Indonesian Journal of Geology, Vol. 7 No. 3 September 2012: 157-166

Nose Structure Delineation of Bouguer Anomaly as the Interpretation Basis of Probable Hydrocarbon Traps: A Case Study on the Mainland Area of Northwest Java Basin

Delineasi Struktur Hidung Anomali Bouguer Sebagai Dasar Penafsiran Kemungkinan Perangkap Hidrokarbon: Studi Kasus Cekungan Jawa Barat Utara Wilayah Daratan

KAMTONO and D. D. WARDHANA

Research Centre For Geotechnology - LIPI
Kompleks LIPI, Jln. Sangkuriang Bandung

ABSTRACT

Two important aspects in the exploration of oil and gas are technology and exploration concepts, but the use of technology is not always suitable for areas with geological conditions covered by young volcanic sediments or limestone. The land of the Northwest Java Basin is mostly covered by young volcanic products, so exploration using seismic methods will produce less clear image resolution. To identify and interpret the subsurface structure and the possibility of hydrocarbon trap, gravity measurements have been carried out. Delineation of nose structures of a Bouguer anomaly map was used to interpret the probability of hydrocarbon traps. The result of the study shows that the gravity anomalies could be categorized into three groups : low anomaly (< 34 mgal), middle anomaly (34 - 50 mgal), and high anomaly (> 50 mgal). The analysis of Bouguer anomaly indicates that the low anomaly is concentrated in Cibarusa area as a southern part of Ciputat Subbasin, and in Cikampek area. The result of delineation of the Bouguer anomaly map shows the nose structures existing on Cibinong-Cileungsi and Pangkalan-Bekasi Highs, while delineation of residual anomaly map shows the nose structures occurs on Cilamaya-Karawang high. Locally, the gas fields of Jatirangon and Cicauh areas exist on the flank of the nose structure of Pangkalan-Bekasi High, while the oil/gas field of Northern Cilamaya is situated on the flank of the nose structure of Cilamaya-Karawang High. The concept of fluid/gas migration concentrated on nose structures which are delineated from gravity data can be applied in the studied area. This concept needs to be tested in other oil and gas field areas.

Keywords: exploration concept, Bouguer and residual anomaly, nose structure, hydrocarbon

SARI

Dua aspek penting dalam eksplorasi migas adalah teknologi dan konsep eksplorasi, namun penggunaan teknologi tidak selalu cocok untuk wilayah dengan kondisi geologi yang tertutup oleh endapan vulkanik muda atau batugamping. Cekungan Jawa Barat Utara wilayah daratan sebagian besar tertutup oleh produk vulkanik, sehingga eksplorasi dengan metode seismik akan menghasilkan resolusi gambar yang kurang jelas. Untuk mengidentifikasi dan menafsirkan struktur bawah permukaan dan perangkap hidrokarbon telah dilakukan pengukuran gravitasi. Delineasi struktur hidung peta anomali Bouguer digunakan untuk menafsirkan kemungkinan adanya perangkap hidrokarbon. Hasil penelitian menunjukkan bahwa anomali Bouguer dapat dikategorikan menjadi tiga kelompok: anomali rendah (<34 mgal), anomali menengah (34 - 50 mgal), dan anomali tinggi (>50 mgal). Hasil analisis kualitatif anomali Bouguer dan anomali sisa menunjukkan bahwa anomali rendah terkonsentrasi di wilayah Cibarusa bagian selatan subcekungan Ciputat dan di daerah Cikampek. Hasil delineasi struktur peta anomali Bouguer menunjukkan bahwa struktur hidung berada pada tinggian Cibinong-Cileungsi dan Tinggian Pangkalan-Bekasi, sedangkan delineasi struktur peta anomali

Manuscript received: December 27, 2011, final acceptance: September, 2012
Corresponding Author: ++6285624158526/tonokemto@yahoo.com

menunjukkan sisa struktur hidung berada pada Tinggian Cilamaya-Karawang. Secara lokal, lapangan gas Jatirangon dan Cicauh berada pada sayap struktur hidung Tinggian Pangkalan-Bekasi, sedangkan lapangan gas dan minyak Cilamaya Utara berada pada sayap struktur hidung Tinggian Cilamaya Karawang. Konsep migrasi suatu fluida/gas yang terkonsentrasi pada struktur hidung yang didelineasi dari data gaya berat dapat diterapkan di daerah penelitian. Konsep ini perlu diujikan pada daerah lapangan minyak/gas yang lain.

Kata kunci: *konsep eksplorasi, anomali Bouguer dan residual, struktur hidung, hidrokarbon*

Introduction

In the last decade, Indonesian oil production has constantly declined, caused by the condition of oil fields in Indonesia which are mostly old and of low exploration drilling. This condition has triggered the idea to find new prospective areas, especially in the frontier areas or to review mature oil and gas fields. In oil and gas exploration, there are two important aspects, those are exploration concept and exploration method or technology (Koesoemadinata, 2011).

Currently, the most reliable technology in oil and gas exploration is seismic method, but the cost of this method is quite high and it often faces many problems during the operation. The problems will occur if the operation is carried out in a densely populated area, rugged and steep topography. Other geologic problems are areas covered by thick young volcanic deposit, limestone deposit, or in areas where the bed rock is thrusted and faulted.

