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2D Modelling Gravity Methods for Mapping Subsurface Basin of Bandar Lampung City

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Abstract. The rapid population growth rate in Bandar Lampung City has an impact on the rapidly increasing demand for groundwater. This study aims to map groundwater basins in the Bandar Lampung area. It is necessary to carry out management and monitoring to monitor the availability of groundwater in the research area with an understanding of the existence of basins in the research area. Mapping of the subsurface basin was carried out using the gravity method to see the distribution of gravity anomalies in the study area. The low Bouguer anomaly which forms a circular closed closure is interpreted as a subsurface basin zone which is assumed to be a groundwater basin flanked by bedrock heights indicated by high gravity anomalies. 2D modeling of the research area can also show the presence of a basin and elevation zone composed of 4 rock layers, namely andesite, sandy tuff, clay tuff, and lava (andesite-basalt). The Bandar Lampung Basin is identified as being in the eastern part of the study area.

INTRODUCTION

Currently, Bandar Lampung City is experiencing rapid development. Supported by the geographical position of Lampung as the gateway to Sumatra and Java, it spurs the acceleration of regional development, economy and population growth rate. The population growth rate in Bandar Lampung is relatively high, namely 1.59% / year, with a population in 2020 reaching 1.29 million people. Meanwhile, 2021 is interpreted as reaching 1.3 million people [1]. The population explosion has an impact on the rapidly increasing demand for groundwater. Groundwater is the second largest freshwater reservoir with a capacity of about 30% of all fresh water on earth, compared to surface water reservoirs which only amount to about 0.3% [2]. The presence of groundwater is influenced by the presence of pyroclastic deposits [3, 4].

Bandar Lampung is an area that is affected by active volcanic activity, so this area has pyroclastic deposits. Bandar Lampung is an area formed from volcanic rock deposits (pyroclastic deposits), breakthrough rocks and a thin layer of sediment at the top [5]. The diversity of the constituent rocks that make up the four rock formations is also influenced by plate tectonic activity so as to form a layer and geological structure. As a result of these tectonic activities, molten insertion and intrusion of igneous rock produce complex basins and aquifer geometries. The basin structure can be identified based on geophysical analysis, one of which is by using the gravity method. The use of the gravity method is able to assist in interpreting the existence of the basin based on the density anomaly measurements below the surface which can then be interpreted for subsurface geological modeling. This basin mapping can be used in preliminary studies as a basis for mapping groundwater basins in the Bandar Lampung City area.

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Regional Geology Setting

The research area is in the city of Bandar Lampung, which is physiographically located in the physiography of Bukit Barisan, based on its morphology it belongs to the morphology of the hilly to flat coastal area [6]. The Bukit Barisan Zone is a hilly zone with a southeast-northwest orientation and has an elongated pattern of about 1,650 km with a width of 100 km [7]. The Bukit Barisan Mountains occupy 25-30% of the sheet area, consisting of igneous and metamorphic rocks and young volcanic rocks. With the existence of steep slopes with a height of up to 500-1,680 m above sea level and coastal areas with diverse topography and often consist of rough hills that reach an altitude of 500 m above sea level and consist of Tertiary and Quaternary volcanic rocks and breakthrough rocks [8].

Bandar Lampung has a complex geological setting, as shown in Figure 1. The bedrock is composed of the Pre-Tertiary Paleozoic (Pzg) Gunung Kasih Complex Formation and was disorganized by tectonic influences and magmatic intrusion of the Pre-Tertiary Cretaceous Granodiorite (Kgds) Formation and the Granite Formation (Tmgr) of Early Miocene Tertiary age. The formation of sedimentary rocks covering the bedrock produces the Campang Formation (Tpoc) and the Tarahan Formation (Tpot) of Paleocene to Eocene age. The Eocene period resulted in the formation of the Lampung Formation (QTI) and the Pleistocene produced the Young Volcano Formation (Qhv) covering most of the Bandar Lampung area. Coastal alluvial deposits (Qa) were formed in the Holocene coastal area. Where, the Lampung Formation (Qtl) with a Quaternary age dominates almost all areas in the Tanjung Karang Sheet. The Lampung Formation is generally widespread in the East and Northeast with a thickness of up to 500 meters which is dominated by rhyolite-tuffaceous and volcaniclastic tuffaceous rocks consisting of pumice tuff, rhyolytic tuff, tuffy solid tuff, tuffaceous claystone and tuffaceous sandstone, which were deposited in terrestrial-fluvial environment of brackish water and unconformably overlaid older rocks [9]. The geological condition of Bandar Lampung City is influenced by the fault structure, which can be seen on the Geological Map of the Tanjungkarang Sheet that there are several faults that cross Bandar Lampung City as traversed by the Lampung-Panjang Fault with a NW-SE direction [9]. The existence of the fault is reflected in the morphological conditions of the hills with steep slopes.

