Prisma Sains: Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram
https://e-journal.undikma.ac.id/index.php/prismasains/index
e-mail: prismasains.pkpsm@gmail.com

July 2026. Vol. 14, No. 3
p-ISSN: 2338-4530
e-ISSN: 2540-7899
pp. 1456-1467

Detection and Characterization of the Grindulu Fault Using TOPEX Satellite Gravity Data: SVD Analysis in the Pacitan Region, East Java

[1]*Arie Realita, [1]Muhammad Nurul Fahmi, [1]Madlazim, [1]Hikmatul Maulidah, [2]Firdha Kusuma Ayu Anggraeni, [3]Uswatun Chasanah

[1]Physics Study Program, Universitas Negeri Surabaya, Surabaya, Indonesia
[2]Physics Education Study Program, University of Jember, Jember, Indonesia
[3]Physics Study Program, Universitas Muhammadiyah Lamongan, Lamongan, Indonesia

*Corresponding Author e-mail: arierealita@unesa.ac.id

Received: October 2025; Revised: January 2026; Published: July 2026

Abstract

The southern part of Java Island is dominated by a volcanic arc system associated with the subduction of the Indo-Australian Plate beneath the Eurasian Plate. This tectonic setting results in a structurally complex region with active fault systems that contribute to an elevated seismic hazard in southern East Java. One prominent structure in this region is the Grindulu Fault in Pacitan Regency, whose trace geometry and subsurface expression remain debated. In this study, we use gravity data to delineate the Grindulu Fault corridor and constrain its spatial configuration. Gravity anomaly data derived from TOPEX satellite observations were corrected to produce Complete Bouguer Anomaly (CBA) values. The CBA data were gridded using kriging with a spacing of $\Delta x = 1$ km ($\approx 0.01°$). To separate regional and residual components, the Second Vertical Derivative (SVD) method was applied directly to the gridded data, enhancing short-wavelength features while suppressing long-wavelength regional anomalies. Structural boundaries were identified based on continuous NE–SW lineaments characterized by SVD zero-crossings with adjacent positive–negative extrema. The inferred Grindulu Fault is expressed as a NE–SW trending corridor extending approximately between 111.11°–111.28°E and 8.04°–8.15°S. The SVD asymmetry observed along several profiles is consistent with a normal-fault-like density contrast geometry in some sections and a strike-slip fault behavior in others. However, fault kinematics cannot be uniquely determined from gravity-derived derivatives alone without independent geological or seismological validation. Overall, the results provide a reproducible gravity-based constraint on the Grindulu Fault corridor, offering valuable insights for future seismotectonic interpretations and disaster risk reduction planning in southern Java.

Keywords: TOPEX satellite gravity; Complete bouguer anomaly; Second vertical derivative; Grindulu fault; Pacitan

How to Cite: Realita, A., Fahmi, M. N., Madlazim, M., Maulidah, H., Anggraeni, F. K. A., & Chasanah, U. (2026). Detection and Characterization of the Grindulu Fault Using TOPEX Satellite Gravity Data: SVD Analysis in the Pacitan Region, East Java. *Prisma Sains: Jurnal Pengkajian Ilmu Dan Pembelajaran Matematika Dan IPA IKIP Mataram*, *14*(3), 1456–1467. https://doi.org/10.33394/j-ps.v14i3.17851

https://doi.org/10.33394/j-ps.v14i3.17851

INTRODUCTION

Geologically, Indonesia is situated at the intersection of four major tectonic plates: the Indo-Australian, Eurasian, Pacific, and Philippine microplate, making it one of the most seismically active regions in the world (Irsyam et al., 2020; Hutchings & Mooney, 2021). The oblique subduction of the Indo-Australian Plate beneath the Eurasian Plate south of Java produces complex tectonic deformation, triggering the formation of a volcanic arc zone and active geological structures, including a fault system along southern Java (Koulali et al., 2016; Widiyantoro et al., 2020). Clear evidence of this deformation is the formation of the Southern Java Mountains and the emergence of active faults developing along the back-arc zone (Setijadji et al., 2006; Smyth et al., 2008; van Gorsel, 2018; Chaves et al., 2021).

