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MIDDLE MIOCENE TO HOLOCENE GEOLOGICAL HISTORY AND POTENTIAL OF BABAKAN JAWA AREAS, MAJALENGKA DISTRICT OF WEST JAVA-INDONESIA

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ABSTRACT

This research activities were conducted in the Sidamukti, Babakan Jawa, Cibodas areas and surroundings, Majalengka District, West Java Province. The main objective of this research is to determine the geomorphological characteristics, lithology, geological structures, and geological potential in the research area. The methods used include field observations, laboratory analysis, interpretation of topographic maps and satellite imagery, as well as structural analysis using stereonet. The research results show that the geomorphology of the study area was formed by the interaction of endogenic forces (tectonic and volcanic) and exogenic forces (weathering and erosion), resulting in five main geomorphological units, namely Very Gentle Denudational Hills Unit, Steep Intrusive Hills Unit, Volcanic-Structural Steep Longitudinal Hills Unit, Structural-Denudational Volcanic Steep Hills Unit, and Structural Sedimentary Hills Unit. The stratigraphy of the area consists of four rock units composed of claystone units, sandstone units, tufan sandstone units, and andesite units ; and alluvium deposit. The developed geological structures indicate the influence of extensional stress with a strike-slip component that forms normal faults and reverse faults trending northwest–southeast. The geological potential of the area includes geological resources such as andesite, sand, and gravel, as well as the geotourism potential of Taman Gunung Batu Karang. On the other hand, steep hilly areas with weathered lithology show vulnerability to mass movements, making them landslide-prone areas. The results of this research are expected to serve as a basis for sustainable natural resource management and geological disaster mitigation.

Keywords: Geomorphology, Rock Units, Stratigraphy, Geological Structure.

INTRODUCTION

The Sidamukti, Babakan Jawa, Cibodas, and surrounding areas in Majalengka District, Majalengka Regency, West Java are located at coordinates 108°11'54.2112‟ E – 108°14'39.21” E and 6°52'54.8652" S – 6°50'9.8664" S. This area is located in a transition zone between volcanic hills and alluvial plains, resulting in diverse morphology and lithology. This area also exhibits complex structures such as folds and faults. This complexity makes the region significant for research in order to understand the distribution of lithology, geological structure characteristics, and geological history that influence the formation and changes of rocks in the area.

This study aims to identify geomorphology, map lithological distribution and stratigraphic relationships, determine the orientation and type of geological structures, compile interpretations of geological history, and evaluate the geological and disaster potential of the study area.

REGIONAL GEOLOGY

Regional Physiography

Van Bemmelen (1949) divided West Java into five main physiographic zones, namely the Jakarta Coastal Plain Zone, the Bogor Zone, the Bandung Zone, the Bayah Mountain Zone, and the Southern Mountain Zone (Figure 1).

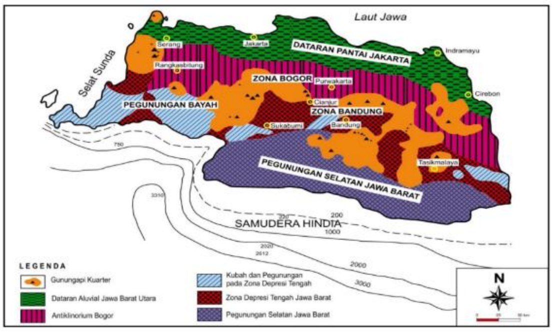


Figure 1. Physiographic map of West Java (modified from Van Bemmelen, 1949)

The study area is located in the eastern part of the Bogor Zone, which is known for its folded hills composed of deep marine sedimentary rocks from the Tertiary period. The anticlinorium structure that dominates this area has undergone additional deformation in several places in the form of faults that are thought to have formed during the Pliocene to Pleistocene periods, in line with regional tectonic activity such as the Lembang Fault and the uplift of the Southern Mountains (Wardhana et al. 2016). The research area also included in the Majalengka Sub-Basin, which is part of the Bogor Basin.

