Scenario Seismic Hazard Analysis of the Mataram "Fault": An Initial Study of Geophysical Approach

Lian Yuanita Andikasari[1*], *Arifan* Jaya Syahbana[1], *Cahya* Damayanti[1,2], *Hasan* Tri Atmojo[3], *Lindung* Zalbuin Mase[4], and *Fikri* Faris[5]

[1]Reseacher Center for Geological Disaster, National Research and Innovation Agency (BRIN), Jl. Sangkuriang No.1, Bandung 40135, Indonesia.
[2]Department of Physics, Faculty of Engineering, Universitas Gadjah Mada, Yogyakarta, 55281, Indonesia
[3]Faculty of Mineral Technology, Universitas Pembangunan Nasional (UPN Veteran), Jl. Padjajaran, Yogyakarta 55283, Indonesia
[4]Faculty of Engineering, Department of Civil Engineering, University of Bengkulu, Bengkulu 38371, Indonesia
[5]Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada, Yogyakarta, 55281, Indonesia

Abstract. Indonesia, as a country in the Ring of Fire, has negative impacts in terms of tectonic and volcanic hazards. As an example of an area frequently hit by earthquakes, One of the area in the country frequently hit by earthquakes is the Special Region of Yogyakarta (DIY). Based on the latest studies, a new source has been discovered, which is the east-west trending "fault" called the Mataram or Tambakboyo "Fault". This "fault" is still in the initial phase of research. This study aims to provide additional information on the Mataram "Fault" from a geophysical point of view, namely by using the gravimetric method. This method provides an understanding of the existence of a fault, namely the indication of a clear contrast difference (order of km) so that the geometry of the Mataram "fault" can be obtained. This parameter will be used in earthquake hazard modeling by using OpenQuake software. It is hoped that with this research, the geometric characteristics of the Mataram "Fault" and the earthquake hazard can be obtained.

1 Introduction

As a country with complex geological diversity, Indonesia has various advantages and disadvantages from a geological point of view. The confluence of the large plates of Australia, Eurasia, Caroline, and Philippines has resulted in many earthquakes in this region [1–3]. The Earthquakes can be caused by various mechanisms. At least until now, it has been caused by background sources, megathrusts, and faults. Research related to the source of the earthquake continues to this day.

* Corresponding author: lian002@brin.go.id

One of the interesting points of the study of earthquake sources is the demand from various parties to be more detailed about the potential hazard in an area, one of which is the Special Region of Yogyakarta (DIY). DIY is one of the provinces located on the island of Java, Indonesia. Located on the southern side of the central part of the island, this area is surrounded by various earthquake sources, namely the background and megathrust on the south side, then the east side with the existence of the Opak Fault [4,5].

The latest study related to the source of the fault is the Mataram fault. In the study, it was stated that the fault was located in the central part of Yogyakarta with a dominant east-west direction. The approach taken is to use morphological and geoelectric methods. This study was carried out to add information on the existence of the fault from a geophysical point of view which was then followed by an analysis of the Scenario Seismic Hazard Analysis (SSHA) to determine the potential hazards posed by the geological structure [6,7].

Scenario Seismic Hazard Analysis (SSHA) is one of the approaches to seismic hazard that allows the calculation of ground motion fields from a single earthquake rupture scenario taking into account ground-motion aleatory variability [8]. The research using OpenQuake to define seismic risk and real-time damage scenarios in Italy [9]. The research demonstrated the effectiveness of OpenQuake in estimating earthquake losses and generating seismic risk maps in real time. Another research, the OpenQuake-engine effectively models economic losses and damage distribution from seismic events, providing valuable data for emergency management and risk assessment [10].

2 Method

2.1 Geophysics

This study begins with geophysical analysis, more precisely by the gravitrimetry method. Gravitymetry is applied in the form of TOPEX satellite data processing to obtain a spatial picture of the Bouguer residual anomaly. The next step is to conduct First Horizontal Derivative (FHD) and Secondary Horizontal Derivative (SHD) analyses to determine the location of the structure. After the geometry of the structure is obtained, it is continued with DSHA analysis.