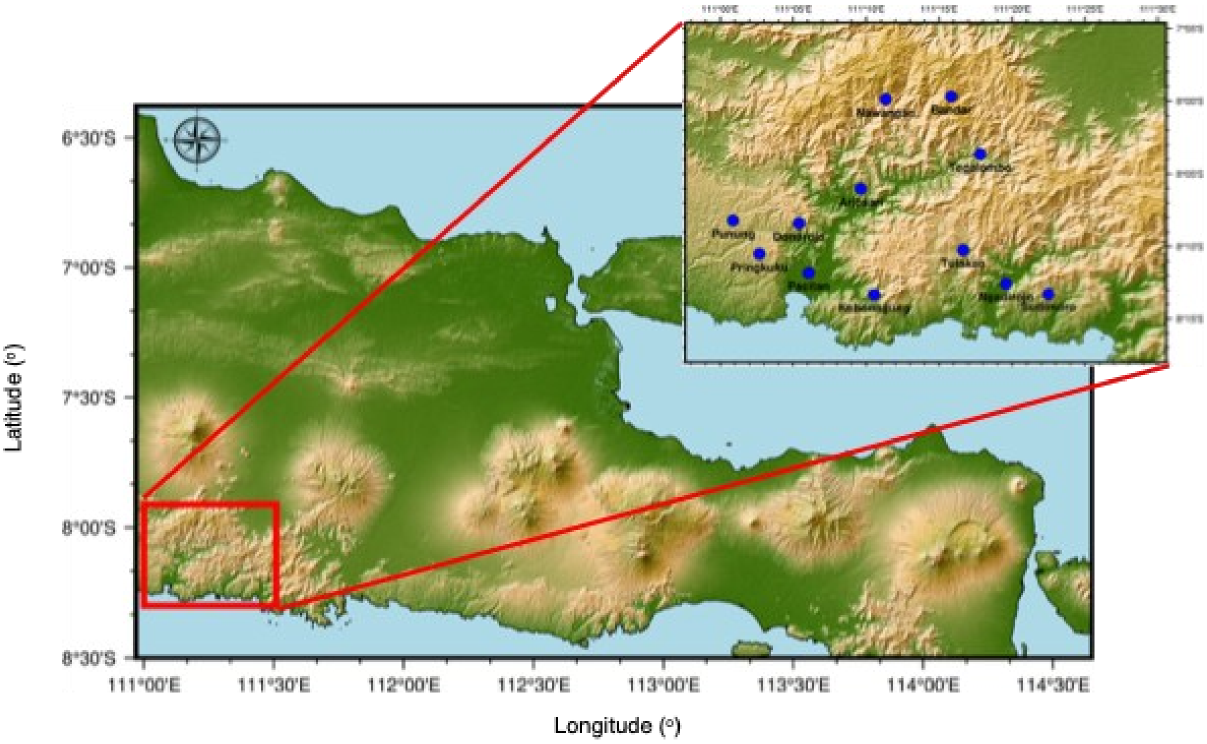


Figure 1. Location of the study area in East Java, Indonesia. The main panel shows the regional topography of East Java. The inset provides a closer view of the study area, highlighting the Pacitan–Grindulu region.

The elastic energy stored in rock layers due to tectonic stress is released in the form of seismic waves when the elastic threshold is exceeded, causing earthquakes (Scholz, 2019). Therefore, active fault lines are a priority area for disaster mitigation studies. Several major faults in Java, such as the Cimandiri Fault, the Opak Fault, and the Grindulu Fault, have been identified as significant contributors to inland seismic activity (Saputra et al., 2018; Supendi et al., 2018; Cholifah et al., 2020; Chaves et al., 2021). The Grindulu Fault in the Pacitan region is the focus of this study. Pacitan is traversed by several fault lines, as shown on regional geological maps, and its structural architecture is complex, reflecting the interaction of various tectonic stress regimes. Although the Grindulu Fault has been reported in several studies, its trace geometry and kinematics in the Pacitan sector are still debated and not well understood, thus encouraging more reproducible geophysical delineation.

The existence of the Grindulu Fault is increasingly relevant to study, given the recent earthquake that struck the Pacitan region on 27 May 2025. According to PVMBG data, the earthquake had a magnitude of Mw 5.7 at a depth of approximately 12 km, with its epicenter southwest of Pacitan and felt as far away as Yogyakarta (PVMBG, 2025). Analysis of the source mechanism indicates that this earthquake was triggered by landward-slip fault movement, with no potential for a tsunami. This earthquake strengthens the suspicion that local fault activity, including the Grindulu Fault, plays a significant role in regional seismic dynamics. Given that faults cross the Pacitan region and are densely populated, an accurate understanding of fault structure is crucial for future disaster risk reduction planning (UNDRR, 2019).

Geophysical methods play a central role in detection and characterization subsurface structures, and one of the most effective approaches for revealing faults is the gravity method. This method utilizes variations in the gravity field due to changes in rock density to detect geological structures, including faults, folds, and intrusions (Barbosa et al., 2007; Essa, 2013; Barbosa et al., 2020; Ming et al., 2021). The advantages of this method include its non-destructive nature, relatively low cost, and the possibility of satellite-based data acquisition

(Maulana & Prasetyo, 2019; Yanis et al., 2019). Interpreting gravity data through CBA correction and advanced processing techniques such as SVD can improve the accuracy of mapping fault boundaries and their orientation (Biswas, 2015; Dinçer & Işik, 2020). Therefore, this study aims to detection and characterization the presence and characteristics of the Grindulu Fault in the Pacitan region using gravity data from the TOPEX satellite, thereby contributing to the scientific understanding of seismic disaster risk mitigation efforts in southern Java.

METHOD

Data, Preprocessing and CBA computation

This study uses secondary gravity data derived from satellite altimetry based gravity products to delineate subsurface structural lineaments in the Pacitan region. The gravity method is non-destructive, cost-efficient, and suitable for regional scale coverage, and it is sensitive to lateral density contrasts associated with geological boundaries such as fault zones and lithologic contacts. Gravity anomaly data were extracted from the TOPEX satellite through the page https://topex.ucsd.edu/cgi-bin/get_data.cgi, for the study window 111.1°–111.3°E and 8.1°–8.2°S, yielding 309 sample points containing latitude, longitude, elevation, and free-air anomaly (FAA) values. The FAA values were converted to CBA by applying the free-air correction, Bouguer slab correction using a reduction density of $\rho = 2.67$ g cm^{-3}, and terrain correction computed from DEM–SRTM using Global Mapper (Eq. 1):

$$CBA = g_{obs} - g(N) + FAC - BC + TC \qquad (1)$$

where g_{obs} is the observed gravity, $g(N)$ is normal gravity, FAC is the free-air correction, BC is the Bouguer correction, and TC is the terrain correction. The resulting CBA was interpolated in Surfer using kriging with a grid spacing of $\Delta x = 1$ km / 0.01° to produce the anomaly maps.

Second Vertical Derivative (SVD)

Based on the CBA results, gravity anomaly contour maps were generated using Surfer. Because the gridded CBA field still contains a combination of long-wavelength (regional) and short-wavelength (local or residual) signals, further enhancement was carried out using the SVD. SVD accentuates short wavelength components and sharpens structural edges associated with density contrast boundaries. The SVD was computed in Surfer using a spatial-domain implementation with smoothing to limit noise amplification commonly introduced by derivative operations. In the spatial-domain approach, the SVD is obtained by applying a matrix based second derivative operator finite-difference convolution kernel, a Laplacian second difference stencil to the gridded anomaly field, which suppresses regional trends and emphasizes residual anomalies. The resulting SVD maps and extracted profiles were then used to delineate candidate structural corridors (fault related lineaments).

Slicing Strategy and Fault Type Criteria

To evaluate the spatial continuity of the inferred structures and to delimit the candidate Grindulu Fault corridor, we analyzed the SVD enhanced field along five cross sectional profiles (A–E). Profile orientations were chosen to be approximately perpendicular to the dominant NE–SW structural grain to maximize derivative contrast across suspected boundaries, since edge detectors are most diagnostic when profiles cut across density contrast contacts or fault-related zones. Along each profile, we identified candidate corridor segments where the SVD response exhibits consistent edge signatures typically a rapid sign change (zero crossing) accompanied by adjacent positive-negative extrema and steep gradients that align spatially across multiple slices and form a coherent NE–SW lineament in map view.

