Basement Configuration Of Labuan Basin, Pandeglang, Based On Gravity Data
Konfigurasi Batuan Dasar Cekungan Labuan, Pandeglang, berdasarkan Data Gayaberat

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Abstract- Pandeglang is located on the coast of the Sunda Strait, which is tectonically active as the source of geological hazards. Basement configuration mapping is required for further understanding in geological characteristic of the land. Gravity method is one of the geophysical techniques that can be applied for the regional subsurface characterization. Gravity measurements were completed in the Pandeglang area, from Tanjung Lesung to Labuan coastline and all passable roads in Pandeglang Regency. The Bouguer anomaly obtained has indicated a steady decreasing anomaly from south-southwest to north-northeast area. The result of residual anomalies analysis and basement depth estimation presented a deep basin in the northeast most of the study area (Labuan – Picung), which indicates a thick sediment layer in this area.

Keywords: gravity anomaly, residual anomaly, basin, basement, Labuan, Pandeglang.

Abstrak-*Pandeglang terletak di pesisir Selat Sunda, yang merupakan daerah dengan tektonik aktif sebagai sumber dari berbagai bencana geologi. Pemetaan konfigurasi batuan dasar diperlukan dalam memahami karakteristik geologi daerah ini lebih mendalam. Metode gayaberat merupakan salah satu metode geofisika yang dapat digunakan untuk melakukan karakterisasi bawah permukaan regional. Survey gayaberat dilakukan di sepanjang pesisir pantai, dari Tanjung Lesung hingga Labuan, dan di sepanjang jalan raya yang dapat dilalui di Pandeglang. Peta anomali Bouguer yang dihasilkan menunjukkan gradasi anomali dari nilai tinggi di bagian selatan – baratdaya semakin rendah di bagian utara – timurlaut daerah penelitian. Hasil analisis nomali sisa dan pendugaan kedalaman batuan dasar menunjukkan adanya cekungan dalam di bagian paling utara daerah penelitian (Labuan – Picung), yang menunjukkan bahwa terdapat lapisan sedimen yang sangat tebal di daerah ini.*

Katakunci: *anomali gayaberat, anomali sisa, cekungan, batuan dasar, Labuan, Pandeglang.*

INTRODUCTION

Java and Sumatra are separated by Sunda Strait as the extensional region. The extension that develops considerable wider at the southwest region than the northeast tip gives an impression of a rotational movement between those two islands.(Mukti, 2018; Nishimura et al., 1986; Schlüter et al., 2002; Susilohadi et al., 2009). The geological correlation between the southernmost of Sumatra and the western most of Java has not been established well yet. Pandeglang Regency is one area that located at the western most of Java Island. In the regional tectonic setting, Pandeglang is located within the active zone of Sunda Strait transitional region. Earthquakes due to extensional strain have been occurred frequently (Harjono et al., 1991; Huchon and Le Pichon, 1984; Susilohadi et al., 2009) and volcanic activity of Krakatau Volcano is imminent. (Abdurrachman et al., 2018; Dahren et al., 2012; Harjono et al., 1991; Jaxybulatov et al., 2011) In addition, both might trigger tsunamis. (Giachetti et al., 2012; Hamzah et al., 2000; Pribadi et al., 2018) The location of Pandeglang hence is in the tectonically active area.

Once thought as a remote area, nowadays has improvement in many aspects of infrastructures due to the designation of Tanjung Lesung as Special Economic Zone. Most of Pandeglang region has an access to Tanjung Lesung and had been experienced a rapid development recently. However, there has very limited studies in geological hazard of the area, which is very important to consider in developing a region. Labuan is the west part of Pandeglang, one of the coast areas in Sunda Strait. The Labuan Basin is a vast area of delta, which was covered by a thick layer of alluvial (Santosa, 1991; Sudana and Santosa, 1992).In addition, a general study of tectonic based on basement mapping might explain the stages of subsidences and uplifts that might have occurred in this area.

The main purpose of this study is to identify the regional condition of basement, which also indicates the thickness of the sediments. We applied the qualitative analysis gravity method to map regional basement of Labuan Basin area. Bouguer gravity and residual anomalies can illustrate regional subsurface condition, which is useful as the basis for further studies in active tectonic, geological resources, and geological hazards.

