Interpretation of surface geological conditions based on Landsat-8 data, DEM and field geological data in the Tulehu geothermal prospect area, Maluku Province

A Kurniawan¹, Y Daud²,³, M A Tifani³, N Latuconsina¹ and F Maulana¹

¹Geoscience Study Program, Faculty of Mathematics and Natural Sciences (FMIPA), Universitas Indonesia, Depok 16424, Indonesia
²Department of Physics, Faculty of Mathematics and Natural Sciences (FMIPA), Universitas Indonesia, Depok 16424, Indonesia
³PT. NewQuest Geotechnology, Jl. Perumahan Pesona Kayangan Estate DC No.12, Depok 16411, Indonesia

Corresponding author’s author: ydaud@sci.ui.ac.id

Abstract. Tulehu is in the eastern part of the island of Ambon, Maluku. The research area is in some village; Suli, Tial, Tulehu, and Waai, Salahutu District, Maluku Province with a research area size of approximately 10 x 10 km². It is an area with a high geothermal prospect. Much research has been carried out here to study the geological, geochemical and geophysical conditions of it. The reservoir is estimated to reach more than 230 °C based on geochemistry. This study will focus on discussing the surface geological conditions of the Tulehu area based on the interpretation of satellite imagery and field observations data that have been carried out in the form of structure and rock unit data. This research image of satellite imagery data consists of Landsat 8, and DEM processed using ArcGIS 10.2.1 software. The results show that the study area is composed of 4 rock units which are sequentially from the oldest to the youngest namely Lava Flow (early Pliocene-middle Pliocene), Pyroclastic Flow (middle Pliocene-late Pliocene), Limestone (Pleistocene-Holocene), and Alluvium (Holocene). The structure that works in the study area has NE-SW and NW-SE directions with two main faults that form like basins in parts N and S of Mount Eriwakang. The results of this study are displayed in a surface geological map and are equipped with a geological cross section.

Keywords: Tulehu, geological maps, geological structures, rock unit

1. Introduction
Ambon Island is an area that enters the Banda arc system with structural hills characteristic formed by volcanic activity at the end of the Pliocene to the early Pleistocene. Rocks of this area are dominated by volcanic rocks in the form of lava and pyroclastic and carbonate sedimentary rocks that carry volcanic rocks. The geological structure that is very influential in the Ambon area is NE-SW and E-W which are formed due to tectonic activity [1]. The Tulehu area is located in the eastern part of the island of Ambon, Maluku. This area is a region with good geothermal potential, seen from the manifestations of hot spring which is quite commonly found, especially in the northern part of Mount Eriwakang and North of Mount Huwe [2]. Based on the research that has been done by JICA, it is obtained that the reservoir
temperature is more than 230 °C which indicates that the area is indeed a very prospective geothermal energy [2, 3]. In the Tulehu area there are 3 mountains, namely Mt. Salahutu which is in the northern part of the research area, Mt. Eriwakang and Mt. Huwe in the southern part of the research area. In addition, there are also manifestations in the form of hot spring which is suspected as an indication of the existence of a geothermal system in the Tulehu area [2]. Geological research is carried out as an initial step in geothermal exploration before being combined with geochemical and geophysical data. The geological conditions of an area cannot be separated from the rocks and structures found in the area. Therefore, in this study we will focus on discussing the surface geological conditions of the Tulehu area based on the interpretation of satellite imagery and data from field observations that have been carried out in the form of structure and lithology data. However, this study did not distinguish lithology in detail, only classifying it according to large lithological groups. in this study called rock units.

2. Data and method
In this study using satellite image data and field observation data. The satellite image data used is Landsat 8 OLI / TIRS C1 Level 1 image data with image acquisition time which is March 24, 2019 and downloaded for free at https://earthexplorer.usgs.gov/ [4]. Besides the Landsat 8 data, DEM data is also downloaded free of charge at http://tides.big.go.id/DEMNAS/ [5]. In this study also uses field observation data taken on 1–14 April 2019. Data taken for this study is in the form of geological structure and rock unit.