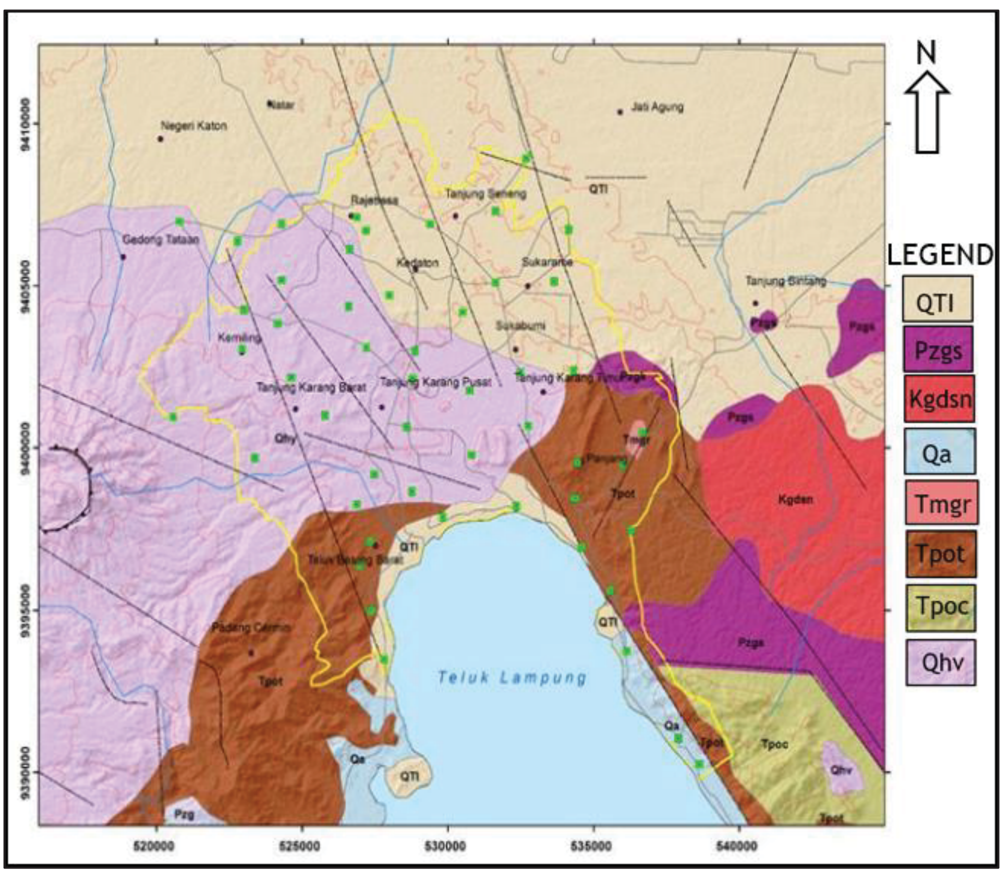


FIGURE 1. Geological Map of Bandar Lampung [10] modified from [9].