Geology and Tectonic Setting

Labuan Delta is a part of the regional tectonic of Sunda Strait, an extension zone between Java and Sumatra since Middle Miocene (Schlüter et al., 2002; Susilohadi et al., 2009)(Figure 1). An indication of extension also observed from an increase of sediment thickness of Upper Eocene from Middle Eocene (Clements and Hall, 2007). In addition, seismic structural studies also presented a complete extensional characteristic since Late Miocene to present day with only several changes of active faults orientation (Yulianto et al., 2007). Active extension movements are observed from the recorded earthquakes in Sunda Strait. But the entire Pandeglang area is also under influence of compression from subducting slab from southwest direction, as indicated by thrust earthquakes at that area (Figure 1A).

Regional gravity anomaly of Sunda Strait well corresponds with the extension hypothesis with the presence of deep basins (Sandwell et al., 2014) . But the land regional gravity anomaly (Untung and Sato, 1978) is not show any particular feature in Pandeglang area, except the high anomaly in southern most of Pandeglang (Figure 1B). In general, Labuan-Panimbang-Cibaliung (from Labuan at north to the southern coast) is in a lower anomaly region between higher anomaly areas at its west and east. Gravity study from Baumann et al. (1973) indicated that Labuan is a low anomaly and low topography area, among recent volcanoes at north, Rangkasbitung segment of high anomaly at east, and West Malingping Low as part of Honje High at south. There is an assumed fault trend along the west coast of the western Java coastline due to the high gradient of gravity anomaly between Honje and West Malingping.
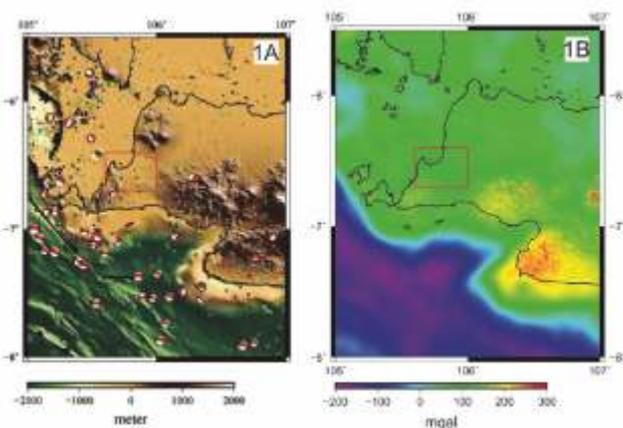
Figure 1. (A) Seismicity of Sunda Strait and southern West Java on the regional topography (Becker et al., 2009). Red beach balls are focal mechanism from the CMT Catalog (Dziewonski et al., 1981; Ekstrom et al., 2012). Red, green, blue dots are epicenters (deep, intermediate and shallow respectively) from NEIC-USGS. (B) Gravity Anomaly of Western Java and Sunda Srait (Sandwell et al., 2014; Untung and Sato, 1978). .

Labuan Delta by the Lada Bay has Quaternary alluvial deposition and is surrounded by mountainous or high topography (Figure 2). At the southern boundary, the high topography was formed by Honje Formation, which consists of volcanic breccia (tuff-andesitic-basaltic lava) and Bojongmanik Formation, which consists of Miocene sandstone and claystone (Sudana and Santosa, 1992). The north and east boundary is dominated by Bojong Formation (sandy clay, limestone lenses, sandstones and tuff), and Cipacar Formation (tuff, sandstone, and claystone) (Santosa, 1991). The high topography and Tertiary age of depositions at the south boundary is continue to the Tanjung Lesung at the west coast and to the south coast of Banten.