Both above data are processed using ArcGIS 10.2.1 software. and for structural analysis, software dips are used. The method used in this study consisted of interpretation of satellite images, field observations, and analysis of geological data (structure and rock unit).

2.1. Interpretation of satellite imagery
Interpretation of satellite imagery is very useful in assisting the overall observation of the research area, so this stage is very much needed in determining the boundaries of rock unit and the withdrawal of geological structures. Before interpretation is made, the data obtained must be corrected to reduce or eliminate the information bias caused by atmospheric conditions, the angle of data collection from the sensor, and the time of data collection. Common corrections are geometric correction and radiometric correction. This correction is also done to improve the quality of the image data [6]. After correction, observations can be focused in the study area because the data downloaded is very large in area. After that, composite image making was done to combine three different bands to display colors according to the RGB (Red Green Blue) format, in this study color composites were carried out with a combination of 5-6-7 bands, this combination would produce a very good false color for observation of geological structures [6-8]. The color composites that have been done still have to be filtered to sharpen, refine, and highlight the surface details and geological structure objects of the research area. Filtering carried out in this study uses Sharpen more in ArcGIS 10.2.1 software. The colors produced from these combinations are used to detail the surface and geological structure objects of the study area. Then, the filtering results are made a bit transparent and combined with good DEM data in giving a morphological picture, thus giving a clearer picture of the geological conditions. DEM is also useful for determining boundaries. The results of the two combined data can be used for interpretation of lithology units and geological structures in the study area [7].

2.2. Field observation
This activity was carried out to find the geological data needed in the study. In this study, the data used are rock unit data and geological structure. Unit rock data is taken based on rocks found on the surface. While the structured data is taken based on the geological structure found in the field and measured using a geological compass to determine the strike and dip, so it can be analyzed the force direction that works in the study area. This activity was also conducted to determine the level of truth of the analysis of satellite imagery that had been done before [7].
2.3. Analysis of geology data
Data obtained from field observations were then analyzed to obtain data on the distribution of rock unit and structures that worked in the Tulehu area. This analysis is in the form of petrological analysis and analysis of geological structures from data from field observations [7]. The results of the interpretation of satellite imagery and analysis of geological data are combined to produce a more accurate geological map [5].

3. Results and discussion
From data processing that has been done, the results are as follows:

3.1. Interpretation of satellite imagery
In this study geometry correction was not carried out because Landsat 8 imagery and SRTM imagery used was at level 1T or already terrain corrected, so the appearance of the river and the road was visible, and the location did not shift far. Color composites are carried out by combining three different band colors with RGB format and composite research as follows:

\[ \begin{align*}
R &= \text{band 5} \\
G &= \text{band 6} \\
B &= \text{band 7}
\end{align*} \]

From the combination the false color is obtained like figure 1. From the composite results of the 567 band, the body of the water, open land, and vegetation are showed by black, bright white, and bright brown color [8]. From figure 1, there are 2 blue colors which are bright blue and rather dark, based on field observations, the built-up area is marked by a rather dark blue color as found in the N-NE section and almost around the study area. Map obtained in figure 1, still not showing surface objects and geological structures. Then filtering must be done [6, 7]. Filtering carried out in this study uses Sharpen more in ArcGIS 10.2.1 software so that it is generated like figure 2.

From the results of filtering, the pattern and formation of surfaces and geological structures can be more visible but have not shown clear morphological conditions. For this reason, it is necessary to combine the results of the Landsat 8 image filtering with DEM (Digital Elevation Model) data, such as figure 3.

![Figure 1. Map of composite results of the 567 band in the Tulehu area.](image-url)
Figure 2. Comparison of Landsat 8 images that have been filtered, (a) before filtering, and (b) after filtering.

