# The extraction and analysis of lineament density from digital elevation model (DEM) in Libungo geothermal area, Gorontalo

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Abstract. Remote sensing often used in geothermal exploration because it was considered has many advantages. The aim of this research is to extract and analyze the lineament density in the Libungo geothermal area based on a Digital Elevation Model (DEM). Lineament is obtained from Digital Elevation Model (DEM) satellite image data downloaded from the Geospatial Information Agency (BIG) page. Digital Elevation Model (DEM) data processing uses Geomatica software to extract the lineament automatically. Extracted lineament is processed using ArcGIS software to produce a lineament density map and processed using Rockworks software to generate direction. Lineament density maps help identify permeability in the Libungo geothermal area. Based on the results of the extraction and lineament density analysis, it is interpreted that the Libungo geothermal area has a high density value. High density values are associated with good permeability. A direction that affect lineaments in the Libungo geothermal area are northwest-southeast in the direction of Gorontalo's main geological structure.

#### 1. Introduction

Lineament is a linear surface in a landscape. Lineament is generally associated with faults, linear fault zones, bending deformation and increased permeability of the earth's crust. Lineament is also associated with linear chains of several geological features such as laccolites and volcanoes. Lineament is expressed in topography [1–3].

Lineament is generally referred to in remote sensing analysis of fractures or structures. Lineament can be observed from space as well as through the air. Aerial imagery, satellite imagery, seismic models, and thematic maps can record lineament [2,3].

Remote sensing is one of the methods used in geothermal exploration because it has many advantages. Remote sensing can determine the lineament of the geothermal area at a low cost. Lineament in a geothermal area can be determined using Digital Elevation Model (DEM) imagery [4–8].

Gorontalo area has potential geothermal resources. One of them is in Suwawa, namely the Libungo geothermal area. The study area is the Libungo geothermal area which is administratively located in Bone Bolango Regency. Astronomically it is located in the coordinates between 123°3'50.39" - 123°10'48.42" E dan 0°28'27.93" - 0°33'25.86". Libungo geothermal area has three manifestation points in the form of hot springs.

The Libungo geothermal area is composed of Bilungala Volcanics (Tmbv), Bone Diorite (Tmb), Pinogu Volcanics (Tqpv), Lake Deposits (Qpl), and Reef Limestone (Ql) (Fig 1). Bilungala Volcanics

(Tmbv) is early to late miocene, composed of breccia, tuff, andesite lava, dacite lava, and rhyolite lava. Bone Diorite (Tmb) is approximately late Miocene, composed of granite, granodiorite, diorite, and quartz diorite. Pinogu Volcanics (Tqpv) is thought to be pliocene to plistocene, composed of tuffs, lapilli tuffs, breccias and lava. Lake Deposits (Qpl) are composed of sandstones, claystones and gravel while Reef Limestone (Ql) is composed of coral limestone and clastic limestone. Both of these units are holocene [9,10].



Fig 1. Regional geology of research area (9).

The regional geological structure in the study area is northwest-southeast and almost north-south. The regional geological structure in the central part of the study area is northwest - southeast intersecting Bilungala Volcanics (Tmbv), Bone Diorite (Tmb), Pinogu Volcanics (Tqpv), and Lake Deposits (Qpl). The regional geological structure in the southern part of the study area which is almost north - south intersecting the previously formed structures that traverse northwest – southeast [9,11].

Previous research that has been carried out in the Libungo geothermal area includes geological, geochemical, geophysical research and gradient thermal well drilling. Geological research describes the morphology, manifestations, hidrology and geothermal systems [12,13]. Geochemical research describes the temperature of the subsurface reservoir [14]. Geophysical research includes magnetic, gravity, electrical and electromagnetic surveys [15–17]. Gradient thermal well drilling describes overburden and cap rock [18].

Previous research using electrical can prove the existence of shallow subsurface structures but cannot prove the effect of tectonics on shallow subsurface structures [19]. Previous research that analyzed the geological structure using the google earth could show lineament but could not explain its effect on permeability and did not explain the tectonics that influenced it [12].

This study aims to extract and analyze lineament density in the Libungo geothermal area using the Digital Elevation Model (DEM) data. Lineament density extraction and analysis can be used to determine the permeability and control of structures in the Libungo geothermal area.

