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Research Article

Identification of Hydrocarbons Sub-Basin Based on Gravity Data Analysis in Lampung Area

Muh. Sarkowi [1,a], Rahmat Catur Wibowo [1,b,*], Suhayat Minardi [2,c], and Indra Arifianto [3,d]

[1] Geophysical Engineering, Engineering Faculty, Universitas Lampung
Jalan Sumantri Brojonegoro, Bandar Lampung 35145, Indonesia
[2] Physics, Mathematics, and Natural Science Faculty, Universitas Mataram
Jalan Majapahit, Kota Mataram 83115, Indonesia
[3] Computational Earthquake Seismology, King Abdullah University of Science and Technology
Thuwal 23955, Saudi Arabia

e-mail: [a] muh.sarkowi@eng.unila.ac.id, [b] rahmat.caturwibowo@eng.unila.ac.id, [c] suhayat.minardi@gmail.com,
[d] indra.arifianto@kaust.edu.sa
* Corresponding Author

Abstract

Gravity Data analyses in Lampung area are carried out to identify potential hydrocarbon sub-basins. The hydrocarbon potential in the Lampung sub-basin is indicated by the presence of hydrocarbon seepage found in Wai Imus, Wai Tahmi, and from oil shown in Ratu-1 and Tujo-1 exploration wells. Spectrum analysis, filtering, gradient, and gravity anomaly modeling determine the presence of potential hydrocarbon sub-basins in the Lampung sub-basin. Our results show that the Bouguer anomaly in the Lampung sub-basin ranges from 0 mGal to 90 mGal. A high anomaly appears in the southern part associated with basement high and a low anomaly in the center area of the western region related to the existence of the large Sumatra fault zone. The Bouguer Anomaly spectrum analysis result shows that basement depth in the Lampung sub-basin is 2400 m to 4400 meters deep. Data analysis of residual Bouguer anomaly, SVD residual Bouguer anomaly, and fault structure identified 18 sub- hydrocarbon potential basins scattered in Way Kanan, Tulang Bawang Barat, Menggala, Mesuji, Terbanggi Besar - Seputih Surabaya (Central Lampung), Sukadana and Labuhan Maringgai (East Lampung) areas. Some volcanic paths were also identified from Ratu-1 well, and Tujo-1 well in the Lampung WKP block. 2.5D modeling results of residual Bouguer anomaly show Kasai, Muara Enim, and Air Benakat, respectively, overburdened rock formations deposited from the top, followed by the Gumai Formation, which acts as a seal formation, while the hydrocarbon reservoirs are from the Baturaja and Talang Akar Formation. Our subsurface depth model has been verified by Ratu-1 and Tujo-1 exploration well.

Keywords: *gravity; hydrocarbon sub-basin; Lampung; modeling*

Identifikasi Sub-Cekungan Hidrokarbon Berdasarkan Analisis Data Gravity di Daerah Lampung

Abstrak

Pengolahan dan analisa data gravity pada daerah Lampung dilakukan untuk mengidentifikasi keberadaan sub-cekungan berpotensi hidrokarbon. Keberadaan potensi hidrokarbon pada sub-cekungan Lampung ditunjukkan dengan adanya rembesan hidrokarbon yang dijumpai di Wai Imus, Wai Tahmi serta hasil pemboran eksplorasi sumur Ratu-1 dan sumur Tujo-1. Analisa spektrum, filtering, gradient dan pemodelan anomali gravity dilakukan untuk mengetahui dan mendapatkan keberadaan sub-cekungan berpotensi hidrokarbon di sub-cekungan Lampung. Hasil penelitian menunjukkan Anomali Bouguer daerah sub-cekungan Lampung mempunyai nilai 0 mGal sampai 90 mGal, dengan anomali tinggi di bagian selatan yang berhubungan dengan batuan dasar yang terangkat di daerah tersebut dan anomali rendah berada bagian barat bagian tengah yang berhubungan dengan keberadaan zona sesar besar Sumatera. Hasil analisa spektrum Anomaly Bouguer menunjukkan kedalaman batuan dasar daerah sub-cekungan Lampung yang berada pada kedalaman 2400 m sampai 4400 meter. Hasil analisa data Anomali Bouguer residual, SVD Anomali Bouguer residual, struktur patahan, keberadaan jalur gunung api, data sumur Ratu-1, Sumur Tujo-1, dan beberapa data usulan pemboran sumur eksplorasi yang ada di blok WKP Lampung dapat diidentifikasi sebanyak 18 sub-cekungan berpotensi hidrokarbon yang tersebar di daerah Way Kanan, Tulang Bawang Barat, Menggala, Mesuji, Terbanggi Besar – Seputih Surabaya (Lampung Tengah), Sukadana dan Labuhan Maringgai (Lampung Timur). Hasil pemodelan 2.5D Anomali Bouguer residual mendapatkan formasi Kasai – Air Benakat dan Muara enim pada bagian atas yang diikuti oleh Formasi Gumai yang berperan sebagai penyekat, sedangkan reservoar hidrokarbon berada pada Formasi Baturaja dan Talang Akar. Hal ini didukung oleh data sumur eksplorasi Ratu-1 dan Tujo-1.

