Jurnal Geofisika (2021) Vol. 19, No. 01 pp. 36-40

Fault Reassessment in Way Huwi Area, South Lampung using Gravity Method

Luhut Pardamean Siringoringo[1,*], Andri Yadi Paembonan[1], dan Virgian Rahmanda[1]

[1]Institut Teknologi Sumatera
*Email: luhut_pardamean@yahoo.co.id

Submit: 2021-08-02; Revised: 2021-09-29; Accepted: 2021-10-09

Abstract: The Age majority of regional geological maps that have been referenced by geologists in Indonesia are about 20-30 years old. One of them is Tanjung Karang Geological Map. Our opinion is that the map is old enough. Some faults features are doubted in the aspect of existence and its trend. It is represented by the dashed line symbol in the maps. Therefore, this research was carried out to provide a more detailed reinterpretation of faults in the Way Huwi area using the Gravity method. This area was selected because it is the new education center and economy in the eastern part of Bandar Lampung. This research was also carried out as part of disaster mitigation. The faults within this research area were identified with Horst-Graben type and formed before Lampung Formation was deposited. The trend of these normal faults is Northeast-Southwest. it is very different from the fault interpretation on Tanjung Karang regional geology map with the Northwest-Southeast direction. The genesis of the Way Huwi Fault is indirectly part of the extensional Sunda Strait.

Keywords: Panjang Fault, Way Huwi, South Lampung, Gravity

Abstrak: Usia mayoritas Peta geologi regional yang saat ini menjadi rujukan para geolog di Indonesia berkisar 20-30 tahun. Termasuk didalamnya adalah peta geologi regional lembar Tanjung Karang. Kekurangan dari peta tersebut yaitu interpretasi sesar yang diragukan dalam hal keberadaanya maupun arahnya. Hal ini dapat diketahui dengan adanya simbol garis putus-putus pada peta. Oleh karena itu penelitian ini dilakukan secara lebih detil untuk menginterpretasi kembali keberadaan sesar di daerah Way Huwi dengan menggunakan metode Gayaberat. Daerah Way Huwi yang menjadi pusat pendidikan dan ekonomi baru merupakan alasan utama penelitian ini dilakukan khususnya dalam bidang mitigasi bencana geologi. Berdasarkan proses yang dilalui, maka dapat disimpulkan bahwa sesar yang ada di daerah penelitian merupakan sesar normal (Way Huwi Fault) berjenis Horst-Graben yang terbentuk sebelum Formasi Lampung diendapkan. Arah sesar normal ini yaitu Timur Laut-Barat Daya. Ini berbeda sekali dengan interpetasi sesar berdasarkan peta geologi regional tanjung karang yang berarah Barat Laut-Tenggara. Keterjadian sesar way huwi secara tidak langsung merupakan bagian dari tektonik ekstensional Selat Sunda.

Kata kunci: Sesar Panjang, Way Huwi, Lampung Selatan, Gravity

1 INTRODUCTION

The Tanjung Karang-Regional Geological Map was produced by Geological Survey Center in 1993. It means the map has been more than 27 years old as academic research, precious material exploration, and natural disaster references in Lampung. Besides that, the scale of this regional geological map is very small that is 1:250.000. It is very influenced by the map resolution in presenting the geological data. From the structural geology aspect, the regional and local geological structures have not been well mapped. This can be seen in the research area location marked by dashed lines symbols (Figure 1). The dashed-lines mean position or existence of fault is still uncertain. This fault namely Panjang Fault. In the research area, Lampung Formation is the youngest rock (quarter age). The Lampung Formation consists of tuff lithology with acid and medium composition. The thickness is up to 200 m (Mangga, Amirudin, Suwarti, Gafoer, & Sidarto, 1993).

