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Subsurface lithological interpretation of the landslide-prone Cipendawa area, Cianjur (Indonesia), using 2D and 3D inversion of aeromagnetic data

Ahmad Ali Muckharom[1], Agus Setyawan[2*], Agustya Adi Martha[3], Bono Pranoto[4] and Tio Azhar Prakoso Setiadi[5]

[1] *M.Sc., Physics Department, Faculty of Science and Mathematics, Diponegoro University, Semarang, Indonesia*
[2] *Professor, Physics Department, Faculty of Science and Mathematics, Diponegoro University, Semarang, Indonesia*
[3] *Ph.D., National Research and Innovation Agency (BRIN RI), West Java, Indonesia*
[4] *M.Sc., National Research and Innovation Agency (BRIN RI), West Java, Indonesia*
[5] *Ph.D., Student, National Research and Innovation Agency (BRIN RI), West Java, Indonesia*

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Summary

Cipendawa, Cianjur (Indonesia), has been declared unsuitable as a permanent housing relocation site for earthquake victims due to the slope of the land, soft soil conditions, and the potential for volcanic eruptions. This research aims to interpret the subsurface structures of the Cipendawa area using the aeromagnetic method, considering variations caused by heterogeneous subsurface lithology. Data acquisition was carried out using a drone-mounted Sensys R3 magnetometer at 135 measurement points, including measurements of total magnetic field. Data processing included IGRF (International Geomagnetic Reference Field) correction, reduction to the pole (RTP), and both two-dimensional and three-dimensional modeling. Qualitative interpretation results indicate three magnetic anomaly patterns. High magnetic anomalies (245 nT-441 nT), observed in the southeastern and northwestern parts of the area, are interpreted as volcanic rocks such as basalt and andesite. Medium magnetic anomalies (193 nT-238 nT), located in the southwestern and central areas, are thought to be sandstone. Low magnetic anomalies (-21 nT-185 nT), found in the northern parts, are interpreted as limestone and sandstone. The analysis of three cross-sections shows variations in rock susceptibility from -23×10^{-4}SI to 54×10^{-4}SI within the depth range of 0-40 meters. It indicates that the northern area consists of sedimentary rocks, such as sandstone, formed by river flow that carries magnetite-rich minerals, while the southern area is composed of volcanic rocks, such as andesite breccia, which align with the geological map due to magma intrusion from Mount Gede in the past. Furthermore, three-dimensional modeling of the Cipendawa area indicates that the landslide-prone sedimentary rock layer is located in the northern part, while the hard rock layer in the southeastern part is more stable. However, the southeastern region could still experience landslides in the event of tectonic activity.

Keywords IGRF, landslides, lithology, subsurface, magnetic method, RTP

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[*] Corresponding author: agussetyawan@fisika.fsm.undip.ac.id

1 Introduction

The Cipendawa area, Cianjur (Indonesia), is an area with significant geological potential, characterized by the presence of various types of volcanic rocks that support geomorphological diversity and mineral resources. Conducting subsurface research in this area is essential to understanding the characteristics of the underlying lithology and the factors affecting soil stability, especially considering the risk of disasters such as earthquakes and landslides, which often occur in areas with steep slopes.

Cipendawa has been declared unfit as a permanent housing relocation site for earthquake-affected victims based on technical studies by the Badan Meteorologi Klimatologi dan Geofisika (BMKG) (2022) and Pusat Vulkanologi Mitigasi Bencana Geologi (PVMBG) (2023). This infeasibility is due to several key factors, including the high degree of land slope and soft soil contours, which increase the risk of earthquake damage. Additionally, the area also has the potential for volcanic eruptions, which further deteriorates the safety level of the site. In this regard, it is important to conduct an in-depth lithological study in the Cipendawa Village area to understand more about the potential geological risks and their impact on community safety.

Based on the regional geological mapping of the Cianjur Sheet compiled by Sudjatmiko (1972), the Cipendawa area is composed of young volcanic rocks from the Quaternary period. The oldest rocks in this area are composed of pyroxene andesite breccia interspersed with andesite lava. The presence of these volcanic rocks indicates a long and diverse history of volcanic activity in the region. In addition, the activity of Mount Gede has contributed significantly to the accumulation of volcanic material in Cipendawa. Some of these rock layers also have potential as aquifers, with the ability to store and transmit groundwater, especially in zones of high porosity and permeability, such as cracks and fractures in andesite breccia and andesite lava (Syafnur et al., 2023).

Geophysical methods have an important role in subsurface interpretation, one of which is the magnetic method based on measuring variations in magnetic field intensity (Abdullah and Sunaryo, 2014). Variations in magnetic field intensity at different depths indicate the presence of magnetic anomalies. These anomalies are typically caused by variations in rock susceptibility across the area. Susceptibility refers to the ability of an object or rock to be magnetized (Blakely, 1995). Furthermore, the characteristics of magnetic anomalies can identify the location and depth of crustal volumes with low magnetization or those that have been fully demagnetized (Bouligand et al., 2014; Caratori Tontini et al., 2019). Therefore, the application of magnetic methods is highly relevant to geological studies, particularly in areas such as Cipendawa, in order to produce precise subsurface models and understand the underlying rock formations.

The purpose of this study is to determine the subsurface lithology in the landslide-prone area of Cipendawa based on aeromagnetic data. Aeromagnetic data were reduced to the pole to generate a monopole grid. Some previous studies have shown the effectiveness of magnetic methods in various geological applications. For instance, Maulidan et al. (2021) successfully identified subsurface lithology in the Mount Kerinci area, and

Sihombing et al. (2023) applied the geomagnetic method to determine the distribution of lithological units in the landslide-prone area of Batu Layang, Deli Serdang. In another research, Yunginger et al. (2024) used magnetic methods to analyze landslide potential in the Suka Damai area, Bone. These findings emphasize the important role of geomagnetic methods in enhancing our understanding of subsurface geological conditions, as a significant approach to landslide disaster mitigation.

2 Research methods

2-1 Geology of the study area

The regional geology of Cipendawa located in the Cianjur Sheet exhibits a close relationship with the geological characteristics of Mount Gede Pangrango. The lithology of the rocks in this area is characterized by river deposits composed of andesitic lava and volcanic breccia (Qyg) (Fig. 1).

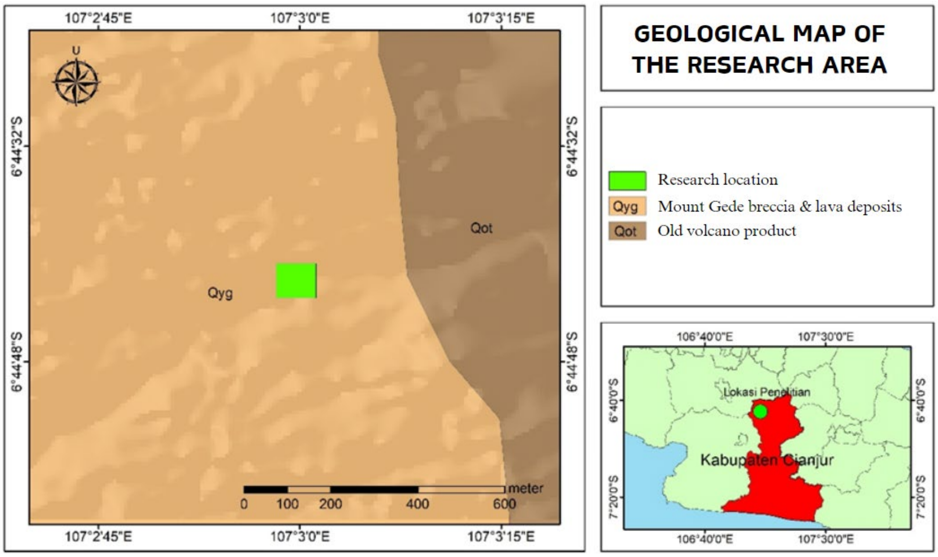

Figure 1. Geology of the research area.