Kata Kunci: *gravity; sub-cekungan hidrokarbon; Lampung; pemodelan*

PACS: 91.30.-f; 91.30.Jk; 93.85.Hj

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I. INTRODUCTION

The South Sumatra Basin covers three sub-basins: the Jambi sub-basin in the north, the South Sumatra sub-basin in the middle, and the Lampung sub-basin in the south [1]. The Jambi and South Sumatra sub-basins are known as prolific hydrocarbon basins. However, the Lampung sub-basin has not been proven as a hydrocarbon producer.

Oil and gas exploration activities in the study area are still minimal. The presence of hydrocarbons was identified by the findings of several seepages of hydrocarbons such as those found in Wai Imus, Wai Tahmi, and an oil stain in exploration wells of Ratu-1 and Tujo-1 [2].

Hydrocarbons exploration in the research area has been carried out since 1992 by Petrocorp Exploration Indonesia. The exploration activities started with seismic reflection acquisition in the Bandarjaya sub-basin area. Pertamina has carried out several drilling activities exploration with sandstone targets from the TAF and carbonate rocks from the Baturaja Formation [3].

The exploration is continued by Prabu Energy in 2013 at Block Ranau (Ranau - Banjit), Bima Sakti Energy in 2016 in Block Bima Sakti Energy (Blampangan Umpu - Tulang Bawang Barat) and Harpindo at Block Harpindo (Kotabumi - BandarJaya - Metro). However, no hydrocarbon has been discovered in the Lampung area to date.

In addition to that, basement structure modeling is essential in oil and gas exploration because basement configuration is associated with the history of a sedimentary basin formation [4]. In some instances, the basement can be modeled by structural contour maps obtained from drilling wells and seismic reflection profiles [5]. Nevertheless, data on drilling wells and seismic reflections are limited in the frontier area. Thus, gravity data analysis can be used as an alternative in describing the basement configuration related to the sub-basin boundary [6-8].

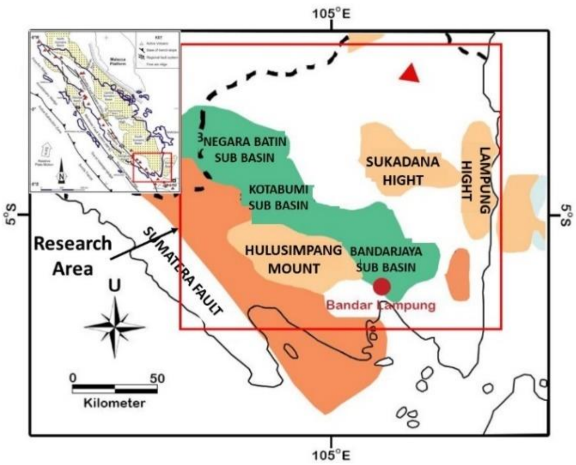

Figure 1. Research location map of the Lampung Sub-Basin (Negara Batin, Kotabumi and Bandarjaya Sub-Basin) - South Sumatra Basin and Sumatra regional tectonic setting [2][8]

Therefore, we try to determine the distribution of potential hydrocarbon sub-basins in the Lampung area by processing and interpreting gravity data with calibration from wells data in the study area. This research aims to delineate the Lampung sub-basins basement structure to assist hydrocarbon exploration activities.

