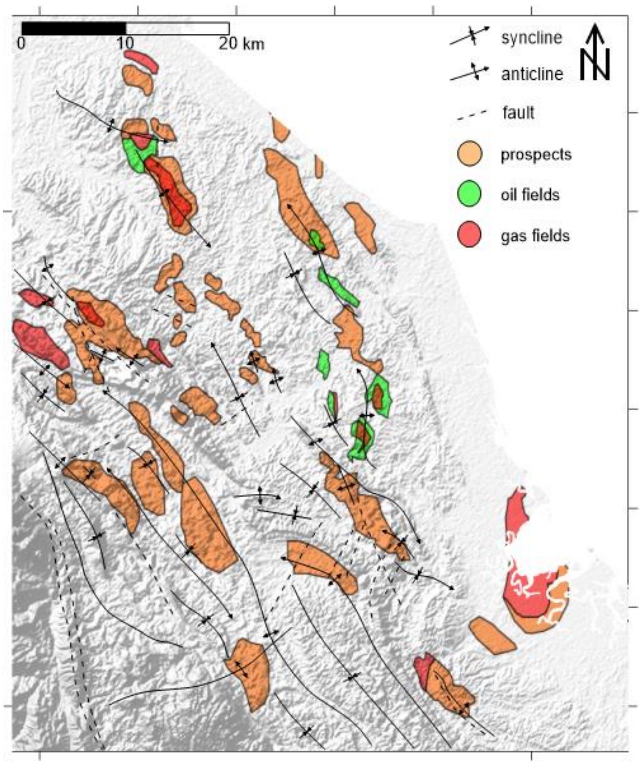

Figure 1 Map of prospects, oil fields, and gas fields in the study area (modified from lionenergy.com and www.energy-pedia.com)

Geological Setting

Regionally research area has very complex tectonic system. There are anticline and syncline in almost every rock formation, especially on tersier sediment rock. Geologically the research area is commonly dominated by sedimentary rocks formation aging from old to young formation consisting of several formations. The oldest formation in this study area is Sembuang Limestone Formation (Mpsl) composing of massive limestones and minor arenites. The second one is Tampur Limestone Formation (Totl) containing of reefal limestones and dolomites with chert nodules. Rampang Formation (Tlr) contains "euxinix" mudstones, siltstones, sand stones volcanics in Lesten basin. Bampo Formation (Tlb) contains dark and black "euxinix" pyritic mudstones, thin sandstones and siltstones. Ramasan Member (Tmpr) contains sandstones, siltstones, mudstones, bioturbation, basal conglomerates. Peutu Formation (Tmp) composes calcareous and carbonaceous muddstones, and fine sandstones. Baong Formation (Tmb) contains calcareous clay, sublittoral sandstone. Keutapang Formation (Tuk) exists sandstones, carbonaceous sandstones, mudsones, and minor conglomerates. Seureula Formation (Tps) composes clastic volcano sandstone and calcareous mudstone. Jalurayeu Formation (QTjr) has tuffaceous sandstone, clay, mudstone alluvial fan. Idi Formation (Qpi) pertains slightly compacted gravel, sand, shale and clay. While Aluvium (Qh) consists coastal sediment and fluvial deposit. Geological structure in this area is highly complex because of the existing of dip layered folding structure. This information was derived from the geological map of the research area as drawn in Figure 2.

Methodology

Satellite gravity data with geographic location and elevation can be accessed from website *http://topex.ucsd.edu/cgi-bin/get_data.cgi* in ASCII-XYZ format. Spatial resolution of latitude and longitude point is 1 min/grid that has error about 0.1 mGal for gravity data and 1 m for elevation data (Smith and Sandwell 1997; Sandwell and Smith 2009). The gravity data is originally provided as Free Air Anomaly (FAA). Then this data should be corrected to remove rock mass effect between measurement points and mean sea level. This correction is called Bouguer correction to get Complete Bouguer Anomaly (CBA). Then, CBA was transformed into a horizontal plane and corrected from regional anomalous effects to obtain residual anomaly. Horizontal and vertical derivative were also computed from Complete Bouguer anomaly. These derivatives anomaly were interpreted to determine density contrast as geological structures. Complete Bouguer anomaly, residual anomaly, horizontal derivative and vertical derivative were interpreted in terms of variations in lithological units, correlated with anticline, gravity data and prospect area, and also correlated between fault interpretation and prospect area. The interpretation then was compared with prospect area, gas fields, and oil fields that have been proved in Figure 1 to see how powerful gravity satellit study in order to delineate prospect area in West Aceh.