Regional Stratigraphy

The area studied is included in the Majalengka Geological Map Sheet (Isnaniawardhani et al., 2020), which depicts the composition of rock types from the youngest to the oldest:

1) Alluvium (Qa) consists of various materials such as clay, silt, sand, and gravel formed as Holocene river deposits.
2) Horenblenda Andesite (ha) is an intrusive rock type that appears as a dike with a width of between 20 and 30 meters.
3) The Citalang Formation (Tpc) is dominated by tuffaceous sandstone, tuffaceous clay, and conglomerate originating from the Pleistocene period.
4) The Kaliwangu Formation (Tpk) includes claystone components and intercalations of tuffaceous sandstone, conglomerate, and limestone, which were formed in a transitional environment during the Pliocene period (Rachman & Winantris, 2023)
5) The Lower Member of the Halang Formation (Tmhl) dominated by breccia with andesite fragments, several tuff, clay, and conglomerate intercalations originating from the Middle to Upper Miocene.
6) The Cinambo Formation Shale Member (Tomcu) consists of shale interspersed with sandstone and limestone that appeared in the Lower Miocene.
7) The sandstone member of the Cinambo Formation (Tomcl) consists of thick greywacke with intercalations of shale and clay, showing a regular layering pattern and turbidite traces that describe deposits from a deep marine environment in the Lower Miocene.

RESEARCH METHOD

This research was conducted in four stages, namely preliminary study, field activity, data processing, and data integration and interpretation. The preliminary study included a literature review, analysis of the Arjawinangun Sheet geological map, and interpretation of satellite imagery to identify alignment patterns, landforms, and flow patterns, which would later be used to plan the activity route.

The field activity process produced primary data that included lithology identification, structural orientation measurements, sediment structure observations, outcrop documentation, and sample collection from a total of 58 observation stations.

Geomorphological observations were conducted to verify the image interpretation results and confirm the relationship between lithology, structure, and topography.

The collected data were processed using microscopy and laboratory analytical parameters, with petrographic analysis applied to determine mineralogy and texture, and micropaleontological analysis performed when fossils were present in the samples. A total of 13 samples were used in this study, consisting of 6 samples formicropaleontological analysis and 7 samples for petrographic investigation. All collected from various locations in the study area to ensure comprehensive spatial representation (Figure 2).

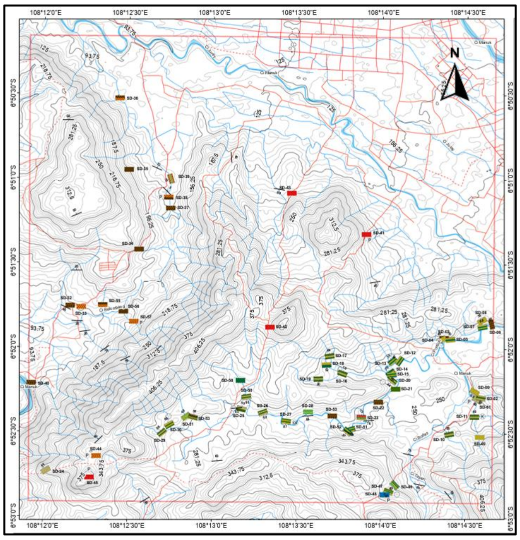


Figure 2. Map of sample analysis collection locations (Scale 1 : 12.500)

Micropaleontological analysis was conducted at the Micropaleontology Laboratory, using a binocular stereo microscope for microfossil picking and a biological microscope + camera for microfossil documentation. Thin section preparation and petrographic examination were carried out at the Petrographic Laboratory, using polarizing microscope . Both laboratories are located at the Faculty of Geological Engineering, Padjadjaran University. All information generated was integrated to create geological maps, correlate rock formations, interpret geological history, and evaluate geological potential and disaster risk in the study area.

RESULT

Geomorphology of the Study Area

Geomorphology is the study of the Earth's surface and the processes that shape it. Geomorphological analysis in this study includes morphography, morphometry, and morphogenetics (Figure 4), which are used to identify landform units in the study area.

Morphography

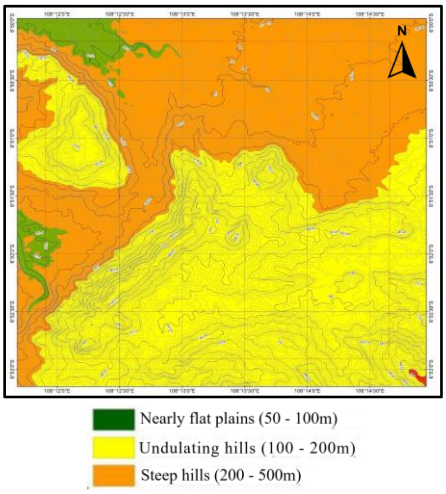
Based on Fossen's classification (2016), the landforms of the study area consist of nearly flat plains, undulating hills, and steep hills (Figure 3a). The nearly flat plains have an elevation of about 50–125 meters with a very low slope and are located in the northwest and southwest of the study area. Undulating hills occupy the northern to central parts with an elevation of 125–200 meters, while steep hills are located in the south-east and part of the northwest with an elevation of 200–375 meters. The river flow patterns that developed included trellis, parallel, and subparallel patterns, indicating the influence of geological structures on the direction of the valleys and the development of landforms (Figure 3b).