In this framework, SVD is treated primarily as an edge enhancer that emphasizes short-wavelength (residual) components and suppresses long-wavelength (regional) trends, rather than as a unique indicator of fault kinematics (Chen et al, 2015; Ganguli & Dimri, 2013). The SVD-based decomposition of gravity anomalies effectively separates regional and residual components, allowing more reliable delineation of density contrast boundaries related to faults or lithological contacts (Zhao & Chen, 2011). Positional uncertainty was quantified by repeating the interpretation under alternative processing options (different continuation or derivative settings and small adjustments in slice placement) and reporting the resulting variability in corridor location as an uncertainty envelope. Because SVD based interpretations can be sensitive to processing choices, the mapped feature is presented as a candidate Grindulu Fault corridor, and fault kinematics (normal or reverse or strike-slip) are not uniquely inferred from SVD alone without independent geological or seismological validation (Abdullah, 2022; Guo et al., 2020).

RESULTS AND DISCUSSION

Results

The gravity data analysis provided a preliminary view of the CBA distribution in the study area, forming the primary basis for identifying subsurface density variations related to geological structures such as faults. After applying field correction and separating regional and local anomalies, the resulting anomaly patterns strongly indicated the presence of the Grindulu Fault line. Figure 2 shows the CBA contour map, where the regional topography and FAA data have been corrected using Bouguer and field corrections. The measured gravity anomaly ranged from -480 to 120 mGal across the study area, with variations in gravity anomaly values represented by a color gradient from purple (low closure) to red (high closure). Higher closure indicates denser subsurface rock structures compared to surrounding areas, a typical pattern observed in fault zones (Barbosa et al., 2007; Altinoğlu et al., 2015; Al-Khafaji et al., 2019).

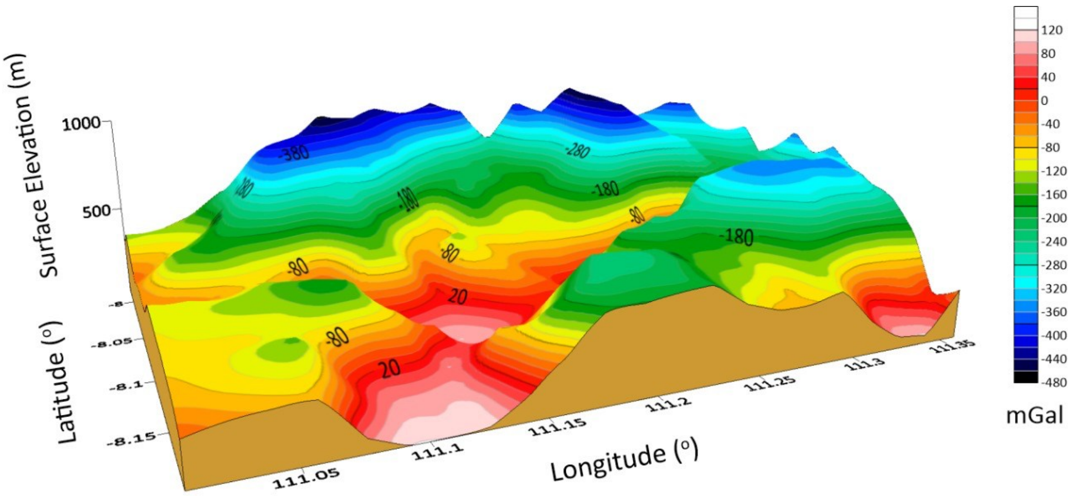


Figure 2. 3D view of the Pacitan region overlaid with CBA modeled using the gravity method.

The CBA contour map reflects the cumulative influence of subsurface rock structures, including anomalies caused by shallow, medium, and deep geological features. These anomalies often overlap, complicating the initial interpretation of subsurface density patterns. Generally, near surface variations generate local anomalies, while deeper structures produce regional anomalies characterized by lower frequencies and longer wavelengths. To separate these two components, SVD filtering with matrix karnel was applied to reduce shallow anomaly contributions and highlight deeper structures (Blakely, 1995; Ravat, 2007; Araffa et al., 2018). This process enhances the spatial resolution of gravity data, allowing for a more accurate definition of geological features such as faults.