II. METHODS

The gravity data used is Bouguer anomaly data from Bandung Geological Development Research Center. The measurements were made in the period of 1990 - 1992 using Gravimeter Lacoste & Romberg type G [9-13]. Bouguer correction calculation uses a density of 2.67 g/cc, while normal gravity correction uses GRS 1967.

Data processing in this study includes analysis of the Bouguer anomaly spectrum to obtain the depth of the regional and residual anomaly boundaries [14]. The results of this spectrum analysis are then used to separate Bouguer anomalies using the moving average technique [15]. Gradient analysis techniques are carried out on the residual Bouguer anomaly to obtain the fault structure pattern, the lithological boundaries, and the high and low boundaries in the area. A 2D forward modeling is performed to obtain a structural or subsurface density distribution model [16].

Finally, correlation analysis and comparison of the results of processing and modeling gravity data are carried out with geological data, well data, and other data to identify potential hydrocarbon sub-basin prospects in the Lampung sub-basin area.

III. RESULTS AND DISCUSSION

The Bouguer anomaly in the Lampung basin has a value of 0 mGal to 90 mGal, with a high anomaly in the southern part, which is associated with basement high, and a low anomaly [17] in the central-western part, which is related to the existence of the large Sumatra fault zone (Figure 2).

Spectral analysis was carried out to determine the boundary of the regional Bouguer anomaly and the residual area of the study [18-19]. The results of this spectral analysis are then used to estimate the window width for gravity anomaly filtering [20]. In this study, the spectrum analysis used Fourier transform [21], where the results are used to estimate the width of the filtering window [22]. The spectrum analysis was carried out by making a cross-section of the Bouguer anomaly as four passes. The spectrum analysis result shows that the Bouguer Residual anomaly depth limit is around 4303 meters.

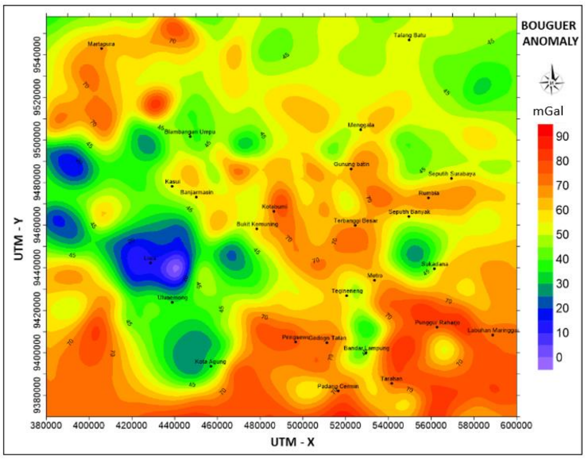

Figure 2. Map of Bouguer anomaly in Lampung sub-basin area

Based on these results, the regional and residual Bouguer anomalies were separated using a moving average filter with a window width of 12 km x 12 km. The residual Bouguer anomaly map from the Bouguer anomaly filtering is shown in Figure 3.

Residual Bouguer anomaly maps have values from -12 mGal to 14 mGal, with anomalous low and high values patterns scattered in the study area. The low anomaly pattern that indicates the basin area needs to be further analyzed to determine the presence of hydrocarbon in the basin. Low anomalies in the West and Southwest, which are in the Sumatra fault zone and the volcanic zone, cause the potential for hydrocarbons in these areas to be very small.

