Geological Hazards Interpretation Using Remote Sensing Method in Cimahi District, Kuningan Region, West Java

Faisal Akbar¹*, Hilyan Asupyani¹, and Hisyam Azhar Azizi¹
¹Student of the Faculty of Geological Engineering, Padjadjaran University, Bandung-Sumedang Road KM.21, Sumedang District, West Java, Indonesia

*faisalakbar.fa465@gmail.com

Abstract. This earth besides having abundant natural resources there is also a geological hazard. All of these disasters have a detrimental effect on life, either in their lives, their assets, and their psychological well-being. The research area has potential geological hazards. This certainly needs to be followed up as a step to reduce the adverse effects that occur. The purpose of this research is to determine the probability of geological hazards in the research area as education for the surrounding community and considered by the local government. This research method is through collecting literature study sources, remote sensing through satellite imagery to determine geomorphology and geological mapping. Geological hazards are disasters caused by a series of events influenced by nature and geological processes. The results of this research indicate that the disaster possibility which can occur due to the geological condition of the area is landslide. This disaster possibility due to a fairly steep slope accompanied by sedimentary rock that is prone to erosion. Besides, this area also has another potential of geological disasters such as volcanic eruptions and earthquakes. Volcanic eruptions can occur in research area with volcanic ash impacts from the Mt. Ciremai. Earthquakes can happen in an area close to the fault zone and subduction path. So it can be concluded that the research area has 3 geological hazards, namely landslide, earthquake, and ash from the volcanic eruption.

1. Introduction
The geological process from endogenous and exogenous forces can cause danger even geological disasters. The danger is a threat that comes from extreme natural events that can have bad consequences or unpleasant circumstances. Meanwhile, disaster is an abnormal condition that occurs in a society that causes loss of both properties and lives, and the conditions in which the community is difficult to get out of the consequences it causes. Landslides, earthquakes, volcanoes, and tsunamis are examples of geological disasters.

The research area, located in a part of the Cimahi District, Kuningan Region, West Java, with an area of 5 x 5 km has several geological hazards such as landslides, earthquakes, and volcanic eruptions. The geological hazards can be interpreted through the regional geology of the surrounding area and remote sensing.

Landslides or mass movement is a process of rock/soil mass displacement due to gravity. Internal factors that cause landslides are constituent material, geological structure, vegetation density, and slope geometry. The value of the compiler material that is commonly used as valuation is cohesion, angle of internal friction, and unit weight. Meanwhile, external factors such as vibrations due to vehicles, climate, and human activities. Landslide potential can be interpreted through remote sensing with morphometric analysis. In addition, geological mapping is carried out to confirm the results of remote sensing. Earthquakes are vibrations that occur in the earth as a result of the sudden release of energy through rocks in the earth's crust that is deformed in the form of faults and subduction zones. The energy released is the accumulation of energy from the process of continuous rock deformation in the form of heat or seismic waves that travel through the earth. When waves reach the surface of the earth, mass movements occur that is felt like an earthquake. The point of this earthquake is spread along the plate boundaries (convergent, divergent, transform), therefore it is closely related to plate tectonic theory. In addition to tectonic earthquakes, there are earthquakes caused by landslides and
volcanic eruptions. However, tectonic earthquakes have greater strength. The existence of a fault zone in Sulawesi can trigger an earthquake. The existence of active faults and active thrusts in Sulawesi directly affects the level of seismicity of the region [8]. The potential for this earthquake can be interpreted through regional geology consisting of faults, as well as satellite imagery by looking at the lineaments.

Volcano eruption is a danger caused by volcanic eruptions in the form of solid, liquid, gas, and mixture that can cause harm to human activities. The area at the foot of a volcano certainly has a high potential to be affected, be it lava flows, rock falls, etc. Meanwhile, areas far enough from volcanoes are only affected by volcanic ash affected by the direction of the wind at the time of the incident. The potential danger from this erupting volcano can be identified through a map of volcanic disaster-prone areas created by the geological agency (Badan Geologi – Pusat Vulkanologi dan Mitigasi Bencana Geologi).