According to Agustin and Bronto (2019), the rocks in this area reflect active volcanism, with complex geological structures resulting from tectonic processes such as shifting and folding along the course of the river. The rocks also display significant hydrothermal alteration, which contributes to the potential for mineral resources in the region (Koesmono, 1976). The geological structure surrounding the Cipendawa River is influenced by tectonic activity in the Mount Gede Pangrango region. Research by Bemmelen (1970) revealed that the area experienced folding and faulting that formed a typical river flow pattern. This geological structure forms a weak zone that allows erosion and deposition of volcanic materials along the river. In addition, results by Situmorang and Hadisantono (1992) show that landslide deposits originating from Mount Gede, extending towards Cianjur, known as Bukit 777, are clear evidence of the interaction between volcanic activity and geomorphologic processes in the area.

The connection between the geology of Cipendawa Sungao and Mount Gede Pangrango is evident not only in the lithology and structure but also in the geothermal potential of the region. According to Purwantoro et al. (2010), the presence of hot springs and fumaroles around Mount Gede indicates that the geothermal system is still active and can affect the quality of river water. This makes the area a strategic location for further research on the utilization of geothermal resources and sustainable environmental management in the Cianjur region (Yasmin et al., 2024).

2-2 Data acquisition

The magnetic data used is secondary data that have been corrected for daily variations and noise, obtained from measurements in the area surrounding the Cipendawa River. Data collection was carried out using a Sensys R3 Magnetometer Drone, with 135 measurement points located between latitudes -6.744794407°S and -6.744779721°S, and longitudes 107.0495116°E and 107.0495562°E, at elevations ranging from 1039 meters to 1060 meters, as shown in Fig. 2. Afterwards, the anomaly data, corrected for diurnal variations (diurnal correction), was further corrected by IGRF (International Geomagnetic Reference Field) correction to obtain the residual magnetic anomaly values, which were then used as input for generating magnetic anomaly contours.

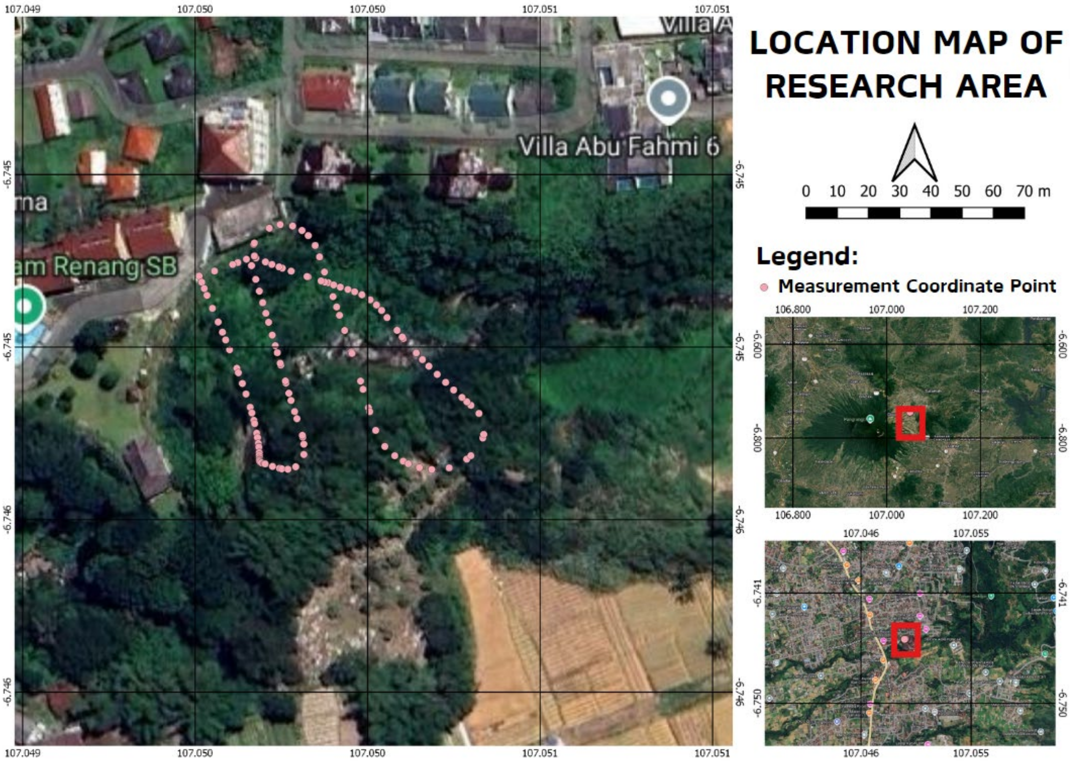

Figure 2. Location map of the study area.

3 Results and discussion

3-1 Topographic map of the study area

The research area is located in Cipendawa, Cianjur, which is part of the volcanic area of Mount Gede Pangrango. The topography of the area (Fig. 3), is the result of interpolation based on the regional distribution of measurement points. The topographic map is a Digital

Elevation Model (DEM) that displays elevations ranging from 1040 meters to 1056 meters. The elevation in the study area has little variation and tends to be flat. The area shown in blue, representing the Cipendawa River estuary area, is a low elevation area (around 1040 meters to 1047 meters), while the area shown in red is a residential area with higher elevation (around 1050 meters to 1056 meters).

3-2 Magnetic field anomaly map

The total magnetic field anomaly contour map represents measured magnetic field intensity at specific locations produced by the magnetic properties of subsurface rocks. It is generated after performing daily variation correction and IGRF correction on the raw magnetic field intensity measurements obtained from field observations. By entering the latitude and longitude coordinates of the measurement points and the corresponding total magnetic field anomaly values into Geosoft software (Oasis Montaj 8.4), the total magnetic field anomaly contour map is obtained. Fig. 4 shows the total magnetic field anomaly contour map for the Cipendawa area, along with the field measurement points.