Results and Discussion

Scripps Institution of Oceanography, University of California San Diego, provides satellite gravity data that has been corrected to free air anomaly. This data should be corrected so we can interpretative geological structure based on CBA (Figure 3). Theoretically, more dense subsurface rock then the gravity anomaly will be higher. The complete Bouguer anomaly map was visually interpreted in term of boundaries between rock formation having different densities.

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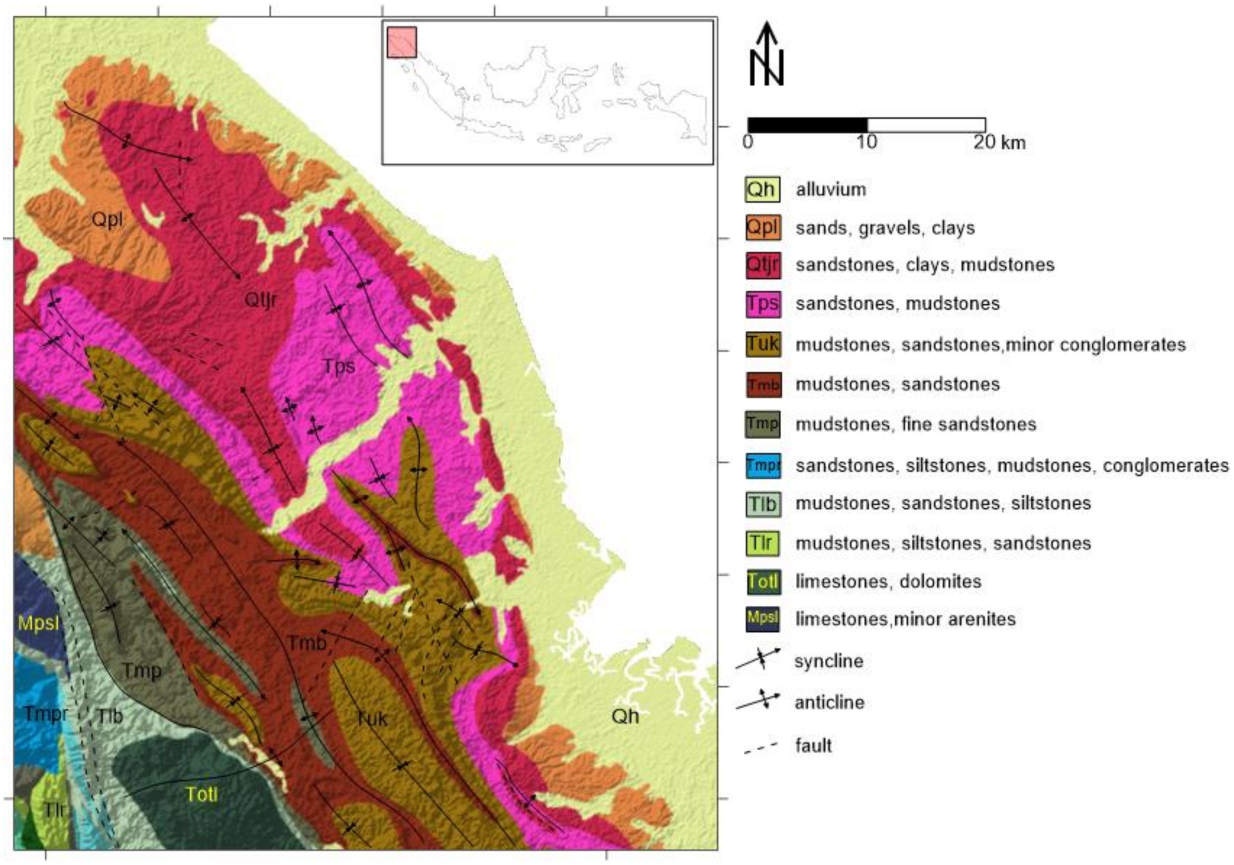

Figure 2 Geological setting of the study area (modified from Cameron et al, 1981)