2.2 Deterministic Seismic Hazard Analysis (DSHA)

Earthquake hazard simulation with this method is limited by considering only the existing structure of this study. Thus, other existing sources of earthquakes are not taken into account. This is done to know exactly the additional potential hazards that exist after this study. The software used is OpenQuake which is based on the Python language. The parameters used in this study are presented in Table 1.

Table 1. Parameter used for simulation.

No	Name	Parameter
1	Segmen_1 (S1), length 4.6 km, Mmax 5.8 Mw	• The epicenter is set at the center of the segment and depth 10 km • GMPE used Boore et.al 2014, Chiou Youngs 2014 and Campbell Bozorgnia
2	Segmen_2 (S2), length 3.3 km, Mmax 5.7 Mw	

No	Name	Parameter
3	Segmen_3 (S3), length 4.9 km, Mmax 5.9 Mw	2014 with equal weight
4	Segmen_4 (S4), length 3.0 km, Mmax 5.6 Mw	
5	Segmen_5 (S5), length 5.3 km, Mmax 5.9 Mw	
6	Segmen_6 (S6), length 4.7 km, Mmax 5.9 Mw	

The overall work steps in this study can be observed in Figure 1.

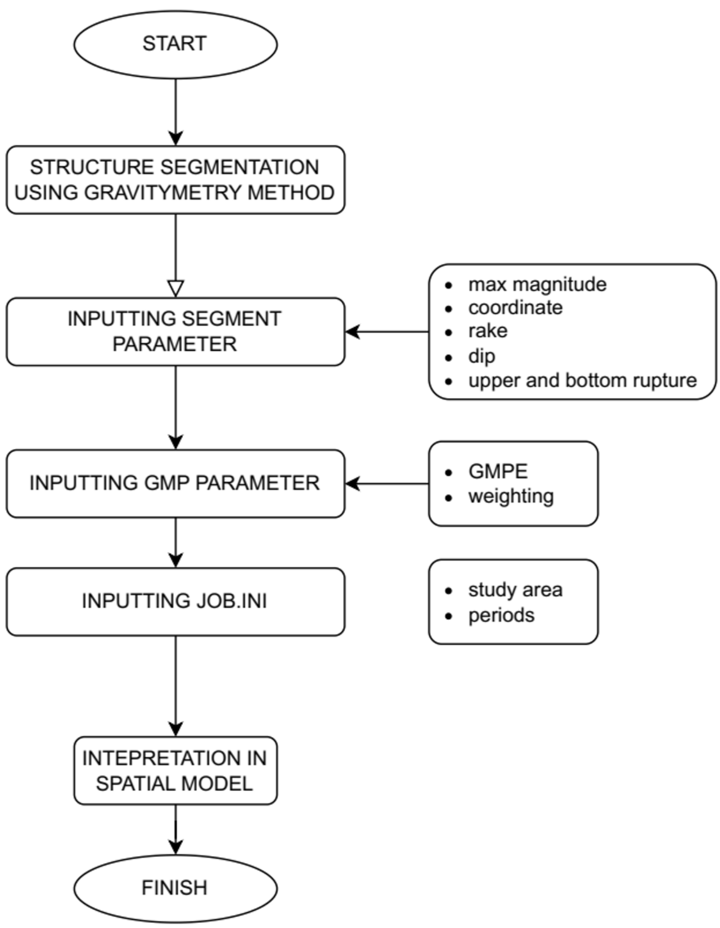
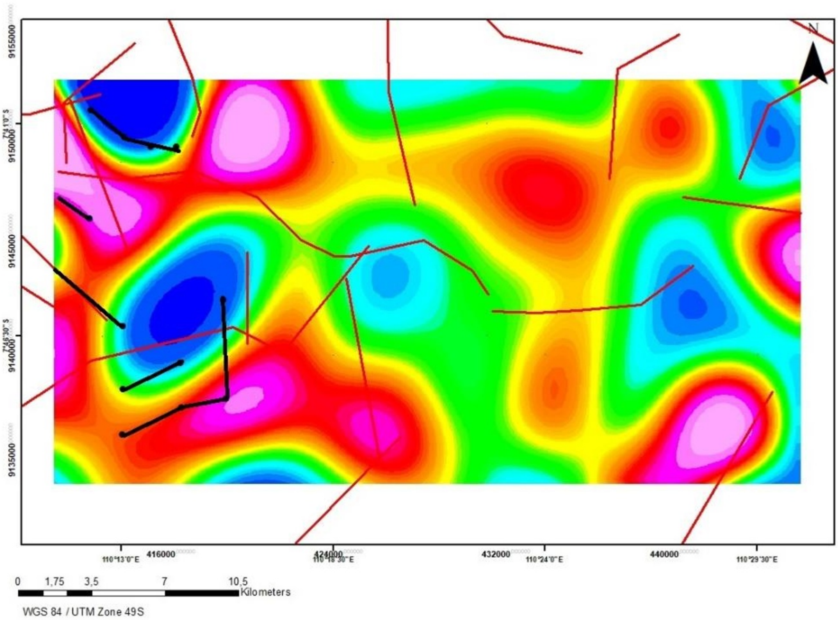