There were at least 3 phases of tectonic activities since Late Miocene to Holocene. During Miocene to Pliocene, Bojongmanik Formation was uplifted and folded. Cipacar Formation was uplifted and folded in Plio-Pleistocene, accompanied by volcanic activities. In Early Plesitocene, it was subsided and formed a shallow basin. The basin then filled with Bojong Formation. There were some increase volcanic activities of Mt. Gede and Mt. Old Danau. In the middle Pleistocene, the volcanic activity produced Lower Banten Tuff and formed a caldera lake of 200 km2. In Middle to Late Pleistocene, there was an eruption of the Mt. Old Danau that produced the upper Banten Tuff. In the End of Pleistocene, there should be a sea level rise due to coral limestones overlying the volcanic product (Lumban Batu and Poedjoprajitno, 2012; Santosa, 1991; Sudana and Santosa, 1992). The swamp deposits were found beneath a survey line of shallow drillings that crossed Pagelaran area. There were at least three ages of swamp had been identified: 4010±140 BP, 5710 ± 130 BP, and 9840 ± 300 BP (Lumban Batu and Poedjoprajitno, 2012). The swamps phenomena were found in several other locations in this area of West Java, with the most recent one is Rawa Danau (Van Der Kaars et al., 2001).
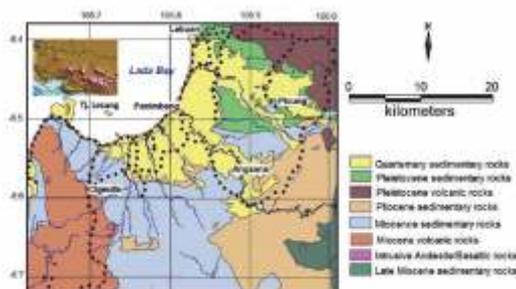
METHOD

Gravity is a passive geophysics method measuring gravity variation of the earth. The principal of gravity method is finding a small anomaly of gravity field, caused by mass variation in the Earth's crust. This method has ability in measuring density differences between a body in a certain area and its ambient. Based on the gravity anomaly, we can further describe the subsurface geological structure. The gravity method specifically is suitable in regional geological structure studies. Density variation distribution is obtained from gravity data from a variable called Bouguer anomaly, which can be simplified as a difference between measured gravity and theoretical gravity values.

We used the La Coste & Romberg type G-804 gravitymeter, which can read 0 – 7000 mGal, with 0.01 mgal resolution and a drift 1 mGal a month. The closed loop observation was applied. The measurement was started and ended at one point, which is the base station (BS). Then the drift can be calculated and corrected to all the obtained value. We measured the gravity field at 186 stations with 1 km spacing (Figure 3). The stations were along the passable-accessible roads.

Assuming a linear drift for daily survey, we applied looping procedure, which is measuring the gravity at the base station at the start and end of the day. The drift correction was applied based on linear model. If the time of measurements fall between base station readings BS1 and BS2, and since BS1 is the beginning of the survey so we have 0 drift at BS1, then the drift correction is:

$$\Delta g_s = m(t_s - t_{BS1})$$

where m is the local slope of the drift calculated from the reading at BS1 and BS2, and $(t_s - t_{BS1})$ is the time difference between the readings. The drift rate in our survey was about 0.013 mgal/hour, which is within the accuracy of the instrument.

Figure 2. Gravity stations (black dots) on the geological map (modified from Santosa, 1991; Sudana and Santosa, 1992). Labuan Delta is the Quarternary alluvial area by the bay (yellow). Insert: West Java, study location in red box.
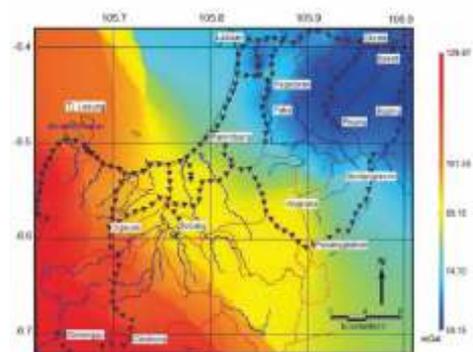
Figure 3. Bouguer Gravity Anomaly Map of Pandeglang.

The gravity reading results was then processed to obtain the Bouguer anomaly. The principal equation for the Bouguer anomaly is as follow:

$$\Delta g = (g_o - 2\pi\rho Gh + Tc) - (\gamma - \beta H) + Ac$$

where g_o is the observation value of gravity, r is the average density of subsurface rocks (2.67 gr/cm3), G is the gravity constant, h is the elevation above the mean sea level, Tc is the terrain correction, g is the normal gravity value, b is the gravity vertical gradient, and Ac is the free air correction. The normal gravity value was calculated based on the International Gravity Formula 1967(Lowrie,W., 2007) :

$$\gamma = 978031.85\ (1 + 0.005278895\ sin^2\ \varphi + 0.000023462\ sin^4\varphi)mGal$$

where φ is the latitude of the stations coordinate. And the free air correction was obtained by

$$Ac = 0,87 - 0,0000965\ h\quad mGal$$

where h is the elevation (meter).

