Lineament mapping using remote sensing and correlation on surface manifestation distribution in Gunung Endut, Banten Province, Indonesia

F H Tanjung, Dhianaufal, A U Rahmadhani, F M H Sihombing, D N Sahdarani and Supriyanto

Geoscience Study Program, Faculty of Mathematics and Natural Sciences (FMIPA), Universitas Indonesia, Depok 16424, Indonesia

Corresponding author’s email: supriyanto@sci.ui.ac.id

Abstract. Remote sensing has become one of the most used methods in geothermal exploration. This technology is used to detect the presence of lineaments located in the area of geothermal exploration. The lineament can be expressed in the form of ridges and valleys. These features are closely related to the existence of geological structures. Geological structures act as weak zones (permeable zones) for the fluid to come out to the surface which will provide the circulation that forms the geothermal system. The research area is geographically located in 06°35'58" S and 106°17'01" E. Overall, the area of the research is about 325 km² included 51 sub-districts in Lebak Regency, Province of Banten. This research area covers the entire area of Mount Endut and east of Mount Talaga and was included in the geological map of Leuwidamar dominated by Pleistocene Endut volcanic rocks (Qpv) which consists of volcanic breccia, lava, and tuff. The geological structures that developed in the study area are in the form of faults and folds. The data used in lineaments extraction were Digital Elevation Model derived from ASTER GDEM which has a vertical accuracy of 10–25 m. Meanwhile, the data on the existence of manifestations were obtained from the Geothermal Potential book published by the Geological Agency, Ministry of Energy and Mineral Resources. In extracting lineaments, the PCI Geomatica software was automatically used with the LINE algorithm. In the calculation of ground surface temperature, ENVI software is used together with The Law of Wien Shift. The general direction of alignments obtained is NNW-SSE. There are 5 unexpected faults related to the distribution of surface manifestations. The results of the structure interpretation in general show the relationship with the existence of surface ground temperature anomalies distribution. This is caused by the existence of a weak zone (permeable zone) as a place for the hot fluid to escape which will affect the surface temperature of the ground.

Keywords: Lineament, geological structures, manifestation, Mount Endut

1. Introduction
The technology of remote sensing is widely used in various fields, one of which is in geothermal exploration. This technology is considered easier to use, accurate, and economical. The purpose of choosing this technology is to delineate the geothermal prospect area which has been a problem all this time [1].
One of the features observed in delineating geothermal prospect areas is lineaments. The lineament types expressed in satellite imagery can be in the form of ridges and valleys or rivers [2]. Observation of lineaments is important to do because lineaments are closely related to the geological structure that develops in the area, either in the form of faults or joints [2]. A sharp turn of the river or a change in the orientation of the ridges that will form a lineaments pattern can be caused by a fault [3].

The knowledge of the existence of geological structures is very important in geothermal energy exploration. The geological structure in the form of faults and fractures acts as weak zones (permeable zones) for the fluid to escape to the surface which will form manifestations on the surface in the form of hot springs, geyser, etc. The fluid that comes out to the surface (discharges) will be replaced with incoming fluid in the form of meteoric water (recharges) which will then be reheated. This process will form a sustainable system called the geothermal system [2].

The structures in the research area will be visible through the lineament features that are automatically identified in the ASTER Digital Elevation Model (DEM) data display. However, not all lineaments are related to faults, it could be caused by differences in geological formations (the lithology of the research area). Manual correction of the lineaments data with the help of regional structure data needs to be done to harmonize the proven structure data in the research area with new structural data that can be seen from the lineaments pattern [3]. The lineaments pattern will then be associated with the distribution of geothermal manifestations on the surface and the ground surface temperatures. Therefore, the purpose of this paper is to delineate the geothermal prospect area by conducting lineament mapping which is associated with the distribution of geothermal manifestations on the surface in the area of Mount Endut.

2. Geological setting of research area

The research area is geographically located in 06°35'58" S and 106°17'01" E. Overall, the area of the research is about 325 km² included 51 sub-districts in Lebak Regency, Province of Banten. This area was included in the geological map of Leuwidamar, Java 1109–03 published by Pusat Penelitian dan Pengembangan Geologi [4].

The constituent lithology of the research area was dominated by Pleistocene Endut Volcanic Rocks (Qpv) located in the middle of the research area which consists of volcanic breccia, lava, and tuff. Pumice tuff, tuffaceous sandstones, conglomerate breccias, and marl which are included in the Pliocene Genteng Formation (Tpg) located in the north of the research area. Bojongmanik Formation (Tmb), which consists of sandstones, limestones, and claystone aged Late Miocene, is located in the Southwest and Northeast of the research area. Bedouin Formation (Tmd) consists of a conglomerate, Sareweh Formation (Tms) consists of claystone, and Andesite rock (Tma), each of which is Middle Miocene-Late Miocene [5].

