

Identification of the Existence of Inferred Menanga Fault based on Gravity Anomaly, Pesawaran, Lampung

Izaina Nurfitriana^{1,*}, Purwaditya Nugraha¹, Rizki Wulandari¹, Erlangga Ibrahim F¹,
Adhi Wibowo²

¹Program Studi Teknik Geofisika, Jurusan Teknologi Produksi dan Industri, Institut Teknologi Sumatera, Lampung Selatan, 35365, Indonesia

²Stasiun Geofisika Kelas III Lampung Utara, Badan Meteorologi Klimatologi dan Geofisika (BMKG), Lampung Utara, 34519, Indonesia

Corresponding author. Email: izaina.nurfitriana@tg.itera.ac.id

ABSTRACT

Inferred Menanga fault is one of fault that is still questionable whether it exists or not. It is located in Pesawaran regency, Lampung, exactly near Ratai Mountain with SE-W orientation and almost crosses the summit of Mount Ratai. The existence is sticking out and needs to be studied since there were swarm's earthquake that occurred on January 2021. The location of the swarm earthquake is exactly on the inferred Menanga Fault, which may become a sign of the activity of this inferred fault. Here we conducted the gravity measurement to confirm its existence by acquiring a local gravity survey of 49 points, which occupy an area of 12 km², crossing the inferred Menanga Fault and the location of swarm's epicentre. We calculated the CBA and upward continuation to obtain residual CBA and create our model from residual anomaly. We propose that the trace for the Menanga Fault is located at about 500 m of Southeast from the inferred Menanga Fault. We also propose another fault that separate of about 700 m and parallel to the proposed Menanga Fault.

Keywords: *Menanga Fault, Gravity anomaly, Inferred fault, Pesawaran*

1. PESAWARAN SWARM, JANUARY 2021

On January 2021, Pesawaran Lampung and its vicinity shocked by moderate earthquakes that last for several days. At least 22 earthquakes were recorded by BMKG and the magnitudes is ranging from 1.7-4 M_{LV}. [1] relocated the hypocenter and obtained the hypocenter spreading out at the region of SE of Mouth Ratai, Pesawaran, Lampung. Mount Ratai itself is a dormant volcano which is still showing the hydrothermal activities. We denote this sequence of earthquakes as swarm because there was no big earthquake following. Another geological feature according to [2] on his geological map, showed an inferred fault, Menanga, with NW-W trending and almost crosses the summit of Mount Ratai. This inferred fault becomes interesting since the location of the swarm is exactly above it. Unfortunately, the information and the studies about this fault are very lack so we could not denote that the source of the swarms is related to this fault. The swarm's occurrence which

spread exactly above the inferred fault could be an indication of the activity of the inferred fault. This fact implies that the inferred fault could be moved underground. Thus, the relation of the swarm and inferred fault become subject that need to be investigated. This study will confirm the existence of the fault and improve the information in local geological map such as Lembar Tanjung Karang map. Base on this background, we make an attempt to investigate this inferred fault based on gravity measurement. Gravity can be measure at any point and can be used to identify and determine the fault or other subsurface geological feature [3].

2. GEOLOGY OF STUDIED AREA

Based on Geological Map of Tanjungkarang Quadrangle by [2], our study area (bordered by red line) is located on the young volcanic deposits of Ratai Mountain which consist of andesite-basalt lava, breccia and tuff. Ratai Mountain is a dormant volcano. We hardly found the reference that discuss about the last volcanic

activity of Ratai Mountain. However, there are hydrothermal manifestation that sufficient to generate electricity power at about 8 km Southeast of Ratai Mountain's summit. The young volcanic deposits of Ratai Mountain lies on Undifferentiated Gunung Kasih Complex consisting of pelitic schist and small amount of gneiss. Meanwhile, the fault system that develop in the study area and its vicinity mainly dominated by the

inferred fault with NW-SE orientation. One of which is the inferred Menanga Fault, interpreted on the middle of research area with the strike of E-SE to W-NW orientation. At the SE part of the study area, in a line but not continuous with Inferred Menanga Fault, there exist a thrust fault that become a boundary between Pzg Formation and Menanga Formation (Km) (Figure 1).