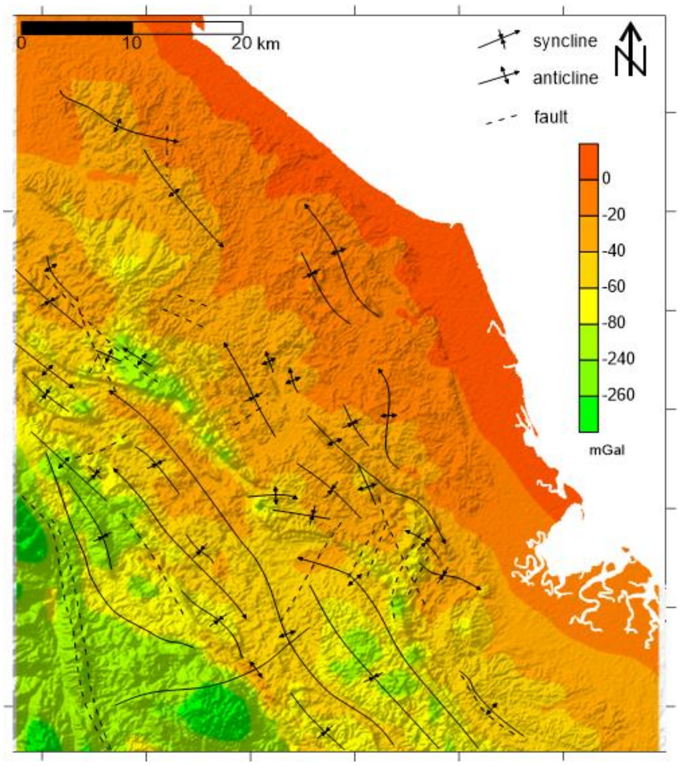

Figure 3 Complete Bouger anomaly

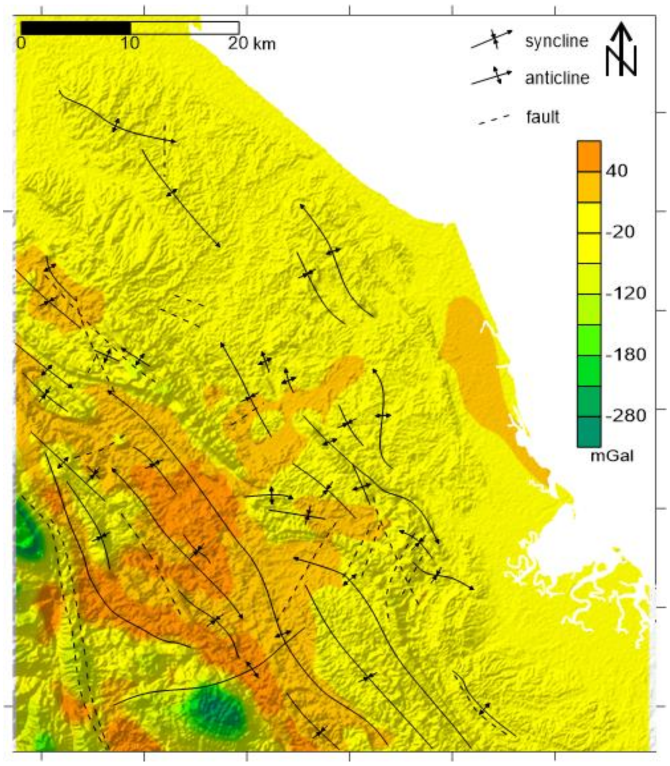

Figure 4 Residual anomaly

It is very clear that, as shown in Figure 3, gravity anomaly response show good correlation with geological boundaries with different rock formation. In general from north-east to south-west, the anomaly is decrease. Unfortunately CBA cannot give us detail anomaly response that is correlated with prospect area (Figure 1). However, some faults, synclines and anticlines show different gravity anomaly with the around study area. From geological setting in the study area and prospects mapping, we can say that mostly hydrocarbon prospect area located in anticline area. After the interpretation of complete Bouguer anomaly that related to shallow and deep anomaly, we can interpret shallow anomaly using residual anomaly map. As we can see from Figure 4, there is no gravity anomaly in oil field area and also in gas field area. But some anomaly are show good correlation with the prospect area. Low anomaly are identified in Tampur Limestone Formation (Totl) and Sembuang Limestone Formation (Mpsl) which is dominated with limestone. On the contrary, high anomaly are identified in Peutu Formation (Tmp) and Baong Formation (Tmb) which is dominaned with calcareous muddstones, carbonaceous muddstones and calcareous clay. In order to make other geological structure interpretation, we used horizontal derivative to see how gravity anomaly changing horizontally in X and Y axis (west-east and north-south) and vertical derivative in Z axis.