As shown in the figure 1, the geological structures that develop in the research area are in the form of faults and folds. Types of faults found are thrust faults, normal faults, and also strike-slip fault (dextral and sinistral) found in the Bojongmanik Formation, Sareweh Formation, and also Bedouin Formation. The fault has a North-South general direction, according to the Sunda pattern which is thought to form in the Late Eocene-Oligocene (52–32 Mya) while the structure of the fold axis has the West-East general direction, according to the Java pattern which is thought to form in the Late Oligocene-Miocene based on geological map of Leuwidamar, Java 1109–03.

3. Methodology

The data used in lineaments extraction is Digital Elevation data with Aster Global DEM type. The data was downloaded on Monday, March 05 2018 on the USGS page (https://earthexplorer.usgs.gov/) [6]. The use of ASTER GDEM data in this study is due to the high resolution of the data for land surface observation in geological studies [5]. The data has an accuracy of 10–25 m produced by U.S. National Aeronautics and Space Administration (NASA) and Japan’s Ministry of Economy, Trade, and Industry
(METI). For processing surface temperature, Landsat 8 satellite image data has been used with Oli Tirs sensor. The data is in path 123 row 64 recorded on August 27, 2017, downloaded on September 14, 2017 on the same page. The band which is used is band 10. While for surface temperature, the data is obtained from the Geothermal Potential book published by the Geological Agency, MEMR.

3.1. Structure delineation

In delineating a fault structure, it is a must to first obtain lineament data extracted using PCI Geomatica software. The algorithm used in straightness extraction uses the LINE (Lineament Extraction) modular algorithm. There are six parameters used, namely, RADI, GTHR, LTHR, FTHR, ATHR, and DTHR with their respective values 10, 60, 30, 3, 30, 20 [2]. Broadly speaking, there are two types of data used, ASTER GDEM data and ASTER GDEM data that have been processed to get Hillshade. The ASTER GDEM data is displayed using the Global Mapper software by setting the configuration in the form of an altitude of 100 m and using the atlas shader display.

In ASTER GDEM data, azimuth variations of 0°, 4°, 90° and 135° are also performed. ASTER GDEM data is given shading using Envi software with an altitude setting of 100 m, and also azimuth angle variation the same as the previous data. ASTER GDEM data is done by shading with the aim to sharpen the appearance of the data, while the azimuth angle variation is done to get different display variations according to the irradiation angle. The total data display used in this study are eight maps. Each of the maps will then be interpolated to get a lineament density map using ArcGIS software. After obtaining lineament density, the geological structure will be interpreted based on lineament density. The interpretation of the geological structure is also guided by regional geological structure data so that the results of the interpretation are expected to be more objective.

3.2. Determination of ground surface temperature

In determining the ground surface temperature, band 10 is used from Landsat 8 data. Band 10 is a thermal band that contains information on the amount of energy radiated by the surface of the ground which then can be processed into surface temperature information through a radiometric calibration process. The information contained in band 10 was originally only in the form of a digital number which would then be calculated to be a radiance value in the form of pixel data. Then the radiance value will be converted to a temperature value (Kelvin). The temperature value in the form of Kelvin will then be calculated to get the temperature value in the form of Celsius (°C). Determination of band 10 usage in calculating surface temperature is based on the Wien Shift Law [7] Finally, the surface temperature information is made in the form of an anomaly map with information that has been categorized first.

![Figure 1. (a) Research area, and (b) geological map of research area.](image)
4. Results and discussion
The general direction of lineaments obtained is N-E. The lineament with another direction is likely as the result of different azimuth angle configuration. The difference in azimuth angle forms shading which is then considered as lineament by software. Overall the direction of lineament still shows the same direction as the regional fault with a general direction of N-E, so that the automatic extraction results of the lineament can still be accepted (figure 2 and figure 3). After interpreting the geological structure, there are five presumed faults (F1, F2, F3, F4 and F5), each of which has a sequential length of 12 km, 14 km, 8 km, 6 km and 4 km. The general direction of the fault plane resulting from the interpretation is NW-SE. Based on the Anderson Fault Concept the main stress (σ1) forming the fault originates from the NW-SE direction so that the type of fault interpreted is a strike-slip fault.

It is also in corresponding with regional fault types that form both sinistral and dextral strike-slip faults. As shown in figure 4 and figure 5, not all lineaments are related to faults, some can also be related to geological formations or geological structures in the form of folds. Hard rocks tend to be resistant compared to other rocks, so that they can form a ridge lineament. Folds will also form the lineament along the direction of the fold axis that is formed. It can be seen in the north and south of the research area, there are folds with west-east fold axis direction. Those folds have lineaments with the same direction, so it can be concluded that those lineaments are not related to fault.