Morphometry

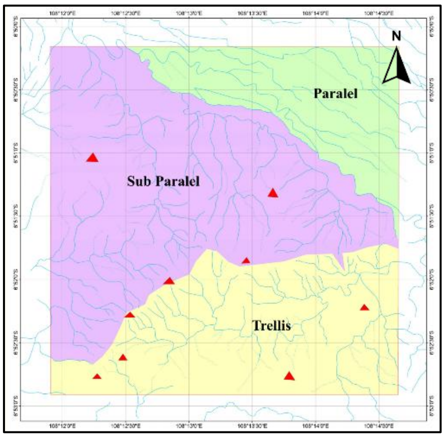
Morphometric analysis shows six classes, namely flat, very gentle, gentle, moderately steep, steep, and very steep (Figure 3c). The flat to very gentle classes are mainly found in the northern part, while the gentle to moderately steep classes dominate the central area. The steep and very steep classes are found on the elongated hills in the Sidamukti and Cibodas areas, reflecting a more rugged topography and potential for slope instability. The distribution of these slope classes indicates elevation changes influenced by structural controls and the lithological characteristics of the hills.

Morphogenetic

The landforms at the study site are the result of interactions between endogenous and exogenous forces. Tectonic activity created northwest-southeast and northeast-southwest oriented lineations, which influenced the formation of elongatd hills and parallel valleys (Figure 3d). Volcanic impacts are evident through the presence of andesite intrusions and tuff deposits, which have caused hard rock outcrops to appear on the surface. On the other hand, exogenous processes such as weathering, erosion, and sedimentation formed valleys and alluvial plains in lower areas. The interaction between these two forces resulted in complex geomorphological variations, ranging from structural hills to young alluvial plains, which are now used for settlement and agriculture.



(a)



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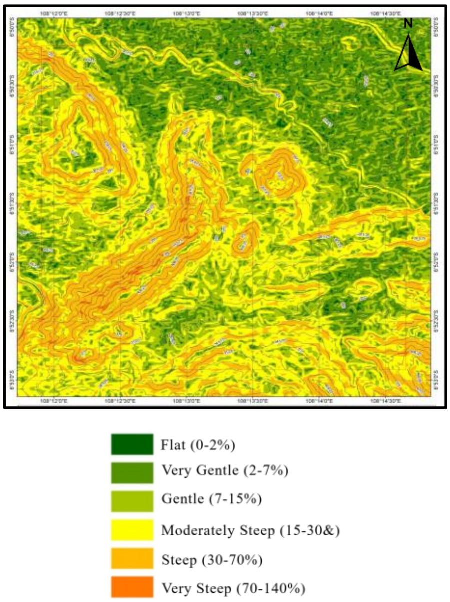

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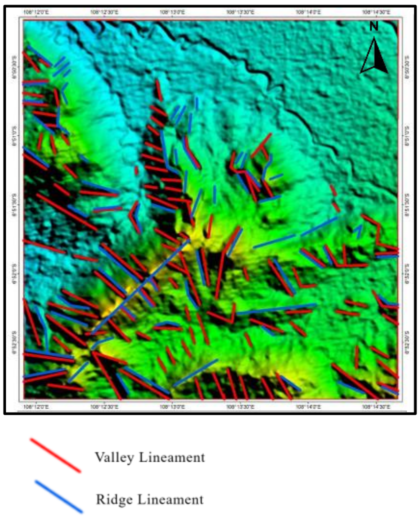


(d)