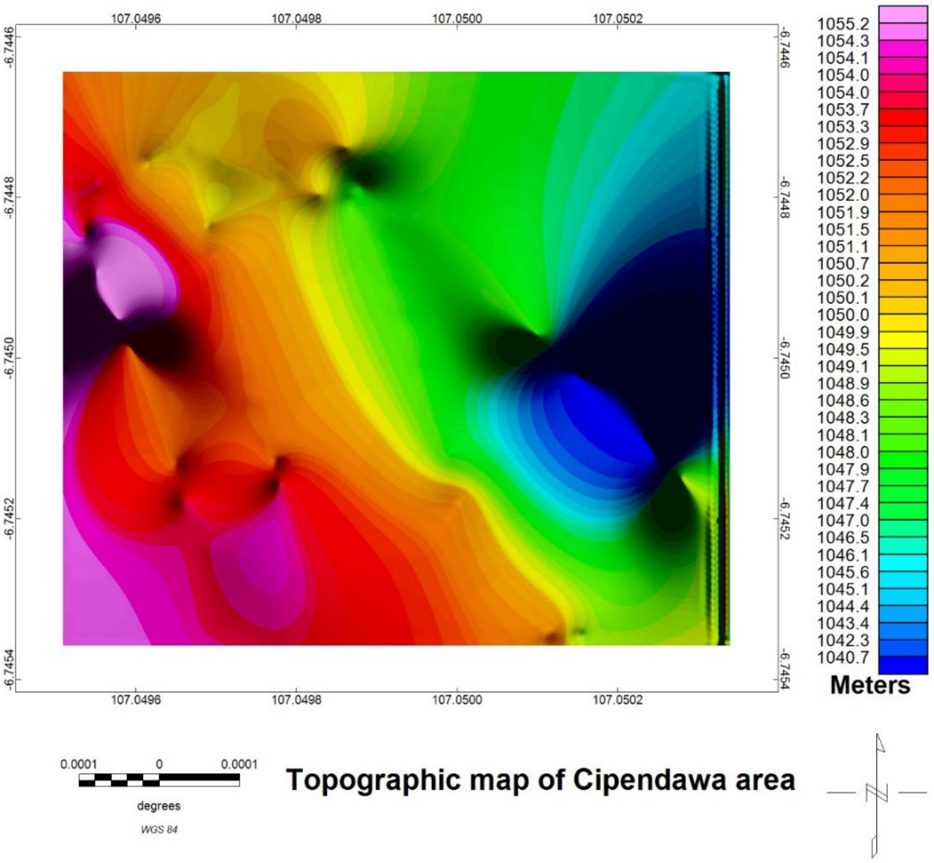

Figure 3. Topographic map of the study area.

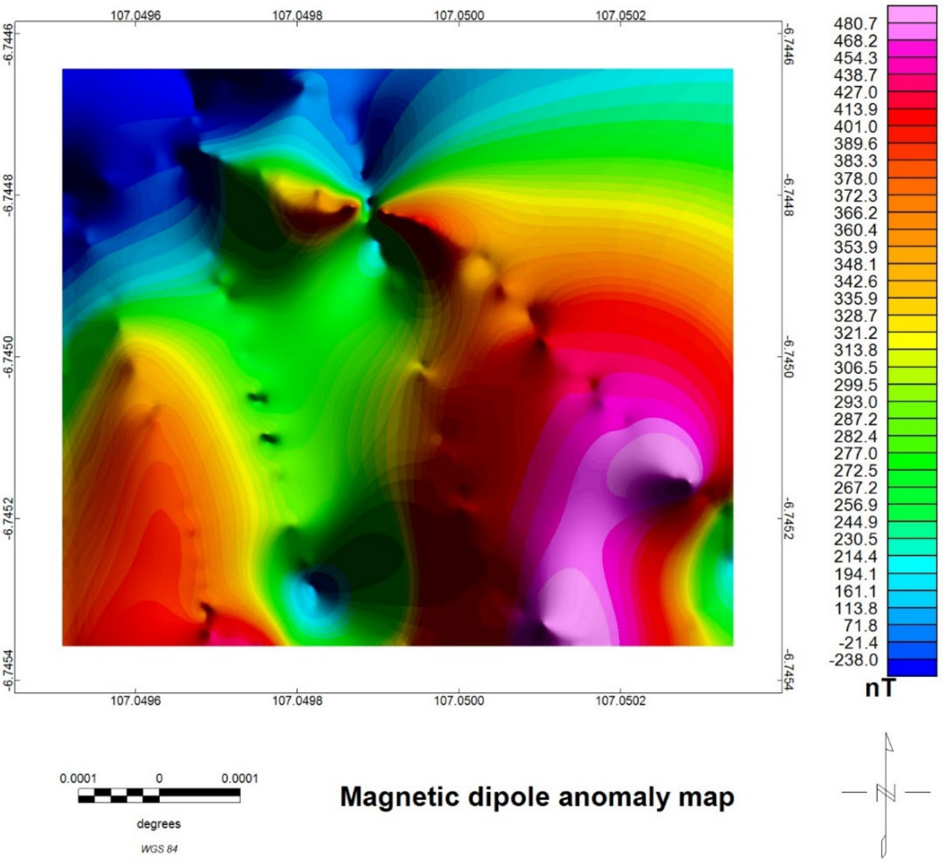

Figure 5. Magnetic field anomaly map.

According to Fig. 5, the magnetic field intensity values range from 238.1 nT to 480.7 nT. Based on the results, dark blue to light blue colors in the map represent low magnetic field intensities (238.1 nT to 230.5 nT), dark green to light green colors represent medium magnetic field intensities (244.9 nT to 306.5 nT), and yellow to pink colors represent high magnetic field intensities (313.8 nT to 480.7 nT).

The magnetic field anomaly contour map shows that there are positive and negative clusters in pairs, indicating that the map still exhibits a dipole nature (with two poles). When looking at the contour map of the total magnetic field anomaly, the location and extent of the objects or rocks responsible for the anomaly cannot be ascertained. Therefore, several steps such as transforming the inclination and declination are required to convert the map into a monopole. The next step is to perform a reduction to the pole.

3-3 Magnetic anomaly map after reduction to the pole

Reduction to the pole is a type of filtering technique in magnetic data processing, applied to the total magnetic field anomaly contour map to eliminate its dipole nature. However, the result is still asymmetric because the magnetic field anomaly values are influenced by the two magnetic poles of the Earth. Therefore, a transformation is needed to obtain monopole closures, which are useful for interpreting the presence or location of the object causing the anomaly. By transforming the magnetic field anomaly data, the measurement area is adjusted with a certain inclination as if it were at the poles by changing the direction of magnetization and orienting the main field in the vertical direction, perpendicular to the horizontal plane. In the Cipendawa area, the inclination value is -30.14946° obtained from the NOAA NGDC (National Oceanic and Atmospheric Administration. National Geophysical Data Center). The results of reduction to the pole in the Cipendawa area are shown in Fig. 6. After reduction to the pole, magnetized rocks will be indicated by the response of high and positive magnetic values. In the results of the reduction to the equator, the minimum magnetic field anomaly value is -255.9 nT and the maximum magnetic field anomaly value is 665 nT.

After transforming the data to the monopole, the difference can be observed when compared to the magnetic field anomaly contours that still have a dipole pattern. Some paired closures have become single closures, but some positive and negative closures remain, suggesting that further study is needed.

