

Identification of Active Fault Traces O “Paleo Earthquakes” Using Gravity Methods in Jangkat, Merangin Regency

Anggi Deliana Siregar¹, Juventa², D. M. Magdalena Ritonga³, Sarwo Sucitra Amin⁴, Maulina Tanjung⁵, Shazkya Annura Rizky⁶, and Pius Lauren Datu Bara⁷

^{1,2,3,4,5,6,7} Universitas Jambi, Jambi, Indonesia

*Corresponding Authors: anggidelianas@unja.ac.id

Abstract

Background: Indonesia is a country with high seismic activity because it is located at the meeting point of four major tectonic plates, resulting in numerous active faults and susceptibility to geological disasters such as earthquakes and landslides. Despite the high risk, data on active faults and geological disasters in Indonesia is still limited. This study focuses on geological mapping to identify Active Fault Traces, specifically “Paleo Earthquakes,” in Jangkat District, Jambi Province. **Objective:** The purpose of this study is to update and verify the position of faults from old geological maps, as well as to interpret new deformation mechanisms resulting from the interaction of geological structures in the field. **Methods:** Through preliminary studies and analysis of field data, as well as secondary geophysical data. Based on the results of geological structure measurements in the field, there are three fault locations consisting of a left-lateral strike-slip fault, a right-lateral strike-slip fault, and a right-lateral strike-slip fault. **Results:** Analysis of the residual map shows residual gravity anomalies with amplitudes of -9.6 to +11.0 mGal. The dominance of positive anomalies in the southwest is interpreted as an active fault and is significantly consistent with the distribution of active faults identified in the field. **Conclusion:** A linear residual anomaly pattern with a relatively high northwest- southeast gradient that correlates directly with the fault segment can be seen on the alignment map, which shows the general direction pattern. The results of the research location analysis are traces of active faults from paleo-earthquakes that have been identified through field and gravity data.

Keywords: Active Faults; Geological Disasters; Gravity

Cite This Article

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INTRODUCTION

Indonesia is one of the countries with a very high level of seismic activity because it is located at the meeting point of major tectonic plates, namely the Indian-Australian, Eurasian, Pacific, and Carolina- Philippine plates. As a result of the movement of these four plates, the Indonesian archipelago is divided into small parts that are largely bounded by active faults. This causes almost all regions of Indonesia to be prone to geological disasters. However, in contrast to these natural conditions, there is still little research on active faults and the resulting geological disasters. A series of geological disasters caused by active faults, especially earthquakes, have been recorded since 2000, making Indonesia an area with a very high potential for disasters. Therefore, sufficient knowledge about active faults and the potential for geological disasters in Indonesia is needed [1].

In Indonesia, ground movement events caused by earthquake activity have resulted in ground movement, such as in Majene, West Sulawesi in 2021, and Southeast Maluku in January 2023. Large and nearby earthquakes can cause significant ground vibrations. Sedimentary and soft soil types can amplify these vibrations and cause ground movement. Therefore, earthquake magnitude is directly proportional to ground movement. In addition to earthquake activity, ground movement can also occur due to high- intensity rainfall. This occurred in Bogor Regency on September 14, 2022, and then in Bogor City on October 12, 2022. According to a report based on a field survey conducted by the Geological Agency after the ground movement occurred, the rocks in Bogor Regency are black shale outcrops that soften when they interact with water. Therefore, continuous heavy rainfall can cause ground movement [2].