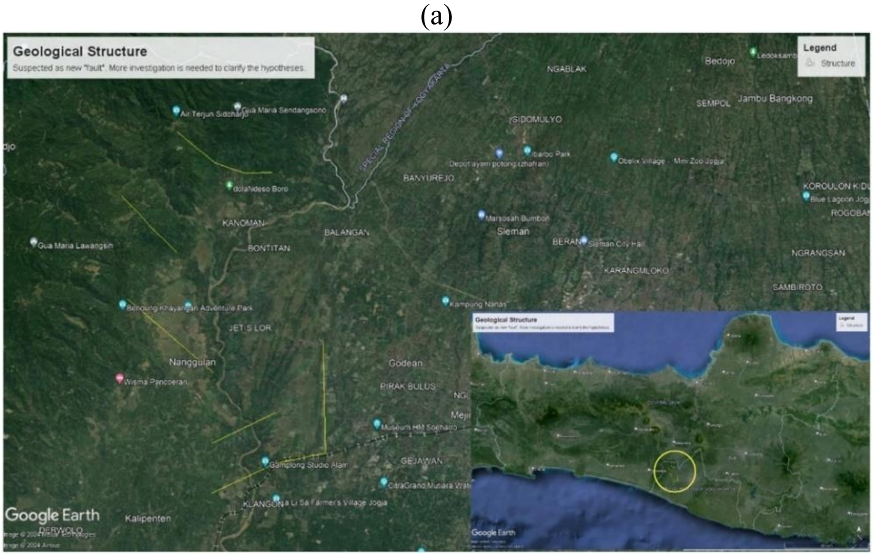
Fig. 1. Work steps for earthquake hazard simulation research using the SSHA method

3 Results and Discussion

Gravimetric analysis using TOPEX satellite data is shown in Figure 2a. The region where the Bouguer anomaly meets low (blue) and high (red) was identified as a structure. This phenomenon is also strengthened by FHD and SHD analysis. Furthermore, the pull of the structure is also in line with previous research [11–13]. Furthermore, the pull of the structure line is then plotted on Google Earth to find out the location of the structure in real conditions in the field. It can be observed that these structures are located in areas with dense activities and settlements (east and south sides of the mountains) (Figure 2b).



(a)



(b)

Fig. 2. The results of the structure line drawing are based on gravity analysis with TOPEX data (a), re-mapping on Google Earth to determine the position of the structure relative to population density (b).

In Figure 2a, there is no indication of the structure on the center side of DIY. The findings do not support existing research [14]. The pull of the structural line is then modeled with SSHA. Several assumptions are used, namely by modeling the maximum magnitude possible for each segment, thus there are six (6) simulation models presented in Figure 3.

