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Analysis of Andesite Rock Distribution in the Batujajar Sub-Basin, West Bandung Regency

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Abstract—*The Batujajar Sub-Basin, located in the western part of the Bandung Basin, features a distinctive basin-like morphology encircled by hills and mountains. This area contains a series of andesite intrusive hills formed through volcanic and magmatic activities in the western Bandung Basin, which effectively separate the Bandung Basin from the Batujajar Sub-Basin. These geological processes are estimated to have occurred during the Pliocene epoch, approximately 4 to 2 million years ago, with a predominantly north-south orientation, resulting in a linear cone-shaped geomorphology. Research indicates that the geomorphology of the Batujajar Sub-Basin ranges from flat to extremely steep, with moderately to strongly undulating hills, V-shaped valleys, and steep slopes. The topography is characterized by a series of hills creating a distinct relief pattern, underlain by volcanic lithology dominated by andesite and tuff. The area holds significant economic potential for the extraction of non-metallic minerals and possesses abundant water resources, including the Citarum River Dam, which flows westward towards the Bandung Basin.*

Keywords— *Batujajar Sub-Basin, Geomorphology, Intrusion, Andesite, Diorite.*

I. INTRODUCTION

Over millions of years, since the formation of the Earth, various landscapes have developed as a result of geological processes. These features, formed by natural forces, are known as geomorphic features. Endogenous processes, such as tectonic and volcanic activities, create distinct landscapes like volcanic and structural landscapes, while exogenous processes lead to the formation of denudational, fluvial, and coastal landscapes. The Bandung Basin, primarily bounded by volcanic mountains to the south due to subduction processes, also includes the northern mountain ranges that delineate the basin and separate the depositional histories of the Bandung and Bogor Basins. According to Bronto and Hartono (2006), the Bandung Basin can be subdivided into three distinct sections: eastern, central, and western.

The Batujajar Sub-Basin is a part of the Bandung Basin located in its western region. The Batujajar Sub-Basin is often associated with the Batujajar Groundwater Basin, although these terms technically refer to different entities. The Batujajar Groundwater Basin specifically pertains to aquifers, recharge areas, and water resources within Batujajar and its surrounding regions (Suwarto, Hadian, & Hendarmawan, 2018). In contrast, the Batujajar Basin itself refers to the earth's surface, which exhibits a basin-like pattern and is encircled by elevated features such as hills or mountains.

The Batujajar area is characterized by a group of andesite intrusive hills (Streckeisen, 1978) formed as a result of volcanic and magmatic activities in the western part of the Bandung Basin. This group of intrusive hills serves as a natural boundary separating the Bandung Basin from the Batujajar Basin, also referred to as the Batujajar Sub-Basin. The magmatic processes are estimated to have occurred during the Pliocene epoch, approximately 4 to 2 million years ago, with a predominantly north-south orientation. This geological activity led to the formation of a series of cone-shaped hills, resulting in a geomorphological pattern that locals have come to identify as Batujajar, consisting of multiple hills.

II. REGIONAL GEOLOGY

The Bandung area is dominated by volcanic and volcanic deposits of the Quaternary, although in some places there is a mixture of Tertiary and Quaternary deposits. The Tertiary mountains within this zone include the Bayah Mountains (Eocene), the Cimandiri hills (a continuation of the Bayah Mountains), the Rajamandala hills, and the Kabanaran hills. These mountains have undergone significant erosion, resulting in a relatively flat surface, known as a peneplain. The peneplain gradually slopes westward towards the Sunda Strait.

Based on the compilation of several geological maps (Figure 1) by Sudjatmiko (1972), Silitonga (1973), Koesmono (1976), Koesoemadinata and Hartono (1981), Dam and Suparan (1994), and Dam (1994), the oldest exposed rock formation in this area is the Rajamandala Formation, which forms the western boundary of the Batujajar Plain. This formation, dating to the Miocene epoch, was deposited in a marine environment. In terms of lithology, these Tertiary rocks include sandstone, shale, sandstone, shale, tuff, and conglomerate. During the Upper Miocene and the Miocene-Pliocene transition, the region experienced uplift and subsidence. Concurrent volcanic activity led to the formation of intrusions that penetrated the Tertiary rocks. In the Lower Pleistocene, continued uplift and volcanic activity resulted in the development of volcanic complexes along the northern and southern boundaries of the basin. Deposits from this period, consisting of older volcanic material, are still observable in certain locations today.

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During the Early Pleistocene to the sub-Recent period, significant faults were formed, which are associated with volcanic activity. Notably, the Lembang Fault, located north of Bandung City, and the Malabar Tilu Fault, situated south of the Bandung Plain, are products of these geological processes. Field observations indicate that along both major faults, the southern block has been uplifted relative to the northern block, resulting in a depression to the north of the faults.