So that the straightness of the geological structure can be drawn. Based on the shape and the resulting color can help determine the limits of the distribution of rock unit. The colors formed from the 5-6-7 band combination provide information on surface conditions as described above and lineament patterns formed through DEM data provide rock unit distribution information. Supported by the geological map from previous studies, a temporary geological map is obtained from the results of remote sensing analysis [1, 8, 9], such as figure 4.
Based on the interpretation of satellite imagery, the study area is composed of 5 rock unit, namely Alluvium, Limestone, Pyroclastic Flow, Lava Flow, and Lava Dome. The alluvium is interpreted with a smooth texture and there is a river pattern. Lava Flow is interpreted with a coarse-smooth texture and quite a high elevation. Lava Dome is interpreted by the texture that forms a book, and Pyroclastic Flow is interpreted with a rough image texture with quite steep morphology [7]. The geological structure formed in the study area is relatively trending NE-SW and NW-SE with a pattern and quite visible elevation differences.

![Figure 3. Combined Landsat 8 and DEM data.](attachment:image)

![Figure 4. Lineament map of geological structure and distribution of rock unit based on interpretation of satellite imagery.](attachment:image)
3.2. Analysis of rock data

Based on field observations that have been conducted (figure 5), indications of dome lava are not found, so that in general in the study area there are 4 rock units that make up the Tulehu region. The rock unit is Alluvium, Limestone, Lava Flow, and Pyroclastic Flow.

The Alluvium group consists of clay, silt, sand, granules, which are found in the NE and SW parts of the study area. Limestone consists of reef limestones found in almost all parts of the study area, except in parts of Mount Huwe, Mount Eriwakang, and parts north of the research area. The Pyroclastic Flow consists of volcanic breccias with tuff, lapilli andesite, and matrix rock fragments found in parts of Mount Huwe, Mount Eriwakang and in the central part of the NW of the research area, and Lava Flow consisting of andesite rocks found in the NW and little in section E of the research area. Based on the interpretation of satellite images and field observation data, supported also by the literature study from JICA [2], it can be produced the withdrawal of rock unit such as figure 6.

**Figure 5.** Map of distribution of observation points.

**Figure 6.** Map of the distribution of rock unit in the Tulehu area.
Sl for lava flow groups from Mt. Salahutu, Sp for the pyroclastic flow group from Mt. Salahutu, Ep for the pyroclastic flow group from Mt. Eriwakang, Hl for lava flow groups from Mt. Huwe, Hp for the pyroclastic flow group from Mt. Huwe, Ql for quarterly limestone groups, and Qa for quarterly alluvium deposits.

3.2. Data analysis of geological structure

Based on field observations that have been carried out, several geological structure points have been found and become evidence, additions, and corrections of faults that have been interpreted satellite images, so that the interpretation of the geological structure in the study area becomes like figure 7.

Based on the directionality obtained from the remote sensing analysis, the dominant direction shows the NE-SW and NW-SE directions depicted in the Rosette diagram on figure 8.

Figure 7. Distribution of structural points from field observations.

Figure 8. Rosette diagram of the direction of the structure of data in the Tulehu area.
In the study area it is thought that there are two main faults that work and affect the appearance of manifestations in the study area. That is, A or what is referred to as the Banda fault located in the northern part of Mt. Eriwakang and B or referred to as Huwe fault in the southern part of Mt. Eriwakang (figure 7), based on the results of field observations Banda fault is a normal fault with a pitch value of around 68°E and has a fault plane towards the Southeast, this is different from previous studies which suspected the fault area towards the Northwest. And fault Huwe is a normal fault with a fault area towards the northwest. This was supported by a fault data analysis that had been carried out which showed that the two faults included normal faults (figure 9).

Figure 9. Fault analysis data from the field use Stereonet diagram.
This shows that Mount Eriwakang is a graben. This is useful for estimating fluid transport pathways from manifestations that appear around Mt. Eriwakang. It is estimated that the fluids originated from the direction of Mt. Eriwakang. From the interpretations and analyses that have been carried out above, a geological map is obtained which describes the structure and distribution of rock unit in the study area (figure 10).

