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Lineament Geomorphologic Analysis to Identify Fault in Mount Semeru, East Java

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Abstract: This research analyzes the morphological lineaments on Mount Semeru, East Java. The morphological lineament is processed using satellite imagery as a digital elevation model (DEM), downloaded on the Badan Informasi Geospasial (BIG) page. The image was processed using Global Mapper software with azimuth angles of 0^0, 45^0, 90^0, 180^0, and 315^0 and produced a lineament map that had been overlaid from all azimuth angles and created a morphological lineament map with various groups of values from high to low. From the analysis that has been carried out, it was found that there are 103 lineaments, most of which are spread in the area west of the crater of Mount Semeru, with the dominant direction showing a west-southwest – east-northeast orientation.

Keywords: DEM; Lineament; Mount Semeru

Introduction

The southern part of East Java is prone to earthquake disasters caused by tectonic dynamics dominated by the India-Australia plate moving north and colliding with the relatively stationary Eurasian plate (Lihayati et al., 2022; Purbandini et al., 2018; Souisa & Sapulete, 2021). Apart from that, earthquakes can also be caused by other fault activity, both regional and local, in South Java (Fashihullisan et al., 2014). One of the critical elements in geological earthquake mitigation research is to carefully map the location of active earthquake-producing fault lines from morphological formations due to movement, as well as quaternary deposits in deformation zones (Pustlitbang PUPR, 2017; Spalletti et al., 2023; Tripathi et al., 2022).

Determining geological lineaments can result in the characterization and identification of active faults, tectonic units and seismically active areas (Bunaga et al., 2022; Ibanez et al., 2022) However, detecting geological lineaments in the field often requires a lot of money and time and sometimes cannot even be done due to physical and geographical challenges. Therefore, over the last decade, the use of remote sensing to detect geological lineaments has become common, providing effective results in various applications (Hajaj et al., 2022; Iqbal & Juliarka, 2019; Rais et al., 2020; Rajasekhar et al., 2018).

According to (Van Zuidam, 1983), there are several geomorphological aspects in an area, including morphological and morphogenetic aspects. Data in geomorphological mapping can produce morphological patterns of lineaments and contour patterns. Lineament is a linear phenomenon on an object on the earth's surface, which is interpreted through remote sensing technology or aerial photography (Neto et al., 2022; Rafi et al., 2023; Wahyuningsih et al., 2019). The lineament phenomenon reflects areas of discontinuity in rocks, such as cracks, joints, and faults, which are morphologically part of developing hill valleys (Owolabi et al., 2021; Supriatno et al., 2017). Lineament is also often referred to as a phenomenon that is linear or curved at surface weak points via remote sensing

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technology (Greg Hall, 2011; Wajid et al., 2021) on an earth surface object interpreted via remote sensing technology or aerial photography. Remote sensing is often used to detect fault movement (Saint Jean Patrick Coulibaly et al., 2021; Viveen et al., 2021). Surface appearances in image data that produce lineaments are a description of geomorphological phenomena (caused by surface relief) (Ahmadi & Pekkan, 2021; Supriatno et al., 2017).

In this research, geomorphological observations will be carried out using digital topographic data DEM (Digital Elevation Model), which is related to fault estimation, to see the structure's condition at the fault junction in Mount Semeru. DEM (Digital Elevation Model) research conducted by explains that DEM can be used to obtain information about geological structures by extracting shaded relief, lineament, slope, aspect, drainage network, and curvature information (Mahbub & Ragil, 2021; Putra et al., 2023; Raharja et al., 2020; Yanis et al., 2019).

The aim of this research is to determine the number of lineaments with the dominant direction of the lineament in the research area. It is hoped that the results of this research can be used as a reference in analyzing active faults using similar methods in other areas that have similar geological conditions and become an ongoing research.