South of the Lembang Fault, a fan-shaped landscape has formed, currently known as the Bandung and Cimahi volcanic fan. This fan consists of young volcanic deposits from Tangkuban Perahu, identified as the Cibeureum Formation. A significant flow of debris from Tangkuban Perahu obstructed the Citarum River at Padalarang, resulting in the formation of a lake within the Bandung Basin. Over time, the lake was gradually filled with sediments, represented by the Kosambi Formation. Sediments from volcanic eruptions, rivers, and debris flows from the lake's periphery contributed to a considerable variation in material at the depositional site. Due to the non-uniform depth of the lake, sediment thickness varies accordingly. In areas where rivers discharge into the lake, such as Soreang, Banjaran, and Majalaya, volcanic-alluvial fans have formed, interlaced with lake sediments.

The lake deposits, known as the Kosambi Formation, are partially interbedded with the Cibeureum Formation and younger Cikidang lavas. The Kosambi Formation was deposited concurrently with the volcanic deposits, with the primary distinction being the proximity to the eruption centre and the mode of deposition. The volcanic fan deposits can be observed at various locations near the boundaries of the Bandung Plain, extending continuously beneath the lake deposits. Generally, the recent deposits consist of floodplain sediments from the Citarum River, comprising hard clays that overlie the lake deposits. These floodplain deposits vary in thickness from 0 to 5 meters (Iwaco, 1990).

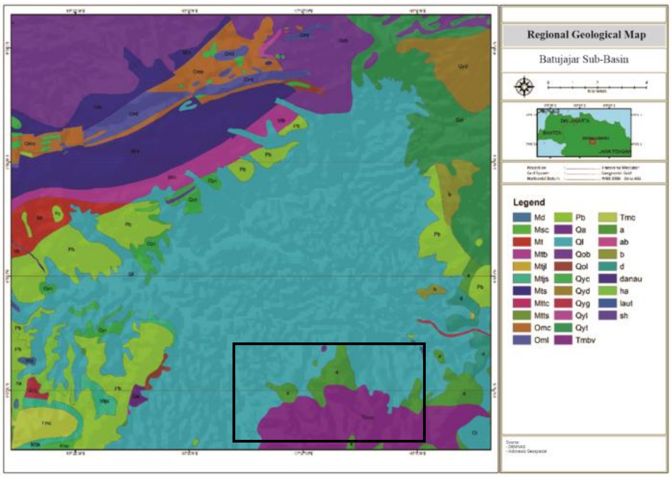

Fig. 1. Regional Geological Map of Batujajar Sub-Basin (Sulaksana et al., 2023)

III. METHOD

The method involved is a surface geological mapping survey conducted through field observations. The fieldwork includes orientation, morphological observations, outcrop and rock examinations, and measurement of geological structures. Data collected from rock outcrops are documented using photographic media and include megascopic characteristics, lithology, rock color, texture, structure, mineral composition, and sampling. Laboratory analysis involves examining the samples obtained in the field through petrographic analysis to determine the rock types present in the study area. Studio analysis encompasses the evaluation of specific data to support and enhance the research results.

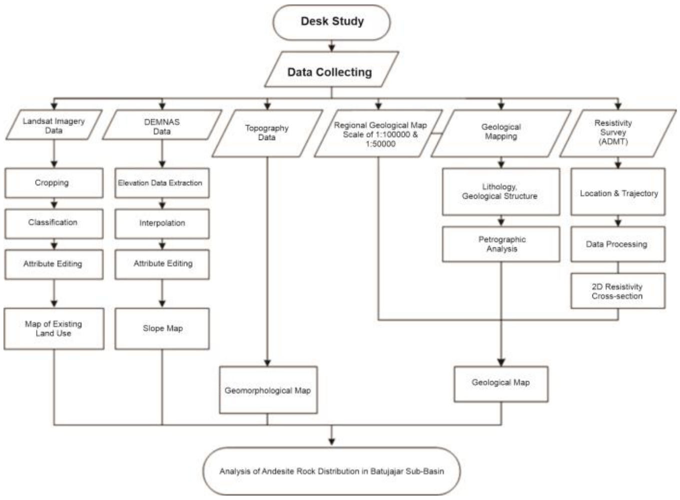

Fig. 2. Research Diagrams

A. *Rock Sample Preparation*

This stage involves selecting rock samples for laboratory analysis. The chosen samples should be fresh and represent various rock lithologies from the research area.

B. *Analysis*

- Geological Mapping
  It determines the type, distribution, and variation of rocks that compose the research area, as well as the geological structure present. The results include a geological map, along with an analysis of the landscape of the research area, leading to the creation of a geomorphological map.
- Petrographic Analysis
  The analysis of thin section rock samples in the laboratory to identify and description of the rocks, allowing the rock types in the research area to be determined through both megascopic and microscopic observations. These petrographic analysis results also help to determine the distribution zones of volcanic rocks in the research area.