Indonesia area is located in the junction of three large plates which are still active. They are Eurasia, Indo-Australia, and Pacific Plate (Setiadi, Setyanta, Nainggolan, & Widodo, 2019). the interactions of these plates produce volcanoes, faults, and earthquakes in the Indonesia area. Sumatera island, a part of the Eurasia plate, is located on the west point of Indonesia island. In addition, it is also part of the subduction of India-Australia plates that moving underneath Sundaland (Crow, 2005). Sundaland is a part of Eurasia plates that including Myanmar, Thailand, Indochina (Laos, Cambodia, Vietnam), Malaysia peninsula, Sumatera, Java, Borneo, and Sunda Shelf (Simons et al., 2007). The subduction process spans from the south of Andaman Islands passes Sumatera Island to East Jawa until South Flores (McCaffrey, 2009). This subduction had begun since the Late Oligocene (Hamilton, 1979). Sumatera fault system, a dextral-strike slip fault type, is resulted from this oblique subduction (Bellier et al., 1997; McCaffrey, 2009). This fault spans along the Sumatera island with more than 1600 km from Northwest to Southeast that active since Miocene (Barber, Crow, & Milsom, 2005) with movement velocity 5.5 ± 1.9 mm/yr (Bellier, Bellon, Sébrier, Sutanto, & Maury, 1999). Another regional fault besides the Sumatera fault is the Panjang fault, which is presumed to have similar Northwest-Southeast trend as the Sumatera fault. The evolution of Panjang Fault was begun with the strike-slip movement then changed to be a normal fault (Pramumijoyo & Sebrier, 1991). Very few references discuss the fault if compared to the Sumatera fault. Considering its relatively young age the fault has the potential to move at any time and therefore has significant urban implication. The research focuses on the Pajang fault existence in the research area boundary by using the Gravity method. The typical data to be collected are fault type, the movement trend, as well as the lithology type and distribution.

According to the data from Lampung-Statistic Central Agency in 2020, the population of Bandarlampung is 1,071 million people. It is the second biggest after Central Lampung regency (BPS, 2020). Geographically, some of data retrieval points were located in this Lampung capital city. Therefore any type of disaster research especially related to the structural geology is critical. This research was done as part of geological disaster mitigation.

2 METHOD

The gravity method is a geophysical method that utilizes earth gravity to imaging subsurface rocks based on their density diversity (Wardhana, Harjono, & Sudaryanto, 2014). This method usually is used as an early hydrocarbon and mineral exploration survey (Setiadi et al., 2019). In this research, the gravity method is only used to determine the condition of sub-surface geology, especially subsurface geological structures. Before further analysis, several corrections are needed, including tide correction, drift correction, free air correction, normal gravity correction, Bouguer correction, and terrain correction. The creation of an anomalous Bouger map used a formula from Telford, Telford, Geldart, and Sheriff (1990) as follows:

$$BA = (g_o + FAC - BC + TC) - g_n \tag{1}$$

where,

$$g_n = 978,03181\{1 + 0,0053024\sin^2\theta – 0,0000058\sin^2(2\theta)\}$$

BA : Bouguer Anomaly
g_o : observation value (measurement)
FAC : free air correction
BC : Bouguer correction
TC : terrain correction
g_n : theoretical or normal value

The measurement of gravity in the field was done using gravimeter Scintrex CG-6. The measurement was done following publics roads and locations that are reachable from East to West with interval range from 0.5 km to 1 km. The observation collects 32 retrieval points gravity data.

We have done separation regional and residual anomaly from Bouguer anomaly through spectral analysis method and filtering Moving Average approach to get more accurate information. The purpose of this separation is to identify anomaly patterns that can describe the existence of subsurface structures from the deepest to the shallowest. The qualitative interpretation involves Bouguer anomaly map and residual anomaly map, whereas quantitative interpretation includes gravity modeling. Interpretation uses software such as Microsoft Excel and Oasis Montaj.