The problem using seismic method happened when exploring the southernmost area of Northwest Java Basin, adjacent to Bogor Basin or Jatiluhur Block. The exploration in the area was done in the late 1990s to get a picture of the condition below the surface, targeting Baturaja Formation buildup. The general problem faced in the area is its rugged topography, partially young volcanic deposit cover, and the geological structure that is quite complex. Thus, the study result using the seismic was not a good method (Adhidjaja *et al*., 2002).

The Northwest Java Basin, especially offshore, has been proven to be a sedimentary basin producing oil and gas, while to the south toward the direction of shelf province, new sub basins have been found, those are Ciputat, Kepuh, and Cipunegara Basins (Bishop, 2000). A new study using gravity method indicated the presence of hydrocarbon potential in Jakarta and surrounding areas (Panjaitan, 2009). A question raises, whether this subbasin still expands to the south to Bogor Basin, and has potential hydrocarbon.

This study will presents a qualitative interpretation of the gravity measurement carried out result in the mainland including West Java Basin adjacent to Bogor Basin, mostly covered by young volcanic deposits. It is assumed that West Java sedimentary basin on land adjacent to Bogor Basin, in stratigraphical and structural contexts has a possibility of having hydrocarbon which theoretically is trapped on the flank or peak of a structural high.

The study result is part of study done in Northwest Java Basin at the southernmost mainland, including: a study of limestone facies of Parigi Formation revealed in Cibinong and Pangkalan. This is to confirm the existence of the basin, as well as a study of the source rock from Cibulakan Formation/Jatiluhur formation to discover the type of hydrocarbon which can be produced by the shale rock in the Cibulakan Formation.

Research Purpose

This study aims to map the value of gravity acceleration using the gravity method. Bouguer anomaly and residual anomaly maps produced were analyzed qualitatively. Structural high and low were identified and combined with a concept from Pratsch (1986) as a reference in interpreting the possibility of a hydrocarbon trap.

Methodology

The framework of this study is the basic theory which states that a basin consists of bedrock and sedimentary rock above it which has different

physical properties. The horizontal density variety will respond to different gravity acceleration value in every point. Gravity acceleration value in every point which has been corrected can be mapped into Bouguer anomaly map which showed a potential field. The gravity map show potential fields, it can be used indirectly to interpret the condition below the surface. The potential fields displayed in Bouguer anomaly map principally responds from the superposition of objects which cause anomaly. Thus, quantitative interpretations by making a model without controlling the density value from the drilling data are often incorrect. Regarding this basic understanding, qualitative analysis which uses the concept of migration of fluid based on gravity data and had been used to explore an oil field in Venezuela was applied in interpreting the possibility of hydrocarbon accumulation, whether oil or gas.

Pratsch (1986) made an approach in determining the direction of a migration of fluid/gas by using a magnetic anomaly map or regional Bouguer anomaly. The anomaly map is considered to be a structural map, and the assumption used is that the direction of a migration of fluid or gas is perpendicular to the contour and will gather in convergence in the nose structure of the structural high or basinward plunging structural high (Figure 1).

Gravity Data Processing:

Bouguer Anomaly calculation was performed by using formulation (Telford *et al.*, 1990)

$$B_A = G._{Obs} - G_n + F_{AC} - B_C + T_C$$

where:

B_A = Bouguer Anomaly
$G._{Obs}$ = Observed gravity value
G_n = Normal gravity value (theoretic gravity value)
F_{AC} = free air correction
B_C = Bouguer correction
T_C = Field correction

To get a complete Bouguer anomaly value using the formulation above, data reduction must be performed first, including tide correction and drift correction.

Besides field correction calculation, inner zone correction must be performed as well, the result of direct observation on the field is observed to the radius of 170 m.