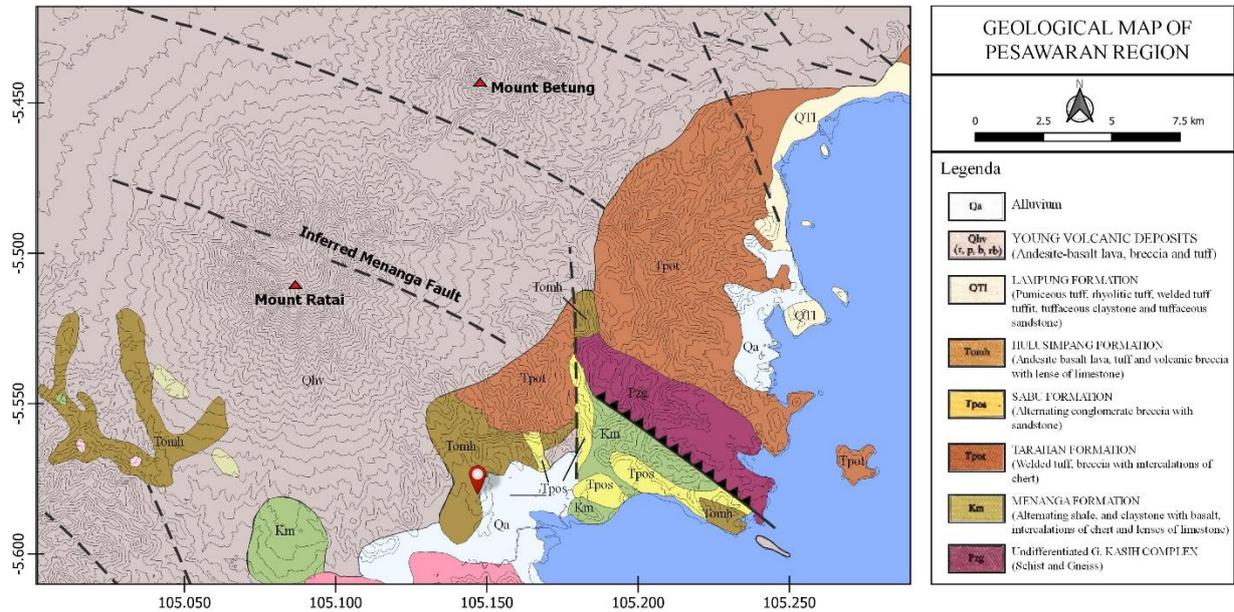


Figure 1. Geological map of study area modified from [2]. Red triangle is the summit of the mountain, red rectangular is the study are, red pin points to the area of hydrothermal manifestation.

3. METHOD: GRAVITY MEASUREMENT

3.1. Data Acquisition and Gravity Corrections

We conducted gravity measurement over the area of swarm hypocenter and its vicinity using Scintrex CG 6 with reference benchmark in ITERA. This measurement occupies approximately 12 km² area and located in the SE of Mount Ratai. This area is a part of protected National Forest. Total of the point measurements are 49 with the interval between point is 500 m. We made the design survey so that the inferred Menanga Fault and the epicenter of the swarms located at the center of the area. The gravity method is carried out with closed loop method. We take the positioning with GPS and altimeter to measure the altitude more accurate. Beside the gravity data, the altitude referred to the mean sea level should be provided to calculate the Bouger anomaly.

All gravity reading were reduced to Bouger Anomaly values by using conventional use according to [4]. Before made any reduction, we corrected the daily

gravity reading for Earth tide and instrument drift. The instrument drift correction is carried out manually.