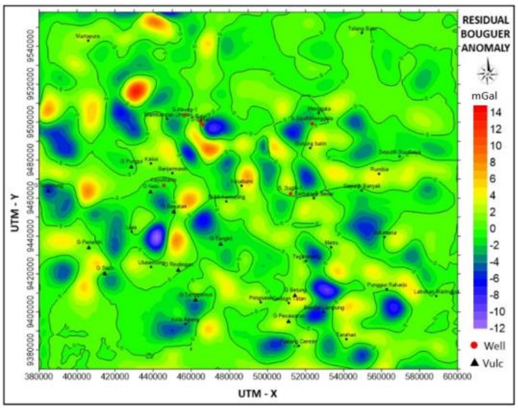

Figure 3. Residual Bouguer anomaly map of the Lampung sub-basin area resulting from the Bouguer anomaly filtering using a moving average filter.

To support the Bouguer Residual anomaly analysis in identifying the fault structure and the lithological boundary and generating the shallow effect anomaly, a vertical gradient analysis of the Bouguer Residual anomaly was performed.

In this study, the SVD anomaly gravity value is calculated using a filtering process through convolution between anomaly gravity and a second vertical derivative filter. This study's second vertical derivative filter is the Elkins (1951) type filter [24]. The SVD map of Bouguer Residual anomaly compiled with low residual Bouguer anomaly contour and fault structure is shown in Figure 4.

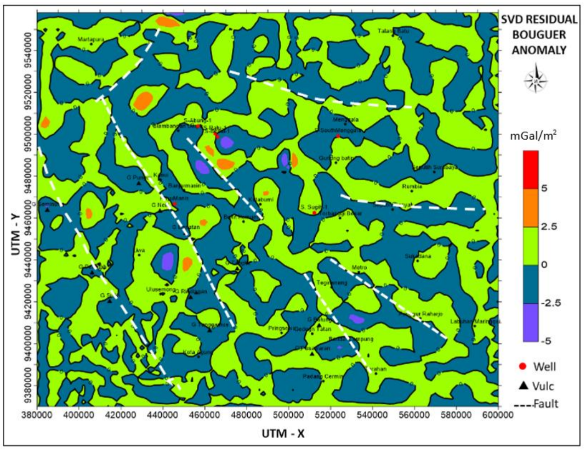

Figure 4. Residual Bouguer anomaly SVD map and fault structure pattern in the area

The main structural pattern in the study area is faulted parallel to the Sumatran fault trending Southeast - Northwest. In contrast, secondary faults are perpendicular to the main fault and West-East direction. The fault structure pattern and volcanic paths will control the presence of hydrocarbon in the study area.

Some data analysis was carried out to obtain the potential of the basin in the Lampung area, such as the Bouguer Residual anomaly, the SVD of the Bouguer Residual anomaly, the fault structure, the presence of a volcanic path, Ratu-1 well, and Tujo-1 well data, and some proposed drilling data. Exploration wells in the WKP Bima Sakti Energy block (south Menggala well), Ranau Block (Kayu Manis well) and Bandarjaya Block (Sugih-1 well). The hydrocarbon potential sub-basin was identified from the low Bouguer anomaly pattern in the area. The sub-basin boundary is derived from the residual Bouguer anomaly's SVD value [25], as seen in Figure 5. From the identification analysis, it is found that the Lampung sub-basin area contains of 18 basins scattered in the following areas: Way Kanan, Tulang Bawang Barat, Menggala, Mesuji, Terbanggi Besar - Seputih Surabaya (Central Lampung), and Sukadana and Labuhan Maringgai (East Lampung).

A 2.5D modeling of residual Bouguer anomaly was carried out to obtain the subsurface structure in the sub-basin area of Lampung. The results of modeling the Lampung sub-basin subsurface structure that passes through the Ratu-1 well and the South Menggala well are shown in Figure 6.

The modeling results show that the Ratu-1 exploration wells and the South Menggala well penetrate to the Baturaja and TAFs located on the flank part of the fault/anticline structure. The Kasai - Air Benakat - Muaraenim Formation is at the top, followed by the GUF, which acts as a seal in the Lampung sub-basin. The reservoir is in the Baturaja and TAFs, while the source rock is in the Kikim formation (LAF).