The purpose of this research is to determine the probability of geological hazards in the research area as education for the surrounding community and considered by the local government.

2. Methods
Research methods carried out through literature studies from previous researchers, remote sensing, and geological mapping. A literature study is carried out by collecting related data such as regional geology and the regional geological structure of the research area. Remote sensing through satellite imagery to determine geomorphology with aspects of morphography, morphometry, and morphogenetics. Morphography describes the landscape, drainage patterns, and lineament. Morphometry explains the slope to determine the level of landslide-prone. Morphogenetic explains the factors that influence the formation of a landscape. Geological mapping aims to confirm the results of interpretations from literature and remote sensing studies.

3. Results and Discussion
3.1. Literature Study
The study area is located in part of the Cimahi District, Kuningan Region, West Java, with an area of 5 x 5 km. The area is included in the Geological Map of the Majenang Sheet and the Regional Structure Pattern of West Java. The Geological Map of the Majenang Sheet was published twice, namely 1975 and 1996. Meanwhile, the Regional Structure Pattern of West Java was published in 2008.

According to Kastowo and N. Suwarna [6] explained that the study area had rock age starting from Early Miocene - Early Pliocene. The order of rock units from old to young from consists of formations:

a. Lawak Formation (Tml)
Lawak Formation is the oldest formation in the research area. Greenish grey marl with thin intercalations of foraminiferal limestone and calcareous sandstone form the upper part of the unit, with a mean thickness of 0.5 m each. The upper part is composed of globigerina marl with thin sandstone intercalation. The presence of foraminifera show a Middle Miocene age. Depositional environment was open marine. 150 m in thickness. Overlies conformably the Rambatan Formation.

b. Pemali Formation (Tmp)
Monotonous beds of greyish blue and green globigerina marl, poorly-well bedded, with sparse intercalation of tuffaceous sandstone and greyish blue sandy limestone. Recognised sedimentary structures are parallel lamination, cross-bedding, convolute lamination, and ripple marks. Presumably, the age is Early Miocene. Thickness about 900 m.

c. Halang Formation (Tmph)
The halang formation consists of tuffaceous sandstone, conglomerate, marl, and claystone, andesitic breccia at the lower part. Sandstone mostly wacke. Deposited as turbidites in an upper bathyal zone. Structures commonly recognised in the unit are graded bedding, parallel lamination, convolute lamination, flute-cast, and load cast, suggesting a deposition in an open marine environment by
turbidity currents. Locally, foraminifera and molluscs are found. Presumably, a Middle Miocene-
Early Pliocene age. Overlain unconformably by Tapak Formation, interfingers with Gununghurip
Member of the Halang Formation and is underlain conformably by the Lawak Formation.

Figure 1. Regional Geological Map of the Research Area.

In Java there are three dominant structural patterns, each of which is the Meratus Pattern, Sunda
Pattern, and Javanese Pattern. However there is an argue that 4 structural patterns are developing in
Java, including:

a. North-South Directional Fault (Sundanese Pattern)
The north-south fault structure is generally found off the coast of the Java Sea, however, it is also
found in a small part of Banten and Sukabumi. The existence of this north-south fault is not only
determined by the results of the interpretation of the remote sensing image but is also characterized
by its traces of magnification in the form of fault mirrors, fault breccias, mylonites, and drag folds.
This north-south structural pattern began to form at the age of Paleogene which is transtensional in
nature. This tectonic activity produces high morphology (horst) and deep (graben) whose formation
is controlled by several normal slip faults (negative flower structure) which are rooted in (deep-
seated). The structure of the Sundanese Pattern is closely related to areas of depression that potentially
contain hydrocarbons. From the seismic picture, it is known that the structure of the Sunda Pattern
experienced reactivation caused by the presence of tectonic compression in the Plio-Pleistocene
Period. This last tectonic besides activating the old faults, also causes all the contents of the sediment
(Tertiary) in the basin to experience lifting, folding and enlargement.