Subsurface Basin

Basin is a depression where sediment accumulates and can act as a depositional vessel. A basin can be formed due to deformation events, such as subduction or due to fault factors. Subduction is indicated by the active continental margin which is characterized by the presence of deep-sea trenches, active volcanic arcs, arc-trench gaps that separate the two. Subduction systems occur more at continental margins than at oceanic arcs. In addition, the basins formed by regional horizontal faults are located along the spreading ridges, along fault boundaries between plates, at continental margins and landmasses within continental plates. Movement along regional horizontal faults can form various pull-apart basins. Basins formed by horizontal faults are generally small, only a few tens of kilometers in diameter, although some are up to 50 km. Because horizontal faults are formed in various geological settings, these basins can be filled with marine and terrestrial sediments. Sediment thicknesses tend to be very thick, due to the high sedimentation velocities produced by erosion from the high elevation surrounding areas, and may be characterized by much localized facies change. In Indonesia, this type of basin is widely found along the Sumatran Fault [11].

Tectonic activity causes the formation of sedimentary basins of Tertiary age behind the volcanic arc or east of the Barisan Mountains, including the back-arc basin. Among these basins are the South Sumatra basin (including Lampung) and the Bengkulu basin where Late Tertiary sedimentary rocks are deposited. At the end of the Tertiary to the Quaternary, tectonic activity continued and caused the sedimentary rocks on the island of Sumatra to be uplifted, faulted and folded [7].

Gravity Anomaly

The gravity method is a geophysical method commonly used for regional characterization of the earth [12]. The measurement of the gravity method is to look for small differences or anomalies in the gravitational field caused by lateral density variations. The measured variation depends on Newton's law of gravitation, which takes into account the difference in mass and distance between the source and the point of observation. The measured gravitational variation called the gravitational anomaly is the difference between the measurement result and the theoretical field. The gravity method is very helpful in mapping the position of the bedrock, the overlying layer and the presence of geological structures [13].

The difference in the depth of the bedrock produces a response to variations in the gravitational potential field. Through extraction, the separation of the residual and regional components can be a solution for interpreting the bedrock and the thickness of the sedimentary rock above it [14]. The presence of fault structures can be recognized by the response of gravity and the total magnetic field [15, 16]. Horizontal gradient and vertical gradient filtering approaches are widely used to delineate the presence of fault structures [14, 17, 18, 19]. The gravity method has been widely used to study subsurface geology, especially groundwater basins [20, 21, 22] and several factors that influence it.

METHOD

The approach to achieving the research objectives is carried out through geophysical methods, namely the gravity method. This research focuses on the analysis of subsurface basins. The measurement of the gravitational field covers the Bandar Lampung area with a space between sampling points of 1 km. Gravity anomaly data will then be extracted to obtain residual components which are then used to examine the thickness of the soft rock layers and potential structural paths. While the regional component, provides information on the depth of the bedrock. The research flow chart is shown in Figure 2.

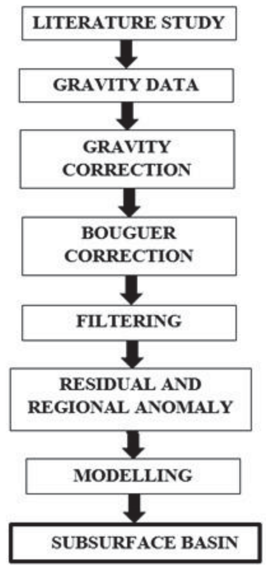


FIGURE 2. Research Chart Flow

RESULT AND DISCUSSION

The acquisition of the gravity method was carried out in Bandar Lampung City. The gravity data is processed using spectrum analysis to separate regional anomalies and residual anomalies. The results of processing gravity data using Oasis Montaj software are obtained in the form of a complete Bouguer anomaly map picture shown in below.