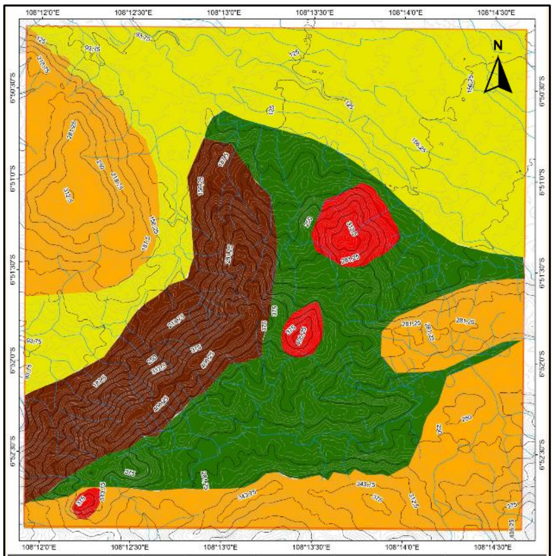
Figure 3. (a) Landform Map of the Study Area (Scale 1 : 12.500); (b) Map of the Flow Patterns in the Study Area (Scale 1 : 12.500); (c) Slope Map of the Study Area (Scale 1 : 12.500); (d) Alignment Map of the Study Area (Scale 1 : 12.500).

Geomorphological Units

The geomorphology of the study area was formed by the interaction of endogenous forces, namely tectonic and volcanic forces, with exogenous forces in the form of weathering, erosion, and sedimentation. This interaction resulted in diverse landforms, ranging from alluvial plains to steep hills controlled by volcanic structures and intrusions. Based on a combination of morphography, morphometry, and morphogenetics (Figure 4).

Description of the geomorphological map.

1) Steep Intrusive Hills Unit (Figure 5a) with red color, characterized by the presence of andesite rock as a result of plutonic intrusion. This unit has an elevation of 200–500 meters with a slope of 30–70%, forming a V-shaped slope as a result of strong vertical erosion. The subparallel flow pattern reflects the homogeneity of lithology and slope. The combination of igneous rock resistance and exogenous processes forms a steep relief dominated by erosion.



Geomorphological Unit	Color Symbol	Drainage	Formation	Tectonic	Landform	Valley Shape	Elevation (m asl)	Class	Slope (%)	Endogen	Exogen	Lithology
Steep Intrusive Hills		Sub-parallel	Andesite (Intrusion)	-	Hilly	V-shaped	200–500	Steep	30–70	Volcanic	Weathering, erosion	Igneous rock (Andesite)
Very Gentle Denudational Hills		Parallel	Citalang, Cinambo, Alluvium	Folding, Fault	Lowland – Hilly	U-shaped	50–200	Very Gentle – Gentle	2–15	Tectonic	Weathering, erosion	Sandstone, tuff, conglomerate, claystone, alluvium
Structural-Denudational Volcanic Steep Hills Unit		Sub-parallel	Citalang, Cinambo, Halang	Fold	Hilly	V-shaped	200–500	Moderately Steep – Steep	15–70	Tectonic, Volcanic	Weathering, erosion	Tuff, breccia, sandstone
Volcanic-Structural Steep Longitudinal Hills Unit		Trellis, Sub-parallel	Citalang	Fault	Hilly	V-shaped	200–500	Moderately Steep – Very Steep	15–140	Tectonic	Weathering, erosion	Tuff, sandstone, breccia, conglomerate
Structural Sedimentary Hills		Sub-parallel, Trellis, Parallel	Cinambo, Halang	Fault, Fold, Joint	Hilly	U–V-shaped	200–500	Flat – Steep	0–70	Tectonic	Weathering, erosion	Breccia, sandstone, claystone

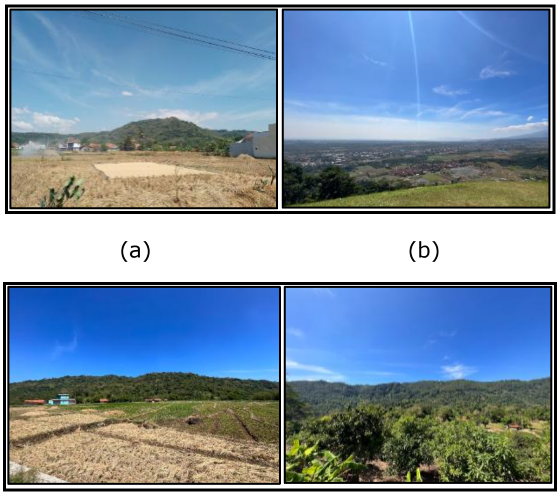
Figure 4. Geomorphological map of the study area (Scale 1 : 12.500); (b)

2) Very Gentle Denudational Hills Unit (Figure 5b), colored yellow, characterized by a landscape that has undergone intensive leveling, composed of the Citalang Formation, Cinambo Formation, and relatively soft alluvial deposits. The elevation of this unit ranges from 50 to 200 meters with a slope of 2 to 15%. Parallel drainage patterns and U-shaped slopes indicate the dominance of lateral erosion and deposition. The morphogenesis of this unit is controlled by tectonic structures that have been modified by long-term weathering and erosion processes.

