The Relation of Fault Fracture Density with the Residual Gravity; case study in Muria

by Fajar Rizki Widiatmoko

J E M T
Journal of Earth and Marine Technology
homepage URL: ejurnal.itats.ac.id/jemt

The Relation of Fault Fracture Density with the Residual Gravity; case study in Muria

Fajar Rizki Widiatmoko *[1], Ratih Hardini Kusuma Putri [1], Huzaely Latief Sunan [2]
[1] Institut Teknologi Adhi Tama Surabaya, Arief Rachman Hakim Rd, No. 100, Surabaya, Indonesia
[2] University of Jenderal Soedirman, Mayjend Sungkono Rd, Km 5, Purbalingga, Indonesia
*e-mail: widiatmoko@itats.ac.id

DOI: leave as blank

Article info
Received:
February 14, 2021
Revised:
March 10, 2021
Accepted:
March 15, 2021
Published:
March 31, 2021

Keywords:
Structure density, magmatic detection, microstructural detection

Abstract
The usages of the FFD analytical method massively are utilized during the last decade, especially in the geothermal preliminary study that can show the prospect reservoir area. This article discusses the correlation of the FFD value with the residual gravity value that is assumed as an indication of the underneath magmatic body. The correlation of FFD value with residual gravity value is applied in Muria mountain. Muria is classified as the volcano body that contains the magmatic body, also exist Genuk volcano and Patiayam hill around Muria. The correlation shows that FFD value and residual gravity value have a relation, but especially for the uninfluenced by structural activity has a low value of FFD. The correlation of FFD and residual gravity is double-checked with the ground truth data, it showing the proof relation. This way of methodology may use for finding the underneath magmatic body, especially applied to the surface that has not been influenced by structural activity.

1. Introduction

Pattern detection is firstly developed by using image data [1]. Pattern detection was used to detect the microstructural pattern by using aerial photos and satellite images [2]. The microstructural pattern was analyzed by its intensity and become Fault Fracture Density (FFD) [2]. The FFD was used to find out the reservoir zone on the geothermal area [3], the FFD also used to know the structural damage caused by its displacement [4], the FFD was used to correlate with the geological and geochemical condition for identifying the subsurface reservoir character and condition [5]. By according to the FFD analysis a conceptual model of a geothermal field is also conducted [6]. The residual gravity is utilized to find the local magmatic product [7]

This research has a curiosity about the relation of FFD to the Residual gravity values and its geological condition. The assumption occurs if the residual gravity value high means locally contain the high-density rock. The high FFD value means there was a frequent structural activity, one of them is the magmatic activity. It is clear that if the high FFD and high residual gravity as one indication for locating the border of the underneath magmatic body, however, both of the values still need to do double-check with the ground truth data as well the geological map.

As a case study, this research is conducted in Muria volcano that located in Central Java Province, around the regency of Jepara, Kudus, and Pati. Previously this area was physiographic mapped that shown as the Quarter volcano and surrounded by the Alluvial plain of northern Java [8]. The Muria Volcano formation was caused by the subduction activity between the Micro-Sunda plate versus the Hindi-Australian plate [9] during Tertiary geological age [10] that creep by direction NE-SW [11]. Locally the Muria volcano contains basaltic lava product (Qvlm) and tuff with lahar product (Qvtm), the Muria volcano formed on the Patiayam Formation (Tpp) and Bulu Formation (Tmb), besides the Muria volcano there was formed the Genuk volcano that contains lava and pyroclastic product [12].

2. Methodology

The method of this research is conducted to prove the magmatic body detection by correlating the FFD value and residual gravity value. Both the FFD value and residual gravity value were then correlated to get the relation between them, as the hypothetic informed that the high FFD value and high residual gravity value called as the underneath magmatic body detection. Thus, there is required to correlate with the ground truth data.

The FFD analysis is conducted from the DEMNAS data that contains the elevation value of each pixel size 7,5 m [13], [14]. The DEMNAS data is analyzed by using pattern detection to get the microstructural pattern [1], then the pattern is analyzed by its microstructural frequency to get the FFD value of each pixel [2]. The residual gravity conducted from the topography and gravity data provider (TOPEX UCSD), has a pixel size of about 1 arc second [15], [16], however, those data require the Bouguer correction to calibrate from gravity influence of elevation, terrain, and latitude [17]. The corrected Bouguer still represents the gravity value of the deep part of the earth, the near-surface gravity value acquisition requires minus by linear regression of the corrected Bouguer that becomes the residual gravity value [18]. The correlation with the ground truth data is conducted by using the geological map that was made before [12].