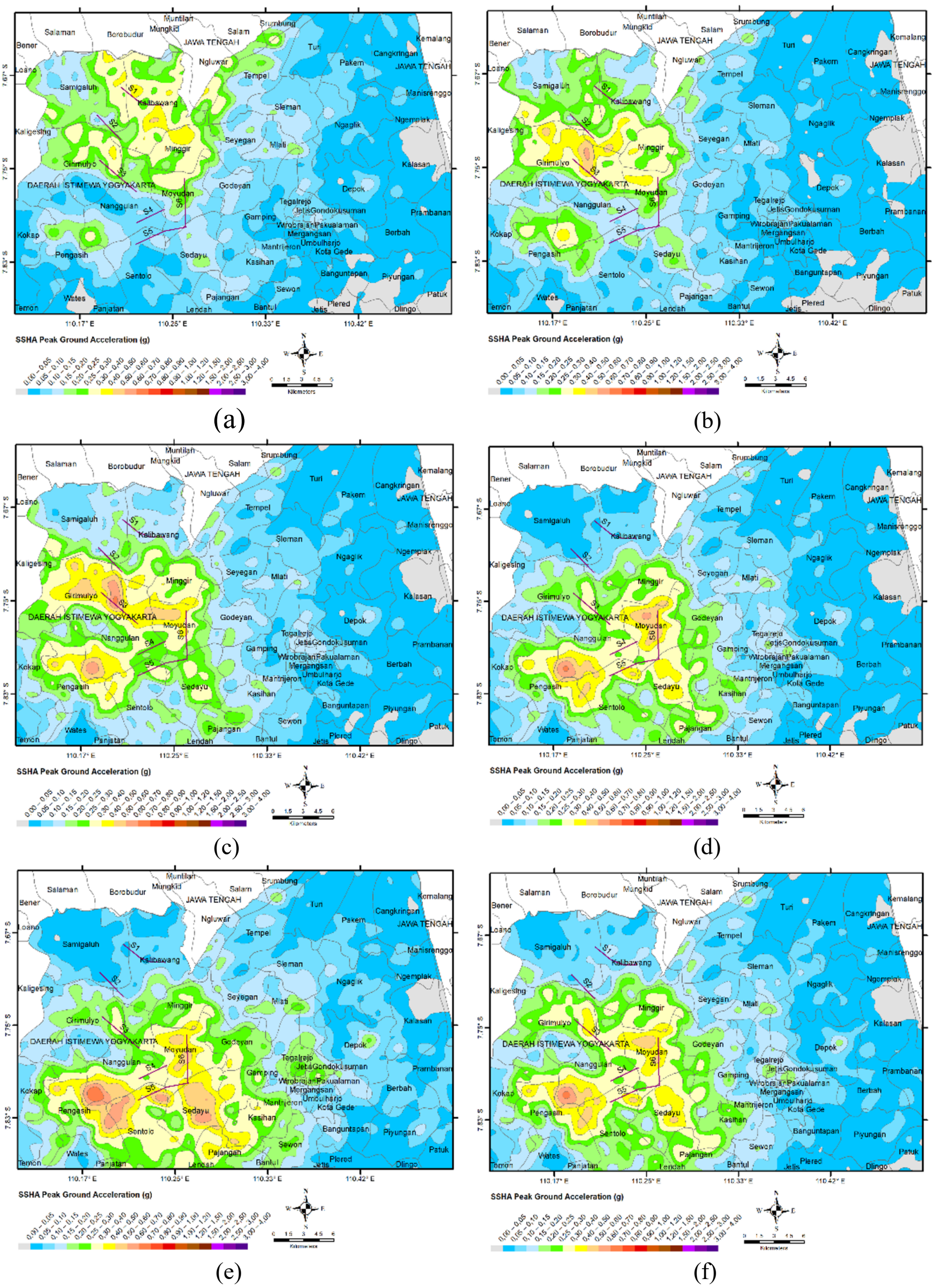


Fig. 3. SSHA modeling using software OpenQuake software: Segmen_1(a), Segmen_2(b), Segmen_3(c), Segmen_4(d), Segmen_5(e), Segmen_6(f).

Figure 3 a-f, assuming all faults have a dip angle of 90°, shows a pattern that tapers outward from the fault geometry. This is consistent with the definition of attenuation, which means the weakening of earthquake energy away from the source [15-17]. In Figure 3a, it can be seen with Segmen_1 modeling, the highest acceleration value is obtained in Kalibawang District, which is 0.5-0.6g. Figure 3b shows that the highest acceleration value is in the area near the Segmen_2, namely Girimulyo District, with a value of 0.7-0.8g. Similar to the Segmen_2 simulation, Segmen_3 showed a higher acceleration result, i.e. 0.9-1.0g at the same location. Segmen_4 to Segmen_6 show the same trend as some previous simulations, namely the highest acceleration value of 0.9-1.0g, but in Nanggulan District. In general, all simulations show that the closer the pattern is to the source of the earthquake, the greater the value of the acceleration compared to the distant area. The results of this analysis are below the results of the Probabilistic Seismic Hazard Analysis (PSHA) at the time of 2500 issued by the National Center for Earthquake Studies/PuSGeN [18].