3 RESULT AND DISCUSSION

3.1 Bouguer Anomaly

After the reduction and correction processes, a Bouguer anomaly map is generated as it can be seen in Figure 2. The anomaly has a general orientation Northeast-Southwest with an exception on the eastern part that is inclined to the North-South trend and on the western part inclined to the West-East trend. The anomaly range in the research area is about 34-77mGal, and it was divided into low, medium, high types. Low anomaly is <48 mGal, the medium anomaly is ranged from 48-72 mGal and the high anomaly is >72 mGal. High anomaly is located in the middle of the lower part that spans to the eastern part with Northeast-Southwest trend. The anomaly indicates eastern trending with the shallower basement. Low anomaly is located in the middle of the upper part that spans until the west that has Northeast-Southwest trend with slight defection to be West-East and then continue with the Northeast-Southwest trend. This low anomaly reflects a basin that is relatively deep and probably controlled by the Northeast-Southwest trending fault. The basin interpretation is based on the assumption that the rocks with low density indicate sedimentary rocks, while rocks with high density are igneous or metamorphic rocks (Evariste et al., 2014). The low gravity also reflects high porosity sediment or volcanic tuff (Lichoro, Árnason, & Cumming, 2019). This finding is consistent with the geological condition of the research area composed mainly by Lampung Formation which consists of tuff lithology. Tuff Lampung formation is one of the four Pliocene-Quarter age pyroclastic deposits. The four are Toba tuf in Northern Sumatera, Padang Tuf in Central Sumatera, and Ranau tuf and Lampung in Southern Sumatera (Gasparon & Varne, 1995).

3.2 Residual Anomaly

The residual anomaly was produced by reducing the Bouguer anomaly with the regional anomaly. The residual anomaly was used to observe anomalies that were only influenced by specific causes. The residual anomaly has a range value from -0.8mGal to 0.6 mGal and mean anomaly 0.028 mGal (Figure 3). This residual anomaly shows a pattern that more complex than the regional anomaly in terms of density and lithology above the basement rocks. The anomalous pattern with a shorter wavelength reflects the shallower effect.

High anomaly is indicated by purple and red color which dominantly occupies the middle part of research area and covers up to 40% of the research area. This anomaly has a range value from 0.3 mGal to 0.6 mGal. The anomaly shows rocks with high contrast of mass density values dominating the research area in the central, west, and northeast parts. The general high anomaly is related with the Way Galih schist. Some of the higher ones are related to the Jatibaru granites intrusion that has higher density.