b. Southwest-Southeast Directional Fault (Sumatra Pattern)
This structural pattern can be identified through topographic straightness, river flow and several traces
of amplification. Regional faults representing this group are found along the line of the Citanduy
River (Ciamis) valley which continues to the northwest through the Kuningan and Majalengka
regions. In the Kuningan and Majalengka areas, this fault line is located around the southwest slope
of Mount Ciremai so it is estimated that the formation of the volcano is related to the fault. From
seismic historical data, this fault line is in a zone of high seismicity.
c. Northeast-Southwest Directional Fault (Meratus Pattern)
The northeast-southwest trending regional fault can be identified through the interpretation of sensory imagery, topographic alignment, and traces of magnification. Regional faults in this group included the Cimandiri Fault (Sukabumi), the Pelabuhan Ratu Fault (Sukabumi) and the Jampang Kulon Fault (Sukabumi). These three paths are relatively limited, relatively parallel to each other and fully a horizontal fault. Through observation of sensory imagery and field data, the Cimandiri fault line joins the Baribis fault line.

d. West-East Directional Fault (Javanese Pattern)
The west-east trending fault group is generally an upward fault type and is the dominant structure among other types of faults. From the structural map description, it is known that the position of the fault line rises to one another relatively parallel to each other, the slope of the fault plane is generally to the south. The west-east fault pattern or referred to as the Javanese Pattern is represented by the Baribis Fault. the Baribis fault line continues to the southeast forming the lineage of the Citanduy River valley.

![Figure 2. Baribis-Cimandiri regional fault in West Java](image)

Based on the above literature, the study area and its surroundings have 3 structural patterns namely Javanese, Sundanese, and Sumatra patterns. The geological structure around the study area formed of a horizontal fault with a north-south direction, a fold of an anticlinal form, and an indication of an upward fault in the northwest-southeast direction. This horizontal north-south trending horizontal fault is possible included in the Sunda pattern because it is transtensional. Besides, the regional geological map contains oil seepage near the study area. This adds to the strong evidence that this fault is included in the Sundanese pattern. The indications for increased faults in the study area are included in the Sumatran or Javanese patterns. This is based on the interpretation of two literature which explains that the upward fault is trending northwest-southeast and that the rock blocks that rise up tend to the south. This fault was a result of the Baribis fault and the Citanduy fault. Based on the Susceptibility to Landslide Zone Map made by the Geological Agency, the study area has 3 levels of vulnerability, namely low, medium and high. A high level of vulnerability is at the foot of Mt. Tangkuban Perahu so that community plantations are threatened when in the rainy season. Meanwhile, the level of medium vulnerability dominates the study area which is spread in the foothills of the elongated hills. The main highways, Margamukti Village and Cimulya Village are of concern because human activities often take place in the area. Therefore, the tree logging is not recommended because it makes the water go straight into the pores of rocks or soil which could one day not be accommodated anymore. The local government needs to plan the strengthening of the slopes to maintain the stability of the slopes.
3.2. Remote Sensing
Remote sensing through satellite imagery to determine geomorphology with aspects of morphology, morphometry, and morphogenetics. Geomorphology of an area is influenced by two forces acting on the area concerned, namely endogenous and exogenous forces. Due to the different geomorphological processes in each region, it will form a certain landscape character.

3.2.1. Morphography Research Area
Morphography broadly has the meaning of a description of the shape of the Earth's surface or Earth's surface architecture. Broadly speaking, morphography can be divided into hills/mountains, mountains or volcanoes, valleys, and plains. Changes in ridge patterns and river drainage patterns can identify tectonic activities in the study area. Morphographic aspects include:

3.2.1.1. Landform
Based on the classification of van Zuidam [15], the morphography of the study area is divided into 2 parts, namely the shape of hilly and plain land.

a. Form of hilly land
Occupies about 70% of the area of research, has an altitude of 101 - 372 meters above sea level. Located in the southwest and central part of the research area.

b. Form of plain
Occupies about 30% of the area of the study, has a height of 64-100 meters above sea level. Located in the southeast and north of the study area.
The shape of the valley is related to the slope and distance between slopes, while the shape of the slope itself is strongly influenced by the value of the slope and the durability of eroded rock. Based on morphographic maps that are dominated by hills, it can be concluded that the valley shape of the study area is generally dominated by slopes V.