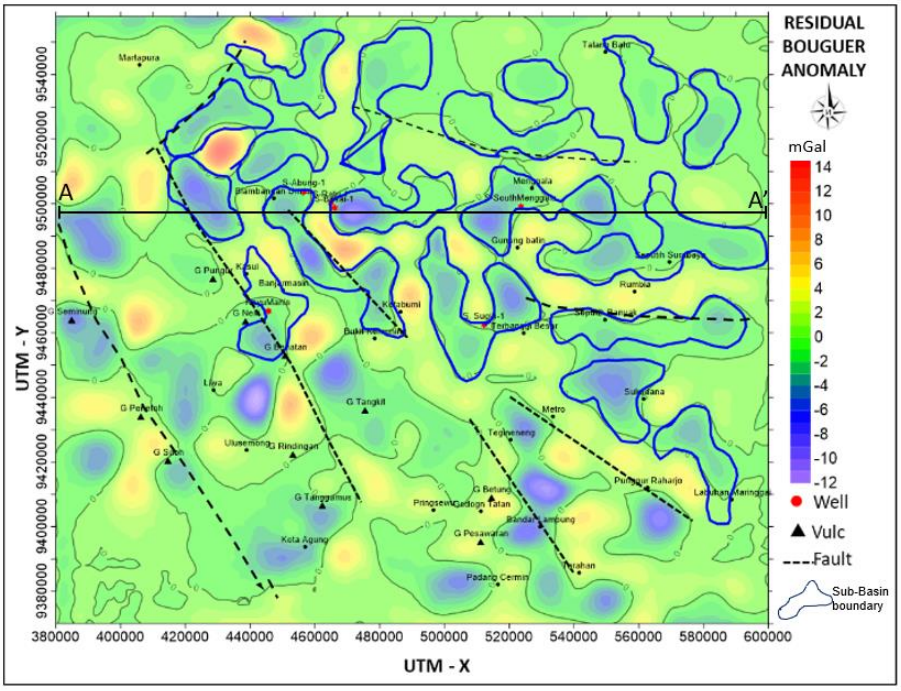

Figure 5. Existence of hydrocarbon potential sub-basins in the Lampung sub-basin.

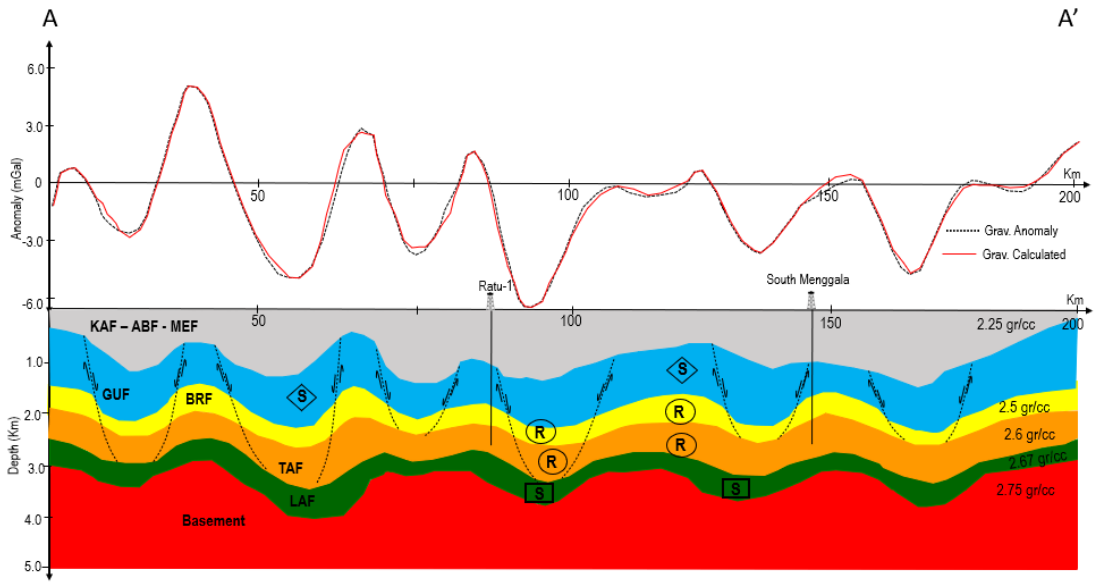

Figure 6. Sections of the subsurface model from the Bouguer anomaly 2D forward modeling through Ratu-1 and South Menggala wells