Sumatra Island is located in an active tectonic zone. This is indicated by the presence of a plate subduction zone in the western part of the island, as well as active fault lines and a chain of active volcanoes stretching from the northern tip of Sumatra Island to the Sunda Strait. Sumatra Island is cut by the active Sumatra (Semangko) fault, which is the longest active fault in Indonesia. The area along this fault is weak and prone to earthquakes. Earthquakes occur due to the release of energy at certain segments along this fault line [3]. Tectonic activity in the Sumatra Island region and its surroundings has been active since the Paleozoic – Mesozoic – Tertiary periods until now, followed by the formation of orogenic belts. Sumatra Island is one of the regions located on the edge of an active plate margin. As a result of this collision, a number of faults have formed on Sumatra Island, both in the prismatic accretion zone located between the subduction zone and the coast of Sumatra Island and on the mainland of Sumatra Island. The main fault on Sumatra Island is the Sumatra Fault, which runs along Sumatra Island from Aceh to Semangko Bay in Lampung Province. The Sumatra Fault can be divided into 19 segments [4].

Western Indonesia, especially the island of Sumatra, is traversed by many active faults that can cause geological disasters, including the Sumatra fault, which divides the Bukit Barisan mountain range for 1,900 km, starting from the Sunda Strait to the Aceh region and the Andaman Sea. The Sumatra fault zone passes through densely populated areas [1]. Faults or fractures are geological structures formed as a result of the shifting of the earth's layers from their normal position. They consist of active faults and passive faults. Active faults are fractures that continue to show movement, while passive faults are fractures that do not move at all [5]. Passive faults can become active faults if there are forces or vibrations that trigger their movement. One of the segments of the Sumatra Fault, namely the Dikit segment, passes through the research area.

In 2009, the province of Jambi, particularly in Kerinci and Merangin districts, experienced an earthquake measuring 7.0 on the Richter scale caused by fault movement. This became the background for this study to identify traces of active faults that have occurred in order to determine the potential for geological disasters, especially earthquakes.

METHODS

The research began with preparatory stages such as preparing topographic map materials using Indonesian Topographic Data (RBI) and Digital Elevation Model (DEM) imagery, creating geological maps and maps interpreting the structures found in the research area. This approach was taken to obtain detailed information about the research area. Then, data related to data processing was collected to determine the fault traces in the study area.

Field data collection and gathering were carried out in two stages, namely geological mapping and identification using geophysics with the gravity method. Geological observations included rock description; geomorphological observations to determine landforms, including morphology, morphometry, and morphogenesis; and measurements of geological structures such as fractures and faults in the form of rock position data to be used for data processing later. This study will focus on faults that developed at the research site. Geological mapping will be carried out to find geological structures with reference to previously created maps. All structural data will be measured using a geological compass and recorded for later data analysis. Geophysical data collection can use secondary data, namely gravity data that can be accessed on GGM Plus to determine the gravity of each predetermined point. The data collected includes Free Air Anomaly (FAA) and topography data. This is used to determine anomalies and for the interpretation of geological structures.

Data processing and analysis are carried out after collecting all the necessary data. The analysis will include creating a complete geological map with geological structures that have been updated and validated during field activities. Data is processed by interpreting geomorphological, petrological, and geological structure data. Geological structure data is processed to determine the type and movement of each fault. This data is compared with the data interpreted before the fieldwork, then secondary data is used to support the field data. For secondary data in the form of gravity data, processing will be carried out to determine deformation in the study area, while FAA data will be processed into complete Bouguer anomalies by performing Bouguer and terrain corrections. Bouguer correction is used to eliminate the influence of masses that are not objects from the datum to the measurement height, while terrain correction is performed to eliminate the influence of uneven rock masses due to the topography of the study area. This correction uses DEM data, after which complete bouguer anomalies are obtained and anomaly contour maps are created. An analysis will be performed to determine the residual gravity anomalies, followed by an interpretation of the structure's existence.

RESULTS AND DISCUSSION

The location of this geological research is in the “Rantau Kermas Village” area, which is in the administrative district of Jangkat, Merangin Regency, Jambi Province. Geographically, the area is located at coordinates x: 803000 and y: 9712000, and geomorphologically it is a volcanic hill and structural valley area. Geologically, this area is part of the QTV Formation, which is dominated by volcanic rocks such as volcanic breccia. The uniqueness of this location lies in its valuable geological heritage sites and landscapes, making it a valuable natural laboratory for stratigraphic, tectonic, and geomorphological studies.