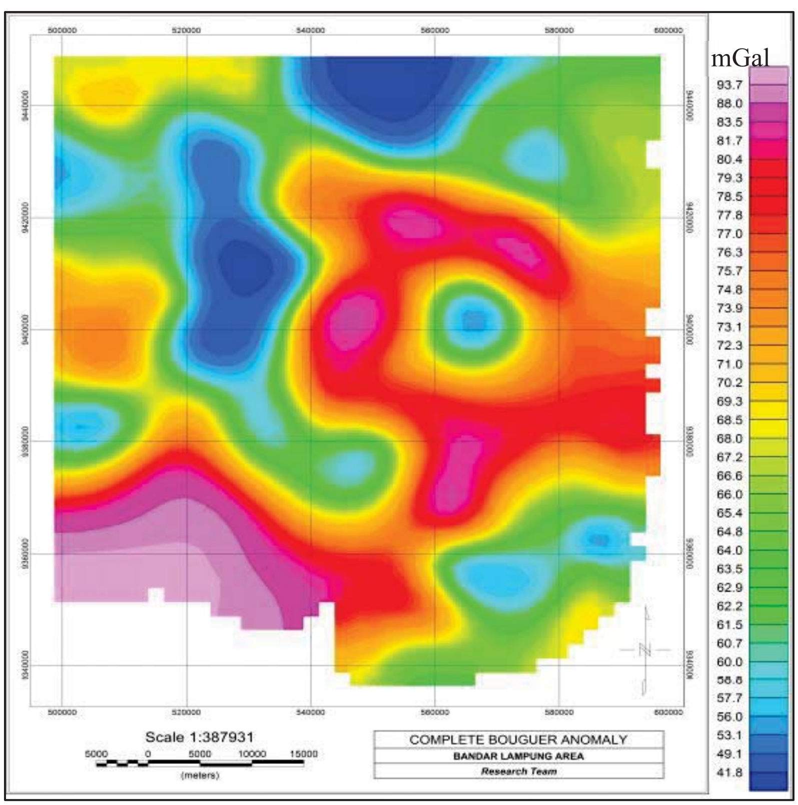
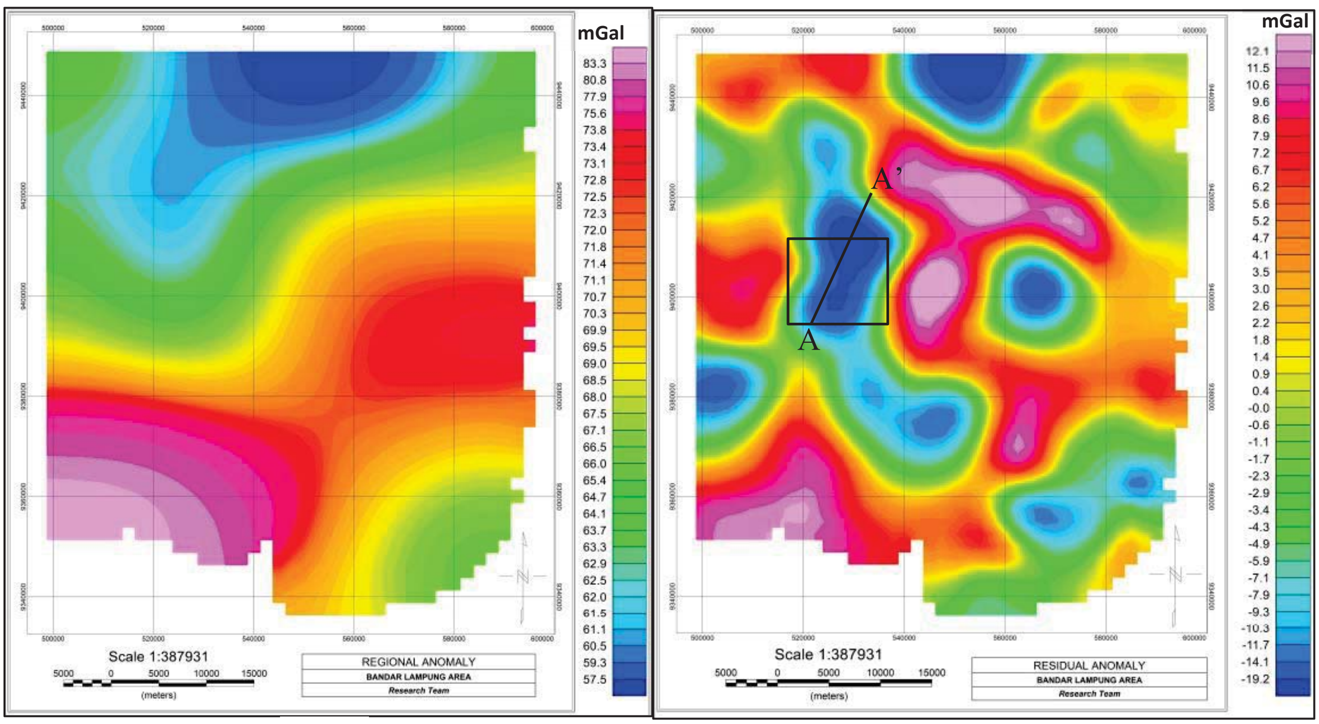