As additional data in the interpretation of the geological structure, it can be seen from the sharp turn of the river and also from the ridge offset. Both can support the existence of faults so that the fault interpretations can become more objective. Based on the results of the research conducted, there is a relation between the structure of the lineament interpretation and the distribution of surface geothermal manifestations. The manifestation lies on the Pleistocene Endut Volcanic Rocks (Qpv) consists of volcanic breccia, lava, and tuff. Surface geothermal manifestations (HS 1, HS 2, HS 3), each of which has a temperature of 57 ºC, 53 ºC and 88 ºC. Not all geological structures of interpretation are related to the presence of surface geothermal manifestations. This may be caused by a lack of data or different formations. Formations that have ductile lithologies will tend to be difficult to break during tectonic compression compared to brittle rocks.

To support the temperature data of surface manifestations, a comparison of ground surface temperature data is made. Ground surface temperatures were obtained sequentially (HS 1, HS 2, HS 3), 29 ºC, 24 ºC and 25 ºC. The temperature between the manifestations and the ground surface is concluded to be unrelated, due to the considerable differences between the two data. The most likely thing which causes large temperature difference is differences in the manifestation data retrieval season. In the summer, the temperature will get high while during the rainy season the temperature will go lower.
Figure 3. Shade relief DEM map of research area with rosette diagram of the lineament, (a) 0º azimuth, (b) 45º azimuth, (c) 90º azimuth, and (d) 135º azimuth.

Figure 4. Lineament density map of research area from ASTER GDEM data, (a) 0º azimuth, (b) 45º azimuth, (c) 90º azimuth, and (d) 135º azimuth.

Figure 5. Lineament density map of research area from shaded relief ASTER GDEM data, (a) 0º azimuth, (b) 45º azimuth, (c) 90º azimuth, and (d) 135º azimuth.
There are ten numbers of ground surface temperature anomalies that may be related to the presence of surface manifestations. Those ten anomalies show temperatures which are relatively higher than the surrounding ground surface temperature. Based on figure 6 and figure 7, the surface temperature anomalies range from 29–32 °C. The structure of the interpretation results in general shows relationship with the existence of the ground surface temperature anomalies distribution. This is caused by the existence of a weak zone (permeable zone) as a place for the hot fluid to escape which will affect the surface temperature of the ground. To make sure this statement, it needs the direct measurement to the research area because the ground surface temperature anomalies may happen due to several reasons, such as the absence of vegetation, elevation, and the presence of buildings. The interpretation of the geological structure of the lineament will then be associated with the distribution of surface geothermal manifestations found in the research area, also with the surface temperature anomaly.

**Figure 6.** Temperature anomaly map from ASTER GDEM data, (a) 0° azimuth, (b) 45° azimuth, (c) 90° azimuth, and (d) 135° azimuth.

**Figure 7.** Temperature anomaly map from shaded relief ASTER GDEM data, (a) 0° azimuth, (b) 45° azimuth, (c) 90° azimuth, and (d) 135° azimuth.
5. Conclusion
Based on the research conducted, authors conclude several things, there are the lineament obtained from the results of automatic extraction shows that there are five presumed faults which have the corresponding direction to the regional faults. In general, there is a relationship between faults resulting from interpretation of lineament data and the distribution of surface geothermal manifestations, although not all presumed faults have direct connection. There is a relationship between ground surface temperature anomalies and the existence of structures resulting from interpretation of lineament data.

Acknowledgments
This work was financially supported by Universitas Indonesia under research grant PITTA 2018 with grant contract number 2316/UN2.R3.1/HKP.05.00/2018.

References
[1] Ke-sheng S and Ming-yuan H 2010 Proc. World Geothermal Congress (Bali, Indonesia) pp 1-4
[2] Herlambang R F and Novranza 2016 E-Journal SNF V 65-72
[3] Pranggawan A, Maryanto S and Rachmansyah A 2016 Jurnal Penginderaan Jauh 13 1-12
[4] Kusnandi D, Rezky Y, Supeno and Raharja B 2007 Penyelidikan Geologi dan Geokimia Panas Bumi Daerah Gunung Endut (Ministry of Energy and Mineral Resource) available at http://psdg.bgl.esdm.go.id/index.php?option=com_content&view=article&id=426&Itemid=431
[5] Adama O, Verdiansyah and Sukartono 2017 Prosiding Seminar Nasional XII, Rekayasa Teknologi Industri dan Informasi (Yogyakarta) (Yogyakarta: Sekolah Tinggi Teknologi Nasional Yogyakarta) pp 217-22
[6] USGS Science for a Changing World 2018 available at https://earthexplorer.usgs.gov/
[7] Wien W 1896 Annalen der Physik Und Chemie 294 662-9