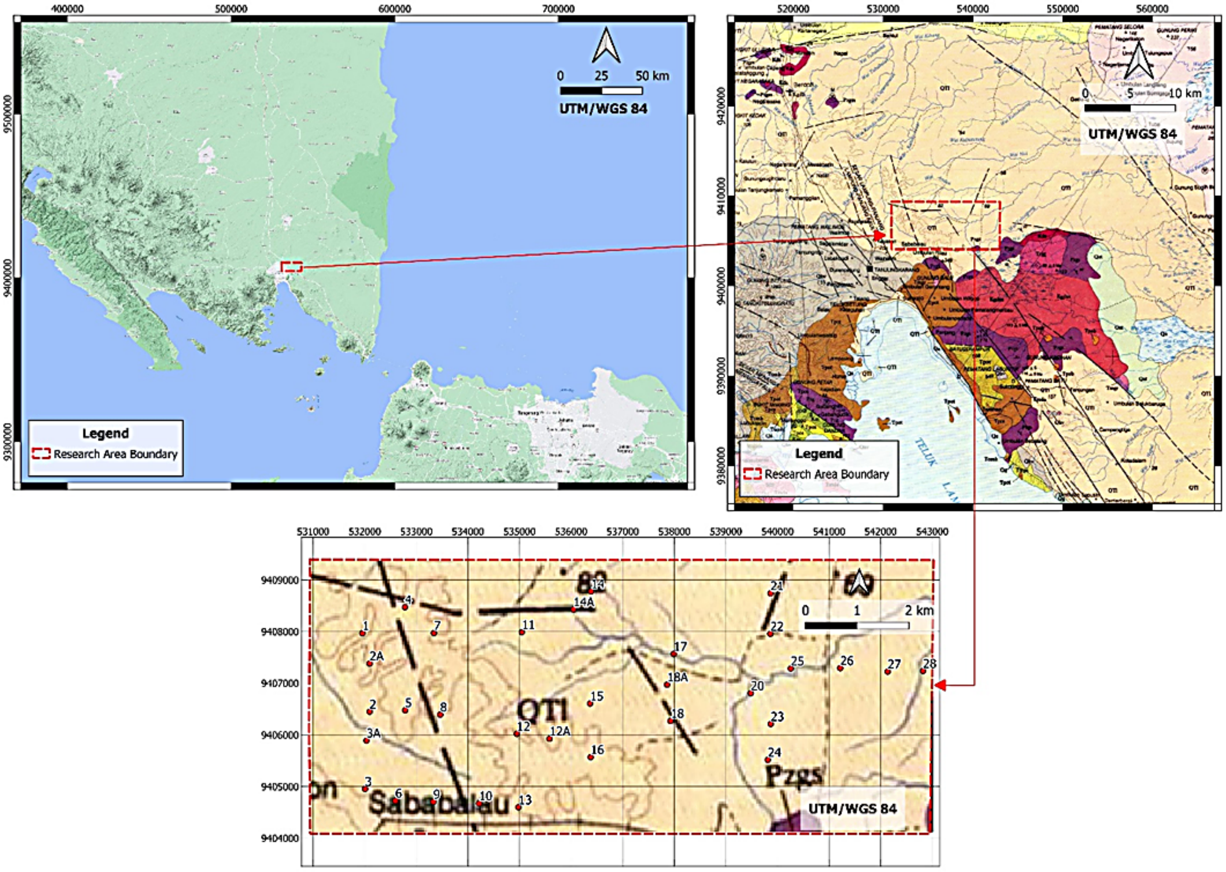

Figure 1. Detailed research area in Sumatera Island (top left) and regional geology (top Right). The bottom picture shows the spreading of measurement points in the research area.

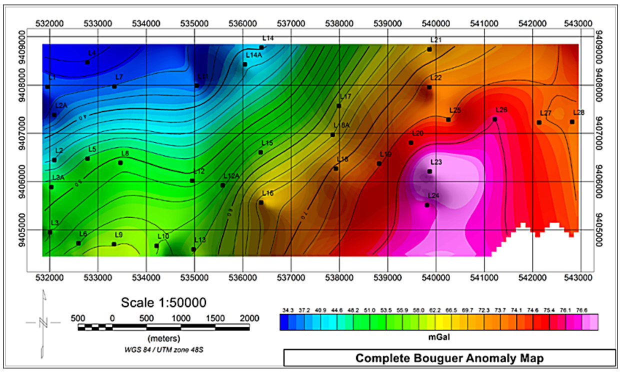

Figure 2. Complete Bouguer Anomaly Map shows general orientation NE-SW trend except for the eastern part inclined to the north-south and western part inclined to the west-east

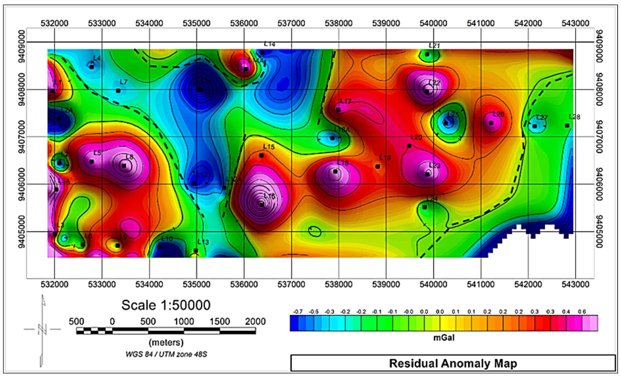

Figure 3. Residual Anomaly Map shows a range from -0.8 mGal to 0.6 mGal, with mean anomaly is 0.028.