In further analysis for basement mapping, we separated residual anomaly from the regional anomaly, which can be written as

$$g_{residual} = g_{Bouguer} - g_{regional}$$

The polynomial concept by least squares was introduced to obtain several order of residual anomalies (Lowrie,W.,2007). In this polynomial fitting, we assumed that the polynomial surface is a regional model plane that is getting smoother in higher order. The regional values can be expressed by a polynomial curve as:

$$g_g = g_o + g_1 x + g_2 x^2 + g_3 x^3 + ... + g_x x^x$$

with x is the point on the horizontal profile. The polynomials then were fitted by the least square method to the observerd gravity profile.

General equation of polynomial for regional anomaly is

$$P_n(x,y) = \sum_{j=0}^{m}\sum_{k=j}^{n}\left(a_{i,j}x^j y^{k-j}\right)$$

with (x, y) is the coordinate point and n is polynomial order.

The regional values for 1st order is:

$$g_1 = a_1 + a_2 X + a_3 Y,$$

and for 2nd order is

$$g_2 = a_1 + a_2 X + a_3 Y + a_4 X.Y + a_5 X^2 + a_6 Y^2,$$

and for 3rd order is

$$g_3 = a_0 + a_1 X + a_2 Y + a_3 X.Y + a_4 X^2 + a_5 Y^2 + a_6 X_2.Y + a_7 X.Y^2 + a_8 X^3 + a_9 Y^3.$$

The polynomials then were fitted by the least square method to the observerd gravity.

Based on the horizontal derivative of gravity, the basement depth was then estimated by the analytical signal solution (Saibi et al., 2006) :

$$|A(x)| = \alpha\ \frac{1}{(h^2+x^2)^{1/2}}.$$

where |A(x)| is the analytic signal anomaly over a contact at x, at depth h, and is the amplitude factor. The residual anomaly calculations and basement depth determination were performed by the Oasis Montaj software.

RESULTS AND DISCUSSION

Bouguer Anomaly

Regional Bouguer anomaly indicates a little variation (Figure 1) but this gravity measurement result has more detail features (Figure 3). The Bouguer anomaly in this region ranges from 59 to 130 mgal. The map shows the low anomaly in the northeast area: Labuan, Saketi, and Picung. The anomaly is increasing to the southwest area: Cimanggu, Cibaliung. Labuan and Picung area at the north is the boundary between the mountainous regions (Gunung Aseupan and Gunung Pulosari) and the wide delta region. The low anomaly in this area is a typical response for a deltaic region. On the other hand, the high anomaly in southwest area is correlated to the south-mountains area. Most of the delta region has middle value of Bouguer anomaly.

Subsurface properties can be observed better by separating the residual anomaly from the regional anomaly. By removing the regional effect of gravity, we have got local or residual anomalies. We calculated three orders of polynomial derivations and obtained the 1st, 2nd, and 3rd residual anomaly maps (Figure 4). The patterns of the three maps are almost identical and quite representative for a regional study. Therefore, we did not consider that the computation of the higher orders was necessary.

The first order residual anomaly map (Figure 4A) displays two apparent negative anomalies closures, bounded by sharp edges of zero residual at about Cigeulis, Cibaliung, Angsana, Pasanggrahan, Cisata, and Sindangresmi. The closures are connected only at the coast area. There are two areas of negative anomalies, at around Picung and in the middle between Sobang and

Cigeulis. A similar general pattern can be observed in the second order residual anomaly map (Figure 4B). However, the closure of Cigeulis-Sobang is a lot smaller, and both closures are separated by a high area of higher anomalies between Panimbang, Angsana, and Pasanggrahan, The area of northern closure does not seem different from the previous order. Nevertheless, the negative anomalies region at the southeast corner should not be regarded since we did not have data in the area. The third order residual anomaly map (Figure 4C) also indicates an identical pattern, with a broader area of the high anomaly at the coast region. Just like the previous order, we disregard the negative region in the south.