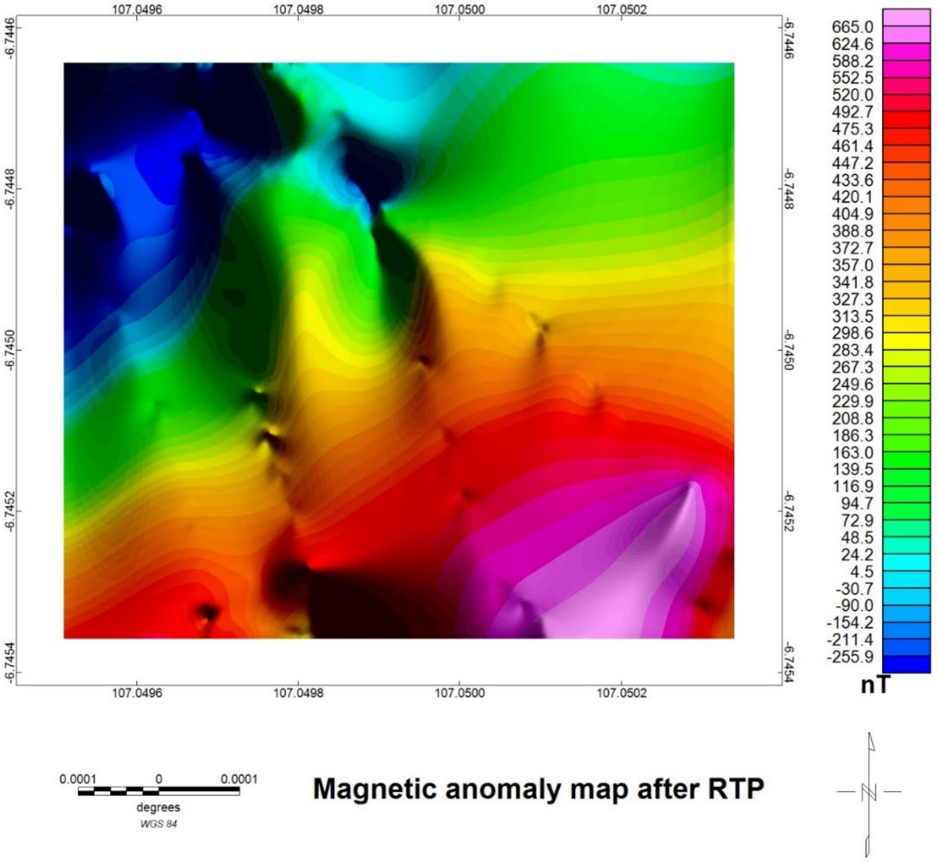

Figure 6. Magnetic anomaly map after reduction to the pole (RTP).

4 Qualitative interpretation

Qualitative interpretation is done by analyzing the total magnetic field anomaly contour map, which has been reduced to the pole and converted into a monopole. In the study area, the contour map of the total magnetic field anomaly is characterized by low-value closures in the north and high-value closures in the southeast. Low-value clasts have values less than 4.5 nT, medium-value clasts range from 4.5 nT to 267.3 nT and high-value clasts are more than 267.3 nT, as seen in Fig. 7. Based on this, the Cipendawa area, characterized by high-value and positive clasts in the southeast, can be recognized as a rock zone and is considered the safest area in terms of landslide risk

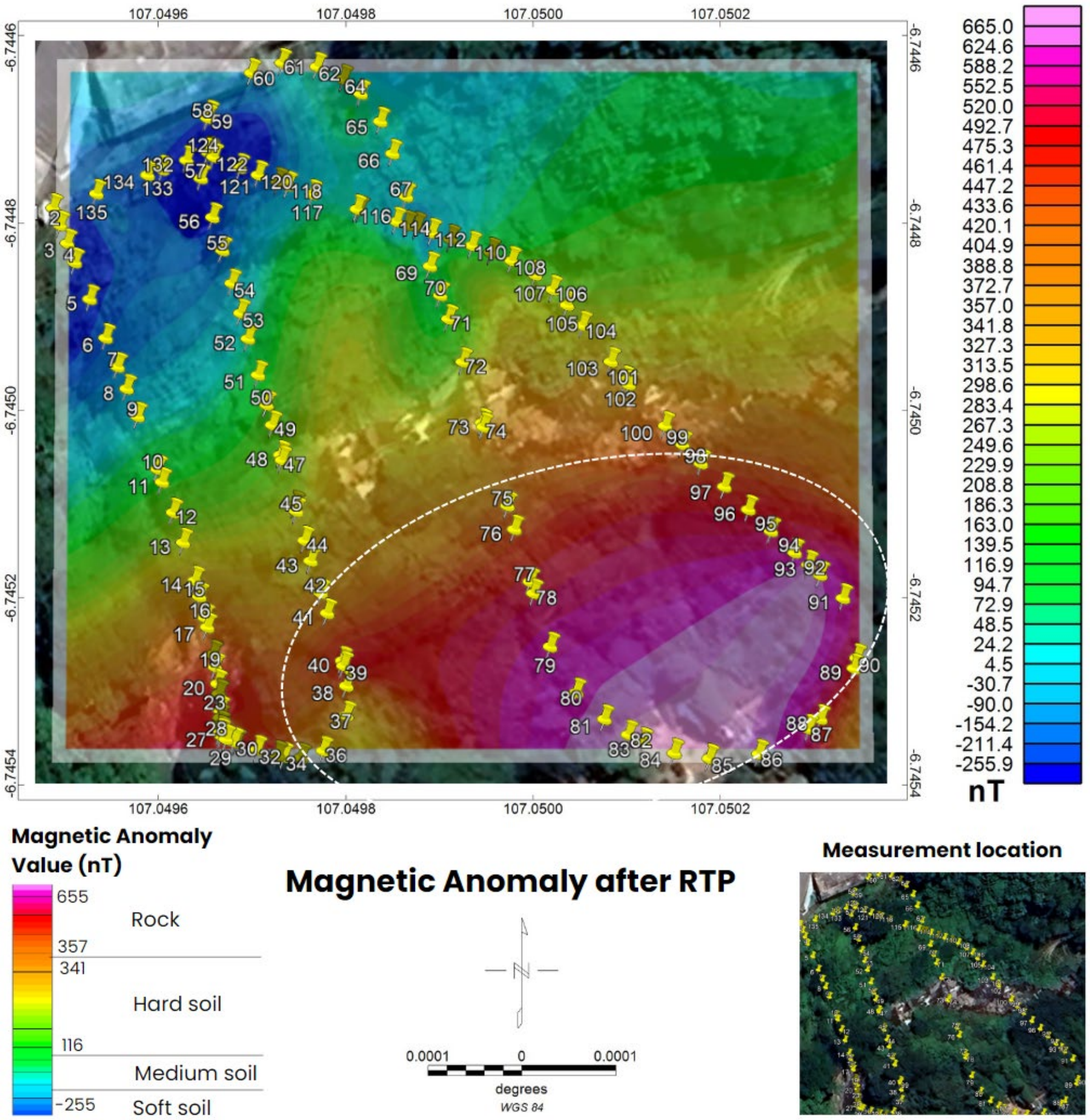

Figure 7. Overlaying the magnetic anomaly map onto Google Earth for the southeastern part of the study area.

Fig. 7 shows a varied distribution of magnetic intensity, reflecting the heterogeneity of the subsurface rocks. Visually, high magnetic anomalies are observed in the southeastern part of the study area, marked with white circles. In the southeast, the high magnetic anomaly suggests the presence of rocks with strong magnetic properties, likely indicating andesite rock. Andesite rocks, products of volcanic activity, are typically rich in ferromagnetic minerals such as magnetite and hematite, which have high magnetic susceptibility. According to Telford et al. (1990), igneous rocks generally exhibit stronger magnetic properties than sedimentary or altered rocks, leading to high magnetic anomalies in this area. The distribution of andesite in the southeast region may also indicate ancient volcanic activity, where magma intrusion caused the formation of igneous deposits rich in magnetic minerals.