The form of the ridge itself means a characteristic of the appearance of a ridge. By connecting the altitude peaks in the same landscape in the study area, it can be concluded that the shape of the ridge in the study area has a ridge extending to the northwest-southeast.

3.2.1.2. Drainage Patterns

Analysis of drainage patterns based on topographic maps as well as the formation of intermittent and major river patterns in the study area which are then compared with the basic drainage and modification flow patterns of Howard [5] in van Zuidam [15], shows that the flow patterns that develop in the study area are sub-dendritic, sub-parallel, trellis, and parallel.

- Sub-Trellis Pattern
  This drainage pattern occupies the northwestern part of the study area, with an area of about 50% of the entire study area. This flowing pattern is characterized by the lithology of sedimentary rocks that have a slope (dip) or folded with clear weathering differences. This type of drainage pattern usually faces on the side along with the subs current flow. This drainage pattern is in the lithology of volcanic breccias, sandstones, claystones, morphometrically in areas with steep slope slopes.
b. Sub-Parallel Pattern
The parallel flow pattern is a flow system formed by slopes that are rather steep to steep. Due to the steep slope morphology, the shape of the river flows will be straight in the direction of the slope with very few river branches. Parallel drainage patterns are formed on slope morphology with a uniform slope. All forms of transition can occur between trellis, dendritic, and parallel flow patterns. Occupying the north-northeast region in the study area as much as 35%. Being in sandstone and claystone lithology.

c. Sub-Dendritic Pattern
This drainage pattern occupies the western part of the study area, with an area of around 15% of the entire study area. This flowing pattern is characterized by patterns that are formed having general shapes such as leaves or fingers. This drainage pattern is formed by tributaries. This flowing pattern is in the claystone and sandstone lithology. Morphometrically, this drainage pattern is in an area with a gentle slope. This pattern of drainage is thought to be formed due to the effects of weathering and intensive erosion and human activities that change the landscape in the area.

3.2.2. Morphometry Research Area
Morphometry is a quantitative assessment of a landform. Morphometry is also a supporting geomorphological element that is very meaningful to morphography and morphogenetics. In morphometric analysis, data collection and calculation of elevation and slope are performed. The area around the study has a slope that is dominated by flat morphometry to gentle slopes consisting of settlements. However, the location of the study boundary has a steep slope to the ramps found in the south and northeast.

Based on the morphometric analysis calculations conducted to group the area based on the determination of the slope, then obtained five dominant slope classifications are: flat, gentle slope, gentle-steep slope, steep slope, and very steep slope.
- Flat, (0 ° - 2 ° / 0% - 2%), is a slope which spread in a small part of the study area about 5%, located predominantly in the west and southeast.
- Gentle slope, (2 ° - 4 ° / 2% - 7%), is a slope which spread in not very wide of the study area but about 15%, located in the west, north, and southeast.
- Gentle-steep slopes, (4 ° - 8 ° / 7% - 15%), spread in 20% of the study area, located at the foot of the hills.
- Steep Slopes, (8 ° - 16 ° / 15% - 30%), there are as many as 30% of the study area, located at the foot of the southwest and central hills.
- Very Steep Slope, (16 ° - 35 ° / 30% - 70%), there are as many as 30% of the study area, located in the hills that extend along the southwest and central regions.
3.2.3 Morphogenetic Research Area
Morphogenetics are factors that influence the formation of a landscape or morphology. In determining the morphogenetic elements that dominate in the study area, namely by comparing the patterns of the river flow that develops and their relationship to the geological structure, and rock lithology in the area.

The constituent material of the study area is dominated by sedimentary rocks such as sandstone and claystone. However, in some areas, there are volcanic rocks that are easily eroded.