3. Results

3.1. The fault fracture density map

The FFD map has shown that the high structural frequency distributed around the slope of the Muria volcano, while there has shown some high structural frequency on the Genuk volcano and Patiayam hill, see figure 1. The low FFD value has been shown on the distal zone of its volcano and the alluvial plain that surrounding the Muria volcano.

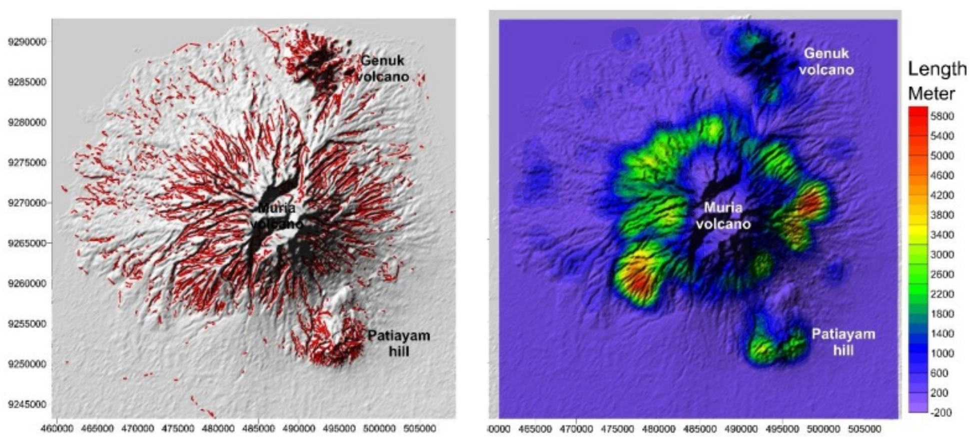
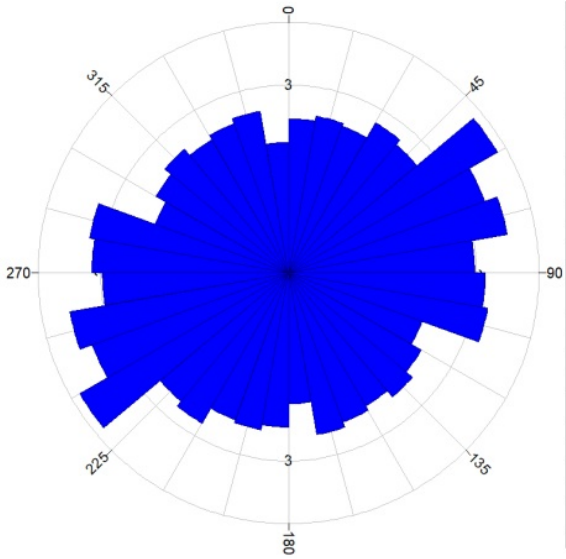


Figure 1. The detected structural pattern map of the Muria volcano (left), the fault fracture density map of the Muria volcano (right)

3.2. The dominant lineament of the structural pattern

The detected structural pattern then analyzed by their direction, the direction of domination has shown at N 72.3^0 E with an accuracy of 95%, the length calculation was used to show the total length of the pattern about 2700 kilometers. The minor pattern occurrence is distributed in several directions that do not become the dominant lineament, see figure 2.



Calculation Method:	Length
Class Interval:	10.0 Degrees
Min.Length Filtering:	Deactivated
Max.Length Filtering:	Deactivated
Azimuth Filtering:	Deactivated
Data Type:	Bidirectional
Population:	3,104
Total Length of All Lineations:	2,761,981.69
Maximum Bin Population:	221.0
Mean Bin Population:	172.44
Standard Deviation of Bin Population:	25.55
Maximum Bin Population (%):	3.56
Mean Bin Population (%):	2.78
Standard Deviation of Bin Population (%):	0.41
Maximum Bin Length:	106,328.19
Mean Bin Length:	76,721.71
Standard Deviation of Bin Lengths:	12,780.54
Maximum Bin Length (%):	3.85
Mean Bin Length (%):	2.78
Standard Deviation of Bin Lengths (%):	0.46
Vector Mean:	72.3 Degrees
	252.28 Degrees
Confidence Interval:	15.7 Degrees
	(95 Percent)
R-mag:	0.09

Figure 2. the result of the dominant lineament analysis

3.3. The residual gravity map

The residual gravity map of Muria and the surrounding area showing that the center of the Muria volcano contains the highest value of the residual gravity map, while the higher residual gravity value is detected on Genuk volcano and Patiayam hill. The low residual gravity value is shown on the distal zone of its volcano and the alluvial plain that surrounded the Muria volcano, see figure 3.