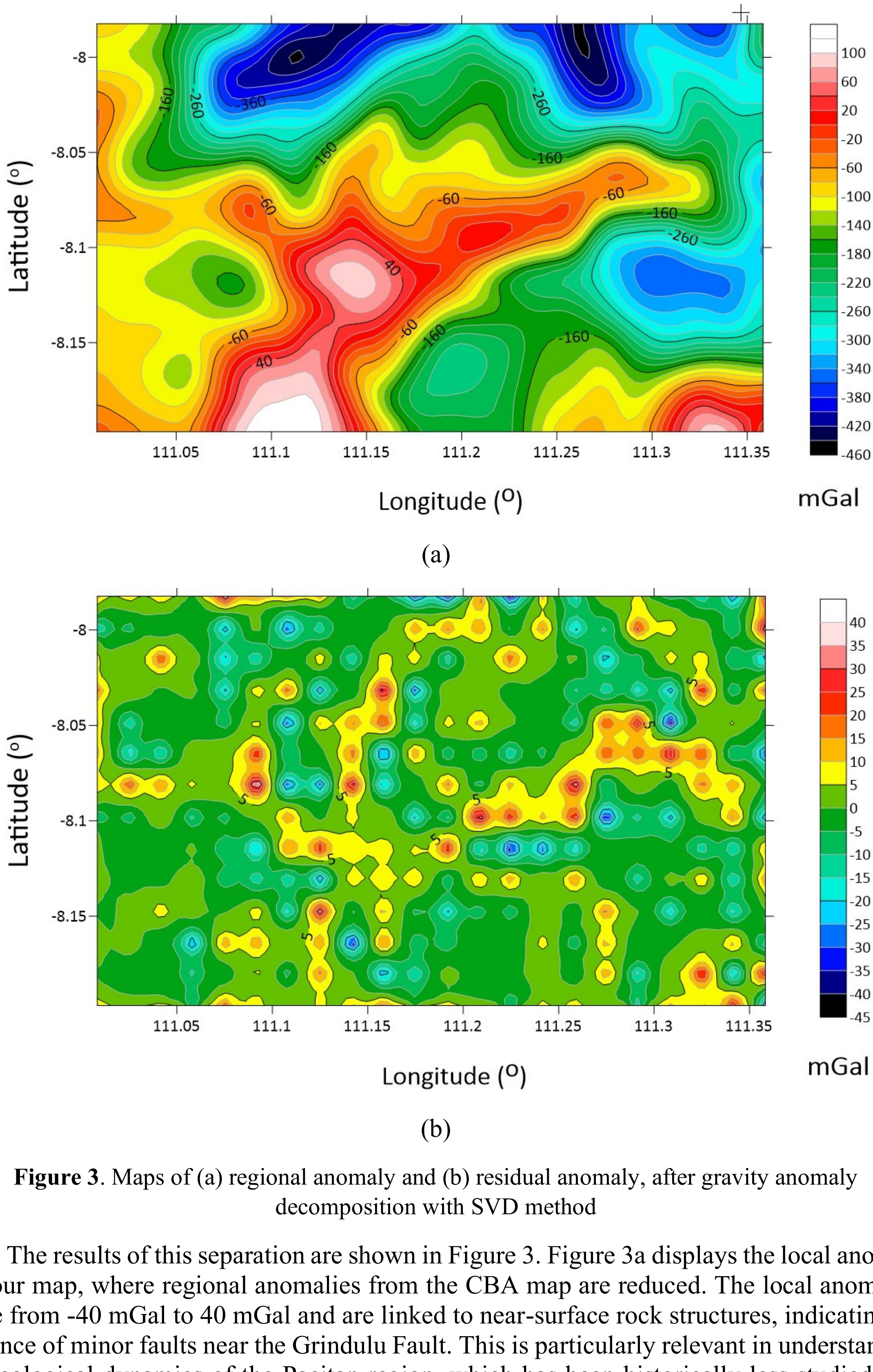


Figure 3. Maps of (a) regional anomaly and (b) residual anomaly, after gravity anomaly decomposition with SVD method

The results of this separation are shown in Figure 3. Figure 3a displays the local anomaly contour map, where regional anomalies from the CBA map are reduced. The local anomalies range from -40 mGal to 40 mGal and are linked to near-surface rock structures, indicating the presence of minor faults near the Grindulu Fault. This is particularly relevant in understanding the geological dynamics of the Pacitan region, which has been historically less studied than northern East Java in terms of tectonic activity (Koulali et al., 2016; Irsyam et al., 2017). The numerous high and low closures on the local anomaly map contrast with the smoother regional anomaly map, supporting the assumption that local anomalies are more sensitive to shallow geological structures.

Figure 3b presents the regional anomaly contour map, where gravity values range from -460 mGal to 100 mGal. These anomalies are attributed to deep sources and are characterized by low-frequency, long-wavelength signals. The smoothness of the contour distribution in Figure 3b reflects the deeper source of these anomalies. The northeastern part of the study area, dominated by low closure (blue) likely represents low density subsurface rocks, possibly due to alluvial deposits or sediment filling the Grindulu River channel (Agustiningrum, 2018; Cholifah et al., 2020). Conversely, high closure (red) in the southwestern part of Pacitan corresponds to the southern mountain arc of Java, formed by the subduction of the Indo-Australian Plate beneath the Eurasian Plate (Setijadji et al., 2006; Soeria-Atmadja et al., 1994; Al Hakim & Sulistijo, 2013; Smyth et al., 2008; van Gorsel, 2018), where volcanic rocks with higher density produce positive gravity anomalies.

The variations in high and low closures along the NE–SW direction reflect the heterogeneity of subsurface lithology. Both the local anomaly map (Figure 3a) and the regional anomaly map (Figure 3b) suggest that the Grindulu Fault is oriented NE–SW, consistent with the geological map of the Pacitan Sheet (Samodra et al., 1992) and previous studies (Gultaf et al., 2015; Fahrudin et al., 2019; Cholifah et al., 2020; Arisbaya et al., 2021).

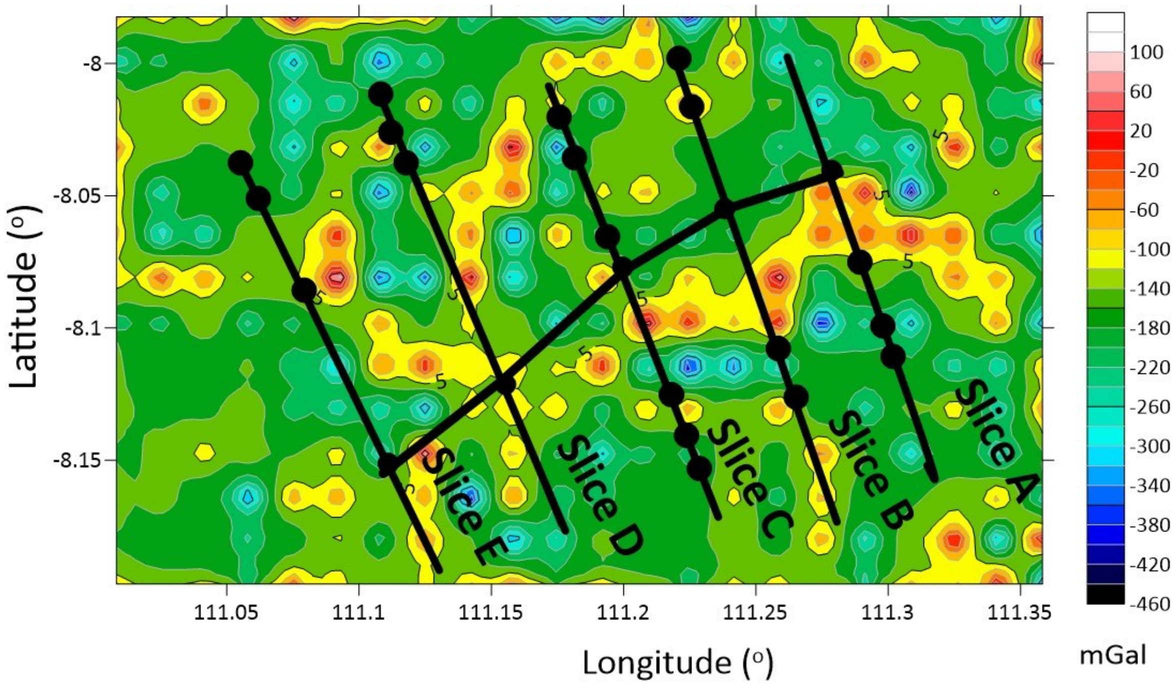
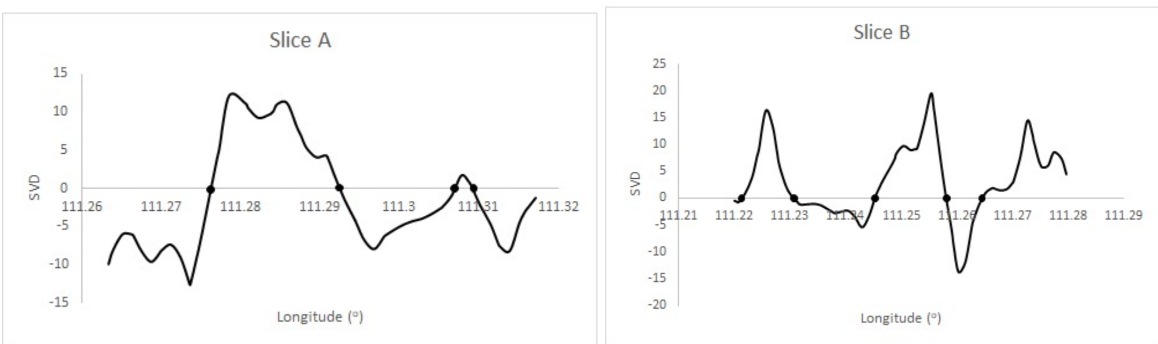


