Fractal Characteristics of Geomorphology Units as Bouguer Anomaly Manifestations in Bumiayu, Central Java, Indonesia

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Abstract. Bumiayu in Central Java, Indonesia, has a typical landform characteristics. Differences of topography on each geomorphological unit indicated by the value of fractal dimension. This research provides important information on the influence of geomorphology conditions and subsurface geological phenomenon of research area based on fractal application. This research methodology relies on laboratory analysis and field observation. Landform is a characteristics of Bouguer anomaly contour manifestation. It is indicated by occurrences of significant correlation between the Bouguer anomaly countour and geological cross section as well topography contour slope and Bouguer anomaly contour slope. Based on spatial analysis, morphology of research area is dominated by very high steep hills (more than 60%). Result of Bouguer anomaly countour analysis also shows that research area dominated by very high steep hills (more than 55%). Statistical analysis between the fractal value of lineament in Digital Elevation Model and fractal value of lineament in Bouguer anomaly countour as well the fractal value of topography countour and fractal value of Bouguer anomaly countour shows that the relationship was not significant. Further, the entire result of this verified research shows clearly that geomorphology conditions represents subsurface geological phenomenon.

1. Introduction

Bumiayu has a complex geological structure and lithology types including plain to steep hills morphology. Variations of this landform are affected by endogenous factors (tectonic style) as well as exogenous factors (weathering and erosion). In understanding the phenomenon of land formation, especially in terms of the influence of endogenous factors, required a special instrument that is able to represent visually Bouguer anomaly phenomenon. One method that can be used is a method of Bouguer anomaly. Qualitative analysis of Bouguer anomaly contour has a tendency to weakness in the form of perceived differences in interpretation of data. Simplification method Bouguer anomaly contour visualization into a simpler form is very important to do. One of the instruments to analyze the quantitative interpretation and simplify the contour map is fractal method. However, the method of fractal has not been developed comprehensively, in particular when it is used to identify the relationship between the landscape and the Bouguer anomaly phenomenon. Based on the presentation, the authors are interested in knowing how the relationship remedies landscapes and Bouguer anomaly phenomenon and to examine various factors that influence such as lithology and geological structure.
2. Methodology

The process of the formation of structure deformation illustrates the long history of an area. Indications of structures that can be recorded on the Earth's surface can be analyzed using several methods, including: Processing of lineament using DEM, performed on the image of ASTER GDEM Bumiayu area. The ASTER GDEM image is processed using the program map information for later withdrawal of lineament, including lineament ridges and lineament of the valley with the help of the Global Mapper program.

Gravity anomaly map is a map that overlay Bouger Anomaly countour and regional Geological map of the study area [3][6] using simple gravity anomaly Bouguer density of 2.18 g / cm$^3$. Each observation point anomaly derived from equations:

\[
AB = g_{obs} - g_{t} + FAC - BC + TC \quad \text{................................................. (1)}
\]

Bouger Anomaly (AB), using Equation (1) is total of Gravity Observation ($g_{obs}$), Theoritic gravity ($g_{t}$), Free Air Correction (FAC = 0.3086 mGal/m), Bouguer Correction slab (BC = 2\pi G \rho mGal/m), Topography Correction (TC). Bouguer anomaly map (Figure 2.1) derived from about 400 observation points Bouguer anomaly that covers the whole of the study, by observation point distribution randomly (random).

The methods used in the calculation of the fractal dimension using a box counting method or the dimensions of the box. This method can be applied to objects that are self-similar statistical or statistical self-affine fractal. The box counting method is done by making certain sided grid ($r$) on a fractal object. [1][2][4][7][8]

We denote the cut or the set-fractal as $F$ and its sum inside the surrounding $r$-sided box is $N_r (F)$. The calculation of this value is done iteratively until the smallest value of fractal is achieved. In this way, the small variation of $F$ value to $r$ can be plotted in a logarithmic graph. The dimension of this calculation can be determined from the slope of the plot.

\[
D = \lim_{r \to 0} \frac{\log N_r (F)}{-\log r} \quad \text{.......................................................... (2)}
\]

The same way done well to get the value of the fractal dimension (equation 2) for other variables, and then tested using statistical probabilistic.

3. Result and Discussion

3.1 Surface Data

Folding direction (either Syncline or anticline) generally has a direction Northwest-Southeast and West-East. Folding form of Syncline in the area of research are Syncline Cisaat and Penujah. Based on observations of the Digital Elevation Model (DEM) and field data [5], an indication of the geological structure in the form of transform dextral fault can be analyzed based on the evidence in the form of offset, the lineament of the ridge, as well as data fractal.

The landscape is a product of tectonic processes and the formation lithology. The landscape in the study area is dominated by fine clastic lithology types. The landscape of steep and very steep hills located in the northwest, South, Northeast-Southeast with different characteristic lithology.

3.2 Subsurface Data
Based on data from the overlay of Bouguer anomaly contour map and topographic contour can be interpreted that in the Central part of the study area are dense anomaly contour, while the topographic contours visible tenuous. This is because the condition of the surface has experienced high attrition with an indication of the form of fine clastic lithology type. In the Northeast to the Southeast Bouguer anomaly contour seemingly tenuous, this is because in these areas there is a region of the magma chamber, while the surface region is an indication of coarse clastic lithologic type. From the results of spatial analysis between the two maps can be analyzed that there is a difference between the surface and geologic conditions below the surface phenomena. This can be caused by several factors, including tectonic activity, erosion intensive, sedimentation, and lithification rocks. While the phenomenon is quite different under the surface because the subsurface region is still plagued Oleg erosion processes and activities such as rock lithification.