Method

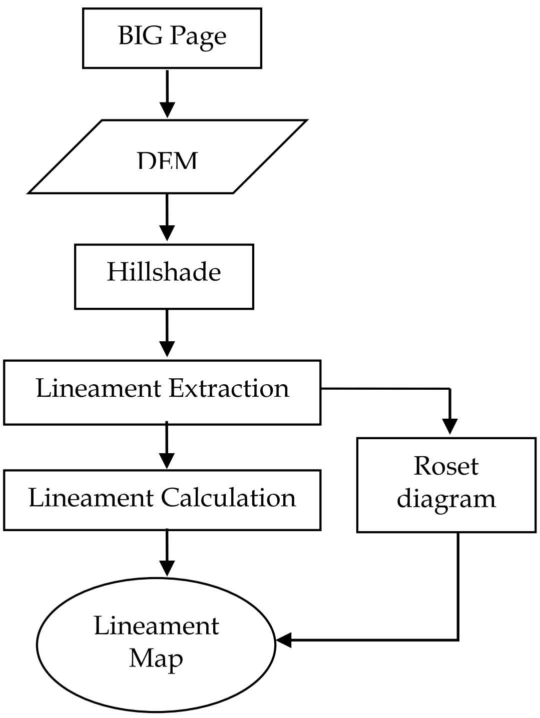

Figure 1. Lineament analysis method

This research was carried out on the Semeru Volcano, located between Malang Regency and Lumajang Regency, East Java Province, Indonesia (see Figure. 1). In analyzing the straightness of the DEM data structure, it is obtained from the Geospatial Information Agency (BIG) website. DEM data is converted into XYZ format where X and Y are positions (Longitude, Latitude) and Z is elevation (m) (Abdelouhed et al., 2021). DEM data produced by SRTM is extracted into the hillshade by providing solar radiation angles of 0^0, 45^0, 90^0, 180^0, and 315^0 and an altitude of 45^0. The varying lighting angles function so that all slopes can be seen from different angles. The altitude is chosen at an angle of 45^o to get the same shadow size as the object hit by the light. Analysis of the topography of the earth's surface provides the appearance of scoured faults and fractures. Next, lineaments are drawn manually based on fault and fracture analysis for each difference in sun elevation angle on the hillshade. Manual (visual) drawing is done by digitizing each joint and fracture using a polyline shape in ArcGIS software. The straight lines obtained from each hillshade are then overlaid. The lineament, which is estimated to be a lineament with the same position, is re-digitized.

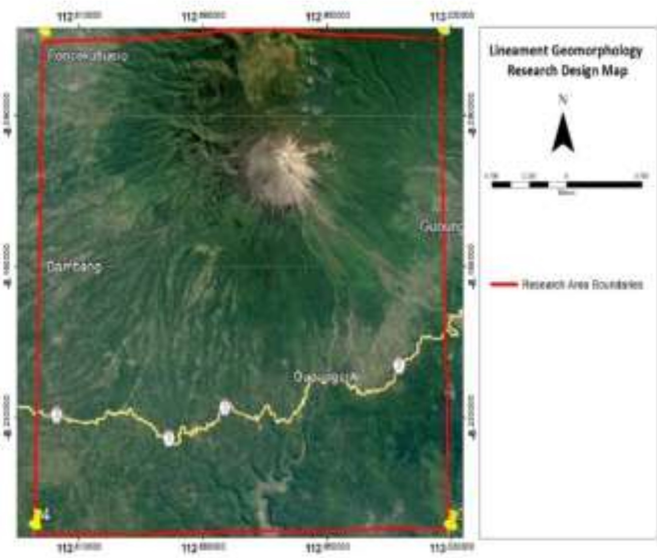

Figure 2. Research Area Design

Result and Discussion

A preliminary study of the geological structure is necessary before one comes to the geophysical method's exploration stages. The geological structure is analyzed because the geological structure in the form of faults and fractures is related to the appearance of lineaments. DEM data extraction was carried out by analyzing lineaments by manually identifying lineaments by generating a hillshade lineament map with various lighting angles. DEM data was obtained from the

Geospatial Information Agency (BIG) website. The lighting angles used are 0^0, 45^0, 90^0, 180^0, and 315^0, as shown in Figure 2.