FIGURE 3. Complete Bouguer Anomaly Map of Bandar Lampung City.

Figure 3 shows the complete Bouguer anomaly as a result of processing the measured data in Bandar Lampung City with values between 41.8 to 93.7 mGal. Low anomalies are indicated by blue colors which are concentrated in the north and northwest of the study area, while high anomalies are indicated by red to pink colors located in the east and southwest of the study area. A high anomaly indicates a rock structure with a high density compared to the surrounding area, and conversely a low anomaly has a rock structure with a low density compared to the surrounding area. The low Bouguer anomaly which forms a circular closed closure is interpreted as a subsurface basin zone which is assumed to be a groundwater basin flanked by bedrock heights indicated by high gravity anomalies. The Bandar Lampung Basin is identified as being in the eastern part of the study area.

Gravity anomalies measured in the field are a combination of regional and residual anomalies that can be separated using the moving average method. Separation of anomalies is done to get the source of the anomaly from regional and residual. Through the moving average method used in this study, regional anomalies are obtained as shown in Figure 4, while to obtain residual anomalies (shallow anomalies) it can be done by subtracting the complete Bouguer anomaly with regional anomalies which can be seen in Figure 5.



(a) (b)

FIGURE 4. (a) Regional Anomaly of Bandar Lampung Area (b) Residual Anomaly of Bandar Lampung Area

Figure 4a shows the regional anomaly values in the study area. The low regional anomaly value is in the northern part of the study area which is indicated by the blue color with values between 57.5 to 62 mGal. Areas that have moderate anomaly values are in the northeast, southeast, and northwest of the study area indicated by green to orange with a range of anomaly values of 62.5 to 72 mGal. High anomaly values are indicated by red to pink color with a value range of 72.3 to 83.3 mGal which is trending east to west of the study area.

Figure 4b shows the residual anomaly value in the study area. The low anomaly indicated by the blue color with a value range of -19.2 to -7.9 mGal is dominated in the areas located in the north and west of the study area, while in the middle and southwest there is a high anomaly indicated by red to pink with a value range of 6.2. up to 12.1 mGal. The results of gravity data processing in the form of regional and residual anomaly maps can then be used to analyze subsurface structures, such as to see the existence of basin areas.