## 2. Methods

## 2.1. Data collecting

The data used in this study is the Digital Elevation Model Nasional (DEMNAS). DEMNAS data is downloaded on the website of the Geospatial Information Agency (BIG). DEMNAS is built from several data sources including IFSAR, TERRASAR-X and ALOS PALSAR data, by adding the stereo-plotting Masspoint data. IFSAR data has a resolution of 5 m, TERRASAR-X has a resolution of 5 m and ALOS PALSAR has a resolution of 11.25 m. DEMNAS 'spatial resolution is 0.27-arcsecond (~ 8 m). This resolution is higher than the resolution of SRTM DEM, ASTER GDEM, or ALOS

PALSAR which has a resolution of 1 arc-second (~ 30 meters).

DEMNAS data is downloaded on the Geospatial Information Agency (BIG) website by opening the DEMNAS grid page. Navigation on the map of Indonesia to the DEMNAS data sheet for the study area was selected using the button provided. The DEMNAS data sheet according to the study area is downloaded using the download link.



Fig 2. Flowchart of the research stages.

#### 2.2 Data processing and analysis

DEMNAS data is displayed in the Geographic Information System (GIS) application. Mosaic was done for several downloaded DEMNAS data sheets. Lineament data extraction is carried out in the Geomatics application. Furthermore, it is processed again using the Geographic Information System (GIS) system application for making a lineament density map. The lineament density map, then analyzed to see the permeability level of the study area.

The next stage is to determine the direction that affects lineament in the research area. Determination of the direction of stress using a rosette diagram. Furthermore, analysis of the direction was carried out against the direction of the main stress in the study area (Fig 2).

## 3. Geology of Research Area

The geomorphology of the study area is composed of volcanic hills, fluvial plains, lake plains and marine plains (Fig 3a). Volcanic hills occupy the southern mountains and mountains in the northeast of the study area. Volcanic hills are composed of andesite and volcanic breccias. The fluvial plain occupies the central part of the study area extending from the east to the west. The fluvial plain is composed of material formed by the fluvial process of the Bone River.

The lake plains occupies the northern part of the study area, extending from the west side of the volcanic hills to the west of the study area. The lake plains is composed of material such as gravel, sand and clay. Marine plains occupy the southern part of the study area, scattered along the coastal areas. Marine plains are formed due to marine processes such as waves and ocean currents in Gorontalo Bay.



Fig 3. a) geomorphology map; b) geology map.

The stratigraphy of the study area is composed of andesite, volcanic breccia, reef limestone, and alluvial deposits (Fig 3b). The Andesite occupies the southern mountains of the eastern part and the mountains of the northeastern part of the study area. Volcanic breccias occupy the southern mountains, extending from the western part of the andesite to the western part of the study area. The alluvial plain occupies the central to the northern part of the study area and the southern part of the study area. Reef limestones occupy the southern part of the coastal area.

#### 4. Results and Discussion

DEMNAS data was extracted in the Geomatica application. The result of DEMNAS data extraction is the lineament of the research area. An lineament was made between the lineament extraction and the regional geological structure of the study area (Fig 4).

The lineament was made in five regions, namely region A, region B, region C, region D, and region E (Fig. 5). Region A is an lineament between lineament extraction with the geological structure trending northwest - southeast. The regional geological structure trending northwest - southeast in region A is a geological structure in the middle of the study area. There is an lineament between lineament extraction with regional geological structures. The regional geological structure trending northwest - southeast is in moderate lineament level with the lineament extraction trending northwest southeast.

Region B is an lineament between lineament extraction with the geological structure trending northwest - southeast. The regional geological structure trending northwest - southeast in region B is a geological structure in the middle of the study area. There is an lineament between lineament extraction with regional geological structures. The regional geological structure trending northwest - southeast is highly lineament level with the extraction of lineament trending northwest southeast.

Region C is an lineament between lineament extraction with geological structures trending almost north - south. The regional geological structure trending north - south is a geological structure that cuts the geological structure trending northwest - southeast in the southern part of the study area. There is an lineament between lineament extraction with regional geological structures. The regional geological structure is trending north - south, in high lineament level with the lineament extraction trending north - south. Region D is an lineament between lineament extraction with the geological structure trending northwest - southeast. The regional geological structure trending northwest - southeast in region D is a geological structure located in the northeast part of the study area. There is an lineament between lineament extraction with regional geological structures. The regional geological structure trending northwest - southeast is in moderate lineament level with the extraction of lineament trending northwest southeast.