3) Structural-Denudational Volcanic Steep Hills Unit (Figure 5c) in orange, formed from a combination of structural, volcanic, and denudation processes. This unit consists of the Citalang, Cinambo, and Halang Formations, which have undergone folding and faulting. The elevation reaches 200–500 meters with a slope of 15–70% and a V-shaped slope profile. The developed flow pattern is subparallel, indicating a strong structural influence despite modification by weathering and erosion processes.

4) Volcanic-Structural Steep Longitudinal Hills Unit (Figure 5d) with brown color, showing the most obvious tectonic influence, marked by ridges northwest-southeast oriented. Elevation ranges from 200 to 500 meters with a slope of 15 to 140%. Trellis and subparallel flow patterns develop following the straightness and fractures of the rock, so that structural control over the morphology is very strong. The constituent lithology is andesite and tuff with varying resistance, resulting in steep slopes with the potential for landslides.

5) Structural Sedimentary Hills Unit with green colour, controlled mainly by tectonic deformation that produces folds, faults, and fractures in the sedimentary rocks of the Cinambo and Halang Formations. This unit has an elevation range of 200–500 meters and a slope of 0–70%, reflecting lithological and structural heterogeneity. Subparallel, trellis, and parallel flow patterns develop following the orientation of the structure. Variations in U- and V-shaped slope profiles indicate a combination of lateral and vertical erosion in breccia, sandstone, and claystone.



(a) (b)

(c) (d)

Figure 5. Geomorphological photos of the research area (a) Steep Intrusive Hills Unit; (b) Very Gentle Denudational Hills Unit; (c) Structural-Denudational Volcanic Steep Hills Unit; (d) Volcanic-Structural Steep Longitudinal Hills Unit.

Stratigraphy of the Study Area

Rock units were classified based on dominant lithology, uniformity of characteristics, stratigraphic sequence, and other lithological features. Data obtained from the stratigraphic analysis in the research area consists of correlations between lithology and fossil content from several rock units to determine age (Pangaribuan et al., 2023). Field observations and analysis resulted in a geological map showing four rock units and alluvium deposit, arranged from youngest to oldest (Figure 6).

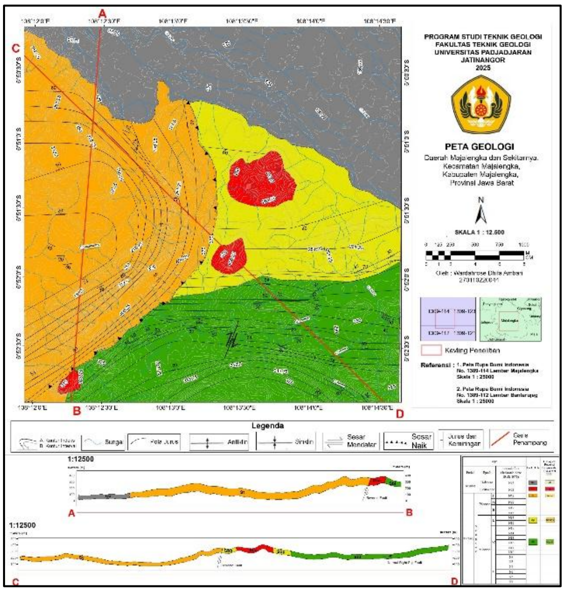


Figure 6. Geological Map of the Study Area (Scale 1 : 12.500).

1) Claystone Unit (Sbl), represented by the color green, has a wide distribution in the east-west direction. Its lithology is dominated by claystone, with intercalations of sandstone, siltstone, carbonate rock (packstone), and breccia insertions. The claystone is grayish brown to blackish brown in color, with a fine texture, soft to moderately compact, and shows parallel layering (Figure 7a).