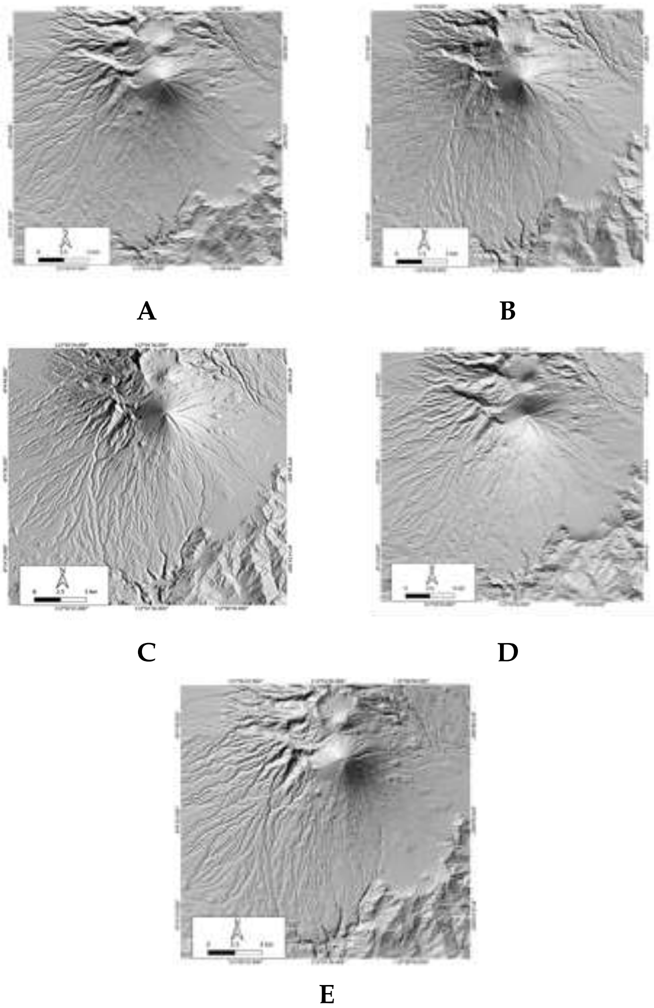

Figure 3. Hilshade map with different azimuth directions (a) 0^0, (b) 45^0, (c) 90^0, (d) 180^0, and (e) 315^0.

DEM data extraction was carried out by analyzing lineaments by manually identifying lineaments by producing hillshade lineament maps with various lighting angles and then combining all angles to obtain the most dominant lineaments or structural morphology in the study area.

Different degrees of illumination make it easier to observe the dominant lineament pattern. The overlay results of all illumination angles are displayed in a lineament map with geometry focusing on lineaments' number, length and orientation.

Based on the results of the lineament analysis taken from hillshade map data, which has been overlaid from various angles, there are 103 lineaments, most of which are spread in the area west of the crater of Mount Semeru with the dominant direction showing a west-southwest – east-northeast orientation (N60^0E – N70^0E) can be seen in Figure 3. From the geological map, the lineament area is formed from Jembangan volcanic deposits, composed of pyroxene andesite lava, porphyre, and sandy tuff. There are also outcrops of pumice rock and andesite lithics. This is to the results of the analysis carried out by analyzing the lineaments on the hillshade map by paying attention to the characteristics of the lineaments, which indicate morphological features in the form of faults, namely sections of straight hillslope segments and relief forms in the form of straight lines which indicate the presence of geological structures.