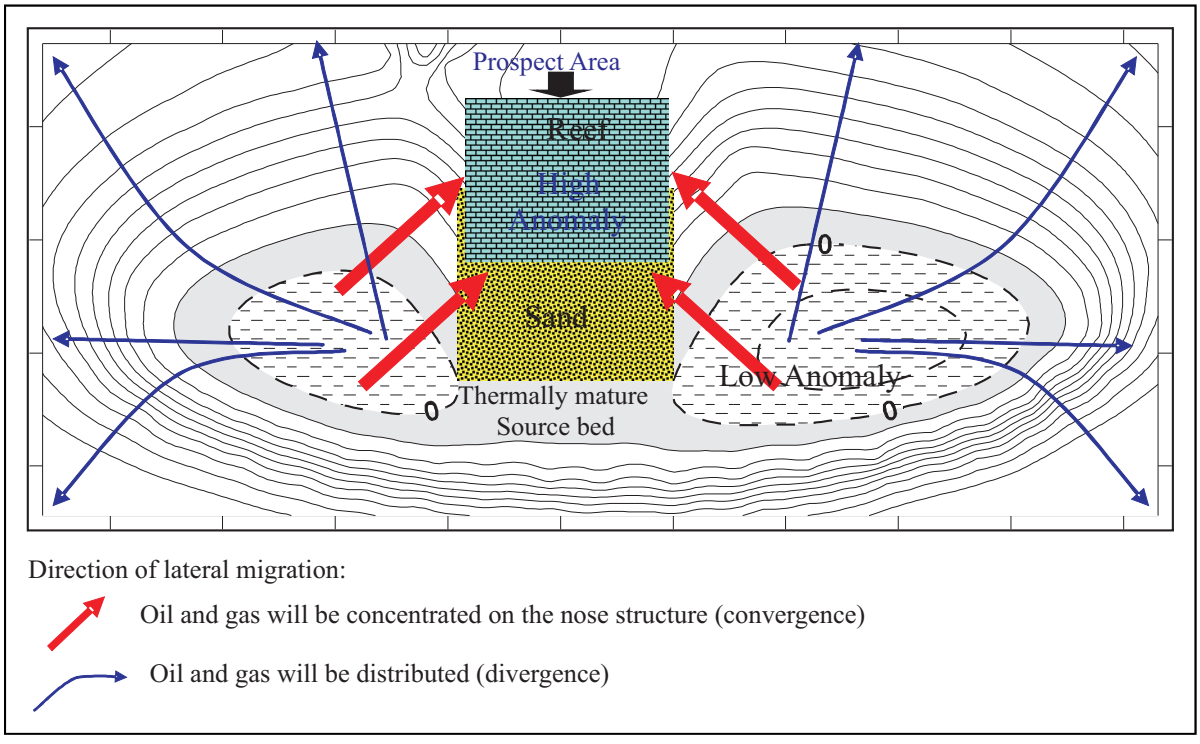

Figure 1. Direction of fluid migration gathered in the nose structure (modified from Pratcsh, 1986).

Bouguer anomaly map and Pratsch's approach (1986) were used for references for the interpretation of a possibility of hydrocarbon trap structure in the southern part of Northwest Java Basin.

Gravity Measurement Location

Gravity measurement was performed with calibrated G. 804 La Coste & Romberg gravimeter tool. The distance between measurement stations is 500 m and 1000 m for a flat area. The measurement location on the western sector is from Ciawi to Lubangbuaya, eastern sector is from Padalarang to Cikampek, and central sector is from Cipanas to Bekasi. Reference station (BS) as the tie point of the measurement is a base reference station point in the Research Center For Geotechnology - LIPI (Table 1).

Besides gravity measurement, oil/gas exploratory well distribution was also plotted. The locations of exploration wells are known to have hydrocarbon, especially gas. Exploration wells targeting the Baturaja Formation were in the depth zone of JRR-3 2,384 m - 2,394 m for Jatirangon Block, and for Baturaja Formation target in Pasundan -1 were 2445.72 m - 2459.43 m in Citarum Block. The position of exploration wells targeting Baturaja Formation were expected to help the interpretation of gravity data (Figure 2).

Stratigraphy And Structure

Regionally, the stratigraphy of northern West Java consists of Jatibarang, Cibulakan , Parigi, and Cisubuh Formations. Middle Cibulakan Formation comprises limestone and in oil industry it is called Baturaja Formation. On the south of this shelf a sedimentary basin characterized by deep-sea sediments which developed from the Early Tertiary and spread from Bogor Zone in the west to Kendeng Zone in the east occurs. Physiographycally, this zone spreads in the middle of Java Island and called Bogor - North Serayu - Kendeng deepwater zone (Satyana and Armandita, 2004). Regional stratigraphy of West Java was schematically made by Martodjojo (1994) then modified by Satyana (2005) (Figure 3).

The geology of the researched area was simplified from Jakarta and Seribu Islands, Karawang, Cianjur, and Bogor geological map sheets (Turkandi *et al*., 1992, Achdan and Sudana,1992, Sudjatmiko, 2003, and Efendi *et al*., 1998) published by the Geological Research and Development Centre in the scale of 1: 100.000. Geologically, the researched area consists of Miocene to Holocene rocks. The youngest Holocene rocks can be found in most part of the researched area especially at the northernmost area which consists of alluvial and floodplain deposits. The Holocene sediments comprise volcanic material which forms an alluvial fan spreading from Cibinong to Jakarta and Bekasi. Pleistocene sedimentary deposit is an old alluvial one consisting of sandstone, silt, and clay which spreads from Jonggol to Bekasi. Pliocene deposit is composed of volcaniclastic sediments (Cihoe Formation) and hornblende andesite existing as intrusion rocks which were revealed at the southeast part of the researched area. Miocene sediments are mode up of rocks of Jatiluhur Formation which is equal to the Cibulakan, Parigi, Subang, and Cisubuh Formations.

Surface geologicals data show that the structure developed in the southern part of the studied area, especially in the Mio-Pliocene rocks. The younger rocks occurring in the northern area it are dominated by alluvial deposits showing no structures. The structure in the southern part is recognized as folds with axes trending WNW - ESE. In the southeast, the folds are cut by a strike slip fault with a NE-SW direction. The lack of structure in the younger sedimentary rocks, makes it to be difficult to compare the surficial structures with the subsurface ones obtained from gravity measuremens.

Table 1. Gravity Measurement Location.