Data collection in geological mapping begins with a systematic field survey aimed at gathering primary data directly in the study area. This activity begins with observation and description of naturally exposed rock outcrops, where parameters such as rock type, mineral composition, grain size, color, and sedimentary structure or fossil traces are carefully recorded. Next, geological structures are measured, including the orientation of bedding planes, joints, faults, and folds using a geological compass to analyze the history of rock deformation. Each observation point is documented in detail through photography, field sketches, and coordinate recording using GPS. Representative rock samples are also collected for further analysis in the laboratory, such as petrographic or paleontological analysis. In parallel, supporting data such as topography and geomorphology are also observed to understand the relationship between rocks and the landscape. All of this field data is then

plotted on a base map to form the basis for interpretation in compiling a comprehensive geological map.

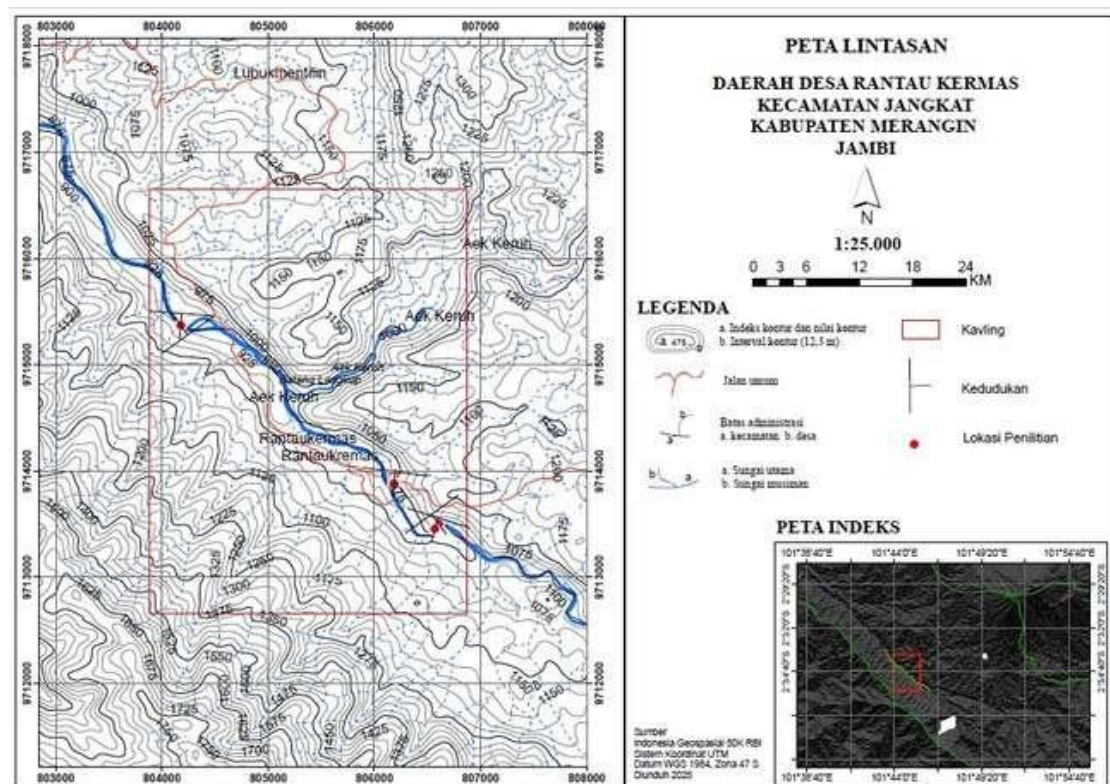


Figure 1. Topographic Map and Research Area Track

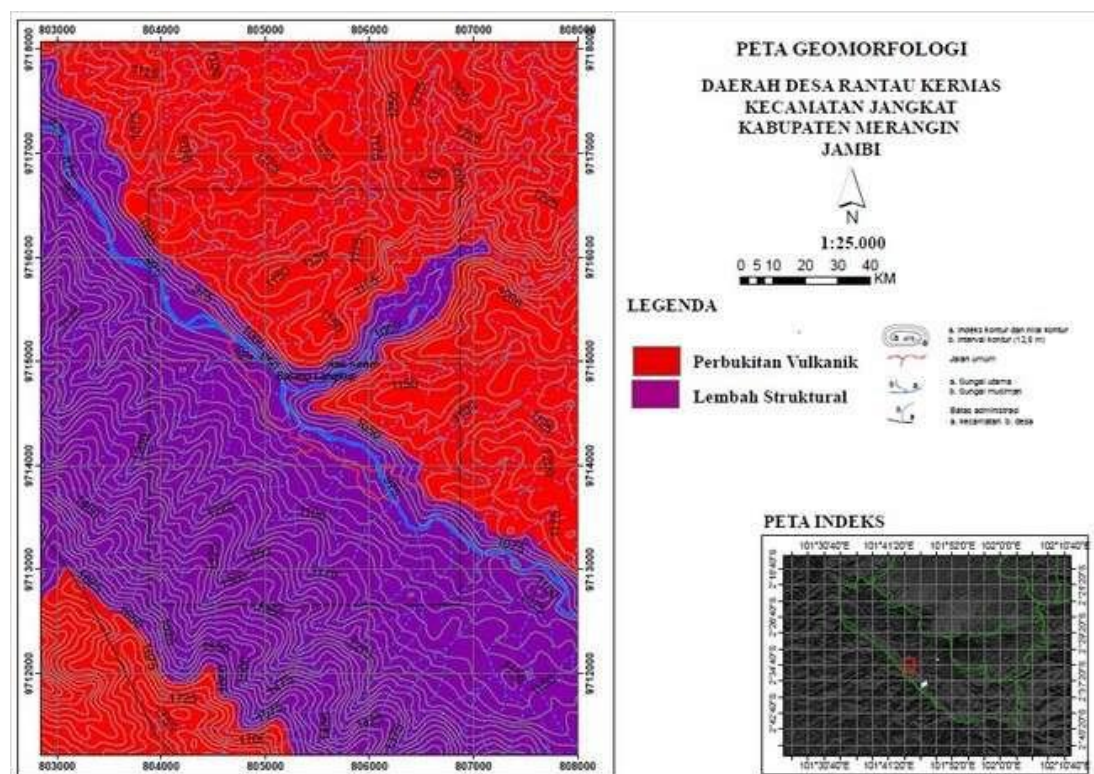


Figure 2. Geomorphological Map of the Research Area

On the geomorphological map above, the research location has two landscapes, namely volcanic hills and structural valleys. The research location has an elevation of 1050-1750

meters above sea level. The volcanic hills are characterized by a landscape formed by volcanic processes, with a morphology that is generally cone-shaped, with convex slopes and relatively gentle to steep peaks. The constituent materials are dominated by