4 Conclusion

First studies related to geological structures that are possible as "faults" have been carried out in this study. The results show that there is a more obvious structure on the west side compared to the central part of DIY. The structure is divided into 6 segments that are predominantly west-east. Furthermore, by simulating using the SSHA method, an acceleration value of 0.9-1.0g was obtained if the earthquake occurred in Segmen_4, Segmen_5, and Segmen_6. More detailed microzoning analysis is needed again to obtain more complex parameters for more precise modeling.

References

1. S. J. Hutchings and W. D. Mooney, Geochemistry, Geophysics, Geosystems **22**, e2021GC009812 (2021)
2. C. Rangin, L. Jolivet, and M. Pubellier, Bulletin de La Société Géologique de France **6**, 889 (1990)
3. M. Irsyam, D. H. Natawijaya, M. R. Daryono, S. Widiyantoro, M. Asrurifak, I. Meilano, W. Triyoso, S. Hidayati, A. Rudiyanto, and A. Sabaruddin, *Proc 19th Int Conf Soil Mech Geotech Eng Seoul* 1525–1528 (2017)
4. A. J. Syahbana, G. L. Goro, O. F. Saputra, D. D. Aditramulyadi, M. Irsyam, M. Asrurifak, and H. Hendriyawan, IJAST **29**, 3138 (2020)
5. K. Sugianti, A. M. Sari, and A. J. Syahbana, Indonesian Journal on Geoscience **2**, (2015)
6. A. Syahbana, M. Wati, J. Zaenurrohman, M. Ridwan, A. Sari, A. Shomim, A. Soehaimi, E. Santoso, F. Novico, and E. Sudjono, *IOP Conf. Ser.: Earth Environ. Sci.* **1192**, p. 012035 (2023)
7. A. J. Syahbana, M. Ridwan, A. Soehaimi, S. Suharsono, E. W. Santoso, and L. Z. Mase, E*3S Web of Conferences* **464***,* p. 02003 (2023)
8. M. Pagani, V. Silva, A. Rao, M. Simionato, and K. Johnson, *OpenQuake Engine manual release 3.18.0.* (2023)
9. M. Faravelli, B. Borzi , M. Pagano, and D. Quaroni, *16th Eur Conf Earthq Eng.* (2018)
10. V. Silva, H. Crowley, C. Yepes, and R. Pinho, *10th US Natl Conf Earthq Eng Front Earthq Eng.* (2014)
11. S. M. MacDonald and Partners, *Report of Groundwater Development Project (P2AT), Directorate General of Water Resources Development, Ministry of Public Works, Government of the Republic of Indonesia*, Sir M MacDonald & Partners in Association with Binnie & Partners, Hunting Technical Se (1984)

12. I. Sudarno, *Kendali Tektonik Terhadap Pembentukan Struktur Pada Batuan Paleogen Dan Neogen Di Pegunungan Selatan, Daerah Istimewa Yogyakarta dan Sekitarnya*, PhD Thesis, Geology Postgraduate Program, Institut Teknologi Bandung (1997)
13. A. Widagdo, S. Pramumijojo, A. Harijoko, and A. Setiawan, *Proceeding Jogja Earthq Reflect.* 41–6 (2016)
14. M. R. Daryono, A. Pamumpuni, D. D. Wardhana, and D. H. Natawidjaja, *IOP Conf. Ser.: Earth Environ. Sci.* **1227**, p. 012003 (2023)
15. D.M. Boore, J.P. Stewart, E. Seyhan, and G.M. Atkinson, Earthq Spectra **30**, 1057–1085 (2014)
16. K.W. Campbell and Y. Bozorgnia, Earthq Spectra **30**, 1087–1114 (2014)
17. B.S.J. Chiou and R.R. Youngs, Earthq Spectra **30**, 1117–1153 (2014)
18. PusGen, *Peta Sumber Dan Bahaya Gempa Indonesia Tahun 2017*, 1st ed. (Puslitbang Perumahan dan Pemukiman, Bandung, 2017)