Station	Latitude	Longitude	Height (m bsl)	Gravity Value (mgal)
BS Geoteknologi - LIPI	-6.88238	107.61114	791	977965.47

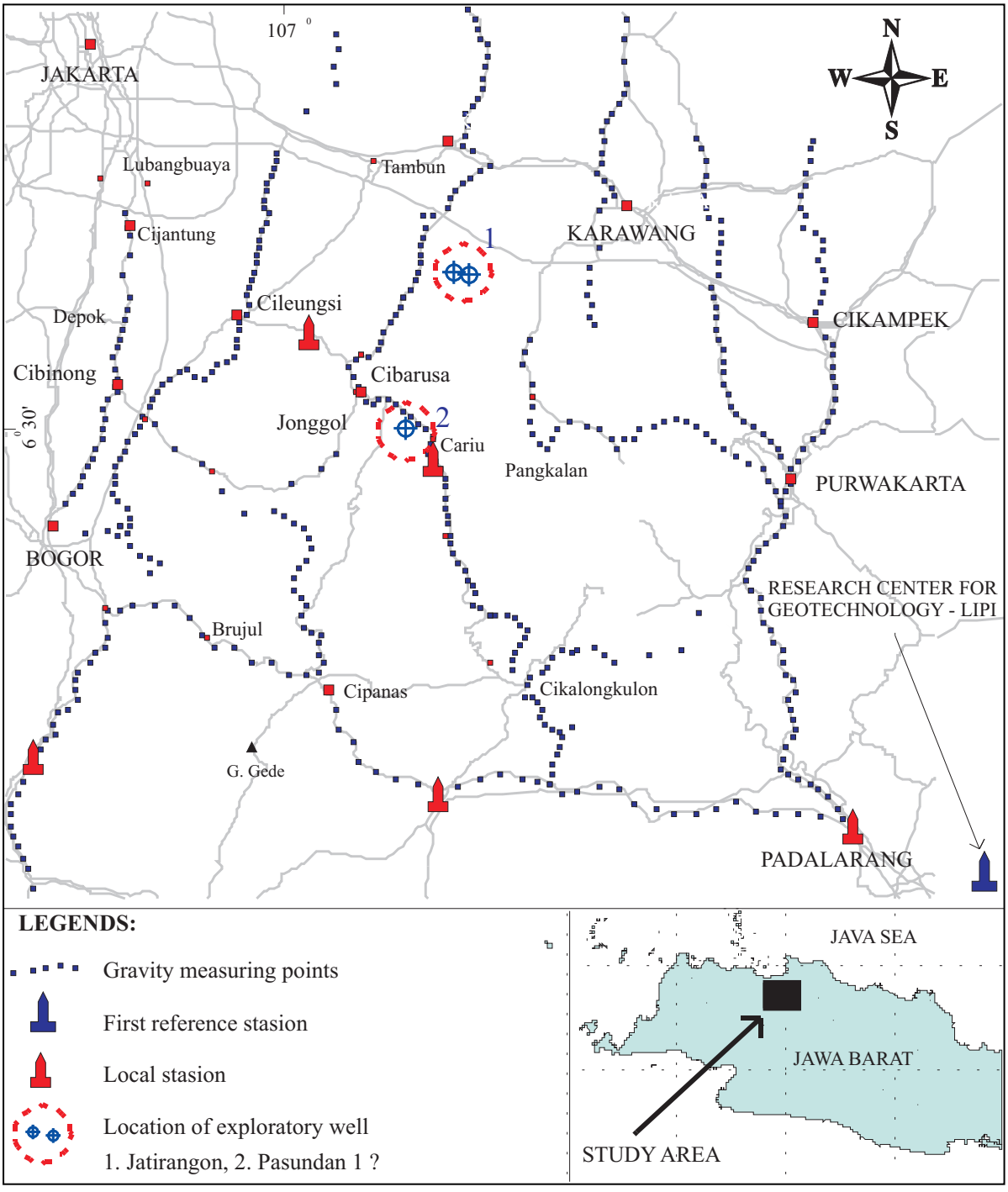

Figure 2. Location of gravity measurement and exploration drilling.

Results

Gravity data processing resulted in Bouguer anomaly and residual anomaly maps. The Bouguer anomaly value can be grouped into three parts, those are low anomaly < 34 mgal, medium anomaly between 34 and 50 mgal, and high anomaly > 50 mgal. Based on Bouguer anomaly map, the low anomaly