volcanic rocks such as pyroclastic (ash, lapilli, and breccia) and lava deposits with varying degrees of weathering. The river flow pattern in this area is a sub-parallel flow pattern, which developed on pyroclastic flow lithology, reflecting the strong control exerted by the nature of the rock itself on the process of valley and river formation. Pyroclastic flows produce lithology that is generally massive, homogeneous, and has relatively uniform resistance to erosion throughout its distribution. These hard and compact physical properties cause dissolution processes that generally control river patterns in rocks, while physical erosion processes become dominant. As a result, the rivers that form tend to flow parallel or nearly parallel to each other, following the original slope of the pyroclastic deposit surface. This pattern is also influenced by the initial topography produced by the pyroclastic deposition process itself, where volcanic material flows and fills low-lying areas, creating a flat surface or consistent slope. The drainage pattern in structural valley landscapes is formed as a direct response to geological structure control, particularly the presence of parallel major faults or fractures. In this landscape, river valleys develop parallel to each other because they follow zones of weakness in the rock, such as fault planes, fractures, or rock paths that are more easily eroded along the axis of anticlines or synclines. River flows, which may initially have a random pattern, will over time be diverted by these geological structures, eventually forming a pattern where tributaries flow into the main river at an almost right angle, forming a fishbone-like pattern on a parallel plane.