The gravity value is still in relative to local base, so we convert the relative gravity to absolute values using absolute gravity ITERA as a local base. After we obtained the observed gravity (gO) value (after tide and drift correction), we reduce with the normal gravity (gN) value on the basis of the 1930 International Gravity Formula, which is described as follows,

$$gN = 978.049(1 + 0.0052884 \sin^2 Y - 0.0000059 \sin^2 2Y) \tag{1}$$

where Y is the latitude of measurement. Next is a free air correction (FAA), in which for every height in meter (h) from measurement point is used to reduce the gravity value by

$$FAC = 0.3086 \cdot h \tag{2}$$

After free air correction, it is followed by the Bouger correction (BC), which is described by

$$BC = 0.0419 \rho h \tag{3}$$

Here, we used the standard density (ρ) of 2.67 g/cm³. The last is the terrain correction (Tc) to take into account the

effect of terrain in the vicinity area of measurement. Despite the study area is in the volcanic environment, but the maximum height of the mountain is only 500s meters.

The resume for all correction is

$$CBA = gO - gN + FAC - BC + Tc \quad (4)$$

Figure 2. shows the CBA for the research area as the result of equation (4). The value is ranging from 32 mGal to 56 mGal. It is showed that the value is getting higher to the SE and relatively low to the NW.

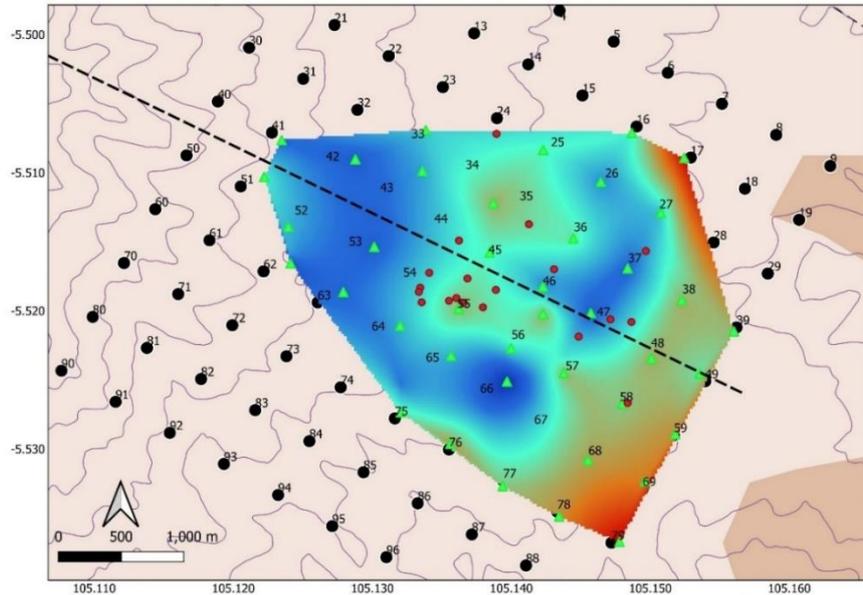


Figure 2. CBA at the research area. Green triangles represent the measurement points, red circle is the epicenter of the swarms, black circle is the target measurement points, dashed line represent the inferred Menanga Fault.

3.2. Upward Continuation

In order to enhance the anomaly, which correspond to a specific local geological structures or features, we need to filter out the CBA. The CBA itself covers both the regional and local anomaly. Here we utilize the upward continuation, which actually brings up the CBA value to the certain level of height above the point measurement. Since the height above point measurements is a free air and no topography profile, so the anomaly respond will much smoother than at the surface [5]. This step separates the interest anomaly from the remaining background anomaly, which implies the deep or broad geological features as a regional anomaly. We carried out the upward continuation projected to 500m above the datum point.

After obtaining the regional anomaly, we can determine the local anomaly by subtracting the CBA with regional anomaly, here we use term of residual anomaly. Residual anomaly represent the local geological structure and feature, thus we modeled the subsurface condition from residual anomaly.