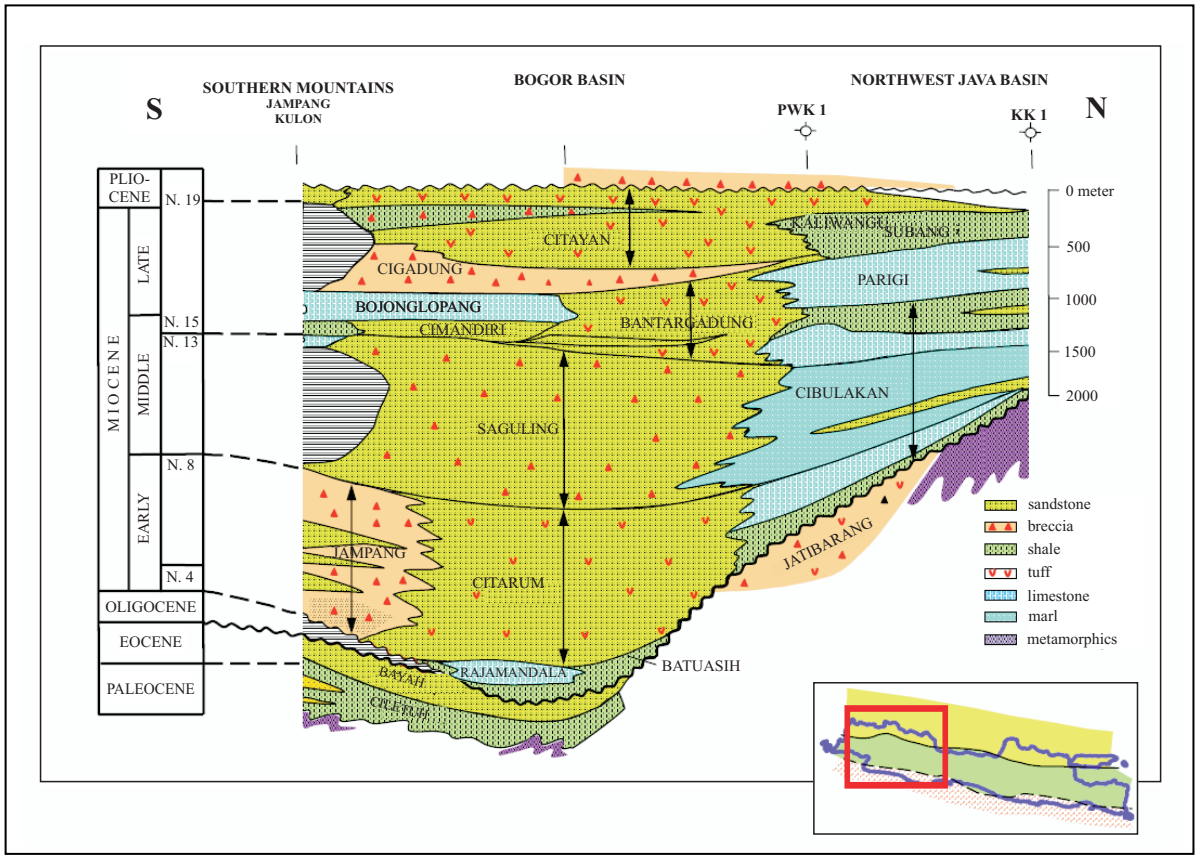

Figure 3. Regional stratigraphy of West Java (Martodjojo, 1994; modified by Satyana, 2005).

shows a closed closure in Cibarusa, Cikampek, and Rengasdengklok areas. The medium anomaly areas are recognized in Lubangbuaya, Cijantung, and Pangkalan to Bekasi which occur in the north northwest - south southeast direction. The high anomaly with value of > 50 mgal is found in the southern area showing a west - east direction from Bogor to Cikalong Kulon.

The residual anomaly map shows a relatively similar pattern with Bouguer anomaly, with a negative anomaly found in Cibarusa, Cikampek, and Rengasdengklok areas. This residual anomaly map shows a positive anomaly in Karawang - Cilamaya area where a low anomaly in Bouguer anomaly maps occurs.

From Jakarta to Jonggol, the Bouguer anomaly and residual anomaly maps indicate a structural low flanked by two structural highs. This is suggested that Ciputat Subbasin spreads to the south to Jonggol area with a depocentre located in the area of Cibarusa. The structural high with medium anomaly value in the western part bounding the Ciputat Subbasin is the Cibinong - Jakarta structural high, while in the eastern part is the Pangkalan - Bekasi structural high in the direction of northwest - southwest. Structural high with anomaly value of > 50 mgal in west - east direction is found in the southern part of the researched area, from Bogor to Cikalongkulon area (Figure 4).

The structural highs with medium anomaly value in northwest - southeast direction are analyzed further to discover whether these structural highs have the nose structure which, in the concept of fluid or gas migration, is the accumulation centre.

Discussion

The gravity interpretation was performed by combining it with geological data, especially data of the distribution of Parigi Formation which is known as oil reservoir in Northwest Java. Besides that, it is