IV. CONCLUSION

Based on the results of gravity research which is supported by exploration well data and geological data in the Lampung sub-basin to determine the existence of sub-basins with the hydrocarbon potential, several conclusions can be drawn. The Bouguer anomaly in the Lampung sub-basin has a high anomaly in the southern part, which is associated with a basement high and low anomaly in the central-western part, which is related to the existence of the large Sumatra fault zone. There are 18 sub-basins in Lampung WKP block that can be identified with hydrocarbon potential. They are scattered in the following areas: Way Kanan, Tulang Bawang Barat, Menggala, Mesuji, Terbanggi Besar - Seputih Surabaya (Central Lampung), Sukadana and Labuhan Maringgai (East Lampung). The 2.5D modeling results of residual Bouguer anomaly show the Kasai-Air Benakat and Muaraenim formations at the top, followed by GUF that act as seals. Meanwhile, the hydrocarbon reservoir is in the Baturaja and TAF. The interpretation is supported by data from the Ratu-1 exploration well, while the source rock is in the LAF.

REFERENCES

[1] Bishop MG. *South Sumatra Basin Province, Indonesia: The Lahat/Talang Akar-Cenozoic Total Petroleum System*. Open-File Report. USA: US Geological Survey; 2001. DOI: https://doi.org/10.3133/ofr9950S.

[2] Wiyanto B, Junaedi T, Sulistiyono, Prabawa H, and Wibowo Y. Potensi Hidrokarbon Sub-Cekungan Bandarjaya Provinsi Lampung. *Lembaran Publikasi LEMIGAS*. 2009; **43**(1): 1–10. Available from: https://journal.lemigas.esdm.go.id/index.php/LPMGB/article/view/121.

[3] PEI Ltd. *Bandar Jaya PSC, South Sumatra, Indonesia*. Jakarta; 1992.

[4] Gabtni H, Jallouli C, Mickus KL, Dhaoui M, Turki MM, Jaffal M, and Keating P. Basement Structure of Southern Tunisia as Determined from the Analysis of Gravity Data: Implications for Petroleum Exploration. *Petroleum Geoscience*. 2012; **18**(2): 143–152. DOI: https://doi.org/10.1144/1354-079311-050.

[5] Pethe S. *Subsurface Analysis of Sundaland Basins: Source Rocks, Structural Trends and The Distribution of Oil Fields*. Thesis. Muncie

Indiana: Ball State University; 2013.

[6] Darisma D, Marwan M, and Ismail N. Geological Structure Analysis of Satellit Gravity Data in Oil and Gas Prospect Area of West Aceh-Indonesia. *Journal of Aceh Physics Society*. 2019; **8**(1): 1–5. DOI: https://doi.org/10.24815/jacps.v8i1.12750.

[7] Florio G. The Estimation of Depth to Basement Under Sedimentary Basins from Gravity Data: Review of Approaches and the ITRESC Method, with an Application to the Yucca Flat Basin (Nevada). *Surveys in Geophysics*. 2020; **41**(5): 935–961. DOI: https://doi.org/10.1007/s10712-020-09601-9.

[8] Argakoesoemah RMI, Raharja M, Winardhi S, Tarigan R, Maksum TF, and Aimar A. Telisa shallow marine sandstone as an emerging exploration target in Palembang High, South Sumatra Basin. *Proceedings of Indonesian Petroleum Association Thirtieth Annual Convention & Exhibition*. 2005; **1**: 101. DOI: http://dx.doi.org/10.29118/IPA.721.05.G.156.

[9] Buyung N, Manurung A, and Walker SDA. *Peta Anomali Bouguer Lembar Baturaja-Sumatera*. Bandung: Pusat Penelitian dan Pengembangan Geologi; 1991.

[10] Sobari I, Mirnanda E, and Walker SDA. *Peta Anomali Bouguer Lembar Bengkulu - Sumatera*. Bandung: Pusat Penelitian dan Pengembangan Geologi; 1992.