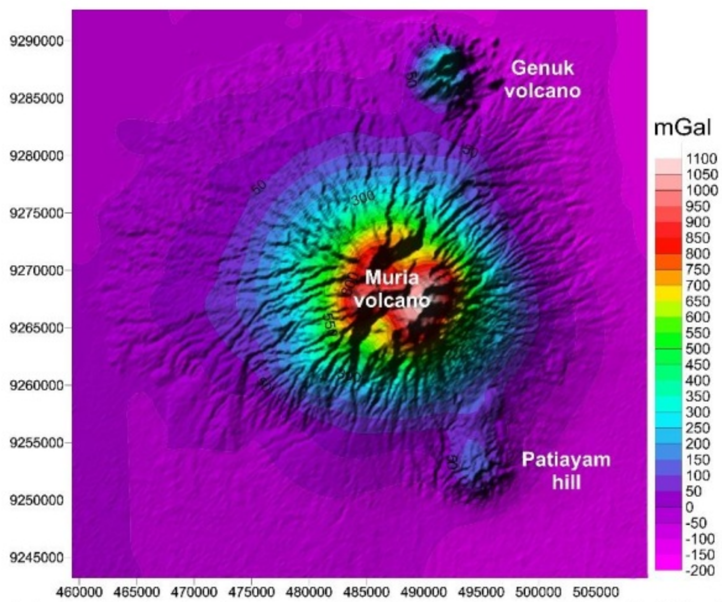


Figure 3. The detected structural pattern map of the Muria volcano (left), the fault fracture density map of the Muria volcano (right)

4. Discussion

The correlation that mentions each data is shown in figure 4. The correlation is shown by using a section profile that slices through Genuk volcano, Muria volcano, and Patiayam hill (figure 4). The correlation section profile through them because of the value changing of each data that has the interest to be discussed. Each of the areas is discussed by point of view from the geological process, volcanology, and structural process.

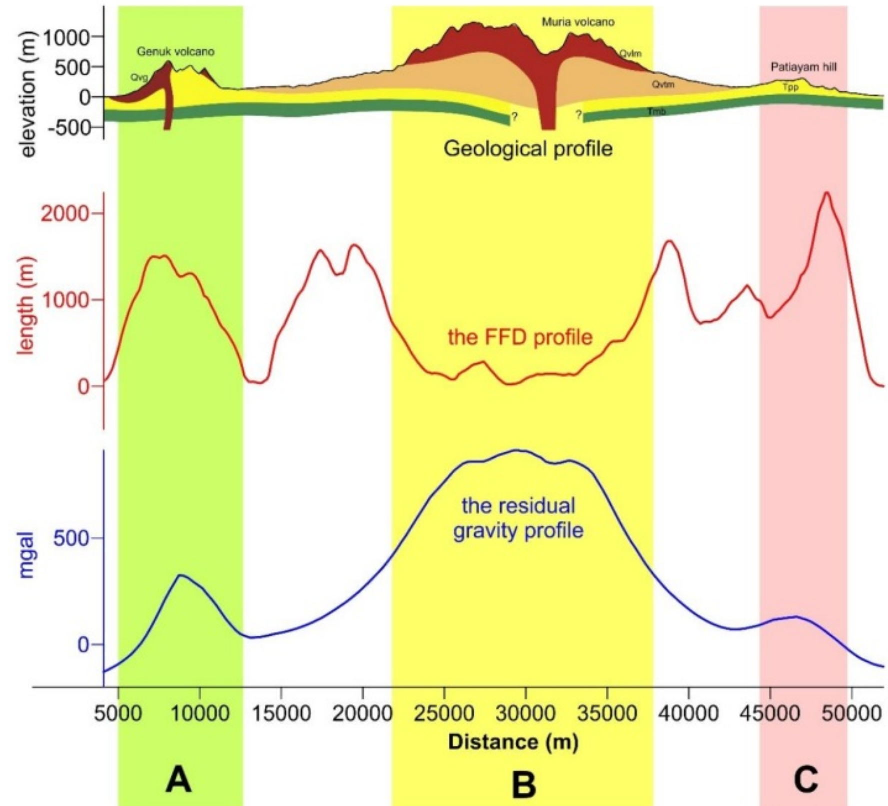


Figure 4. The correlation of each data that showing interest to be discussed on A, B, and C. the geological profile adapted and modified from [12] (top side), the FFD profile (middle part), and the residual gravity profile (bottom side)