The three order residual anomalies have indicated the existence of 2 subsurface basins in the Labuan region. The two basins are separated by a distinct high-density area between Panimbang and Angsana. The low anomalies in Labuan – Picung, Cigeulis - Sobang areas and the high anomalies in Panimbang – Angsana, were supported by adequate measurements stations throughout the region.
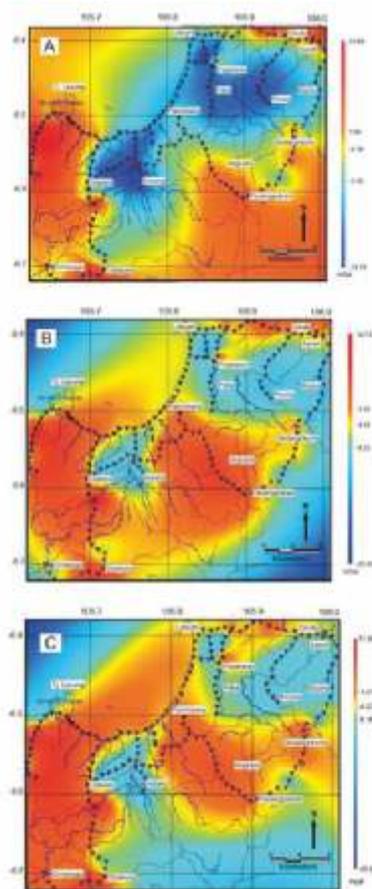
Figure 4. (A) First order, (B) Second Order, and (C) Third Order of Residual Gravity Anomaly Maps

The estimation for the depth of basement presented a different pattern of basins configuration (Figure 5). In this 3D perspective of view, a wide basin appeared from Cigeulis on the west to Labuan on the east, with a broad ridge in the middle (Sobang). However, the eastern basin is more extensive and profound than the one in the west. The maximum depth of the western basin is only about 2500 m, while the depth of the east basin reaches 4000 m. The forms of the basins are comparable to the closures pattern in residual anomaly maps. However, the depths of the basins are more defined by the analytical signal solution for the depth estimation.

Two possible basins (Picung and Sobang) are located in different lithology. Cigeulis-Sobang is located within the area of Miocene sediment, while Labuan-Picung is within the area of Quaternary sediment. Therefore, we could assume that the sediment layer should be thicker in Labuan-Picung area. This deduction appeared in the basement estimation depth. The obtained basement map shows a deep basin with center in Picung area (Figure 5). The basement deepest depth is projected as much as 4000 meter.

Discussion

Cilemer watershed delta is located in front of Lada Bay, from Labuan Town (north) to Citeureup (southwest). The region is a wide lowland surrounded by mountainous region (Figure 2). The lowland is formed by Quaternary alluvial deposition (Qa), surrounded by Tertiary rock formations: Cipacar, Bojongmanik, and Honje Formations (Sudana dan Santosa, 1992). Such topography and geological patterns do not represented by the Bouguer Anomaly map (Figure 4). However, the first order residual anomaly distribution shows the low residual anomaly in the area of alluvial delta (Figure 4). Based on this gravity anomalies and spectral analysis, the depth of the basement can be estimated. The basement map indicates the presence of a deep basin in Labuan (Figure 5). The basin is surrounded by high-density mountainous regions, which consist of high-density igneous rocks, at north and east side. A smaller closure of negative residual anomaly at the west appeared as the shallow basin in later spectral calculation due to the small variation in the anomaly values. The deep basin in the east of Labuan might be related to the subsidence in Early Pleistocene, which was filled with sedimentary rocks of Bojong Formation and now covered by most recent Quaternary Alluvial. This basin also might related to swamp deposit found beneath the shore deposition in Pagelaran (Lumban Batu and Poedjoprajitno, 2012) .
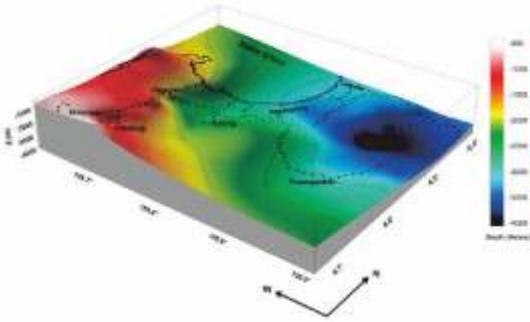
Figure 5. Basement depth estimation.