3.3. Modelling Gravity Anomaly

We utilized Oasis Montaj to make the 2D subsurface model from the residual gravity anomalies. We chose an area which show a strong gradient between high and low anomaly. This strong gradient indicates two different densities in a narrow place which could be a sign of the trace of dip-slip fault structure. Where one block move upward or downward relative to each other, it will result in different density structure. Thus, the boundary between contrast density could indicate the fault plane. The modelling involve iterating modeling where the gravitational filed due to the model is compared to the residual anomaly. This attempt is repeated until we obtain a small error and a model which is reasonable and make sense from geologic point of view. In our research, the error is still 0.74 and we still observe the calculated gravity field which do not match (Figure 4) properly to the residual gravity. We suspect this un-match is caused by the topographic effect.

4. DISCUSSION

4.1. Gravity Anomaly in Research Area

Figure 4 shows the residual anomaly as measured over the epicenter and Menanga fault on Pesawaran, Lampung. The range anomaly is from -3.6 to 5.6 mGal.

Here, we will use this residual anomaly to model the subsurface of research area. According to [2], Menanga fault is located as indicated by the dashed line in the middle of the map. According to [6], The Menanga fault is suggested active in Cretaceous period. Since then, there are no study of Menanga Fault activity until the swarm event on January 2021. However, the trace of Menangan Fault is still inferred. Thus, we conducted gravity survey to support us tracing the inferred Menanga Fault.

Most of the case, the fault location is traced by the contrast anomaly between low and high area of residual gravity anomaly. There are several areas that show the contrast anomaly, but our interest is the contrast that have trend to the NW which is parallel to the trend of inferred Menanga Fault. We also considered the NE dip orientation which have been derived from the distribution of swarm hypocentre by [1]. This consideration allow us to decide the interest contrast anomaly area (Figure 4) which located about 500 m of Southwest from the trace of the inferred Menanga Fault by [2] since the swarm hypocentre distribute on the South – Southwest of it.

4.2. 2D Gravity Modelling

We take the profile as shown in Figure 4 from south to north A-A' for modelling the subsurface structure of the interest area. Based on the Geological Map, two formations construct the area of interest. These formations are Pzg with the density of 2,76 g/cc [7] and Qhv with the density of 2.5 g/cc [8]. Though Qhv is a quarternary volcanic deposits, but it consists of andesite-basalt lava, breccia and tuff, which contribute the high-density value to this formation. Considering the density of each formation and residual anomaly, we propose that the trace of Menanga Fault is located about 500 m of Southwest from the inferred Menanga Fault by [2] (Area of interest in Figure 3).

From the model, it is showed a trace of thrust fault in the middle of profile, which is interpreted as the trace of Menanga Fault. This fault cuts the Pzg and Qhv formations. The curved shape of the formation boundary on the footwall and hanging-wall around the Menanga Fault is interpreted as the drag effect due to the fault activity (Figure 4). We also propose another fault that separate of about 700 m and parallel to the proposed Menanga Fault (bold dashed line in Figure 3).