Figure 4. Residual anomaly contour map with slices (A–E) for SVD interpretation.



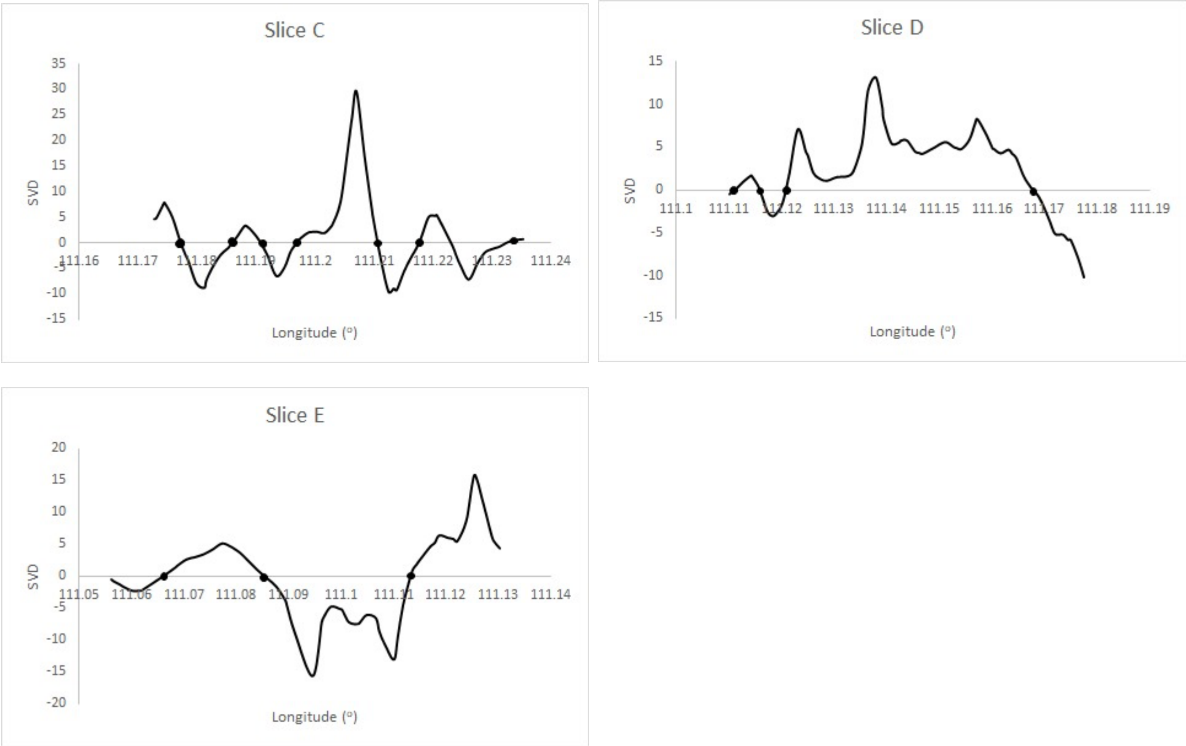


Figure 5. SVD derived graph showing fault locations from five slices (A–E).

To further strengthen the evidence for the Grindulu Fault, initially indicated by gravity anomaly contour analysis, we applied the SVD technique. This method enhances the detection of subsurface geological structure boundaries by sharpening density contrasts in residual anomaly data. The procedure began with the digitization of five transverse slices, which were oriented perpendicular to the suspected NE–SW direction of the Grindulu Fault. These slices were labeled A, B, C, D, and E, based on the residual anomaly contour map in Figure 3b.

The data from these slices were then processed using the SVD method, and a graph showing the maximum and minimum values of the vertical gradient was produced. The SVD graph (shown in Figure 4) was analyzed based on the zero-crossing points (SVD = 0), which are indicative of fault location markers (Purnomo et al., 2013; Al-Khafaji et al., 2019; Dinçer & Işik, 2020). In Figure 5a (slice A), four potential fault locations were identified, including a major fault at approximately 111.28° East and 8.04° South Latitude and three minor faults. Based on the symmetry of the maximum and minimum values, the fault in slice A was interpreted as a strike-slip fault. In Figure 5b (slice B), the major fault was located at 111.24° East and 8.07° South Latitude, with the maximum value considerably greater than the minimum, indicating a normal fault. A similar result was observed in Figure 5c (slice C), where a strike-slip fault was detected at 111.19° East and 8.04° South Latitude. In slice D (Figure 5d), a fault with strike-slip characteristics was observed at 111.17° East and 8.15° South Latitude, while slice E (Figure 5e) indicated a dip-slip fault at 111.11° East and 8.15° South Latitude.