The A area (see figure 4) as the Genuk volcano area shows the high FFD frequency and high gravity profile. There correlates with FFD value, residual gravity value, and containing the magmatic body. The high FFD value occurrence is caused by the high intensity of structural activity, the activity represents from the compression and or extensional earth processes [19]. The high value of the residual gravity profile represents the existence of high-density rock underneath [18]. Booth of the FFD value and residual gravity value correlates with the ground truth data that containing magmatic product on the surface and interpreted contain magmatic body underneath [12]. The formation of structural pattern on the surface is formed from the underneath magmatic activity that commonly has inflation and deflation process [20]

The B area (see figure 4) as Muria volcano shows the low FFD value and high residual gravity value, there is no correlation between booth of FFD value and residual gravity value. The low FFD value occurrence is caused by the low intensity of structural activity, the low activity represents from the young age rock that relatively not influenced by structural activity [21]. But on the slope side of Muria volcano (outside B area), there has high value of FFD that represent high structural activity from compression and or extension earth process [19], the structural pattern on that area formed from the radial force that comes from the central volcano process [20]. The high value of the residual gravity profile represents the existence of the underneath of high-density rock [18]. Booth of the FFD value and residual gravity value correlates with the ground truth data that containing magmatic product on the surface and interpreted contain magmatic body underneath [12], the high FFD on the side slope does not detect the underneath magmatic body that formed from the force of the central part of its volcano [20]. The formation of structural pattern on the surface is formed from the underneath magmatic activity that commonly has inflation and deflation process [20]

The C area (see figure 4) as the Patiayam hill area shows the high value of FFD and medium value of residual gravity. There has small relation between FFD value and residual gravity value. The high FFD value represents the high structural activity that formed from compression and extension of the earth process [19]. The structural pattern formation is caused by the force that comes from the central part of the volcano [20]. The medium value of residual gravity represents the existence of medium rock density [18], the sedimentary rock is classified as the medium rock density that exist as Patiayam formation (Tpp) and Bulu formation (Tmb) [12].

5. Conclusion

All of the correlated data both analyzed data and ground truth data show their correlation. The structural pattern is detected on the surface that has been influenced by structural activity, while the low FFD value comes from the uninfluenced by structural activity. The residual gravity data are relatively correlated with the ground truth data based on rock density. In the end, the relation of FFD value and residual gravity value shows its relation and is proofed by the ground truth data, but in case the uninfluenced area has a low FFD value.

6. Acknowledgment

Our acknowledgment is delivered to the agency of BIG that has provided DEMNAS data, to TOPEX UCSD that has provided the topo and gravity data, and our thank to every part that has supported this work.

References:

[1] J. Canny, “A Computational Approach to Edge Detection,” *IEEE Trans. Pattern Anal. Mach. Intell.*, 1986, doi: 10.1109/TPAMI.1986.4767851.

[2] J. M. Vermilye and C. H. Scholz, “The process zone: A microstructural view of fault growth,” *J. Geophys. Res. Solid Earth*, 1998, doi: 10.1029/98jb00957.

[3] H. H. Wibowo, “Application of Fault and Fracture Density (FFD) Method for Geothermal Exploration in Non-Volcanic Geothermal System; a Case Study in Sulawesi-Indonesia,” 2010.

[4] H. M. Savage and E. E. Brodsky, “Collateral damage: Evolution with displacement of fracture distribution and secondary fault strands in fault damage zones,” *J. Geophys. Res. Solid Earth*, 2011, doi: 10.1029/2010JB007665.

[5] . O., D. A. Ramadhan P, F. R. W, and R. T. A, “Identification of Geothermal Potential Based on Fault Fracture Density (FFD), Geological Mapping and Geochemical Analysis, Case Study : Bantarkawung, Brebes, Central Java,” *KnE Energy*, 2015, doi: 10.18502/ken.v2i2.369.