In the cross section below (figure 10), the Banda fault and Huwe fault form like a basin or Graben which causes Mt. Eriwakang is depressed. Based on the regional geological map of Ambon sheet, it is assumed that bedrock in the study area is metamorphic [9]. Based on the research conducted by JICA [2, 3], if it is connected to the geological map produced, information is obtained that the age sequence of the 4 groups from the oldest to the youngest is Lava Flow (early Pliocene-middle Pliocene), Pyroclastic Flow (middle Pliocene-late Pliocene), Limestone (Pleistocene-Holocene), and Alluvium (Holocene) (figure 10).

4. Conclusion

The research area consists of 4 rock units namely Alluvium, Limestone, Pyroclastic Flow, and Lava Flow. This is based on a combination of interpretation of satellite images (Landsat 8 and DEM) to determine the limit and geological data from field observations and is supported by literature studies to determine the type of rock. The age order of the four rock units comes from the oldest and the youngest is Lava Flow, Pyroclastic Flow, Limestone, and Alluvium. The structure that works in the study area is
relatively NE-SW and NW-SE with two main faults (normal faults) in the North and South of Mount Eriwakang and form a graben that causes Mt. Eriwakang is depressed.

Acknowledgments
This work was financially supported by Universitas Indonesia under research grant PITTA 2019. The author also thanked PT PLN Persero for allowing us to conduct research and retrieve data, and management PT NewQuest for supporting data processing and knowledge sharing.

References
[1] Vandani C P K, Sari I W A, Mulyaningsih E, Utami P and Yunis Y 2014 Prosiding Seminar Nasionalkebumian Ke-7 (Yogyakarta) (Yogyakarta: Repository UGM) M2O-06 available at https://repository.ugm.ac.id/135143/1/356-369%20M2O-06.pdf
[2] PT. PLN (Persero) 2011 JICA Preparatory Survey for Tulehu Geothermal Power Plant (Indonesia: Japan International Cooperation Agency, West Japan Engineering Consultants) available at https://openjicareport.jica.go.jp/pdf/12039947.pdf
[3] Sunaryo J and Susilo A 2015 NATURAL B 3 158-65
[4] USGS Science for a Changing World 2019 available at https://earthexplorer.usgs.gov/
[5] Seamless Digital Elevation Model (DEM) and Batimetri Nasional 2019 available at http://tides.big.go.id/DEMNAS/
[6] Herlambang R F and Novranza K 2016 Prosiding Seminar Nasional Fisika (E-Journal) vol. 5 (Jakarta) available at http://journal.unj.ac.id/unj/index.php/prosidingsnf/article/view/4593/3445
[7] Agista Z, Rachwibowo P and Aribowo Y 2014 Geol. Eng. E-J. 6 278-93
[8] Putra I D, Nasution R A F and Harijoko A 2017 Prosiding Seminar Nasional Kebumian Ke-10 Grha Sabha Pramana (Yogyakarta) (Yogyakarta: Gajah Mada University) available at https://www.researchgate.net/profile/Illham_Putra10/publication/321906104_Aplikasi_LANDSAT_8_OLITIRS_Dalam_Mengidentifikasi_Alterasi_Hidrotermal_Skala_Regional_Studi_Kasus_Daerah_Rejang_Lebong_dan_Sekitarnya_Provinsi_Bengkulu/links/5a38e8bb0f7e9b7c48700def/Aplikasi-LANDSAT-8-OLI-TIRS-Dalam-Mengidentifikasi-Alterasi-Hidrotermal-Skala-Regional-Studi-Kasus-Daerah-Rejang-Lebong-dan-Sekitarnya-Provinsi-Bengkulu.pdf
[9] Tjokrosapoetro S, Rusmana E and Achdan A 1993 Geological Map of The Ambon Sheet, Maluku (Bandung, Indonesia: Pusat Penelitian dan Pengembangan Geologi)