   The components included clay minerals, fine quartz, and calcite, breccia intercalations are thought to originate from submarine landslides. The carbonate rocks show packstone rich in bioclastic fragments, indicating deposition in a moderately energetic shallow sea. Analysis of foraminifera fossils at several stations shows that Sbl is relatively Middle Miocene in age (N9–N15) with a bathyal (200–2000 m) depositional environment. Regional comparability shows that Sbl has similar lithology, age, and depositional environment to the Cinambo Formation Shale (Nmcsh) (Isnaniawardhani et al. 2020).

2) Sandstone units (Sbp), represented by the yellow color, are widely distributed in the west-central part of the study area. The lithology is dominated by sandstone, with minor intercalations of claystone and breccia. Weathered colors range from grayish brown to blackish brown, while fresh colors range from light gray to black. Grain size varies from very fine to coarse sand, generally medium to coarse, subangular to subrounded in shape, with good sorting, tight packing, and moderate to good porosity and permeability (Figure 7b). Sedimentary structures include parallel lamination, graded bedding, and load casts, indicating deposition in a fluctuating energy environment.

   Petrographic analysis shows dominant mineral composition of quartz, with feldspar, rock fragments, and carbonate cement. Foraminiferal fossil analysis indicates a relative age of Late Miocene–Early Pliocene (N16–N18) with a Neritic–Bathyal (200–2000 m) depositional environment, indicating deposition in shallow seas transitioning to land. Regional comparability shows that Sbp is similar to the Halang Formation Breccia (Nmhbx) in lithology and distribution patterns (Isnaniawardhani et al. 2020).

3) The Tufan Sandstone Unit (Sbpt), represented by the color orange, dominates the western part of the study area. Its lithology consists of coarse tuff as the dominant component, tufan sandstone, breccia, and volcanic conglomerate. The weathered color ranges from reddish brown to brownish gray, while the fresh color ranges from yellowish black to blackish gray. The grain size is generally coarse, angular–subangular in shape, poorly sorted, loosely packed, and brittle to hard in texture. The massive structure and tuff texture indicate the deposition of reworked volcanic material through water, with environmental energy phases varying from high to moderate, possibly in

a fluvial to proximal deltaic environment (Figure 7c).

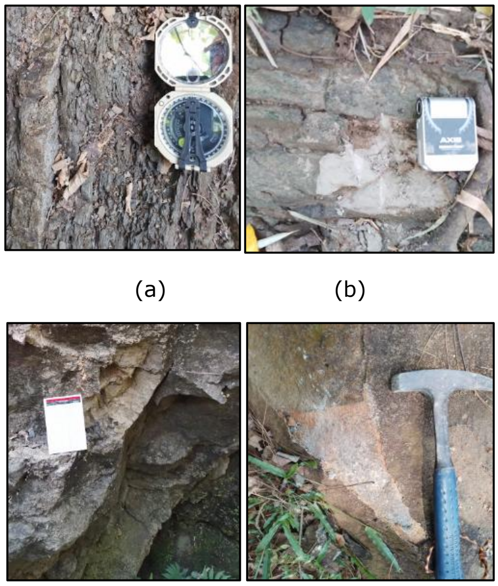
Petrographic analysis shows a dominance of volcanic rock fragments, vitric, quartz, pyroxene, feldspar, and oxide minerals. Regional comparison shows that Sbpt is similar to the Citalang Formation Limestone (Npcs), which dates back to the Late Pliocene and was formed in a terrestrial environment (Isnaniawardhani et al., 2020). This finding is consistent with the interpretation of the Citalang Formation lithofacies as a fluviatile depositional environment in the form of braided rivers (Al hakim and Rizal, 2022).

4) The Andesite Unit (Sba), represented by the color red, is distributed across three areas in the north-south part of the study area and cuts through all previous units. Its lithology consists of porphyritic to aphantic andesite with an inequigranular-hypidiomorphic granular texture and hypocrystalline crystallinity (Figure 7d).

   The main minerals consist of plagioclase, quartz, biotite, pyroxene, hornblende, and accessory minerals in the form of iron oxides. The massive structure and absence of layering indicate an intrusive origin, consistent with the mineralogical composition observed. Regional comparability shows that Sba has similar lithological characteristics, age (Late Pliocene–Early Pleistocene), and terrestrial deposition environment to the andesite in the surrounding area (Isnaniawardhani et al. 2020).