This anomaly distribution pattern also provides insights into the tectonic and volcanic history of the Cipendawa area. The southeast region of the study area is closer to the source of ancient volcanic activity, Mount Gede, which produces andesite rocks. This is also consistent with the geological map of the research area (Fig. 1), which shows the distribution of breccia deposits and Mount Gede land. Breccia rocks are formed by explosive volcanic eruptions, where silica-rich andesitic magma cools and breaks into large fragments, which then accumulate around the volcano or are transported by gravity flow (Caratori Tontini et al., 2019).

The magnetic anomaly map that has been reduced to the pole, also shows very low magnetic anomaly values in the northern part of the study area, which are represented in blue to dark blue colors in Fig. 8. These low anomaly values suggest the presence of subsurface rocks or materials with very weak magnetic properties. Based on geophysical theory, such low anomaly zones are often associated with sedimentary rocks, weathered rocks, or alluvial minerals that lack significant amounts of magnetic minerals (Telford et al., 1990).

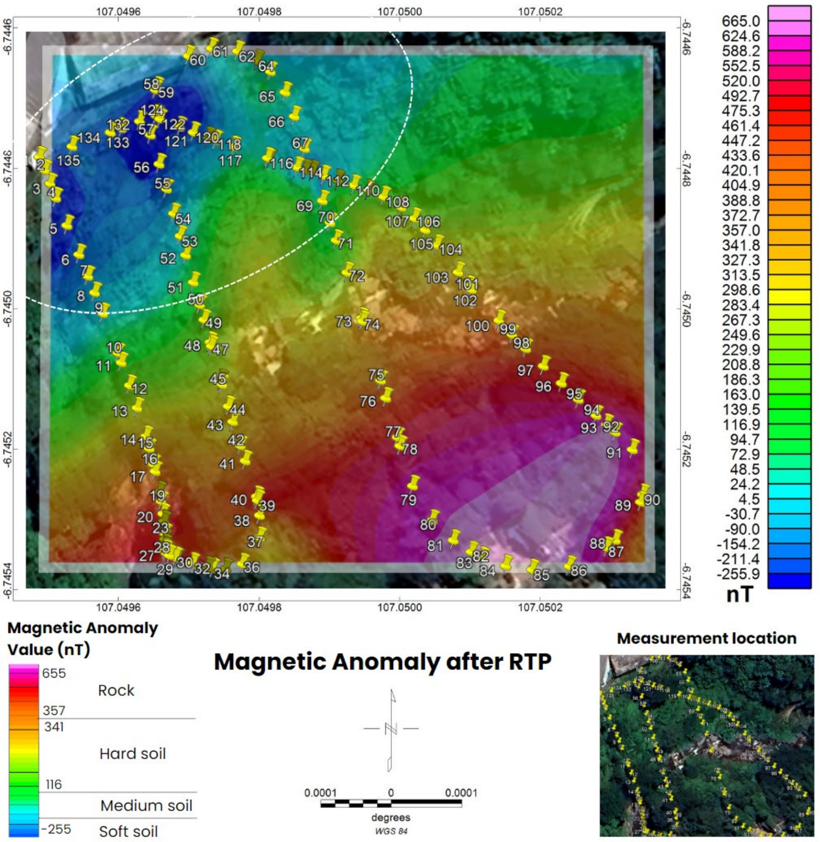

Figure 8. Overlaying the magnetic anomaly map onto Google Earth for the northern part of the study area.

Fig. 8 shows that the northern part of the map exhibits low anomaly intensity, which may reflect the dominance of sedimentary rocks or alluvial minerals deposited through local geomorphological activities, such as erosion and sedimentation from the Cipendawa River flow. These materials have low magnetic mineral content because they result from transportation and weathering processes, during which ferromagnetic minerals such as magnetite tend to be released or broken down into finer, non-magnetic fractions (Telford et al., 1990). In addition, alluvial materials can also form as a result of deposition in low-lying areas, which are often associated with zones of low magnetic anomalies. This low magnetic anomaly pattern may also be related to the hydrogeological conditions in the area. The northern part of the map is most likely located in a zone with high groundwater content, which may lead to a decrease in the magnetic anomaly value. The presence of groundwater, especially in large volumes, can reduce the effective magnetization of rocks due to its high electrical conductivity (Blakely, 1995). This is also consistent with the possible presence of depressions that allow the accumulation of groundwater and sediments. Moreover, the low magnetic anomaly zone in the northern part of the study area may also indicate the presence of old rocks that have undergone intensive weathering processes. Chemical weathering processes can alter magnetic minerals, such as magnetite, converting them into non-magnetic minerals, such as hematite or geothite. This process often occurs in areas with tropical climates, such as Indonesia, where high rainfall accelerates the chemical weathering of rocks (Blakely, 1995).

The presence of low anomalies in the north also provides valuable information about potential geological resources. This area may lack potential for metal-based mineral exploration due to the low magnetic mineral content. However, if the zone is a sedimentary basin, there may be potential for the exploration of groundwater or even hydrocarbon resources, depending on the thickness and characteristics of the sedimentary rocks.

5 Quantitative interpretation

Quantitative interpretation is an in-depth analysis of the RTP (Reduction To Pole) map obtained through two-dimensional modeling by using an incision in the RTP map of the study area. This two-dimensional modeling is performed to determine the susceptibility of rocks beneath the surface of the Cipendawa

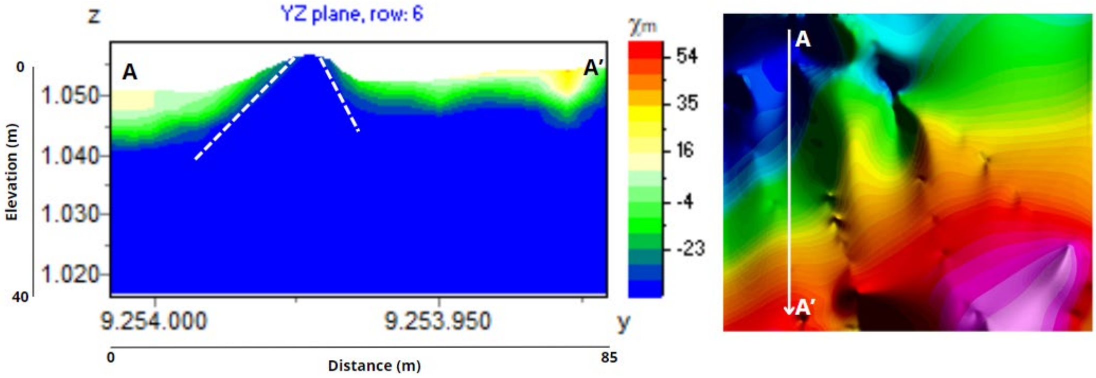

Figure 9. Cross section 1 along distance A- A'.

area using Zondgm2d software. The modeling is divided into three incision sections from north to south, which cut through the Cipendawa River area, as shown in Figs. 9, 10, and 11.