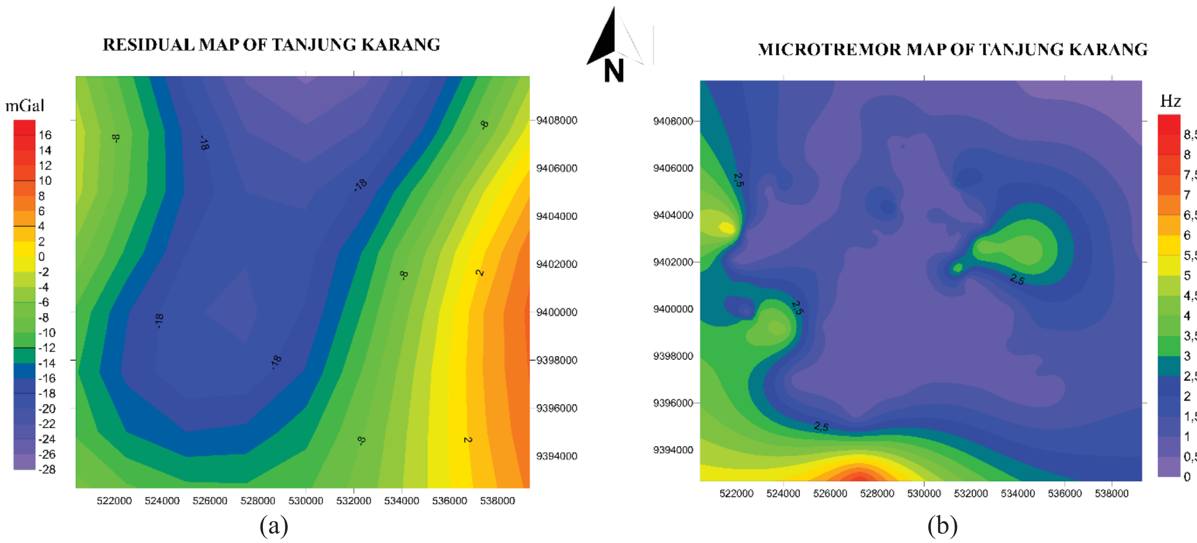


FIGURE 5. (a) Residual Anomaly of Bandar Lampung Area, (b) Dominant Frequency of Bandar Lampung Area [24]

Based on Figure 5a, it shows that the research area is an area with a dominant frequency value that tends to be low which is marked in blue. The low anomaly is indicated by the blue colour with a value range of -28 to 16 mGal. A low dominant frequency (f0) indicates the presence of a soft soil layer or sediment. Where sediment deposits are usually collected in a basin. Based on Figure 5b, shows that the research area is an area with a dominant frequency value that tends to be low which is marked in blue. Thus, areas with low dominant frequency and low gravity anomaly are identified as basin zones. This is what underlies the determination of the 2D gravity data modelling trajectory as shown in Figure 6.

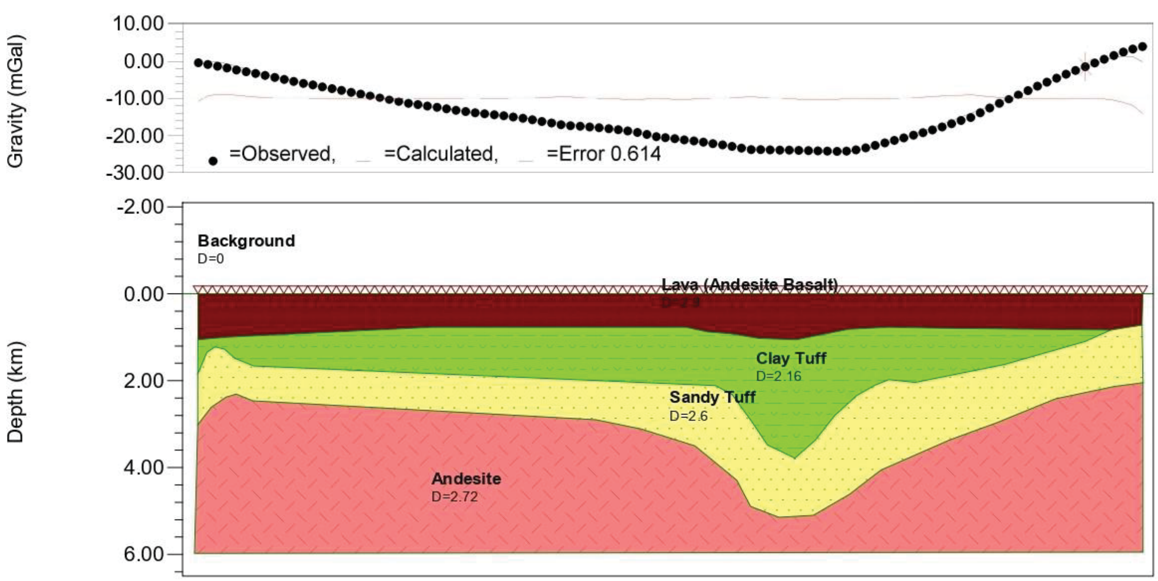


FIGURE 6. 2D Modeling of Gravity Data in Bandar Lampung City

To make it easier to analyze the subsurface structure, 2D modeling of gravity data was made as shown in Figure 6. The 2D modeling was carried out to a depth of 5 km with an error value of 0.588 and it can be seen that the black line (calculated data) coincides with the point -black dot (observed data). This proves that this 2D modeling has resembled the actual shape of the subsurface. Based on 2D modeling of gravity data, it can be seen that the study area is composed of 4 rock layers, namely andesite, sandy tuff, clay tuff, and lava (andesite-basalt). The estimated density value of andesite is 2.72 gr/cc, sandy tuff is 2.6 gr/cc, clay tuff is 2.16 gr/cc, and lava (andesite-basalt) is 2.9 gr/cc.