Fig 4. Extracted lineament and regional geological structure of study area lineament.

Region E is an lineament between lineament extraction with the geological structure trending northwest - southeast. The regional geological structure trending northwest - southeast in region E is a geological structure in the middle of the study area. There is an lineament between lineament extraction with regional geological structures. The regional geological structure trending northwest - southeast is in low lineament level to the extraction of lineament trending northwest southeast.

DEMNAS data extracted and processed using Geomatics applications and Geographic Information Systems (GIS) produces a lineament density map (Fig 6). The lineament density map can be used to determine the permeability of the Libungo geothermal area. Areas with good permeability have high lineament density values.

Based on the lineament density map, it is interpreted that the Libungo geothermal area is divided into high, medium and low density areas. The high density areas occupy the eastern, northeastern and central parts of the study area. The area of medium density occupies the southern part and some parts in the northern part of the study area. The low density area occupies in the northern part of the study area.



Fig 5. Geological structure with extracted lineament.



Fig 6. Lineament density of study area.

The eastern, northeastern and central parts of the study area are included in the high density areas because they are associated with the geological structure of the study area that is northwest-southeast trending and the structure of the study area that is almost north-south trending. The central part of the study area is also the area where the Libungo hot springs appear. Geological structure trending northwest - southeast and trending almost north - south causing the formation of lineament in the study area. The geological structure in the study area causes a high lineament density which has implications for good permeability.

The southern and northern parts of the study area are included in the medium and low density areas. These two parts are not associated with the geological structure of the study area. The central part of the study area is the lake plain and fluvial plain. Lack of lineament in the south and north of study area causes a low level of lineament density which implies poor permeability.

Based on the lineament density map, the study area is dominated by high density areas. The high density areas are scattered in the eastern, northeastern and central parts of the study area so that in general the research area has a good level of permeability. A geothermal area with a good level of permeability is interpreted as an area with a good water infiltration rate. The presence of lineament in the study area affects the geothermal fluid circulation in the study area.



Fig 7. The rose diagrams show the lineament directions.

The direction of stress that affects lineament in the study area is determined using a rosette diagram. Based on the rosette diagram analysis, it was found that the direction of stress in the study area was northwest - southeast (Fig 7). The direction of stress based on this rosette diagram analysis is the same as the direction of the main stress in the Gorontalo area.

## 6. Conclusions

Based on the results of the lineament extraction of the study area with the regional geological structure of the study area, it was found that there was a lineament between the geological structure and the lineament extraction. Based on the lineament density map, the research area is dominated by high density areas so that in general the research area has a good permeability level. Libungo geothermal area has a good level of permeability, the rate of water infiltration and circulation of geothermal fluids in the study area is included in the good category. Ground-checking is necessary to prove that areas with high density values are associated with geological structures in the field.