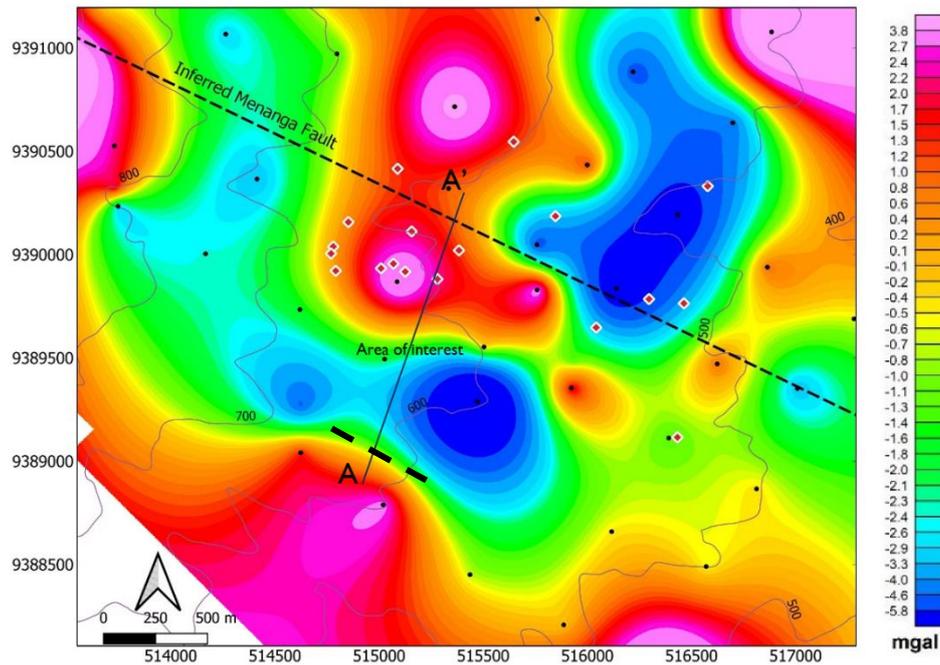


Figure 3. Residual gravity anomaly along research area. Colour scale indicates the value of anomaly. Red diamonds represent the epicentre of Pesawaran swarms, dashed line represents inferred Menanga Fault by [2], black dots represent the measurements point. Colour contour outside the outer measurement points is resulted from an extrapolation and it is negligible. Grey lines represent the topographic contour. Grey arrow point to the area of interest, which suggested as the location of Menanga fault trace based on gravity anomaly.