The SVD results from all five slices show distinct density contrasts in each slice, reinforcing the interpretation of the presence of a fault structure in the area. Points from the coordinate analysis, suspected to represent major faults, were then remapped onto the regional anomaly contour map (Figure 4), forming a straight line oriented NE–SW. This alignment suggests the presence of the Grindulu Fault, with coordinates ranging from 111.11°–111.28° East and 8.04°–8.15° South. The detection of minor faults nearby, likely branches or ruptures of the main fault, further supports this hypothesis.

The NE–SW orientation identified in this study is consistent with previous geological studies (Gultaf et al., 2015; Agustiyaningrum, 2018; Fahrudin et al., 2019; Cholifah et al., 2020; Arisbaya et al., 2021). The SVD-derived results suggest that the Grindulu Fault exhibits a combination of dip-slip and strike-slip characteristics, which corroborates findings from paleotectonic analysis (Gultaf et al., 2015). However, discrepancies in previous studies (e.g., Parera et al., 2015; Yusvinda et al., 2020) that classified the fault as dip-slip, and studies by Cholifah et al. (2020) and Arisbaya et al. (2021) that identified it as strike-slip, highlight the complexity of the subsurface structure along the Grindulu Fault. These conflicting interpretations emphasize the need for more integrated and comprehensive geophysical studies to fully understand the fault's dynamics and behavior.

Discussion

The gravity data, after correction and filtering, effectively highlight subsurface density contrasts, which are indicative of major geological boundaries such as faults. The SVD method plays a critical role in enhancing edge detection, making it possible to delineate candidate fault corridors. The identified anomalies align well with known structural features and indicate that the Grindulu Fault is likely oriented NE–SW, consistent with previous geological interpretations of the region's tectonics.

Unlike traditional gravity data separation methods such as upward continuation, which focus on separating regional and local anomalies to study broader structural trends, the SVD method in this study is specifically designed for detecting fault locations. This approach allows for a direct enhancement of short wavelength components that are more closely related to fault related density contrasts. SVD amplifies the high-frequency components, which helps sharpen the edges of fault zones without the need for separating regional and residual anomalies via upward continuation. This method prioritizes the detection of fault boundaries rather than removing shallow anomalies, making it well-suited for this study's goal of fault identification. Therefore, the SVD method was applied to highlight structural edges and lineaments, directly linking gravity anomalies to fault locations, particularly in the Grindulu Fault corridor.

The use of SVD in this study primarily focused on edge/lineament detection, which provided insights into possible fault locations but does not allow for definitive fault-type classification (e.g., normal vs. reverse vs. strike-slip). Since SVD enhances short-wavelength anomalies, it is particularly effective in identifying boundaries associated with fault zones but does not have the capacity to differentiate between specific fault types without additional supporting data such as seismic or geological evidence. As such, the kinematic behavior of the fault is classified as tentative, and further verification using complementary geophysical and geological techniques is necessary.

The NE–SW orientation of the Grindulu Fault detected in this study is consistent with prior geological and geophysical studies (Samodra et al., 1992; Gultaf et al., 2015). However, discrepancies in the interpretation of fault type persist in the literature. Some studies suggest a strike-slip behavior (Cholifah et al., 2020; Arisbaya et al., 2021), while others interpret it as a dip-slip fault (Yusvinda et al., 2020; Parera et al., 2015). These differing interpretations underscore the complexity of the subsurface structure and highlight the need for a more integrated approach to fault classification, combining multiple methods and data sources.

Satellite gravity data, while effective for identifying density boundaries, cannot conclusively confirm faulting or its kinematics. The positional uncertainty of the inferred Grindulu Fault trace is influenced by several factors, including the choice of processing settings (SVD parameters), gridding methods, and slice placement. While we have provided an uncertainty envelope around the inferred trace, the accuracy of the fault's position must be verified using additional data sources, such as seismicity, field mapping, and GNSS measurements.

Additionally, density-based interpretations from gravity data should be approached with caution. Multiple subsurface models can yield similar gravity anomaly patterns, meaning that the interpretation of density anomalies alone cannot fully resolve the fault's kinematics. Therefore, while gravity data provide essential constraints, they cannot delineate detailed fault behavior or the full geological context of the Grindulu Fault without complementary data sources.

CONCLUSION

This research successfully identifies the Grindulu Fault in the Pacitan region of East Java using gravity data derived from TOPEX satellite anomalies. A series of data processing steps, including Bouguer and topographic corrections (CBA), separation of local and regional anomalies using upward continuation, and spatial analysis via the SVD, provided a comprehensive understanding of the subsurface conditions in the study area. The results indicate that the Grindulu Fault has a NE–SW orientation, with coordinates ranging from 111.1°–111.3° E and 8.1°–8.2° S. The northeastern segment intersects the main flow of the Grindulu River, while the southwestern segment is located within the southern volcanic arc of Java. The pronounced gravity anomaly contrast between these regions suggests significant variations in subsurface rock density, supporting the presence of an active fault. The SVD analysis revealed that the Grindulu Fault exhibits characteristics consistent with both normal faults and strike-slip faults, aligning with previous studies. Furthermore, this research contributes to a more detailed geospatial estimate of the fault's position, confirming the presence of minor faults surrounding the main fault. However, it is important to note that fault kinematics cannot be definitively determined from gravity data alone and would require further validation through seismic and geological methods. This study not only confirms the spatial and structural existence of the Grindulu Fault but also highlights opportunities for further geodynamic research in southern Java, particularly through integration with seismicity, GNSS measurements, and field mapping.

RECOMMENDATION

Future studies should refine the geometry and kinematics of the Grindulu Fault by integrating higher-resolution observations and more robust modeling. A dense ground gravity survey (including careful terrain correction) is recommended to validate the satellite-derived anomalies and to better resolve short-wavelength features that may represent splays or segmented fault strands. The interpretation would also be strengthened through multi-method integration, such as magnetic data, earthquake hypocenter focal mechanism analysis, microtremor (HVSR) site characterization, and geodetic observations (GNSS/InSAR) to constrain active deformation and reduce ambiguity in fault type. Methodologically, applying 3D gravity inversion (and, where possible, joint inversion with other datasets) with realistic density constraints from regional geology and rock samples is recommended to minimize the non-uniqueness of potential-field interpretation. Extending the analysis beyond the current window and adding more cross-sections would help map the fault continuity and its relationship with surrounding minor faults, supporting more reliable seismic hazard zoning for the Pacitan region.