[6] F. R. Widiatmoko, M. N. Hadi, D. Kusnadi, S. Iswahyudi, and F. Fadlin, “The conceptual model of Wae Sano Geothermal field based on geology and geochemistry data,” *J. Earth Mar. Technol.*, 2020, doi: 10.31284/j.jemt.2020.v1i1.1189.

[7] F. R. Widiatmoko *et al.*, “Possibility of geothermal offshore in Sangihe archipelago, northern part of Sulawesi, Indonesia,” *IOP Conf. Ser. Mater. Sci. Eng.*, 2021, doi: 10.1088/1757-899x/1010/1/012004.

[8] R. W. Van Bemmelen, “The Geology of Indonesia. General Geology of Indonesia and Adjacent Archipelagoes,” *Government Printing Office, The Hague*. 1949, doi: 10.1109/VR.2018.8447558.

[9] P. Bird, “An updated digital model of plate boundaries,” *Geochemistry, Geophys. Geosystems*, 2003, doi: 10.1029/2001GC000252.

[10] R. Soeria-Atmadja, R. C. Maury, H. Bellon, H. Pringgoprawiro, M. Polve, and B. Priadi,

"Tertiary magmatic belts in Java," *J. Southeast Asian Earth Sci.*, 1994, doi: 10.1016/0743-9547(94)90062-0.
[11] F. R. Widiatmoko, A. Zamroni, M. A. Siamashari, and A. N. Maulina, "REKAMAN STASIUN GPS SEBAGAI PENDETEKSI PERGERAKAN TEKTONIK, STUDI KASUS: BENCANA TSUNAMI ACEH 26 DESEMBER 2004," in *Prosiding Seminar Teknologi Kebumian dan Kelautan*, 2019, vol. 1, no. 1, pp. 236–240, [Online]. Available: https://ejurnal.itats.ac.id/semitan/article/view/856.
[12] T. Suwarti and R. Wikarno, "Geological map of the Kudus Quadrangle, Java," Bandung, Indonesia, 1992.
[13] BIG, "DEMNAS," *DEMNAS*. 2020.
[14] M. Y. Iswari and K. Anggraini, "DEMNAS: MODEL DIGITAL KETINGGIAN NASIONAL UNTUK APLIKASI KEPESISIRAN," *OSEANA*, 2018, doi: 10.14203/oseana.2018.vol.43no.4.2.
[15] D. T. Sandwell and W. H. F. Smith, "Marine gravity anomaly from Geosat and ERS 1 satellite altimetry," *J. Geophys. Res. B Solid Earth*, 1997, doi: 10.1029/96JB03223.
[16] W. H. F. Smith and D. T. Sandwell, "Global sea floor topography from satellite altimetry and ship depth soundings," *Science (80-.).*, 1997, doi: 10.1126/science.277.5334.1956.
[17] R. Vajk, "BOUGUER CORRECTIONS WITH VARYING SURFACE DENSITY," *GEOPHYSICS*, 1956, doi: 10.1190/1.1438292.
[18] M. Bonafede and C. Ferrari, "Analytical models of deformation and residual gravity changes due to a Mogi source in a viscoelastic medium," *Tectonophysics*, 2009, doi: 10.1016/j.tecto.2008.10.006.
[19] W. R. Buck, F. Martinez, M. S. Steckler, and J. R. Cochran, "Thermal consequences of lithospheric extension: Pure and simple," *Tectonics*, 1988, doi: 10.1029/TC007i002p00213.
[20] S. Bronto, *Geologi Gunung Api Purba*. 2013.
[21] S. Bronto, "Fasies gunung api dan aplikasinya," *Indones. J. Geosci.*, 2006, doi: 10.17014/ijog.vol1no2.20061.

The Relation of Fault Fracture Density with the Residual Gravity; case study in Muria

ORIGINALITY REPORT

3%	3%	0%	0%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	ejurnal.itats.ac.id Internet Source	2%
2	www.arpnjournals.org Internet Source	1%
3	eprints.upnyk.ac.id Internet Source	<1%

Exclude quotes	On	Exclude matches	Off
Exclude bibliography	On		

The Relation of Fault Fracture Density with the Residual Gravity; case study in Muria

GRADEMARK REPORT

FINAL GRADE

/0

GENERAL COMMENTS

Instructor

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6