Low anomaly is displayed in darker color with a range from -0.8 mGal to -0.1 mGal. The low anomaly indicates rocks with low contrast of mass density values located in the Northwest and Southeast of the research area. Medium anomaly with range value from -0.1 mGal to 0.3 mGal is dominated by Lampung Formation volcanic eruption materials. The residual anomaly map can also be interpreted as faults based on tighten and straightness contours or boundary between high and low anomaly. Some straightness and faults observed in the research area are located in the West and Southeast parts (Figure 3). In comparison, we had done filtering with SVD (Second Vertical Derivative) operator to delineate the existence of fault and straightness. The zero SVD contour value (black lines) may indicate faults existence in this research area (Figure 4). The dashed lines are therefore interpreted as faults. Based on the SVD anomaly contour pattern, the faults structures are related to subsurface structures and shown with the dashed lines. The fault structures pattern however does not have the position and trend similarities with the geological maps. This un-

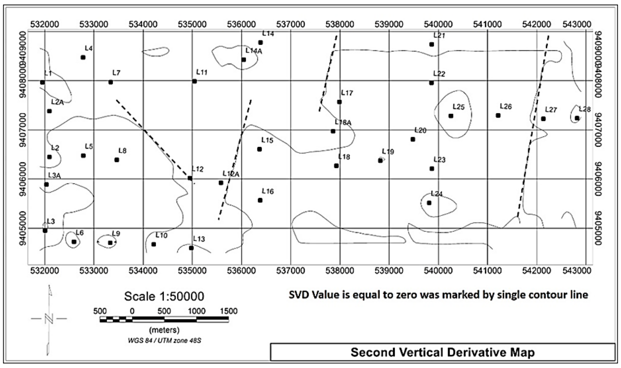

Figure 4. The second Vertical Derivative Map shows lineaments (dashed lines) based on contour patterns.

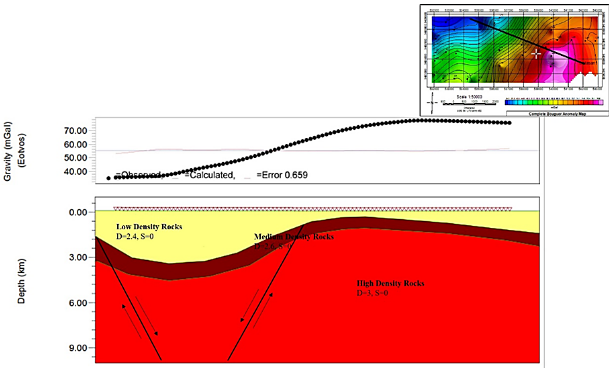

Figure 5. 2D gravity modeling shows horst-graben structure and distribution of lithology and its thickness.

similarity is due to the fault interpretation in the regional geological map only using remote sensing method.

3.3 2D Gravity Modelling

In order to understand the image of subsurface rocks structure and the possibility of the structural control, we made the 2D gravity section model. According to the Tanjung Karang-Regional Geology Map, there are three rocks types within the research area with a range density from 2.4 gr/cc to 3 gr/cc. The rocks with density 2.4 gr/cc is Lampung Formation, the rocks with density 2.6 gr/cc is Way Galih Schist, and the rocks with density 3 gr/cc is Jatibaru Granite.

The gravity model cross-section (Figure 5) that has Northwest-Southeast trend was made perpendicular to contour, then it was found two normal faults that facing each other or called as Horst-Graben. These faults have a Northeast-Southwest trend. This cross-section can be seen JatiBaru granite intrusion dominates in the research area with the same thickness in the whole research area. Volcanic rocks are the characteristic of the Lampung Formation that is seen widely in the whole research area with significant thickness in normal faults setting. This explanation shows that Lampung Formation was deposited after the normal fault formed. The thickness of Way Galih schist tends to be the same in the whole research area.

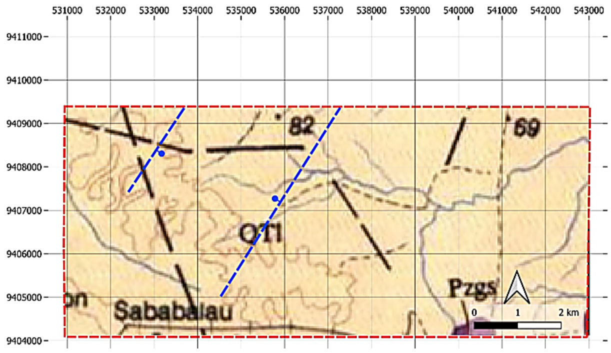

Figure 6. Final fault interpretation. The illustration shows the estimated presence of faults (blue lines) on the regional geology map.