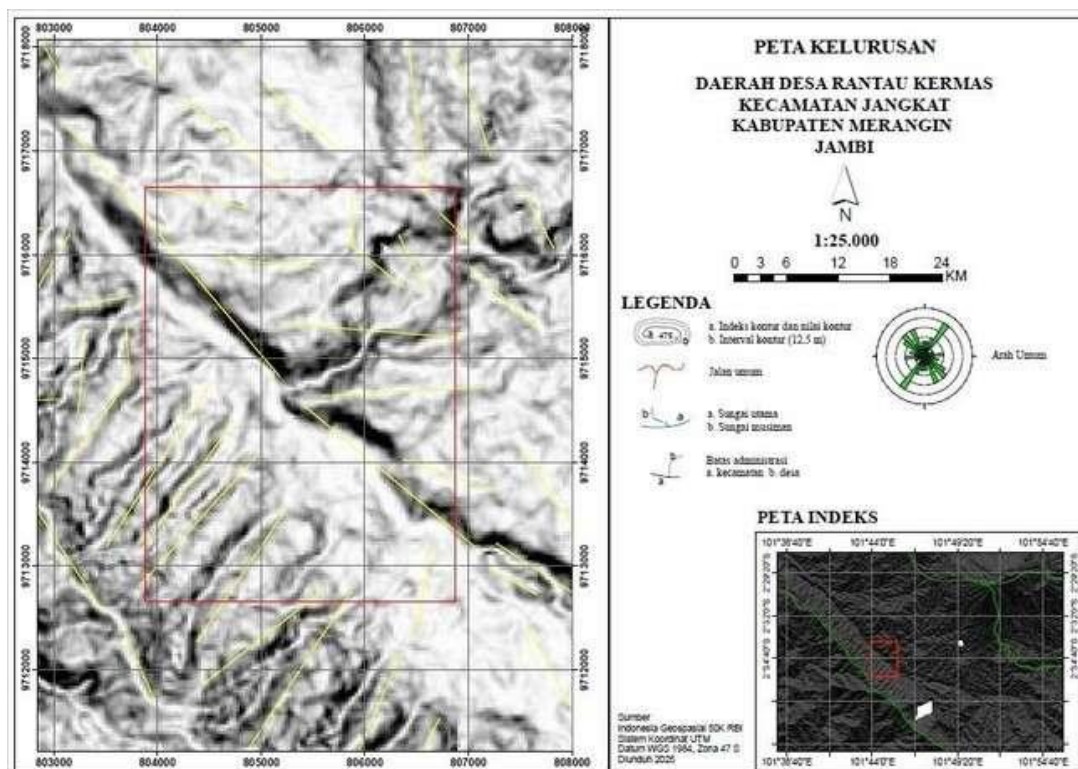


Figure 3. Research Area Straightness Map

The results of the analysis of the straight lines drawn in the study area show a general direction pattern. The southwestern part of the study area has a general direction of southwest to northeast, and the northeastern part of the study area has a general direction of northwest to southeast, as shown in Figure 3. The results of drawing a map of the straight lines of the faults and the general directions correspond to the field data.