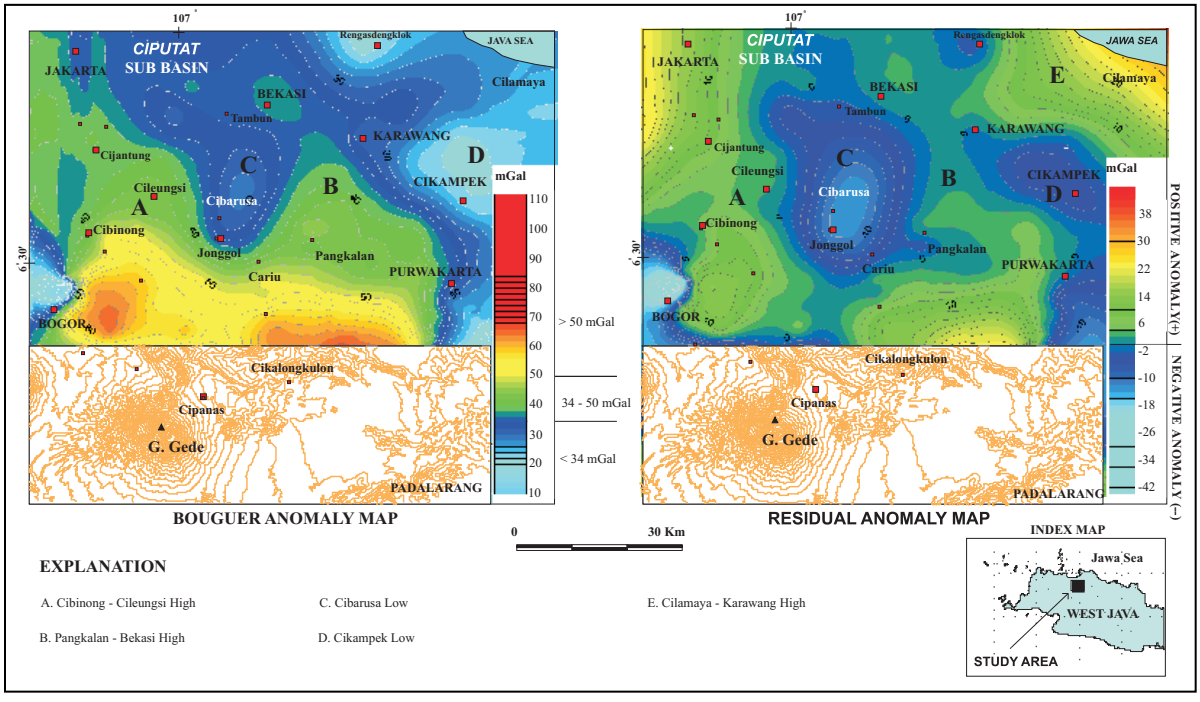

Figure 4. Bouguer and residual anomaly maps of the researched area.

referred to hydrocarbon migration concept based on regional gravity data performed by Pratsch (1986) with a case study in Venezuela.

The Bouguer anomaly data show two structural highs, those are Cibinong - Cileungsi structural high and Pangkalan - Bekasi structural high which display a nose structure (Figure 5a). While residual anomaly data also show the nose structure in Karawang - Cilamaya structural high which separates Cikampek and Rengasdengklok structural lows (Figure 5b).

These highs enable the formation of hydrocarbon trap in the flank and peak of the highs as places for the accumulation of hydrocarbon, whether in the form of oil or gas. The source of hydrocarbon or source rocks which can generate hydrocarbon is expected to be the Cibarusa depocentre or Cikampek low. Gravity data show that the Cibarusa depocentre has a low anomaly and to the northwest it is connected to the Ciputat Subbasin which is a depression area having a high possibility of containing source rock which can generate hydrocarbon or as a kitchen area.

The result of gravity data processing by removing regional anomaly which produced the residual anomaly that has a similar pattern with the Bouguer anomaly still give an image of a nose structure which may be a place for the accumulation of hydrocarbon. An example of nose structure delineation from residual anomaly is in the Karawang - Cimalaya high with the kitchen in Cikampek low.

Compilation of the Bouguer anomaly map with the location of exploration drill and the distribution of gas/oil field in Northwest Java shows the position of Baturaja Formation as a target of the exploration in the flank of Pangkalan - Tambun and Karawang – Cilamaya highs. This shows that the concept of fluid/gas migration based on gravity data from Pratsch can be applied in the researched area, where the accumulation of gas/fluid is not on the peak, but at the flank of a high instead.

Hydrocarbon type in the southern part of Northwest Java Basin is generally gas. It remains a question whether this is caused by the biogenic source rock or the influence of intrusion in the southern part.

By referring to the gravity data, geological data of the surface and the distribution of gas/oil in onshore of Northwest Java basin can interpretatively describe a subsurface trajectory from Cibinong to Cicauh area (Figures 6 and 7).