Fig. 9 shows the results of cross section 1 of two-dimensional modeling based on RTP data that illustrates the distribution of magnetic susceptibility values in the subsurface of the Cipendawa area at depths ranging from 0 to 40 meters. The detected range of susceptibility is from -23×10^{-4} SI to 54×10^{-4} SI, suggesting a variety of subsurface geological materials (Table 1). This distribution shows a negative anomaly at the center of the cross-sectional model, which most likely indicates sedimentary material, while positive anomalies on the left and right sides suggest the presence of more massive igneous rocks.

The negative susceptibility values (-23×10^{-4} SI to 0 SI) detected in the center reflect the dominance of materials with non-magnetic properties. Based on the magnetic susceptibility reference table of Telford et al. (1990) (Table 1), these values correspond to sedimentary rocks, such as clays, sands, or tuffs, that are rich in paramagnetic or diamagnetic materials. These sedimentary rocks likely accumulated in structural basins associated with ancient river courses or sedimentation basins. This pattern supports the theory that riverine areas are often places where loose material is deposited due to erosion and transportation processes.

Conversely, positive anomalies with high susceptibility values (0 to 54×10^{-4} SI), located on the left and right sides of the cross section, indicate the presence of rocks rich in ferromagnetic minerals such as magnetite. These values are consistent with the characteristics of mafic igneous rocks, like basalt or andesite, which are typically found as bedrock or as the result of shallow intrusions in volcanic regions. The presence of these rocks can be interpreted as horst or structural high zones, which are more resistant to erosion than the surrounding sediments.

Geologically, the magnetic susceptibility distribution in Fig. 9 reflects significant lithological differences. Local tectonic processes likely played an important role in creating structural controls, such as faults or folds, which led to selective sedimentation in the basin area. Positive anomalies indicate the presence of hard rocks, which may be the result of past magmatic activity, consistent with the history of volcanism in this area.

Table 1. Susceptibility value and rock type at cross section 1 (Telford et al., 1990).

Susceptibility Range (SI)	Rock Type	Depth (m)
-23×10^{-4}-0	loam, shale, sand	(20-40) m
0-16×10^{-4}	volcanic breccia, tuff	(10-20) m
16×10^{-4}-50×10^{-4}	andesite, basalt	(0-10) m

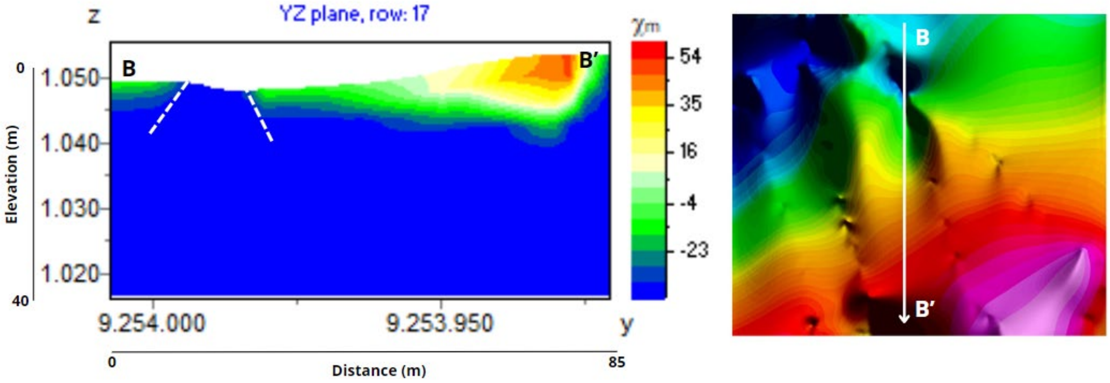

Figure 10. Cross section 2 along distance B-B'.

Fig. 10 shows cross section 2 of the two-dimensional modeling of the Cipendawa area, at depths ranging from 0 to 40 meters. The range of susceptibility values varies from -23×10^{-4} SI to 54×10^{-4} SI. The magnetic anomalies in Fig. 10 show contrasting differences between rocks with high susceptibility (red and yellow colors) and low susceptibility (blue and green colors). This indicates significant lithological variation in the subsurface, which can be interpreted as the presence of igneous or sedimentary rocks with different magnetic properties. On the left (dark blue color), low susceptibility values up to -23×10^{-4} SI indicate the presence of sedimentary rocks, such as clay or sandstone. These sedimentary rocks generally contain non-magnetic minerals, in accordance with the susceptibility range in Table 2, showing values close to zero or negative. This area likely represents the alluvial layer deposited around the river. The red-colored area with susceptibility reaching 54×10^{-4} SI on the right part of the image indicates the presence of rocks with high magnetic content. These high susceptibility values are typically found in igneous rocks, such as basalt or gabbro, which are rich in ferromagnetic minerals like magnetite. The presence of this anomaly suggests the possibility of igneous intrusions or older bedrock layers.

The dotted lines in Fig. 10 show depressions or normal faults, which are most likely the result of tectonic activity. These structures may indicate the displacement of sedimentary layers by

Table 2. Susceptibility value and rock type at cross section 2 (Telford et al., 1990).

Susceptibility Range (SI)	Rock Type	Depth (m)
-23×10^{-4}-0	loam, shale, sand	(20-40) m
0-16×10^{-4}	volcanic breccia, tuff	(10-20) m
16×10^{-4}-50×10^{-4}	andesite, basalt	(0-10) m
$>50\times10^{-4}$	diabase, gabbro, magnetite-rich granite	(0-5) m

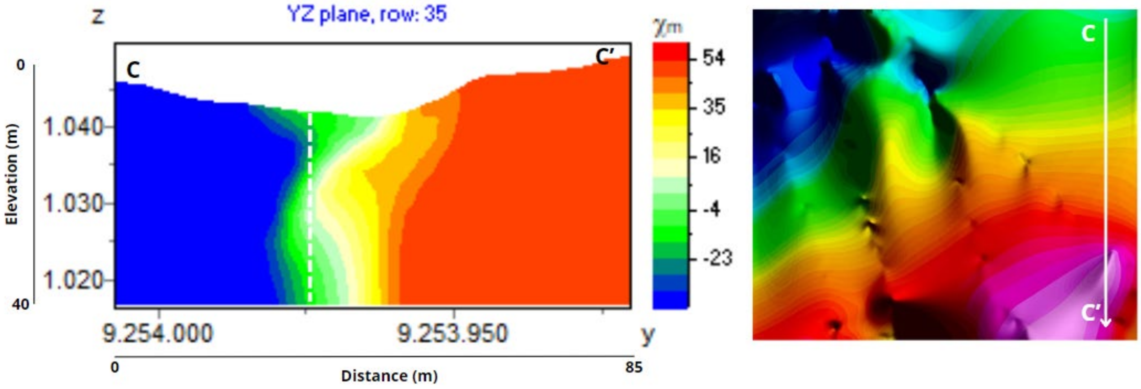

Figure 11. Cross section 3 along distance C-C'.

underlying igneous rocks, which have uplifted the harder rock layers. The depth of this structure is estimated to be about 10-20 meters below the surface.

Cross section 3 (Fig. 11) displays the results of the two-dimensional modeling of the RTP map for the Cipendawa River area at depths ranging from 0 to 40 meters. This model illustrates the distribution of magnetic susceptibility values, reflecting the characteristics of subsurface rocks. Based on the color scale, the susceptibility values range from -23×10^{-4} SI to 54×10^{-4} SI. This variation in values reflects differences in the magnetic properties of materials associated with specific types of rocks or geological structures (Table 3).