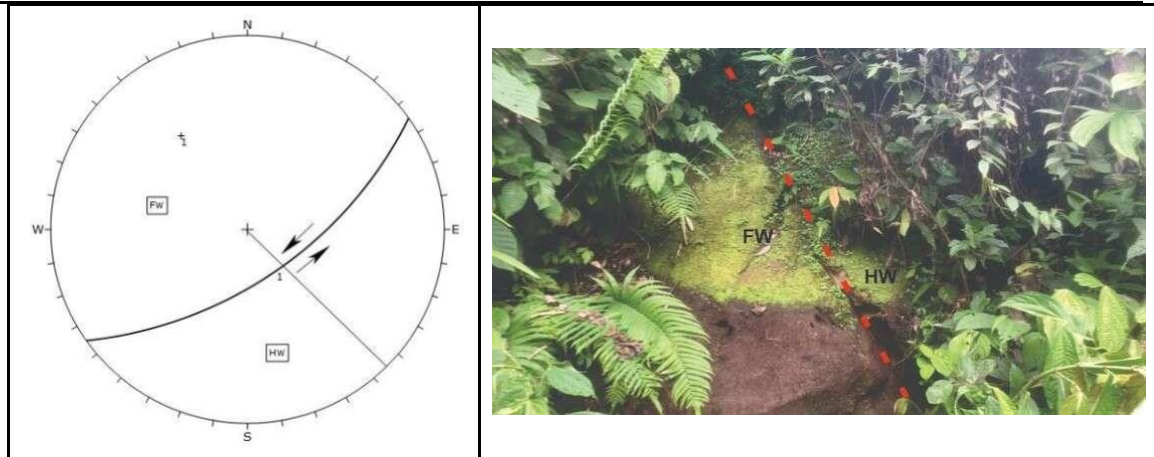


Figure 4. Analysis and Exposure of Normal Left-Slip Fault

At the first stop site, with coordinates x: 0806605 and y: 9713502 at an elevation of 1002 meters above sea level. It has an azimuth of N 10° E. The measurement analysis results show a strike dip of N 55° E/61°, with a bearing and plunge value of N 135° E/72° and a rake value of 76°. The field measurement results were analyzed stereographically manually and digitally using dips software. The fault above is named a Normal Left-Slip Fault.

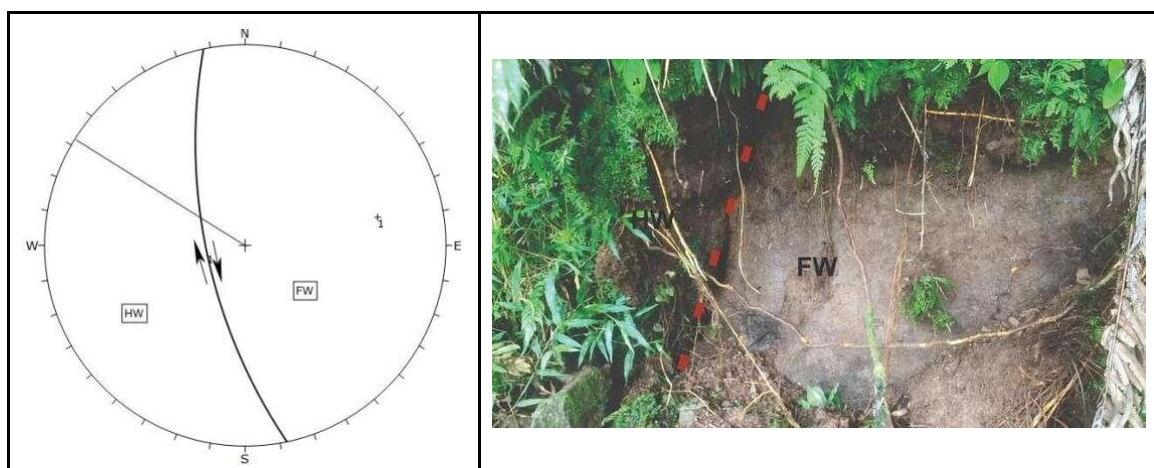


Figure 5. Analysis and Exposure of Right-Dextral Strike-Slip Fault

At the first stopsite, with coordinates x: 0806570 and y: 9713450 at an elevation of 1003 m above sea level. It has an azimuth of N 310° E. The measurement analysis results show a strike dip of N 108° E/ 68°, with a bearing and plunge value of N 302° E /16° and a rake value of 33°. The field measurement results were analyzed stereographically manually and digitally using dips software. The fault above is named a Right-Dextral Strike-Slip Fault.