This model is made by referring to the regional geology of the Tanjung Karang Sheet Map which is known that this zone is located in the Young Volcano Deposit (Qhv) and the Lampung Formation (QTl). Where, the Young Volcano Sediment Formation (Qhv) is composed of lava (andesite-basalt) and breccia, while the Lampung Formation (QTl) is composed of pumice tuff, rhyolytic tuff, solid tuffy tuff, tuffaceous claystone, and tuffaceous sandstone. It can be seen in the 2D model that there are 2 basin structures in the research area, this is also reinforced by the research of Rustadi et al (2020) which states that there is the Bandar Lampung Basin which is in the southwest, formed through a grabben pattern from bedrock with grabben cover material interpreted as an alternation between the Lampung Formation (QTI) and the results of the volcanic activity of Mount Betung in the form of pyroclastic and andesite-basalt lava (Qhv) melts.

CONCLUSION

Based on the gravity anomaly map of the study area, the presence of a low Bouguer anomaly that forms a closed circular closure is interpreted as a subsurface basin zone which is assumed to be a groundwater basin flanked by bedrock heights indicated by a high gravity anomaly. Based on the 2D gravity modeling of the research area, it can be seen that there is a basin and elevation zone composed of 4 rock layers, namely andesite, sandy tuff, clay tuff, and lava (andesite-basalt). The Bandar Lampung Basin is identified as being in the eastern part of the study area.

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REFERENCES

1. BPS Bandar Lampung. 2020. Total Population of Bandar Lampung City 2010-2020. https://bandarlampungkota.bps.go.id/statictable/2015/12/08/19/jumlah-penduduk-kota-bandar-lampung-2010-2020.html (accesed on June 25th, 2021).
2. A. Shiklomanov. Appraisal and Assessment of World Water Resources. Water International, pp. 11-32, (2000).
3. M. Aubert, G. Camus, and C. Fournie, Resistivity and Magnetic Surveys in Groundwater Prospecting in Volcanic Areas-Case History Maar of Beaunit, Puy De Dome, France, Geophysical Prospecting, p. 554–563, (1984).
4. S. Hurwitz. Groundwater Flow, Heat Transport, and Water Table Position Within Volcanic Edifices: Implications for Volcanic Processes in The Cascade Range. Journal of Geophysical Research, (2003).
5. Rustadi. Breakthrough Rocks and Prospects of Metal Mineralization in Bandar Lampung. MIPA Science Journal, April 2018, Vol. 18, No. 1, pp. 19 – 22. ISSN 1978-1873. (2018).
6. R. Mulyasari, I.G.B. Darmawan, D.S. Effendi, S.P. Saputro, Hesti, A. Hidayatika, and N. Haerudin. Application of the Geoelectrical Resistivity Method for Slip Field Analysis and Avalanche Characteristic Studies on Suban Highway, Bandar Lampung. Journal of Exploration Geophysics Vol. 6/No. 1, March 2020: 66-76. (2020).
7. Van Bemmelen, R.W. The Geology of Indonesia, Volume 1A, Government Printing Office, The Hague, Netherlands. (1949).
8. R. Mulyasari, N. Haerudin, Karyanto, I.G.B. Darmawan, and Y. Arifianti. Zoning of Potential Areas for Mass Movement along the Lampung-Panjang Fault in Bandar Lampung City. National Seminar Proceedings SINTA FT UNILA Vol. 1 2018. (2018).
9. S. A. Mangga, Amirudin, T. Suwarti, S. Gafoer and Sidarto, Geological Map Sheet Tanjungkarang, Sumatera, Bandung: Geological Research and Development Center, (1993).
10. Rustadi, Arief I.H., Ahmad Z., N. Haerudin and Suharno. Delineation of the Bandar Lampung Groundwater Basin as a Conservation Foundation to Maintain Sustainable Availability. Prosiding Seminar Teknologi Kebumian dan Kelautan (SEMITAN II) Institut Teknologi Adhi Tama Surabaya (ITATS), Indonesia. 12 Juli 2020. Vol. 2, No. 1, July 2020. ISSN 2686-0651 (2020).