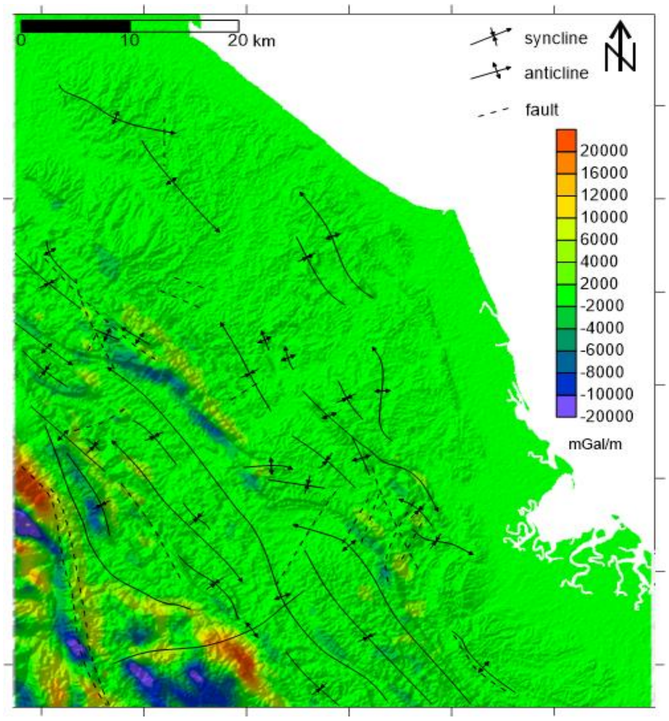

Figure 5 Horizontal derivative total anomaly

From horizontal derivative map (Figure 5), faults are normally identified as low gravity zone which also can be interpreted as geological boundary although sometimes the gravity anomaly show high gravity anomaly that depends on rock densities around survey area. Mostly the identified faults have trending NW-SE shown with red and blue colour. When compared to horizontal derivative, anomaly from vertical derivative map (Figure 6) shows good correlation with geological boundaries although some anomalies are not correlated with fault as we can see from geological map. It is means that the anomaly is from deep structure or fault causing low gravity anomaly.

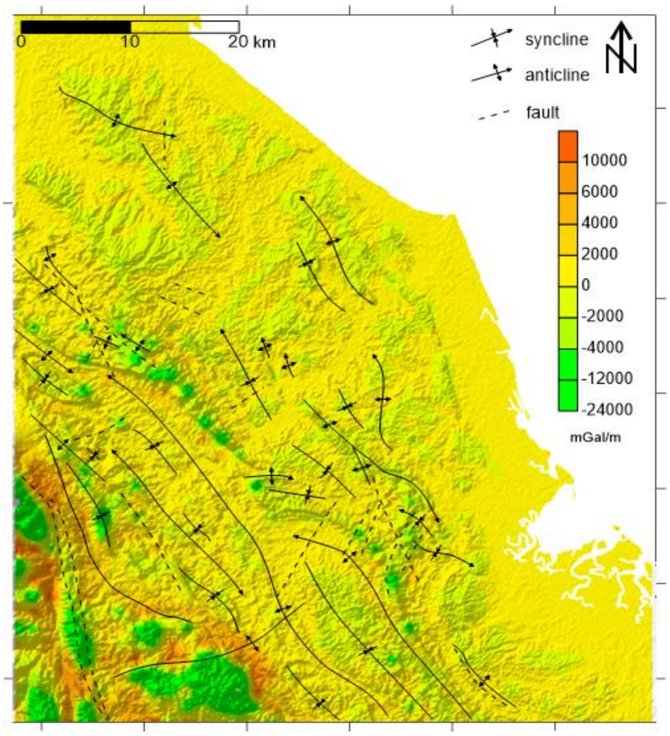

Figure 6 Vertikal derivative total anomaly

Conclusions

Complete Bouguer anomaly map produced from the satellite gravity data provided complementary information that assisted in the delineation of the boundary between the different rock domains in addition to the enhancement the linear features which is in most cases represent structural elements such as faults. From CBA, the anomaly show good correlation with geological boundaries with different rock formation and the anomaly is decrease from NE-SW. For shallow structures, residual anomaly gives some good correlation with some prospect areas and geological features for lithology boundaries and faults in the southwest. Furthermore, horizontal derivative and vertical derivative also show good correlation with geological structure or fault but in some areas the anomaly related with deep structure

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cannot be seen on the surface or geological map. In conclusion, satellite gravity analysis can be used to identify regional anomaly and also fault that related with hydrocarbon anomaly area for preliminary survey.

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