Bouguer anomaly along the coast was decreasing from south to north, from 100 mgal at Citeureup, 85 mgal at Panimbang , and 70 mgal at Labuan. The anomaly values could not be correlated with either the flat topography or the low anomaly closures in residual anomaly distribution. If we assumed that the deltaic deposition occurred in relatively similar range of time, the alluvial thickness is about the same, so one of possible condition is there are different types of rocks in at least two parts of the area. The rock layers beneath the Citeureup-Panimbang area (at south) should have higher density than beneath the Pagelaran – Labuan (at north). Geological map from Sudana and Santosa (1992) indicated that the rock beneath Citeureup – Panimbang is a part of Bojongmanik Formation and Honje Formation of Early Miocene. While the north part (Labuan area) is a part of Bojong Formation of Quarternary. The different age of rock's layers might differentiate the rocks' densities. Tanjung Lesung area, which is the cape located at a narrow area

of the beach extending to the Sunda Strait, has an unexpected high Bouguer Anomaly value. It might be due to that this part of region is a segment of the southern mountainous region with a relatively older rock deposition.

CONCLUSION

The gravity method is a practical approach to obtain the basement configuration. In this research, we applied the method in Pandeglang region, on the coast of Sunda Strait. The Bouguer anomaly indicates a high anomaly at the southwest, and decreasing to the northeast area. General implication is that from southwest to northeast direction, the basement is getting deeper. In addition, the circular pattern at the northeast (Labuan) also suggests the presence of a basin. The more definite basins features were obtained from the three orders of residual anomaly maps. Two basins are observed at the delta area of Pandeglang, with the one in Labuan is more prominent. The basement depth determination has indicated a deep basin in Labuan to Picung area, where the estimated deepest depth reaches 4000 meter.

REFERENCES

Abdurrachman, M., Widiyantoro, S., Priadi, B., Ismail, T., Abdurrachman, M., Widiyantoro, S., Priadi, B., Ismail, T., 2018. Geochemistry and Structure of Krakatoa Volcano in the Sunda Strait, Indonesia. Geosciences 8, 111. doi:10.3390/geosciences8040111

Baumann, P., Genevraye, P.D.E., Samuel, L., Mudjito, Sajecti, S., 1973. Contribution to the Geological Knowledge of South West Java, in: Proceeding Indonesian Petroleum Association, 2nd Annual Convention. pp. 105–113.

Becker, J.J., Sandwell, D.T., Smith, W.H.F., Braud, J., Binder, B., Depner, J., Fabre, D., Factor, J., Ingalls, S., Kim, S.H., Ladner, R., Marks, K., Nelson, S., Pharaoh, A., Trimmer, R., von Rosenberg, J., Wallace, G., Weatherall, P., 2009. Global Bathymetry and Elevation Data at 30 Arc Seconds Resolution: SRTM30_PLUS. Mar. Geod. 32, 355–371. doi:10.1080/01490410903297766

Clements, B., Hall, R., 2007. Cretaceous to Late Miocene stratigraphic and tectonic evolution of West Java, in: Proceedings of the Indonesian Petroleum Association. pp. IPA07-G-037.

Dahren, B., Troll, V.R., Andersson, U.B., Chadwick, J.P., Gardner, M.F., Jaxybulatov, K., Koulakov, I., 2012. Magma plumbing beneath Anak Krakatau volcano, Indonesia: evidence for multiple magma storage regions. Contrib. to Mineral. Petrol. 163, 631–651. doi:10.1007/s00410-011-0690-8

Dziewonski, A.M., Chou, T.-A., Woodhouse, J.H., 1981. Determination of earthquake source parameters from waveform data for studies of global and regional seismicity. J.~Geophys.~Res. 86, 2825–2852.

Ekstrom, G., Nettles, M., Dziewonski, A.M., 2012. The global CMT project 2004 – 2010? Centroid-moment tensors for 13,017 earthquakes. Phys. Earth Planet. Inter. 201, 1–9. doi:10.1016/j.pepi.2012.04.002

Giachetti, T., Paris, R., Kelfoun, K., Ontowirjo, B., 2012. Tsunami hazard related to a flank collapse of Anak Krakatau Volcano, Sunda Strait, Indonesia. Geol. Soc. London, Spec. Publ. 361, 79–90. doi:10.1144/SP361.7

Hamzah, L., Puspito, N.T., Imamura, F., 2000. Tsunami Catalog and Zones in Indonesia. J. Nat. Disaster Sci. 22, 25–43.