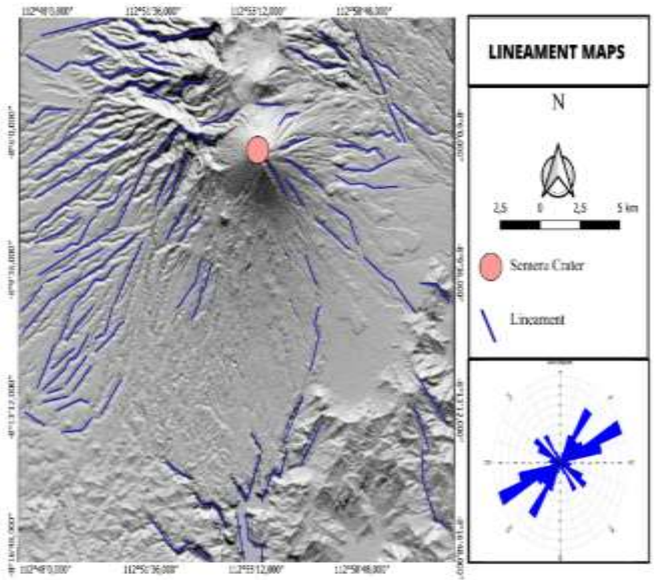

Figure 4. Lineament Map of the Research Area

The characteristics of faults and fractures can be seen based on length, curvature, segmentation, separation, direction, and so on. Determining the direction of a lineament resulting from the extraction means that the lineament data is converted into a rosette diagram. The rosette diagram will represent straightness values based on vector parameters (direction and magnitude) of the phenomenon in a specific direction and the number of events (Ahmad, 2021). According to (Petrov et al., 2017) lineaments with more than 2000 m lengths can indicate more accurate faults. Therefore, the straightness analysis is analyzed using the lineament length classification shown in Figure 4.

Based on the rose diagram, lineaments with less than 1000 m in length show a west–southwest–east–northeast (N70ᴼE – N80ᴼE) orientation (Figure 4. a). This orientation is the same as the lineament with a length of more than 2000 m (N60ᴼE – N70ᴼE) (Figure 4. c). Furthermore, the long lineament of 1000 to 2000 m length shows a southwest-northeast orientation (N40ᴼE – N50ᴼE). (Figure 4. b).

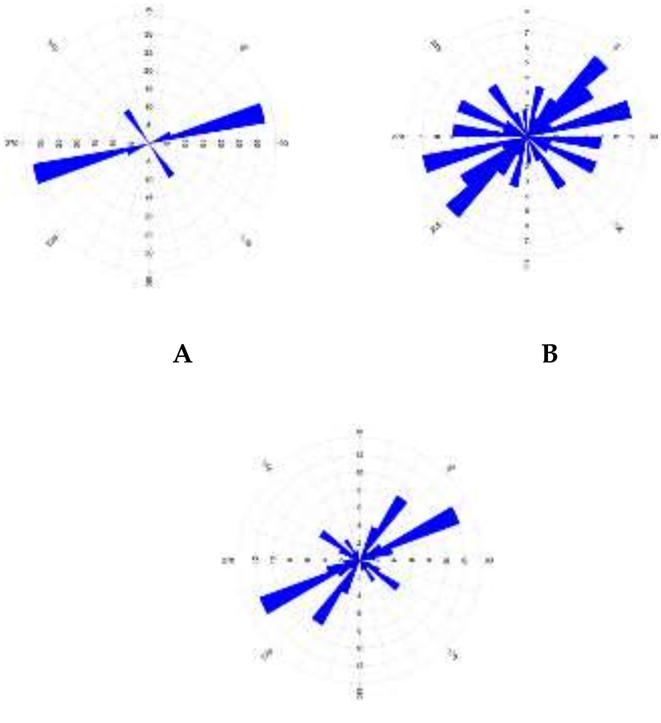

Figure 5. Lineament analysis using a number accumulation rose diagram with lineament length classifications (a) less than 1000 m, (b) 1000 to 2000 m, and (c) more than 2000 m.

Conclusion

DEM data can be used to obtain information about geological structures through extraction of lineament information. Analysis of gemorphological features in the form of lineaments which indicate that faults in the study area have a dominant orientation in the west-southwest - east-northeast direction (N60^{O}E - N70^{O}E). Analysis of DEM data in general can only determine indications of where faults are found, while the type and direction of faults cannot be interpreted from the DEM.

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Author Contribution

Author contributions include Sukir Maryanto and Alamsyah M.Juwono: focusing on methodology, reviewing, etc.; Dian Pratiwi Malik: collecting data, processing data, analyzing data, and writing the original manuscript.

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Conflicts of Interst

The authors declare that there is no conflict of interest regarding the publication of this paper

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