5) Alluvium deposits (Qa), dominate the northern part of the study area, are gray in color, and occupy flat to gently sloping areas in urban and residential areas. Its lithology consists of loose material in the form of gravel, pebbles, sand, and silt with poor sorting, mostly originating from surrounding rocks such as andesite, tuff, and sandstone. This unit is not yet consolidated and was formed by erosion, transportation, and deposition processes that are still active, reflecting a modern fluvial to alluvial environment.

   Regional comparisons show that this unit has similar lithological characteristics, age (Holocene), and terrestrial deposition environment to alluvial deposits in the surrounding area (Isnaniawardhani, et al. 2020).



(a) (b) (c) (d)

Figure 7. Close-up photos of each rock unit (a) Claystone Unit; (b) Sandstone Unit; (c) Tufan Sandstone Unit; (d) Andesite Unit.

Geological Structure of the Study Area

Analysis of the geological structure in the study area was conducted through observation of strike, dip, and determination of the presence of faults and folds. The pattern that emerged showed a main northwest-southeast direction, reflecting the impact of tectonic pressure that formed elongated hills and parallel valleys.

1) Joints

   Joints were observed at one main location (ST-11). Joints analysis shows a pattern of fractures that reflects an extensional stress regime with a tendency toward strike-slip faulting mechanisms according to Fossen (2016) classification.

2) Faults

   The results of the fault analysis show a combination of normal-flat faults with a right-lateral slip component. This mechanism describes an extensional state accompanied by a rightward block shift, consistent with the alignment pattern. In addition, an uplift fault was found in the western part of the plot, which is thought to be a normal fault that has undergone inversion due to regional compression.

3) Folds

The folds that grow in the research area mainly consist of anticlines and synclines with a northwest to southeast direction. The types of anticline and syncline folds found include variations from open to closed folds, with varying slopes, ranging from steep to sharply sloping, and weak to fairly strong thrusting.

DISCUSSION

Geological History of the Study Area

Reconstruction of geological history describes the depositional history of formations in the study area from the Miocene to the Holocene. This interpretation is obtained through stratigraphic analysis, which includes correlation between lithologic units, fossil content identification for age determination, and petrographic analysis to determine rock composition (Adam & Rochmana, 2022). The geological history of the study area shows a gradual development from a deep marine to a terrestrial environment.

The oldest unit observed in outcrops at Babakan Jawa is the Middle Miocene Claystone Unit, formed in a deep marine turbidite environment and characterized by flute cast structures and parallel lamination, indicating deposition by high-energy currents. The observed turbidite sequences also display well-developed Bouma sequences, providing further evidence for a deep-marine depositional setting (Firdaus et al., 2023). Above it is the Late Miocene Sandstone Unit, which depicts the process of basin shallowing to a shallow marine environment and transition to land. The presence of cross bedding and graded bedding structures which formed during and after the deposition of the sandstone, indicates an increase in the amount of sediment from the land. The relationship between the claystone and sandstone units in stratigraphy shows a difference in age based on microfossil data, indicating an unconformable relationship .

At the end of the Pleistocene, volcanic activity produced the Tufan Sandstone Unit, which covered older sediments, followed by the formation of the Andesite Intrusive Rock Unit, which cut through the previous unit and marked the magmatic phase after the deposition process. The intrusion becomes a younger unit that penetrates rock units that are older in age based on the law of cross-cutting relationships. Deposition of the unit occurred from the Early Miocene to the Late Pleistocene with depositional environments ranging from deep marine, shallow marine, to terrestrial volcanic deposits. This is similar to deposition in the Majalengka Sub-Basin which occurred from the Early Miocene to the Late Pleistocene (Philetas et al., 2019).

The youngest unit is the Holocene to Recent Alluvium Deposits, consisting of clay, silt, sand, and gravel formed from modern weathering and sedimentation processes. These deposits are found in lowlands, river valleys, and foothills and are still being formed today.

The age of the rock units was determined using an integrated approach. For units containing microfossils, foraminiferal analysis provided bio-stratigraphic age control. For fossil-free units, relative age was established through interpretation of stratigraphic contacts and structural relationships such as intrusive cutting, and all were correlated with regional stratigraphic data (Isnaniawardhani et al., 2020).