Harjono, H., Diament, M., Dubois, J., Larue, M., 1991. Seismicity of the Sunda Strait: Evidence for Crustal Extension and Volcanological Implications. Tectonics 10, 17–30.

Huchon, P., Le Pichon, X., 1984. Sunda Strait and Central Sumatra fault. Geology 12, 668–672. doi:10.1130/0091-7613(1984)12<668:SSACSF>2.0.CO;2

Jaxybulatov, K., Koulakov, I., Seht, M.I., Klinge, K., Reichert, C., Dahren, B., Troll, V.R., 2011. Evidence for high fluid/melt content beneath Krakatau volcano (Indonesia) from local earthquake tomography. J. Volcanol. Geotherm. Res. 206, 96–105. doi:10.1016/j.jvolgeores.2011.06.009

Lowrie, W., 2007. Fundamentals of Geophysics, second edition. Cambridge University Press, Cambridge, UK. doi:10.1017/CBO9780511807107

Lumban Batu, U.M., Poedjoprajitno, S., 2012. Quaternary Geological Phenomena in Labuhan Area , Pandeglang Regency , Banten Province Fenomena Geologi Kuarter Daerah Labuhan ,. Indones. J. Geol. 7, 211–226.

Mukti, M.M., 2018. Structural Configuration and Depositional History of the Semangko Pull-Apart Basin in the Southeastern Segment of Sumatra Fault Zone. Ris. Geol. dan Pertamb. 28, 115–128. doi:10.14203/risetgeotam2018.v28.954

Nishimura, S., Nishida, J., Yokoyama, T., Hehuwat, F., 1986. Neo-tectonics of the Strait of Sunda, Indonesia. J. Southeast Asian Earth Sci. 1, 81–91. doi:10.1016/0743-9547(86)90023-1

Pribadi, S., Puspito, N.T., Mahfud, M., Setyahagi, A.R., 2018. Tsunami scenario for Anyer and Cilegon. AIP Conf. Proc. 1987 020020, 020020. doi:10.1063/1.5047305

Saibi, H., Nishijima, J., Ehara, S., Aboud, E., 2006. Integrated gradient interpretation techniques for 2D and 3D gravity data interpretation. Earth, Planets Sp. 58, 815–821. doi:10.1186/BF03351986

Sandwell, D.T., Müller, R.D., Smith, W.H.F., Garcia, E., Francis, R., 2014. New global marine gravity model from CryoSat-2 and Jason-1 reveals buried tectonic structure. Science (80-.). 346, 65–67. doi:10.1126/science.1258213

Santosa, S., 1991. Geological Map of Anyer Quadrangle. Geological Research and Development Center, Bandung.

Schlüter, H.U., Gaedicke, C., Roeser, H.A., Schreckenberger, B., Meyer, H., Reichert, C., Djajadihardja, Y., Prexl, A., 2002. Tectonic features of the southern Sumatra-western Java forearc of Indonesia. Tectonics 21, 1–15. doi:10.1029/2001TC901048

Sudana, D., Santosa, S., 1992. Geological Map of Cikarang Quadrangle. Geological Research and Development Center, Bandung.

Susilohadi, S., Gaedicke, C., Djajadihardja, Y., 2009. Structures and sedimentary deposition in the Sunda Strait, Indonesia. Tectonophysics 467, 55–71. doi:10.1016/j.tecto.2008.12.015

Untung, M., Sato, Y., 1978. Gravity and geological studies in Jawa, Indonesia, Spesial Pu. ed. Direktorat Geologi, Indonesia, Bandung.

Van Der Kaars, S., Penny, D., Tibby, J., Fluin, J., Dam, R.A.C., Suparan, P., 2001. Late quaternary palaeoecology, palynology and palaeolimnology of a tropical lowland swamp: Rawa Danau, West-Java, Indonesia. Palaeogeogr. Palaeoclimatol. Palaeoecol. 171, 185–212. doi:10.1016/S0031-0182(01)00245-0

Yulianto, I., Hall, R., Clements, B., Elders, C.R., 2007. Structural And Stratigraphic Evolution of The Offshore Malingping Block, West Java, Indonesia, in: Proceedings of Indonesian Petroleum Association. pp. IPA07-G-036.