3.4 Implication to The Geology of Research Area

Based on the analysis of Bouguer anomaly map, the residual anomaly, and 2D gravity cross-section model, Way Huwi is a volcanic area consists of igneous rocks, metamorphic rocks, and volcanic rocks. The main structures are normal faults (Way Huwi Fault) which are the antithetic of Panjang Fault. These faults have a relatively Northeast-Southwest trend. The fault existences become more indicative from the hot water spring in Umbul Niti village, located 7 km in the North part of the research area. The Way Huwi fault is expected to be formed since 5 Ma and is closely related with the Sunda strait extensional tectonic (Pramumijoyo & Sebrier, 1991). This extension was caused by the movement of the Southwest Sumatera block to the Northwest along the Sumatera Fault Zone (Jarrard, 1986). This Sunda Strait extensional dynamics in agreement with the Sumatera rotation moved on clockwise direction as 40° relatively towards Java since 2 Ma (Nishimura, Nishida, Yokoyama, & Hehuwat, 1986). Our research therefore propose a geological map improvement within the research area based on the gravity modeling and interpretation (Figure 6).

4 CONCLUSIONS

The Bouguer anomaly and the residual anomaly maps indicate a low anomaly controlled by the Northeast-Southwest trending fault within the research area. The 2D gravity map confirms the fault interpretation is related to the Way Huwi fault along the Northeast-Southwest trending as the antithetic of the Panjang fault. The formation of this fault may be closely related to the extensional tectonic Sunda Strait. The lithologies of the research area consist of the Lampung Formation tuff which is deposited following the normal fault movement, the very massive thickness Way Galih schist and JatiBaru granite intrusion. Our research proposes two potential Northeast-Southwest fault planes to improve the existing geological map within the research area based on the findings.

ACKNOWLEDGMENTS

We want to thank the Sumatera Institute of Technology leaders for their support in this research and the division of

Research and Community Service of the Sumatera Institute of Technology for the care of all author administrations. We also thank the editorial team and the reviewer of the HAGI geophysics journal who helped the process of this published article.

References

Barber, A. J., Crow, M. J., & Milsom, J. (2005). Sumatra: Geology, resources and tectonic evolution. In (Vol. 31). Geological Society of London.

Bellier, O., Bellon, H., Sébrier, M., Sutanto, & Maury, R. C. (1999, November). K–ar age of the ranau tuffs: implications for the ranau caldera emplacement and slip-partitioning in sumatra (indonesia). *Tectonophysics*, *312*(2-4), 347–359. Retrieved from `https://doi.org/10.1016/s0040-1951(99)00198-5` doi: doi:10.1016/s0040-1951(99)00198-5

Bellier, O., Sébrier, M., Pramumijoyo, S., Beaudouin, T., Harjono, H., Bahar, I., & Forni, O. (1997, September). Paleoseismicity and seismic hazard along the great sumatran fault (indonesia). *Journal of Geodynamics*, *24*(1-4), 169–183. Retrieved from `https://doi.org/10.1016/s0264-3707(96)00051-8` doi: doi:10.1016/s0264-3707(96)00051-8

BPS. (2020). *Perkembangan indikator makro sosial ekonomi lampung triwulan i 2020* (Tech. Rep.). Badan Pusat Statistik Provinsi Lampung (BPS-Statistics of Lampung Province). Retrieved from `https://lampung.bps.go.id/publication/2020/07/15/38f56a4c89586bdb9364a0b5/perkembangan-indikator-makro-sosial-ekonomi-lampung-triwulan-i-2020.html`

Crow, M. J. (2005). Chapter 8 tertiary volcanicity. *Geological Society, London, Memoirs*, *31*(1), 98–119. Retrieved from `https://doi.org/10.1144/gsl.mem.2005.031.01.08` doi: doi:10.1144/gsl.mem.2005.031.01.08