Geological and Disaster Potential of the Research Area

The research area has considerable geological resources, especially in terms of geotourism and land use. One of its main attractions is the Soliter Intrusion Hill in Gunung Batu Karang Park, which consists of andesite rocks. The isolated hill with steep slopes is unique and has high scientific value, making it a potential educational tourist site for learning about rock intrusion processes and how igneous rocks are resistant to erosion. In addition, the potential for nature tourism is further enhanced by the presence of the Gunung Panten Paragliding area (Figure 8a) and Gili Rafting Majalengka (Figure 8b). Both places utilize the shape of the hills and river flows for sports-based recreational activities and education about the shapes of the earth's surface. In addition, the alluvial plains in the study area also have high economic potential as agricultural land. The fertile soil and adequate irrigation system support farming and corn cultivation activities carried out by the local community.

(a)

(b)

(c)

Figure 8. Geological and Disaster Potential of the Study Area (a) Gunung Panten Paragliding Tourism; (b) Gili Rafting Majalengka Tourism; (c) Landslide in Sidamukti Village, Majalengka.

The research area also shows the possibility of geological disasters, especially landslides (Figure 8c), The research area also shows the possibility of geological disasters, especially landslides, which are closely related to steep terrain, geological structure, and rainfall patterns (Selaby et al., 2021; Fathaya et al., 2023). Slopes with a gradient of 30-70 percent and the presence of geological structures such as tectonic plates and weathering zones increase the likelihood of landslides. Several landslide events in the surrounding area indicate that weak areas on slopes often become the starting point for soil and rock release.

Weathering factors such as high rainfall in Majalengka Regency also increase the risk of landslides because they increase water saturation and reduce the resistance of slope materials. Human activities such as clearing land for agriculture on steep slopes without implementing soil conservation measures further destabilize the slopes. The combination of factors such as rock type, geological structure, slope inclination, rainfall, and land use makes landslides a major geological hazard. Therefore, mitigation efforts such as land use regulation, improvement of drainage systems, and public education are needed to reduce the risk of disasters.

CONCLUSION

Based on the results of field activity and data analysis, it can be concluded that there are five geomorphological units, namely Very Gentle Denudational Hills Unit, Steep Intrusive Hills Unit, Volcanic-Structural Steep Longitudinal Hills Unit, Structural-Denudational Volcanic Steep Hills Unit, and Structural Sedimentary Hills Unit.

The stratigraphic aspect shows four rock units from old to young, namely the Claystone Unit (Sbl), Sandstone Unit (Sbp), Tuff Sandstone Unit (Sbpt), and Andesite Unit (Sba); and Alluvium Deposit (Qa). This sequence illustrates the shallowing of the basin from a deep marine (turbidite) environment to the present-day land.

Geological structure analysis indicates the influence of an extensional regime with a horizontal shear component, reflected in the NW–SE alignment pattern and the presence of dextral normal–horizontal faults. In the western part, there are also thrust faults resulting from the inversion of normal faults due to regional compression. In addition, anticline–syncline folds with a general NW–SE orientation are also widespread.

The geological history of the study area shows a change from deep sea to land. Initially, there were Middle Miocene claystone layers in a turbidite environment. Later, Late Miocene sandstone layers appeared, indicating a process of shallowing and an increase in sediment supply from the land. At the end of the Miocene to Pliocene, forces formed a normal fault in the western part of the study area (shown on the map as a thrust fault due to its current position) (Figure 6). The formation of this normal fault caused the northern part of the area to subside, forming a basin that would later be filled with younger sedimentary layers (alluvial deposits). This structure was initially seen as a normal fault, as evidenced by the age difference, where the layers on the hanging wall block are younger (tufan sandstone unit) than those on the foot wall block (claystone and sandstone units.

With the continuation of tectonic activity, this fault underwent a change in direction due to compressive forces from the surrounding area and transformed into a thrust fault. Furthermore, this process created a fold structure, which was the result of deformation due to compression in the western and southern parts of the study area. At the end of the Pliocene, volcanic activity produced tuffaceous sandstone layers, followed by andesite intrusions as part of the magmatic phase after the deposition process was complete. This sequence of layers ends with alluvial deposits from the Holocene to the Recent period, which were formed by modern weathering and sedimentation processes (Hutomo & Firmansyah,2020).

Geologically, the study area has positive potential in the form of shallow aquifers (the presence of porous volcanic and sedimentary rocks), minerals (andesite, sand, gravel), and geotourism potential. Agricultural potential is also developing on the alluvial plains. However, this area is prone to landslides due to steep slopes, weathered lithology, and high rainfall, and is influenced by active tectonic structures. Therefore, land use and geohazard mitigation need to be carefully planned.

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