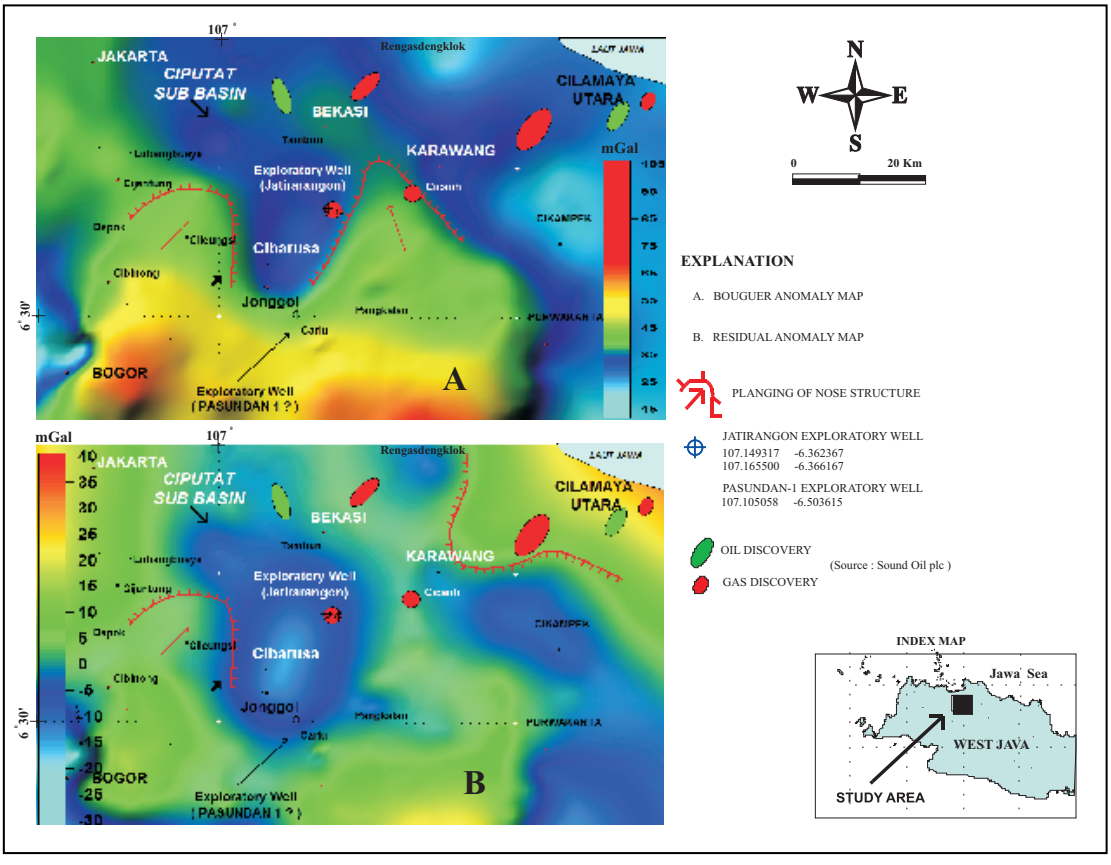

Figure 5 Qualitative interpretation of nose structure from the Bouguer anomaly and residual anomaly data.

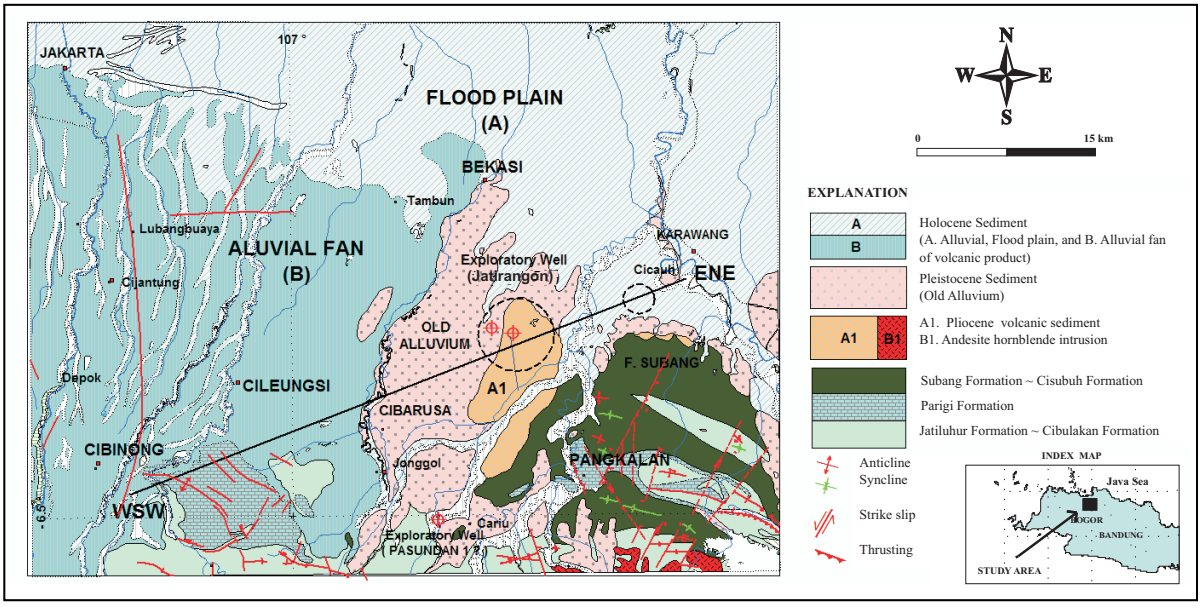

Figure 6. Geological map of the researched area (Achdan and Sudana, 1992; Turkandi *et al*., 1992; Efendi *et al*., 1998; and Sudjatmiko, 2003).