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## References

- Abdullah A, Akhir JM, Abdullah I. Automatic mapping of lineaments using shaded relief images derived from digital elevation model (DEMs) in the Maran - Sungi Lembing area, Malaysia. Electron J Geotech Eng. 2010;15 J:1–9.
- [2] Muthumaniraja CK, Anbazhagan S, Jothibasu A, Chinnamuthu M. Remote sensing and fuzzy logic approach for artificial recharge studies in hard rock terrain of South India. In: GIS and Geostatistical Techniques for Groundwater Science. Elsevier; 2019. p. 91–112.
- [3] Florinsky I V. Lineaments and Faults. In: Digital Terrain Analysis in Soil Science and Geology. Elsevier; 2016. p. 353–76.
- [4] Galetto A, García V, Caselli A. Structural controls of the Domuyo geothermal field, Southern Andes (36°38'S), Argentina. J Struct Geol [Internet]. 2018;114:76–94. Available from: https://doi.org/10.1016/j.jsg.2018.06.002
- [5] Soliman A, Han L. Effects of vertical accuracy of digital elevation model (DEM) data on automatic lineaments extraction from shaded DEM. Adv Sp Res [Internet]. 2019;64(3):603–22. Available from: https://doi.org/10.1016/j.asr.2019.05.009
- [6] Giordano G, Pinton A, Cianfarra P, Baez W, Chiodi A, Viramonte J, et al. Structural control on geothermal circulation in the Cerro Tuzgle-Tocomar geothermal volcanic area (Puna plateau, Argentina). J Volcanol Geotherm Res [Internet]. 2013;249:77–94. Available from: http://dx.doi.org/10.1016/j.jvolgeores.2012.09.009
- [7] Iqbal M, Juliarka BR. Analisis Kerapatan Kelurusan (Lineament Density) di Lapangan Panasbumi Suoh-Sekincau, Lampung. J Sci Appl Technol. 2019;3(2):61.
- [8] Saepuloh A, Haeruddin H, Heriawan MN, Kubo T, Koike K, Malik D. Application of lineament density extracted from dual orbit of synthetic aperture radar (SAR) images to detecting fluids paths in the Wayang Windu geothermal field (West Java, Indonesia). Geothermics [Internet]. 2018;72(June 2017):145–55. Available from: https://doi.org/10.1016/j.geothermics.2017.11.010
- [9] Apandi T, Bachri S. Peta Geologi Lembar Kotamobagu, Sulawesi. In Bandung: Pusat Penelitian dan Pengembangan Geologi; 1997.
- [10] Bachri S. Stratigrafi lajur volkano-plutonik daerah gorontalo, sulawesi. J Geol dan Sumberd Miner [Internet]. 2006;XVI(2):94–106. Available from: http://jgsm.geologi.esdm.go.id/index.php/JGSM/article/download/140/137
- Bachri S. Structural Pattern And Stress System Evolution During Neogene Pleistocene Times In The Central Part Of The North Arm Of Sulawesi. J Geol dan Sumberd Miner [Internet].
   2011 Jun 11 [cited 2019 Aug 19];21(3):127–35. Available from: http://jgsm.geologi.esdm.go.id/index.php/JGSM/article/view/140
- [12] Rezky Y, Hasan AR, Dirasutisna S. Penyelidikan Geologi Daerah Panas Bumi Suwawa Kabupaten Bone Bolango – Gorontalo. In: Pemaparan Hasil Kegiatan Lapangan Subdit Panas Bumi 2005. 2005.
- [13] Manyoe IN. Geologi dan Manifestasi Thermal Libungo. Gorontalo: UNG Press; 2019.
- [14] Suleman B, Angsari. Geokimia Daerah Panas Bumi SUwwa Kab. Bone Bolango-Gorontalo. In: Pemaparan Hasil Kegiatan Lapangan Subdit Panas Bumi. 2005.
- [15] Idral A. Hasil Penyelidikan Geomagnit Daerah Panas Bumi Suwawa Kab.Bone Bolango Propinsi Gorontalo. In: Pemaparan Hasil Kegiatan Subdit Panas Bumi 2005. 2005.
- [16] Situmorang T, Djudjun A, Sudjadi AS. Penyelidikan Gaya Berat Daerah Panas Bumi Suwawa Kabupaten Bone Bolango, Provinsi Gorontalo. In: Pemaparan Hasil Kegiatan Subdit Panas Bumi 2005. 2005.

- [17] Widodo S, Mustang A, Zarkasyi A. Penyelidikan Geolistrik dan Head On Daerah Panas Bumi Suwawa Kabupaten Bone Bolango Provinsi Gorontalo. In: Kolokium Badan Geologi. 2005.
- [18] Nanlohi F, Risdianto D. Pemboran Sumur Landaian Suhu Sww-1 Lapangan Panas Bumi Suwawa Kabupaten Bonebolango - Gorontalo. In: Pemaparan Hasil Kegiatan Lapangan dan Non Lapangan Tahun 2006, Pusat Sumber Daya Geologi. 2006.
- [19] Manyoe IN. Subsurface Shallow Modelling Based on Resistivity Data in The Hot Springs Area
  o. J Geosci Eng Environ Technol [Internet]. 2020 Jun 26 [cited 2020 Aug 31];5(2):87–93.
  Available from: http://journal.uir.ac.id/index.php/JGEET