FUNDING INFORMATION

This research received no external funding.

AUTHOR CONTRIBUTIONS STATEMENT

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Arie Realita	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	
Muhammad Nurul Fahmi		✓	✓	✓	✓			✓	✓	✓	✓			
Hikmatul Maulidah				✓		✓	✓	✓		✓	✓			
Firdha Kusuma Ayu A.				✓		✓	✓			✓				
Uswatun Chasanah				✓	✓					✓	✓			

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. Authors state no conflict of interest.

DATA AVAILABILITY

The gravity anomaly data (free-air anomaly) supporting the findings of this study were obtained from the TOPEX satellite gravity database (UC San Diego) via https://topex.ucsd.edu/cgi-bin/get_data.cgi for the study. Topographic data used for terrain correction were obtained from the Shuttle Radar Topography Mission (SRTM) digital elevation model. The derived datasets generated during the analysis (CBA grids, upward-continuation separated regional and residual fields, SVD outputs, and extracted profiles) as well as processing parameters are available from the corresponding author (A.R., arierealita@unesa.ac.id) upon reasonable request.

REFERENCES

Abdullah, F. (2022). Subsurface mapping of fault structure in the Weh Island by using a 3D density of global gravity. *International Journal of GEOMATE, 23*(7), 121–128.

Agustiyaningrum, L. (2018). *Interpretasi struktur bawah permukaan dan identifikasi jalur sesar mayor Grindulu berdasarkan data anomali medan magnet* [Skripsi, Universitas Jenderal Soedirman].

Al Hakim, A. Y., & Sulistijo, B. (2013). Integrated exploration method to determine Cu prospect in Seweden district, Blitar, East Java. *Procedia Earth and Planetary Science, 6*, 64–69.

Al-Khafaji, W. M. S., & Al-Dabbagh, H. A. Z. (2019). A geophysical correlation between near-surface radioactivity and subsurface faults detected by gravity method for a region located in the western desert of Iraq. *Iranian Journal of Earth Sciences, 11*(2), 95–103.

Altinoğlu, F. F., Sari, M., & Aydin, A. (2015). Detection of lineaments in Denizli basin of western Anatolia region using Bouguer gravity data. *Pure and Applied Geophysics, 172*, 415–425.

Araffa, S. A. S., El-Bohoty, M., Heleika, M. A., Mekkawi, M., Ismail, E., Khalil, A., & El-Razek, E. M. A. (2018). Implementation of magnetics and gravity methods to delineate the subsurface structural features of the basement complex in central Sinai area, Egypt. *NRIAG Journal of Astronomy and Geophysics, 7*(1), 162–174.

Arisbaya, I., Lestiana, H., Mukti, M. M., Handayani, L., Grandis, H., Warsa, & Sumintadireja, P. (2021). Garsela Fault and other NE-SW active faults along the southern part of Java Island. *IOP Conference Series: Earth and Environmental Science, 789*, Article 012065.

Barbosa, V. C. F., Menezes, P. T. L., & Silva, J. B. C. (2007). Gravity data as a tool for detecting faults: In-depth enhancement of subtle Almada's basement faults, Brazil. *Geophysics, 72*(3), B59–B68.

Barbosa, V. C. F., & Oliveira, L. L. (2020). Gravity-based methods for fault detection in tectonic settings: A review of approaches and recent developments. *Geophysics, 85*(4), 123–137.

Biswas, A. (2015). Interpretation of residual gravity anomaly caused by simple shaped bodies using very fast simulated annealing global optimization. *Geoscience Frontiers, 6*, 875–893.

Blakely, R. (1995). *Potential theory in gravity and magnetic applications*. Cambridge University Press.

Chaves, L. P., et al. (2021). Satellite-derived gravity anomalies for subduction zone studies: A case study from the Java Trench. *Journal of Geophysical Research: Solid Earth, 126*(1), e2020JB020465.

Chen, Y., Zhang, L., & Zhao, B. (2015). Application of singular value decomposition (SVD) in extraction of gravity components indicating the deeply and shallowly buried granitic complex associated with tin polymetallic mineralization in the Gejiu tin ore field, Southwestern China. *Journal of Applied Geophysics, 123*, 63–70.

Cholifah, L., Mufidah, N., Lazuardi, E., Santosa, B. J., Sungkono, & Haryono, A. (2020). Identification of the Grindulu Fault in Pacitan, East Java using magnetic method. *Jurnal Penelitian Fisika dan Aplikasinya, 10*(1), 22–23.

Dahrin, D., & Irsyam, M. (2020). Fault identification and seismic hazard assessment using gravity data: A case study of the West Java region. *Tectonophysics, 823*, 225–236.

Dinçer, B., & Işik, V. (2020). Determination of structural characteristics of Tuzgölü Fault Zone using gravity and magnetic methods, Central Anatolia. *Bulletin of the Mineral Research and Exploration, 162*, 145–174.

Essa, K. S. (2013). Gravity interpretation of dipping faults using the variance analysis method. *Journal of Geophysics and Engineering, 10*(1), 1–7.

Fahrudin, Hidayatullah, A. S., & Maulana, M. J. (2019). Tectonic relationships and structural development between Arjosari, Pacitan, East Java and Tawangmangu, Karanganyar, Central Java. In *The 1st International Conference on Geodesy, Geomatics, and Land Administration, KnE Engineering* (pp. 47–56).

Ganguli, S., & Dimri, V. (2013). Interpretation of gravity data using eigenimage with Indian case study: A SVD approach. *Journal of Applied Geophysics, 95*, 23–35.

Gultaf, H., Sapiie, B., Syaiful, M., Bachtiar, A., & Fauzan, A. P. (2015). Paleostress analysis of the Grindulu fault in Pacitan and surrounding area in its implication to the regional tectonic of East Java. *Proceedings, Indonesian Petroleum Association*, IPA15-G-059, 1–34.

Guo, L., Chen, Y., & Zhao, B. (2020). Application of singular value decomposition (SVD) to the extraction of gravity anomalies associated with Ag-Pb-Zn-W polymetallic mineralization in the Bozhushan Ore Field, Southwestern China. *Journal of Earth Science, 32*(2), 310–317.