11. Boggs, S. Jr. Principles of Sedimentology and Stratigraphy, 4th edition. New Jersey: Pearson Prentice Hall. (2006).
12. Mahed, G. Gravimetry and Its Application to Geohydrology: A Review, South African Journal of Geomatics, 5(3). (2016).
13. Anbazhagan, S. and Jothibasu, A. Geoinformatics in Groundwater Potential Mapping and Sustainable Development: A Case Study from Southern India, Hydrological Sciences Journal. Taylor & Francis, 61(6), pp. 1109–1123. doi: 10.1080/02626667.2014. 990966. (2016).
14. Rosid, M. S. and Siregar, H. Determining Fault Structure Using First Horizontal Derivative (FHD) and Horizontal Vertical Diagonal Maxima (HVDM) Method: A Comparative Study, AIP Conference Proceedings, 1862. doi: 10.1063/1.4991275. (2017).
15. Xu, C. Wang, H. Luo, Z. Liu, H. and Liu, X. Insight into Urban Faults by Wavelet Multi-Scale Analysis and Modeling of Gravity Data in Shenzhen, China', Journal of Earth Science, 29(6), pp. 1340–1348. doi: 10.1007/s12583-017-0770-4. (2018).
16. Dmitrijeva, M., Plado, J. and Oja, T. The Luusika potential field anomaly, Eastern Estonia: Modelling results', Estonian Journal of Earth Sciences, 67(4), pp. 228–237. doi: 10.3176/earth.2018.18. (2018).
17. Setianingsih, Efendi, R. Kadir, W.G.A. Santoso, D. and Alawiyah, S. Gravity gradient technique to identify fracture zones in Palu Koro strike-slip fault', Procedia Environmental Sciences 17, 248-255. (2017).
18. Wahyudi, E. J., Kynantoro, Y. and Alawiyah, S. Second Vertical Derivative Using 3-D Gravity Data for Fault Structure Interpretation, Journal of Physics: Conference Series, 877(1). doi: 10.1088/1742-6596/877/1/012039. (2017).
19. Ekinci, Y. L. and Yiŀitbaş, E. Interpretation of gravity anomalies to delineate some structural features of Biga and Gelibolu peninsulas, and their surroundings (north-west Turkey), Geodinamica Acta. Taylor & Francis, 27(4), pp. 300–319. doi: 10.1080/09853111.2015.1046354. (2015).
20. Kazama, T., Tamura, Y., Asari, K., Manabe, S., and Okubo, S. Gravity Changes Associated with Variations in Local Land-Water Distributions: Observations and Hydrological Modeling at Isawa Fan, Northern Japan. 309–331. (2012).
21. Creutzfeldt, B., Güntner, A., Wziontek, H., and Merz, B. Reducing Local Hydrology from High-Precision Gravity Measurements: A Lysimeter-Based Approach. Geophysical Journal International, 183(1), 178–187. (2010).
22. Smith, A. B., Walker, J. P., and Western, A. W. Detection of a Soil Moisture and Groundwater Signal in Ground-Based Gravity Observations. 30th Hydrology and Water Resources Symposium, December (2006).
23. N. Haerudin, Rustadi, F. Alami and I. B. S. Yogi. The effect site analysis based on microtremor data using the Horizontal to Vertical Spectral Ratio (HVSR) method in the Bandar Lampung City. The 9th International Conference on Theoretical and Applied Physics (ICTAP). Journal of Physics: Conference Series. 1572, 012075. (2020).