Based on the analysis and interpretation of landforms Bouguer anomaly contour, in the Northeast part of the study area are likely to experience the eruption of magma to the surface caused by the eruption of Mount Slamet. This led to the formation of a landscape seen in the form of plateaus or hills. In the Central and Southern regions experienced research indicated a fairly intensive process of erosion. This was shown by the data morphometry Bouguer anomaly contour that shows landform steep hills, while the shape of the landscape seen today by exposure to map morphometry or slope is very gentle form of plain land.

3.3 Fractal Data

Statistical interpretation of results between fractal lineament Bouguer anomaly contours and lineament fractal surface using statistical analysis test t-Test. Based on statistical analysis test, t-test showed that the value of t = -7.1136, and table = 2.0032. T-count table may mean that statistical analysis t-test were not significantly different, and Ho is unacceptable, so the value of fractal lineament of Bouguer anomaly with a value of fractal lineament of maps Digital Elevation Model (FLDEM) is the same, or not significantly different.

![Figure 1 Fractal Lineament of surface and subsurface](image)

Based on the results of statistical test, fractal Bouguer anomaly contour and fractal topographic contours, table value obtained from the calculation of the statistical analysis of -7.7423 and 2.0129 T-count (Figure 1). Based on this data, Ho is accepted that there is a relationship between the Bouguer anomaly contour topographic contours. H1: $\mu_1 \neq \mu_2$ there is no real difference between the value of
fractal contour Bouguer anomaly (FCBA) with fractal topographic contours of topographic maps (FCT).

The results of different test t-test Variance Two Samples Assuming Unequal show t-count < t-table. It can be interpreted that there is no significant difference between the value of the fractal Bouguer anomaly contour gradient (FCBA) with topographic slope value of the topographic map (FCT) with significance level of $\alpha = 5\%$. Therefore the surface contour (topography) is different under the surface contour (Bouguer anomaly contour).

Different test results Two Samples t-test showed t-count Assuming Equal Variance < t-table. It can be interpreted that there is no significant difference between the value of Bouguer anomaly contour gradient (FCBA) with topographic contour value (FCT) with significance level $\alpha = 5\%$. Statistical test results using t-Test can be seen that the value of the Bouguer anomaly contour topographic contour values were not significantly different.

Below the surface contour basically has not undergone sedimentation or erosion, while the contour of the surface has undergone sedimentation in a long time. In addition contours on the surface have also experienced the effect of erosion and deposition of volcanic material.

Data values drainage density (Dd) and value drainage fractal pattern that has been obtained from the previous analysis will be tested hypotheses regarding the correlation between the density of the existing drainage pattern of the fractal pattern value stream drainage patterns in the area of research (Figure 2). This hypothesis test is also intended to determine that the value of fractal patterns jetting flow patterns play a role on the drainage pattern density value (Dd) in the research area.

4. Conclusion

The result of this research supports the assumption that the surface geomorphology (landscape) in Bumiayu area and the surrounding is a reflection of the Bouguer anomaly. The application of the fractal concept supports the conclusion that the characteristics of fractal unit geomorphology represent the Bouguer anomaly in this particular area. The T-test statistical analysis on the fractal dimension of the Bouguer anomaly contour and the contour topographic have a relationship that is insignificantly different, while the value of river density (Dd) to the value of fractal rivers, have a high correlation, this shows the value of the fractal dimension of river flow patterns correlated with deformation patterns in the study area.
5. Acknowledgement

Authors are grateful to all those who have helped in the research, preparation until the publication of this research. Primarily to Laboratory of Geomorphology and Remote Sensing and Laboratory of Geophysics Faculty of Geology, Padjadjaran University.

References

[1] Aviles, C. A., and C. H. Scholz., 1987 Journal of Geophysical Research V.92 no.B1 331-344.
[2] Bunde A. and Havlin S., 1994. A brief introduction to fractal geometry. In ‘Fractals in Science’, pp 1-25, Springer-Verlag, Berlin
[3] Djuri, M., Samodra, H., Amin, T.C., Gafoer, S. 1996. Geological Map of Purwokerto and Tegal Quadrangle, Java. Scale 1 : 100.000. Bandung: Geological Research and Development Centre
[4] Falconer, K., 1990. Fractal Geometry. John Wiley & Sons
[5] Hirnawan, F., 2009, A Measure of Intense tectonic in West and Central Java Through Manifestation of River Basin Morphometry Development on Quaternary Volcanic Deposits, Jurnal Geologi Indonesia, Vol. 4 No.4 December 2009: 285-300
[6] Kastowo, dan Suwarna, N., 1996. Geological Map of Majenang Quadrangle. Scale 1:100.000. Bandung: Geological Research and Development Centre
[7] Mandelbrot, B. B., 1982. The Fractal Geometry of Nature. San Francisco, W. H. Freeman and Company
[8] Turcotte, D. L., 1992. Fractals and Chaos in Geology and Geophysics. Cambridge University Press. 221 p.