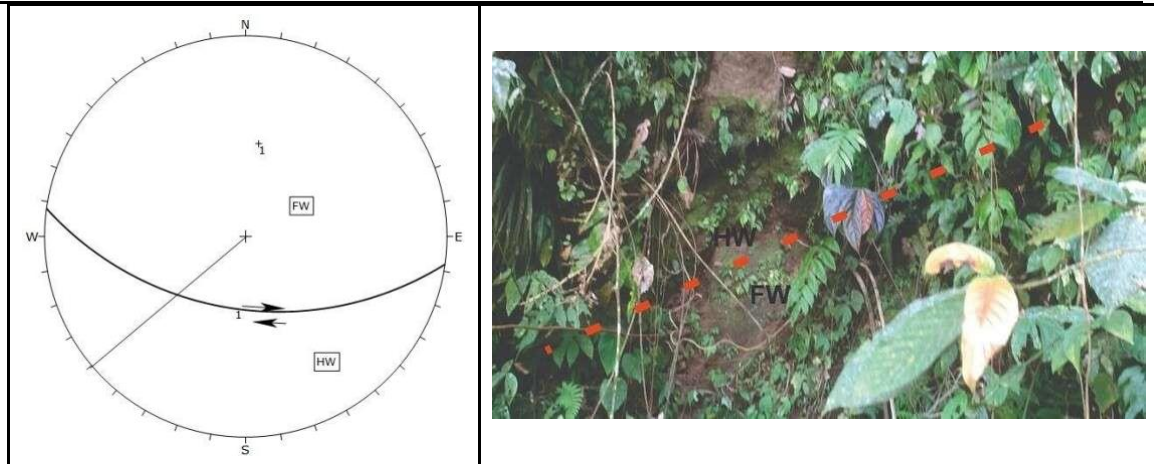


Figure 6. Analysis and Exposure of Normal Right-Slip Fault

At the first stopsite, with coordinates x: 0806184 and y: 9713881 at an elevation of 998 m above sea level. It has an azimuth of N 348° E. The measurement analysis results show a strike dip of N 98° E/ 50°, with a bearing and plunge value of N 348° E /72° and a rake value of 61°. The field measurement results were analyzed stereographically manually and digitally using dips software. The fault above is named a Normal Right-Slip Fault.