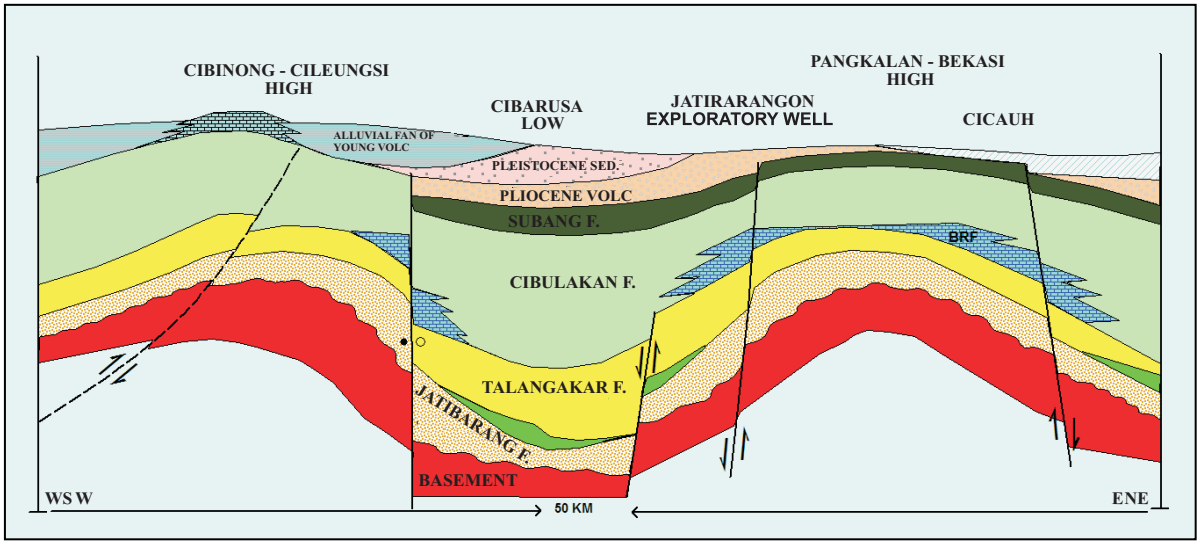

Figure 7. Interpretative geological model of Cibinong - Cicauh trajectory.

The Baturaja Formation as an exploration target is suggested to develop on the western and eastern flanks of the Pangkalan - Bekasi Highs. These highs appear in the Bouguer anomaly map, shown by a northward plunging structural high. The existence of Jatirarangon and Cicauh gas fields, if projected downward, is situated on the flank of the high. It assures that delineating a nose structure from gravity data can help in early interpretation of a hydrocarbon trap.

Conclusion

Ciputat Subbasin which spreads to the south of Jonggol area and is bordered by two highs is very possible to be a kitchen area. The Cibinong - Cileungsi High, Pangkalan - Tambun High, and Karawang - Cilamaya high are possible as hydrocarbon traps.

The concept of exploration using gravity data can be applied for early explorations of hydrocarbon deposits with a case study in the southernmost of Northwest Java Basin. This concept should be tested in other areas having identical geological characteristics, such as areas covered by volcanic sediments or limestone.

Acknowledgements–The author would like to thank Dr. Iskandar Zulkarnain, the Head of the Research Center for Geotechnology, who has provided the research facilities, and to technical engineer team, especially Drs. Karit Lumban Gaol and Yayat Sudrajad, who have helped during the data preparation, collection, and processing of this paper.

References

Achdan, A. and Sudana, D., 1992. *Geologic Map of the Karawang Quadrangle, Java*, *scale 1:100.000*. Geological Research and Development Centre, Bandung.

Adhidjaya J. I., Davioff, A. J., and Novianti I. R., 2002. PSDM Enhances reef Interpretation in Jatiluhur Block, West Java. *Proceedings of 28th Annual Convention of Indonesia Petroleum Ass*ociation, p.31-43

Bishop, M.G., 2000. *Petroleum systems of the Northwest Java Province, Java and offshore Southeast Sumatra, Indonesia*: Open file report, U. S. Geological Survey, 34pp.

Efendi, A.C., Kusnama, and Hermanto, B., 1998. *Geologic Map of the Bogor, Java*, *scale 1:100.000*. Geological Research and Development Centre, Bandung.

Koesoemadinata, R.P., 2011. The importance of new ideas in the development of hydrocarbon exploration concepts. *Pemaparan Workshop roadmap eksplorasi hulu migas Kementerian ESDM*, Jakarta 28 Juni 2011.

Martodjojo, S., 1994. Data Stratigrafi, pola tektonik, dan perkembangan cekungan pada jalur anjakan lipatan di Pulau Jawa, *Kumpulan Makalah Seminat Geologi dan Geotektonik Pulau Jawa sejak Akhir Mesozoik hingga Kuarter, Geology Department*, University of Gadjah Mada, P.15-26.

Panjaitan, S., 2009. Aplikasi metode gaya berat untuk identifikasi potensi hidrokarbon di dalam Cekungan Jakarta dan sekitarnya. *Jurnal Sumber Daya Geologi*, 19 (6), p.341-350

Pratcsh,1986. *Bouguer anomaly map identify regional basin structure and resultant preferred directions of lateral oil and gas migration*, IGC Footnote series, 3 (1), (http://www.igcworld.com., 1995).

Satyana, A.H. and Armandita, C., 2004. Deep-water play of Java, Indonesia: regional evaluation on opportunities and risks. *Proccedings, International Geoscience Conference of Deepwater and Frontier Exploration in Asia and Australasia*. Indonesian Petroleum Association and American Association of Petroleum Geologists, p.293-320.

Satyana, A.H., 2005. Oligo-Miocene Carbonates of Java, Indonesia: Tectonic - Volcanic setting and petroleum implications. *Proceedings, 30th Annual Convention and Exhibition Indonesia Petroleum Ass*ociation, p. 217-249

Sudjatmiko, 2003. *Geologic Map of the Cianjur Quadrangle, Java*, *scale 1:100.000*. Geological Research and Development Centre, Bandung.

Telford, W.M., Geldart, L.P., and Sheriff, R.E., 1990. *Applied Geophysics, 2nd edition*, Cambridge University Press, Cambridge.

Turkandi, T., Sidarto, Agus Setyanto, D.A., and Purbohadiwidjojo, M.M., 1992. *Geologic Map of the Jakarta and Kepulauan Seribu Quadrangle, Java*, *scale 1:100.000*. Geological Research and Development Centre, Bandung.