Zone with low susceptibility values, ranging from -23×10^{-4} SI to -4×10^{-4} SI, is represented in blue on the left side of the model. This zone likely consists of alluvial or river sediments, such as sand, gravel, and clay, which are either non-magnetic or very weakly magnetic. The depth of this zone extends up to 40 meters, corresponding to the characteristics of sediments deposited through river transport processes. Based on geological theory, this material typically originates from the erosion of upstream rocks, which are carried downstream by river flow.

A zone with medium susceptibility values, ranging from -4×10^{-4} SI to 16×10^{-4} SI, is observed in the green area at the center of the model. This zone is likely composed of old volcanic rocks, such as tuff or volcanic breccia, which contain moderately magnetic minerals like hematite. These rocks reflect the results of past volcanic activity deposited in the form of pyroclastics or tuff layers. The depth of this zone extends to 40 meters, suggesting that the material has been buried beneath younger sedimentary layers.

Zones with high susceptibility values, ranging from 16×10^{-4} SI to 54×10^{-4} SI, are represented by orange to red colors and dominate the right side of the model. This zone can be interpreted as igneous rocks, such as basalt or andesite, which are rich in magnetic minerals like magnetite. The presence of this zone suggests past igneous intrusion or lava flow activity in the area. These structures potentially reflect magma intrusion zones, which are linked to the history of volcanic activity in the Cipendawa region.

The significant susceptibility gradient observed around the green to yellow area at the center of the model suggests the possible presence of a fault or geological contact zone. This zone could represent the boundary between alluvial sediments and volcanic rocks or intrusive igneous rocks. The presence of this structure is significant because it may indicate magma migration pathways or potential mineral traps. Based on the interpretation results, this model provides in-depth information about the variation in rock types and subsurface geological structures in the Cipendawa river area. Magnetic methods, such as RTP, are very effective for identifying lithologic distribution, detecting geological structures, and studying the potential of natural resources. Thus, these results can be applied to mineral resource exploration and geotechnical studies.

The modeling analysis aims to understand the detailed subsurface structure and identify potential aquifer zones, which is essential for determining landslide-safe areas. This analysis is conducted using three-dimensional modeling, which provides a visual representation of the physical variation of subsurface rocks, helping to identify stable hard rock layers as well as alluvial layers that may be susceptible to land movement. In the Cipendawa area of Cianjur, characterized by active tectonic activity and high rainfall potential, this analysis is crucial to determine safe zones for development and to manage groundwater resources sustainably.

Table 3. Susceptibility value and rock type at cross section 3 (Telford et al., 1990).

Susceptibility Range (SI)	Rock Type	Depth (m)
-23×10^{-4}-0	loam, shale, sand	(20-40) m
0-16×10^{-4}	tuff, volcanic breccia	(10-20) m
16×10^{-4}-50×10^{-4}	andesite, basalt	(0-10) m
>50×10^{-4}	basalt, magnetite-rich andesite (igneous rock)	(0-5) m

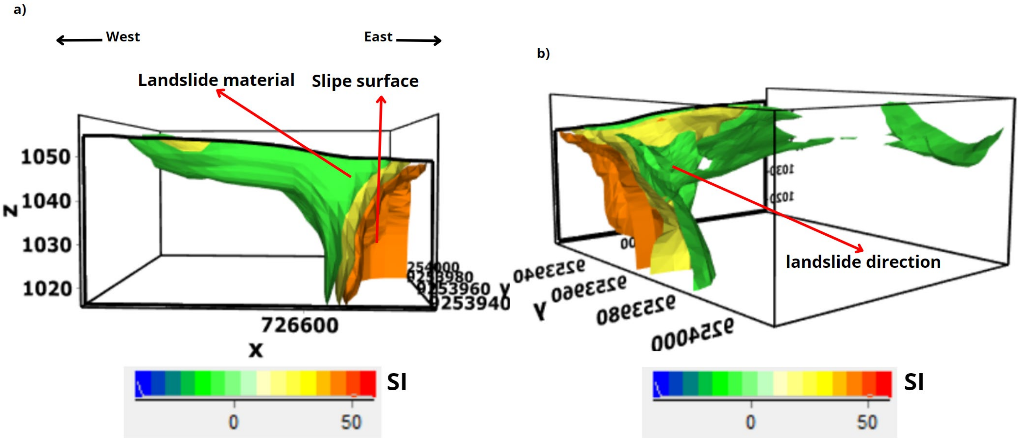

Figure 12. 3D modeling of slip surface and (a) landslide material, (b) landslide direction.

After analyzing the 2D inversion model, a 3D isosurface model was made to visualize the shape of rocks acting as landslide material, such as sedimentary rocks like clay, shale, and sandstone, as well as rocks that act as sliding planes, like andesite and volcanic breccia (Fig. 12).

Fig. 12 shows the results of 3D isosurface modeling of the Cipendawa area, illustrating the potential for ground mass movement or landslides. In Fig. 12a, the landslide material is shown in green, while the slope surface is colored orange. The orientation of the model is indicated by the X and Z axes, with a west to east direction. The colors in the model represent the Stability Index (SI) values, with a color scale ranging from blue to red to indicate the level of soil stability. High values (red) represent more critical conditions. In Fig. 12b, the direction of the landslide shows the movement of material to a lower section. Avalanche material further away from the sliding surface is shown in green with irregular contours, indicating the distribution of soil movement due to gravity and local geology. With this model, further analysis of slope stability and disaster mitigation potential in the Cipendawa area can be conducted.

In Table 4, criteria and vulnerability of landslide potential in Cipendawa area are listed. Landslide triggering factors are based on the Guidelines for Spatial Planning in Landslide Prone Areas. In Table 5, suspension assessment in determining the typology of disaster-prone areas is listed. The results show that the study site belongs to type B area, which has factors that cause landslide vulnerability. The presence of these factors resulted in a score of 2.31 for the study site, which is interpreted as an area with low stability. The findings of this study are align with the research conducted by Setiawan et al. (2015), which reported that 43% of the total area

Table 4. Criteria and vulnerability of landslide potential in Cipendawa area (Menteri Pekerjaan Umum, 2007).

No.	Indicator	Weight	Verifier	Score	Result
1	land slope	30%	Land with 30-35% slope	2	0.6
2	ground conditions	15%	The land is composed of thick (>2m), loose and easily permeable soils, such as residual soils, which typically overlie the bedrock (andesite, breccia, claystone). Moreover, sedimentary rocks overlie the underlying andesite.	3	0.45
3	rock type	20%	Soil is composed of rocks with discontinuity planes or fracture/bridle structures in the rock.	3	0.6
4	rainfall	15%	Rainfall is moderate (ranging from 30-70 mm/hour), lasts no more than 2 hours and does not occur every day (100-2500 mm annually), because the area is a mountain slope.	2	0.4
5	slope water management	7%	It is rare for water seepage or springs to appear on slopes, especially where there is a contact area between impermeable rock and permeable soil layers.	2	0.14
6	earthquake	3%	Slopes in volcanic, earthquake-prone areas are affected by mountainous terrain. An earthquake occurred in 2023.	3	0.09
7	vegetation	10%	Reeds, grasses, shrubs, herbaceous plants	3	0.03
	Total	100%			2.31

Table 5. Suspension assessment in determining the typology of disaster-prone areas (Menteri Pekerjaan Umum, 2007).