The drainage pattern of the study area is dominated by sub-trellis because it is composed of sedimentary rocks that are easily folded. However, other patterns of drainage were formed such as sub-dendritic and sub-parallel. Subparallel formed due to the slope of a steep slope so it tends to easily breakthrough, while the sub-dendritic is in the plain which causes lateral erosion that forms a diffuse pattern.

The geological structure of the study area is related to drainage patterns such as the presence of folds in several areas causing the formation of sub-trellis river drainage patterns.

3.3. Geological Mapping
The geological mapping of the study area aims to confirm the remote sensing analysis relating to the possibility of geological hazards. The data were taken in the form of rock lithology, geological structure, and observation of landslide-prone areas.

The rock of the study area is dominated by sandstone, claystone, and breccias. In the study area several indications of geological structure were found in the form of 2 slickenside and joint.

![Figure 8. Rock Outcrop of Research Area.](image)

First slickenside was found at coordinates S 7°02'08.0" and E 108°41'11.7" with the strike / dip = N 204°E/74°, Pitch = 42°, SW orientation, Footwall smoothing up. Based on the classification of fault naming based on Rickard, 1972, it has the name of a reverse left slip fault. Second slickenside was found at coordinates S 7°01'34.3" and E 108°41'00.0" with the strike / dip = N 52°E/89°, Pitch = 7°, NE orientation, hanging wall smoothing up. Based on the classification of fault naming based on Rickard, 1972, it has the name of a right slip fault.

In addition, there are indications of other geological structures at coordinates S 7°02'05.6 "and E 108°41'26.0" in the form of joints. Measurements were made using the 1x1m window method with the following results: N 240°E/75° length 75 cm, N 235°E/70° length 100 cm, N 239°E/76° length 30 cm, N 232°E/77° length 100 cm, N 47°E/79° length 80 cm, N 42°E/65° length 100 cm, N 46°E/58° length 75 cm, N 242°E/77° length 50 cm, N 312°E/70° length 35 cm, N 120°E/80° length 67 cm, N 315°E/79° length 10 cm, N 330°E/74° length 10 cm, N 320°E/76° length 9 cm, N 139°E / 81° length 50 cm, N 350°E/47° length 8 cm, N 236°E/75° length 45 cm, N 330°E/77° length 20 cm, N 344°E/73° length 20 cm, N 115°E/70° length 50 cm, and N 330°E/74° length 17 cm.
Figure 9. Right Slip Fault (Left), Reverse Left Slip Fault (Right)

Figure 10. Joint (1x1m).

Figure 11. Geology Framework Map.
4. Conclusions
Based on the results of the analysis of research data, it can be concluded as follows:
a. The study area has 3 potential geological hazards namely landslides, earthquakes and volcanic eruptions.
b. The dominance of the hills causes the study area to have a landslide hazard. This is caused by a zone of vulnerability to mass movement, morphometry, and geological conditions. Based on these 3 factors that need attention, namely Margamukti Village, Cimulya Village, and Road as the main access to transportation.
c. The research area located north of the subduction zone and faults in regional geology has an earthquake hazard. This was confirmed by indications of the geological structure in the study area, namely fault and joint. The measurement results on the slickensides states that the name of the fault in the study area are Reverse Left Slip Fault and Right Slip Fault. Joints in the study area can confirm that the study area belongs to the area that is controlled by a high geological structure. It should be noted that Margamukti Village is just above the fault line, to prevent damage must make buildings that are earthquake resistant.
d. The danger of volcanic eruptions can occur in research areas with volcanic ash impacts from the Mt. Ciremai. This happens when the wind blows to the east.
e. More detailed geological mapping is needed for more accurate results.

Acknowledgments
Thank you to the Department of Mines and Energy, Directorate General of Geology and Mineral Resources, Center for Geological Research and Development, Bandung, with a regional geological map of the Majenang sheet as a research reference. Additional thanks to the Ministry of Energy and Mineral Resources, Geology Agency, Center for Volcanology and Geological Disaster Mitigation with a map of the vulnerability of Kuningan regency mass movement and a map of the Ciremai volcano prone area as a research reference.

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