Evariste, N. H., Genyou, L., Tabod, T. C., Joseph, K., Severin, N., Alain, T., & Xiaoping, K. (2014, February). Crustal structure beneath cameroon from EGM2008. *Geodesy and Geodynamics*, *5*(1), 1–10. Retrieved from `https://doi.org/10.3724/sp.j.1246.2014.01001` doi: doi:10.3724/sp.j.1246.2014.01001

Gasparon, M., & Varne, R. (1995, December). Sumatran granitoids and their relationship to southeast asian terranes. *Tectonophysics*, *251*(1-4), 277–299. Retrieved from `https://doi.org/10.1016/0040-1951(95)00083-6` doi: doi:10.1016/0040-1951(95)00083-6

Hamilton, W. B. (1979). *Tectonics of the Indonesian region* (Vol. 1078; Tech. Rep.). doi: doi:10.3133/pp1078

Jarrard, R. D. (1986). Terrane motion by strike-slip faulting of forearc slivers. *Geology*, *14*(9), 780–783.

Lichoro, C. M., Árnason, K., & Cumming, W. (2019, January). Joint interpretation of gravity and resistivity data from the northern kenya volcanic rift zone: Structural and geothermal significance. *Geothermics*, *77*, 139–150. Retrieved from `https://doi.org/10.1016/j.geothermics.2018.09.006` doi: doi:10.1016/j.geothermics.2018.09.006

Mangga, S., Amirudin, A., Suwarti, T., Gafoer, S., & Sidarto. (1993). *Peta geologi lembar tanjungkarang, sumatera.* Pusat Penelitian dan Pengembangan Geologi.

McCaffrey, R. (2009, May). The tectonic framework of the sumatran subduction zone. *Annual Review of Earth and Planetary Sciences*, *37*(1), 345–366. Retrieved from `https://doi.org/10.1146/annurev.earth.031208.100212` doi: doi:10.1146/annurev.earth.031208.100212

Nishimura, S., Nishida, J., Yokoyama, T., & Hehuwat, F. (1986, January). Neo-tectonics of the strait of sunda, indonesia. *Journal of Southeast Asian Earth Sciences*, *1*(2), 81–91. Retrieved from `https://doi.org/10.1016/0743-9547(86)90023-1` doi: doi:10.1016/0743-9547(86)90023-1

Pramumijoyo, S., & Sebrier, M. (1991, January). Neogene and quaternary fault kinematics around the sunda strait area, indonesia. *Journal of Southeast Asian Earth Sciences*, *6*(2), 137–145. Retrieved from `https://doi.org/10.1016/0743-9547(91)90106-8` doi: doi:10.1016/0743-9547(91)90106-8

Setiadi, I., Setyanta, B., Nainggolan, T. B., & Widodo, J. (2019, May). Delineation of sedimentary subbasin and subsurface interpretation east java basin in the madura strait and surrounding area based on gravity data analysis. *BULLETIN OF THE MARINE GEOLOGY*, *34*(1). Retrieved from `https://doi.org/10.32693/bomg.34.1.2019.621` doi: doi:10.32693/bomg.34.1.2019.621

Simons, W. J. F., Socquet, A., Vigny, C., Ambrosius, B. A. C., Abu, S. H., Promthong, C., … Spakman, W. (2007, June). A decade of GPS in southeast asia: Resolving sundaland motion and boundaries. *Journal of Geophysical Research*, *112*(B6). Retrieved from `https://doi.org/10.1029/2005jb003868` doi: doi:10.1029/2005jb003868

Telford, W. M., Telford, W., Geldart, L., & Sheriff, R. E. (1990). *Applied geophysics.* Cambridge university press.

Wardhana, D. D., Harjono, H., & Sudaryanto, S. (2014, May). STRUKTUR BAWAH PERMUKAAN KOTA SEMARANG BERDASARKAN DATA GAYABERAT. *Jurnal RISET Geologi dan Pertambangan*, *24*(1), 53. Retrieved from `https://doi.org/10.14203/risetgeotam2014.v24.81` doi: doi:10.14203/risetgeotam2014.v24.81