Classification of stability	**Score range**	Regional typology
stabel	1-1.69	A
less stable	1.7-2.39	B
unstable	2.4-3	C

of Cianjur has the potential for landslides. In addition, 44% of the study area was also categorized as affected and vulnerable to landslides. Research conducted by Satria et al. (2007) showed that the general characteristics of landslide locations in the study area are dominated by slopes greater than 40%, annual rainfall exceeding 3000 mm, and rock types such as volcanic breccia and tuffaceous sandstone from Mount Gede. Thus, the analysis of landslide potential using the geomagnetic method in this area further strengthens the evidence that the study area has a high landslide risk. Therefore, the findings can be used as a reference for the community as well as a basis for stakeholders in landslide mitigation efforts.

6 Conclusion

Qualitative interpretation of the RTP magnetic field anomaly contour maps in Cipendawa, Cianjur, reveals anomaly distributions that reflect subsurface rock heterogeneity and volcanic history of the region. The southeastern part is dominated by high anomalies, presumably related to magnetic mineral-rich andesitic rocks, while the northern part shows low anomalies, possibly related to sedimentary, alluvial or weathered older rocks, with aquifer potential in this zone. The cross sections show susceptibility variations ranging from -23×10^{-4}SI to 54×10^{-4}SI at depths of 0-40 meters, indicating the presence of non-magnetic sedimentary materials in the negative susceptibility zones and volcanic rocks in the high susceptibility zones. The cross sections also illustrate the interaction between sediments and igneous intrusions, as well as the distribution of alluvial sediments and igneous rocks, with significant gradients indicating potential geological contacts. The landslide potential at the research site is classified as type B, where the area is less stable due to lithological, topographical and geological factors that increase vulnerability to landslides. This study serves as a foundation for future studies in developing strategies to mitigate the impact of landslide risk at the site.

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References

Abdullah, M. F., and Sunaryo, S., 2014, Pendugaan Jenis Batuan Bawah Permukaan Daerah Bandungan Karangkates Menggunakan Metode Geomagnetik: Physics Students Journal, **2**(1), 741–744.

Agustin, F., and Bronto, S., 2019, Volkanostratigrafi Inderaan Jauh

Kompleks Gunungapi Gede dan Sekitarnya, Jawa Barat, Indonesia: Jurnal Geologi Dan Sumberdaya Mineral, **20**(1), 9.

Badan Meteorologi Klimatologi dan Geofisika (BMKG), 2022, Laporan Hasil Kajian Kelayakan Lahan Relokasi.

Bemmelen, R. W., 1970, The Geology of Indonesia: Martinus Nijhoff.

Blakely, R. J., 1995, Potential Theory in Gravity and Magnetic Applications: Cambridge University Press, Cambridge Core.

Bouligand, C., Glen, J. M. G., and Blakely, R. J., 2014, Distribution of buried hydrothermal alteration deduced from high-resolution magnetic surveys in Yellowstone National Park: Journal of Geophysical Research: Solid Earth, **119**(4), 2595–2630, https://doi.org/10.1002/2013JB010802.

Caratori Tontini, F., Tivey, M. A., de Ronde, C. E. J., and Humphris, S. E., 2019, Heat flow and near-seafloor magnetic anomalies highlight hydrothermal circulation at Brothers Volcano Caldera, Southern Kermadec Arc, New Zealand: Geophysical Research Letters, **46**(14), 8252–8260, https://doi.org/10.1029/2019GL083517.

Koesmono, M., 1976, Peta geologi lembar Sindangbarang dan Bandarwaru, Jawa (Geologic map of the Sindangbarang and Bandarwaru).

Maulidan, I. F., Tri Suci, R., Mahendra, A., and Putra, A., 2021, Interpretation of subsurface structure based on the magnetic data at Semurup Geothermal Area Kerinci: Jurnal Ilmu Fisika Universitas Andalas, **13**(2), 101–108, https://doi.org/10.25077/jif.13.2.101-108.2021.

Menteri Pekerjaan Umum., 2007, Peraturan Menteri Pekerjaan Umum No 22/PRT/M/2007 tentang Pedoman Penataan Ruang Kawasan Rawan Bencana Longsor, Menteri Pekerjaan Umum.

Purwantoro, T., Rachman, A., and Silaban, M., 2010, Potensi dan Rencana Pengembangan Lapangan Panas Bumi Patuha Jawa Barat: 39th IAGI Annual Convention and Exhibition.

Pusat Vulkanologi Mitigasi Bencana Geologi (PVMBG), 2023, Analisis Potensi Bahaya Geologi di Cianjur.

Satria, D. P. B., Kusratmoko, E., 2007, Tanah longsor di sekitar Pacet - Cianjur (Provinsi Jawa Barat).

Setiawan, A., Supriatna, Waryono, T., Wibowo, A., and Saraswati, R., 2015, Declined Revisions (Author Decided to Cancel the Whole Submission), Universitas Indonesia.

Sihombing, S., Dewi, I. K., and Sibuea, C. H. G., 2023, Identifikasi Litologi Bawah Permukaan Daerah Rawan Longsor Menggunakan Metode Geomagnetik di Tikungan Tirtanadi Desa Batu Layang Kecamatan Sibolangit Kabupaten Deli Serdang: Jurnal Teknik Kebumian, **10**(1).

Situmorang, T., and Hadisantono, R., 1992, Peta geologi Gunungapi Gede, Cianjur, Jawa Barat: Direktorat Vulkanologi.

Sudjatmiko, 1972, Peta Geologi Lembar Cianjur, Jawa Barat, Bandung: Pusat Penelitian dan Pengembangan Geologi.

Syafnur, A., Jibran, H., Tonapa, W. D., Sae, A., and Nurdin, N. H., 2023, Investigation of groundwater aquifer using electrical resistivity method Wenner-Schlumberger array Mattoangin Village, Bantimurung

District, Maros Regency: Jurnal Geocelebes, 7(1), 89–98, https://doi.org/10.20956/geocelebes.v7i1.23302.

Telford, W., Geldart, L., and Sheriff, R., 1990, Geofisika Terapan (2nd ed.): Cambridge University Press.

Yasmin, H. S., Pirzada, S. J., Sahroni, T. R., Soekarno, H., Pranoto, B., Puspa, A. D., and Alfisah, 2024, 2D geological structure identification in Mount Ciremai Geothermal Area using the GGMplus data: IOP Conference Series: Earth and Environmental Science, **1344**(1), https://doi.org/10.1088/1755-1315/1344/1/012017.

Yunginger, R., Sandi, F. Y., Setiawan, D. G. E., Husen, M. H., Zulkifli, and Ardiyanto, K., 2024, Analysis of landslide potential based on magnetic susceptibility of rocks using geomagnetic methods in Suka Damai Village, Bulango Utara Subdistrict, Bone Bolango Regency: Jurnal Penelitian Fisika Dan Aplikasinya (JPFA), **14**(1), 49-66, doi: 10.26740/jpfa.v14n1.p49-66.