[11] Walker SDA and Buyung N. *Peta Anomali Bouguer Lembar Lahat - Sumatera*. Bandung: Pusat Penelitian dan Pengembangan Geologi; 1991.

[12] Subagio, Suharyono S, Buyung N, and Walker SDA. *Peta Anomali Bouguer Lembar Menggala - Sumatera*. Bandung: Pusat Penelitian dan Pengembangan Geologi; 1991.

[13] Mirnanda E, Siagian HP, Susilo A, and Setyana B. *Peta Anomali Bouguer Lembar Tulung Salapan - Sumatera*. Bandung: Pusat Penelitian dan Pengembangan Geologi; 2002.

[14] Yanis M, Marwan M, and Ismail N. Efficient Use of Satellite Gravity Anomalies for mapping the Great Sumatran Fault in Aceh Province. *Indonesian Journal of Applied Physics*. 2019; **9**(2): 61-67. DOI: https://doi.org/10.13057/ijap.v9i2.34479.

[15] Moore D. Full Spectrum Gravity: a Case Study from the South Sumatra Basin. *ASEG Extended Abstracts*. 2018; **2018**(1): 1–2. DOI: https://doi.org/10.1071/ASEG2018abP028.

[16] Shafie NH, Hamzah U, and Samsudin AR. Analysis of Cheshire Basin by Gravity Method: Some Preliminary Results. *AIP Conference Proceedings*. 2014; **1614**(1): 644–650. DOI: https://doi.org/10.1063/1.4895278.

[17] Kanthiya S, Mangkhemthong N, and Morley CK. Structural Interpretation of Mae Suai Basin, Chiang Rai Province, Based On Gravity Data Analysis and Modelling. *Heliyon*. 2019; **5**(2): e01232. DOI: https://doi.org/10.1016/j.heliyon.2019.e01232.

[18] Nguimbous-Kouoh JJ, III SN, Mbarga TN, and Manguelle-Dicoum E. Use of the Polynomial Separation and the Gravity Spectral Analysis to Estimate the Depth of the Northern Logone Birni Sedimentary Basin (CAMEROON). *International Journal of Geosciences*. 2017; **8**(12): 1442–1456. DOI: https://doi.org/10.4236/ijg.2017.812085.

[19] Shafie NH, Hamzah U, Samsudin AR, and Ibrahim A. Basement Depth Estimation of Cheshire Basin in Northwest England By Power Spectrum Analysis of Gravity Data. Electronic *The Electronic Journal of Geotechnical Engineering*. 2016; **21**(1): 395–408.

[20] Kebede H, Alemu A, and Fisseha S. Upward Continuation and Polynomial Trend Analysis as a Gravity Data Decomposition, Case Study at Ziway-Shala Basin, Central Main Ethiopian Rift. *Heliyon*. 2020; **6**(1): e03292. DOI: https://doi.org/10.1016/j.heliyon.2020.e03292.

[21] Odegard ME and Berg JW. Gravity Interpretattion Using The Fourier Integral. *Geophysics*. 1965; **30**(3): 424–38. DOI: https://doi.org/10.1190/1.1439598.

DOI: https://doi.org/10.1190/1.1437648.

[22] Bahrudin NFD, Hamzah U, and Yaccob WZW. Estimation of Earth Structure by Satellite Gravity Analysis of Peninsular Malaysia. *Sains Malaysiana*. 2020; **49**(7): 1509–1520. DOI: http://dx.doi.org/10.1757/jsm-2020-4907-04.

[23] Elkins TA. The Second Derivative Method of Gravity Interpretation. *Geophysics*. 1951; **16**(1): 29–50.

[24] Hududillah TH, Simanjuntak AVH, and Husni M. Identification of Active Fault Using Analysis of Derivatives with Vertical Second Based On Gravity Anomaly Data (Case Study: Seulimeum Fault in Sumatera Fault System). *AIP Conference Proceedings*. 2017; **1857**(1): 030004.
DOI: https://doi.org/10.1063/1.4987063.