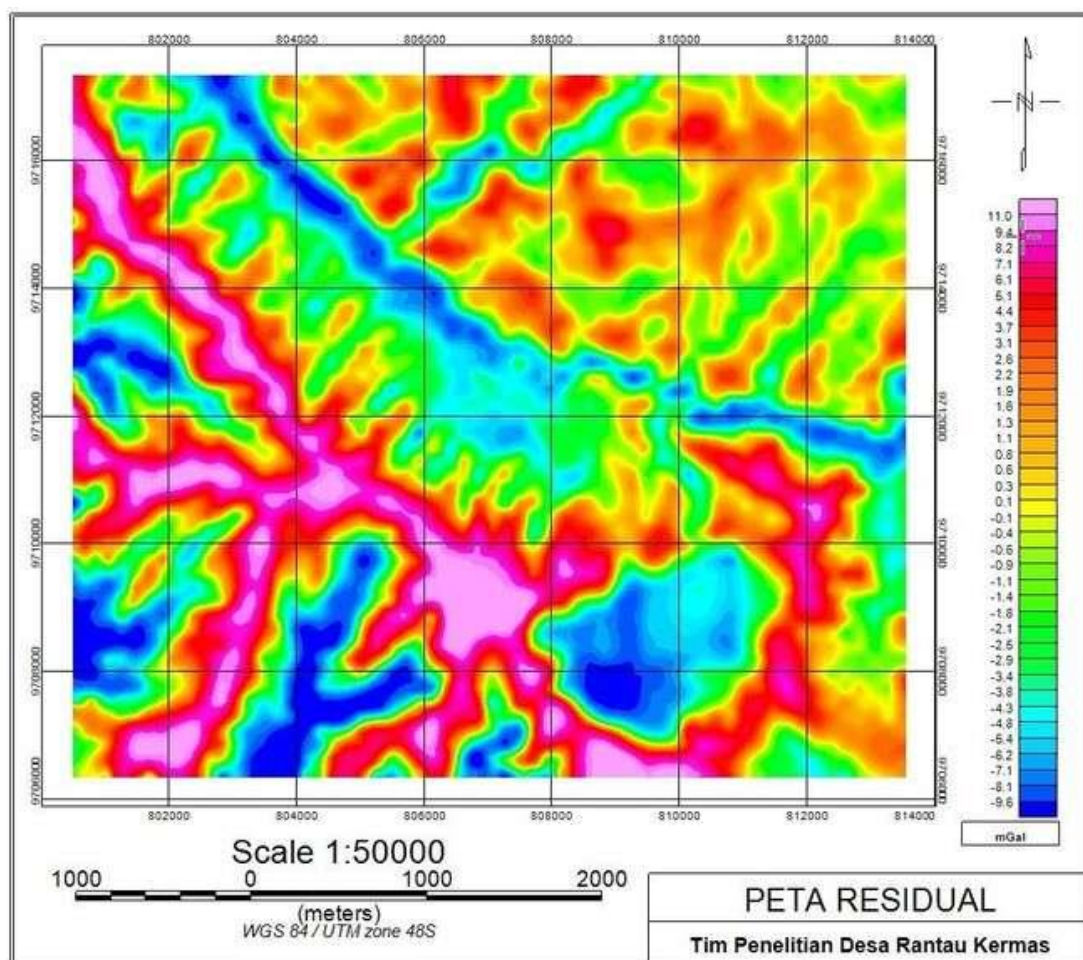


Figure 7. Residual Map of the Research Area

The results of the residual map analysis show residual gravity anomalies with amplitudes ranging from -9.6 to +11.0 mGal. The dominance of positive anomalies in the southwest is interpreted as an active fault. The negative anomaly gradient in the northeast forms a valley that separates two hills, with indications of positive anomalies being traces of active faults stretching from the northwest to the southeast of the study area.

The results of the residual anomaly map analysis show significant conformity with the distribution of active faults identified in the field. The linear residual anomaly pattern with a relatively high northwest-southeast gradient on the residual map correlates directly with the fault segments that can be seen on the alignment map showing the general direction pattern. Therefore, it can be seen that the research location is the trace of an active fault from the results of paleo-earthquakes that have been identified through field and gravity data.

CONCLUSIONS

Based on the results of research identifying traces of active “ancient earthquakes” in the Jangkat area, Merangin Regency, using the gravity method, it can be concluded that variations in complete Bouguer anomaly values indicate differences in subsurface rock density, which indicates the existence of active geological structures. The anomaly pattern that forms a northwest-southeast and northeast-southwest alignment represents the existence of a shear fault that still shows tectonic activity. The results of two- and three-dimensional modeling show that the low anomaly zone is associated with a weak zone that is the path of ancient fault movement. These findings confirm that the Jangkat area is a region that holds records of past seismic activity and has active tectonic potential that needs to be considered in earthquake disaster mitigation efforts. Thus, the gravity method has proven to be effective in identifying and mapping subsurface structures related to active fault traces in the study area.

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AUTHOR CONTRIBUTIONS

The first author prepared all related administration from the beginning to the end of the research. The second, fifth, and sixth authors collected geological field data and processed field data. The third and fourth authors analyzed geophysical data.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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