Gupta, V. K., & Ramani, N. (1980). Some aspect of regional-residual separation of gravity anomalies in a Precambrian terrain. *Geophysics, 45*(9), 1412–1426.

Hutchings, S. J., & Mooney, W. D. (2021). The seismicity of Indonesia and tectonic implications. *Geochemistry, Geophysics, Geosystems, 22*(9).

Irsyam, M. I., Widiyantoro, S., Natawidjaja, D. H., Meilano, I., Rudiyanto, A., Hidayati, S., ... Faizal, L. (2017). *Peta sumber dan bahaya gempa Indonesia tahun 2017*. Pusat Studi Gempa Nasional dan Pusat Litbang Perumahan dan Permukiman, Kementerian PUPR.

Koulali, A., Susilo, S., McClusky, S., Meilano, I., Cummins, P., Tregoning, P., ... Syafi'i, M. A. (2016). Crustal strain partitioning and the associated earthquake hazard in the eastern Sunda-Banda Arc. *Geophysical Research Letters, 43*, 1943–1949.

Maulana, A. D., & Prasetyo, D. A. (2019). Analisa matematis pada koreksi Bouguer dan koreksi medan data gravitasi satelit Topex dan penerapan dalam geohazard: Studi kasus Sesar Palu Koro, Sulawesi Tengah. *Jurnal Geosaintek, 5*(3), 91–100.

Ming, Y., Niu, X., Xie, X., Han, Z., Li, Q., & Sun, S. (2021). Application of gravity exploration in urban active fault detection. *IOP Conference Series: Earth and Environmental Science, 660*, Article 012057.

Parera, A. F. T., Bunaga, I. G. K. S., & Yusuf, M. (2015). Permodelan tiga dimensi anomali gravitasi dan identifikasi sesar lokal dalam penentuan jenis sesar di daerah Pacitan. *Prosiding Seminar Nasional Fisika Universitas Negeri Jakarta (e-Journal), 4*, 46–48.

Purnomo, J., Koesuma, S., & Yunianto, M. (2013). Pemisahan anomali regional-residual pada metode gravitasi menggunakan metode moving average, polynomial, dan inversion. *Indonesian Journal of Applied Physics, 3*(1), 10–20.

Pusat Vulkanologi dan Mitigasi Bencana Geologi. (2025, May 27). *Analisis geologi kejadian gempa bumi baratdaya Pacitan, Jawa Timur tanggal 27 Mei 2025*. Badan Geologi, Kementerian Energi dan Sumber Daya Mineral. https://geologi.esdm.go.id/media-center/analisis-geologi-kejadian-gempa-bumi-baratdaya-pacitan-jawa-timur-tanggal-27-mei-2025

Ravat, D. (2007). Gravity anomaly filtering techniques: Upward continuation and regional-residual separation. *Journal of Geophysical Research, 112*(B7), B07306.

Samodra, H., Gafoer, S., & Tjokrosapoetro, S. (1992). *Peta geologi lembar Pacitan, Jawa*. Pusat Penelitian dan Pengembangan Geologi.

Saputra, A., Gomez, C., Delikostidis, I., Zawar-Reza, P., Sri Hadmoko, D., Sartohadi, J., & Setiawan, M. A. (2018). Determining earthquakes susceptible areas southeast of Yogyakarta, Indonesia: Outcrop analysis from Structure from Motion (SfM) and Geographic Information System (GIS). *Geosciences, 8*(132), 1–31.

Scholz, C. H. (2019). *The mechanics of earthquakes and faulting* (3rd ed.). Cambridge University Press.

Setijadji, L. D., Kajino, S., Imai, A., & Watanabe, K. (2006). Cenozoic island arc magmatism in Java Island (Sunda Arc, Indonesia): Clues on relationships between geodynamics of volcanic centers and ore mineralization. *Resource Geology, 56*(3), 267–292.

Soeria-Atmadja, R., Maury, R. C., Bellon, H., Pringgoprawiro, H., Polve, M., & Riadi, B. (1994). Tertiary magmatic belts in Java. *Journal of Southeast Asian Earth Sciences, 9*(1), 13–27.

Smyth, H. R., Hall, R., & Nichols, G. J. (2008). Cenozoic volcanic arc history of East Java, Indonesia: The stratigraphic record of eruptions on an active continental margin. *Geological Society of America Special Paper, 436*, 199–222.

Supendi, P., Nugraha, A. D., Puspito, N. T., & Daryono. (2018). Identification of active faults in West Java, Indonesia based on earthquake hypocenter determination, relocation and focal mechanisms analysis. *Geoscience Letters, 5*(31), 1–10.

United Nations Office for Disaster Risk Reduction. (2019). *Global assessment report on disaster risk reduction: GAR 2019*. United Nations.

Van Gorsel, J. T. (2018). *Bibliography of the geology of Indonesia and surrounding areas: Java, Madura, Java Sea* (Ed. 7.0). Bibliography of Indonesia Geology.

Widiyantoro, S., Muhari, A., Daryono, W., Lestari, D., Rosalia, S., Nugraha, A. D., Susilo, S., Afnimar, A., Meilano, I., & Zulfakriza, Z. (2020). Implications for megathrust earthquakes and tsunamis from seismic gaps south of Java Indonesia. *Scientific Reports, 10*(1), 15274.

Yanis, M., Marwan, & Ismail, N. (2019). Efficient use of satellite gravity anomalies for mapping the Great Sumatran Fault in Aceh Province. *Indonesian Journal of Applied Physics, 9*(2), 61–67.

Yusvinda, M. N., Puspitasari, S. W., Wafi, N. M. P., Aziz, K. N., Darmawan, D., Katriani, L., Handayani, N. T., & Wibowo, N. B. (2020). Structure interpretation using gravity spectral analysis and derivative method in Grindulu Fault, Pacitan, East Java. In *Proceedings of the 7th International Conference on Research, Implementation, and Education of Mathematics and Sciences (ICRIEMS 2020)* (Vol. 528, pp. 415–420).

Zhao, B., & Chen, Y. (2011). Singular value decomposition (SVD) for extraction of gravity anomaly associated with gold mineralization in Tongshi gold field, Western Shandong Uplifted Block, Eastern China. *Nonlinear Processes in Geophysics, 18*, 103–109.