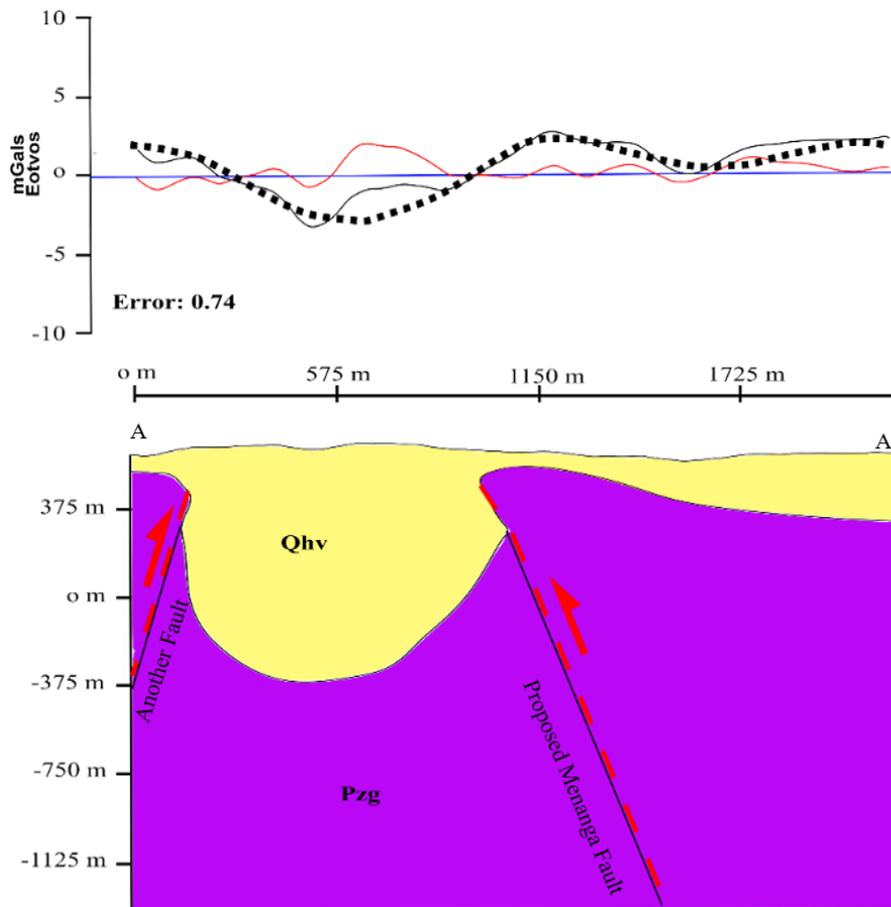


Figure 4. Proposed model produced by inverting the residual gravity anomaly (black dots) as shown in Fig.3 from A-A'. The black line is the calculated residual anomaly and red line is the error. The identifiable geological structure as the result from this inverse modelling represent by red dashed line and the arrow indicates the movement direction.

5. CONCLUSION

We conducted gravity measurement to trace the presence of Menanga Fault at Pesawaran, Lampung. This study was conducted as a respond to the 19 swarms' events occurred around the inferred Menanga Fault yet the study of the fault still lacks. Based on the gravity anomaly, we find several gravity anomaly contrast striking East Northeast to West Southwest at some part of the research area. The trace of the inferred Menanga Fault by [2] is correspond to the one of these gravity anomaly contrast. However, based on the study of distribution of swarms epicentre by [1], which shows NE of dipping orientation, the trace of this inferred Menanga Fault become unreliable. We propose that the trace for the Menanga Fault is located at about 500 m of Southeast from the inferred Menanga Fault by [2]. This trace is more correlate to the distribution of the epicentre of swarm event on January 2021.

AUTHORS' CONTRIBUTIONS

IN performed the data CALCULATION, MODELLING, DESIGNED the ANALYSIS and

WROTE the paper, PN performed the data CALCULATION, RW, EIF, and AW helping to perform the ANALYSIS.

ACKNOWLEDGMENTS

The authors thank LP3 ITERA, which has been funding this research under the Hibah Penelitian ITERA 2021. Thank Mohammad Tri Fitrianto, a geologist colleague, for the brainstorming and discussion. Thank academic assistants and student who involved and helped us collecting the data.

REFERENCES

- [1] I. Nurfitriana, A. Wibowo, R. Rudianto, Relokasi Gempa Bumi Swarm Di Pesawaran-Lampung, Januari 2021, J. Geoelebes, vol. 5, no. 1, pp. 91–101, 2021, doi: 10.20956/geoelebes.v5i1.13328.
- [2] Mangga, S.A., Amirudin, Suwarti, T., Gafoer, S., Sidarto, Peta Geologi Lembar Tanjung Karang, Sumatera (skala 1:250.000), Bandung: Pusat Penelitian dan Pengembangan Geologi.

- [3] S. Kobayashi, S. Yoshida, S. Okubo, R. Shichi, T. Shimamoto, T. Kato, Two-Dimensional Analysis Gravity Anomaly across the Rokko Fault System, *J. Phys Earth*, vol. 44, 1996, pp. 357–372.
- [4] W. J. Hinze, C. Aiken, J. Brozena, B. Coakley, D. Dater, G. Flanagan, R. Forsberg, T. Hildenbrand, G.R. Keller, New standards for reducing gravity data: The North American gravity database, *Geophysics*, vol. 70, no. 4, 2005, doi: 10.1190/1.1988183.
- [5] I. Budiman, Interpretation of gravity data over central Jawa, Indonesia, The University of Adelaide, 1991.
- [6] R. Suharno, B. Aritonang, A. Zainudin, Rustadi, Geothermal system of Cisarua Natar Lampung Selatan, *Tek. Geofis. Univ. Lampung*, 2012.
- [7] B. R. Juliarka, M. Iqbal, 2D-gravity model to reveal subsurface geological structures in geothermal areas of Natar, *Buletin Sumber Daya Geologi*, vol. 15, 2020.
- [8] Y. Tarigan, Fault structure analysis and modelling of southern Lampung region using gravity method, *ITERA*, 2020.