IV. RESULT AND DISCUSSIONS

Igneous rocks are formed from one or more minerals as a result of magma solidification. Based on their texture, igneous rocks can be categorized into plutonic and volcanic types. The difference lies in the size of the minerals that make up the rock. Plutonic igneous rocks generally form from the slow solidification of magma, resulting in relatively large mineral grains. Meanwhile, volcanic igneous rocks typically form

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from the rapid solidification of magma, leading to smaller mineral grains.

Andesite is one of the mining materials that is widely needed by the community for purposes such as building foundations, road paving, bridge construction, river gabion construction, and many more. Andesite deposits in abundant quantities and located near construction project sites have significant economic value for mining. An exploration stage is required before mining activities begin. This exploration aims to assess the potential and conditions of the mining materials and to determine the appropriate methods and technologies to be applied in the mining process.

A. Geomorphology of Batujajar Sub-Basin

In terms of geomorphology, the Batujajar area and its surroundings can be divided into 9 geomorphological areas. These geomorphological units are classified based on landforms, rock types or formations, and the geological structures present. The geomorphology of the Batujajar Sub-Basin includes several units, as illustrated in Table 1 and Figure 2.

- Plains Denudation Unit
  This geomorphological unit has a plain morphology, characterized by a dendritic drainage pattern and U-shaped valleys. The slope ranges from 0-2%, classifying it as a plain slope type. The morphogenetic process of this unit is denudation.
- Weakly Undulating Denudation Unit
  This unit features a plateau landform morphology with a dendritic drainage pattern and U-shaped valleys. The slope ranges from 3-7%, characterized by a weak concave slope type. The morphogenetic process of this unit is denudation.
- Weakly to Strongly Undulating Structural Unit
  This unit features hilly landforms with a rectangular drainage pattern and U- to V-shaped valleys. The slopes have a gradient of 8-13%, characterized by a weak to strong slope type. The morphogenetic process of this unit is structural.
- Strongly Hill Structural Unit
  This unit features hilly landforms with rectangular drainage patterns and V-shaped valleys. The slopes have a gradient of 21-55%, characterized by a strong hilly-cut slope type. The morphogenetic process of this unit is structural.
- Volcanic Plains Unit
  This unit features a plain landform with a dendritic drainage pattern and U-shaped valleys. The slope gradient ranges from 0-2%, characterized by a plain slope type. The morphogenetic process of this unit is volcanic.
- Weakly Undulating Volcanic Unit
  This unit features a plateau landform with a dendritic to subparallel drainage pattern and U-shaped valleys. The slopes have a gradient of 3-7%, characterized by a weakly undulating slope type. The morphogenetic process of this unit is volcanic.
- Weakly To Strongly Undulating Volcanic Unit
  This unit features a hilly plain landform with parallel drainage patterns and U- to V-shaped valleys. The slopes have a gradient of 8-13%, characterized by a weak to strong cable-like slope type. The morphogenetic process of this unit is volcanic.
- Strongly Undulating To Hilly Volcanic Unit
  This unit features hilly landforms with parallel to subradial drainage patterns and V-shaped valleys. The slopes have a gradient of 14-20%, characterized by a strongly undulating to hilly slope type. The morphogenetic process of this unit is volcanic.
- Strongly Hilly Volcanic Unit
  This unit features hilly and intrusive hilly landforms, centrifugal to radial drainage patterns, and V-shaped valleys. The slopes have a gradient of 21-55%, characterized by a strongly hilly to cut slope type. The morphogenetic process of this unit is volcanic.

TABLE I. Geomorphological Units of Batujajar Sub-Basin

Geomorphological Units	Symbol	Morphology			Morphometry		Morphogenetic
		Landform	Drainage Pattern	Valley Form	Slope (%)	Slope Types	
Plains Denudation Unit		Plains	Dendritic	U Shape	0 - 2	Plains	Denudation
Weakly undulating denudation unit		Plateau	Dendritic	U Shape	3 - 7	Weakly Undulating	Denudation
Weakly to Strongly Undulating Structural Unit		Hills	Rectangular	U-V Shape	8 - 13	Weakly-Strongly Undulating	Structural
Strongly Hill Structural Unit		Hills	Rectangular	V Shape	21 - 55	Strongly Hill	Structural
Volcanic Plains Unit		Plains	Dendritic	U Shape	0 - 2	Plains	Volcanic
Weakly Undulating Volcanic Unit		Plateau	Dendritic-Subparallel	U Shape	3 - 7	Weakly Undulating	Volcanic
Weakly to Strongly Undulating Volcanic Unit		Hills	Parallel	U-V Shape	8 - 13	Weakly-Strongly Undulating	Volcanic
Strongly Undulating to Hilly Volcanic Unit		Hills	Parallel-Subradial	V Shape	14 - 20	Strongly Undulating to Hilly	Volcanic
Strongly Hilly Volcanic Unit		Intrusive Hills	Radial Centrifugal	V Shape	21 - 55	Strongly Hilly	Volcanic

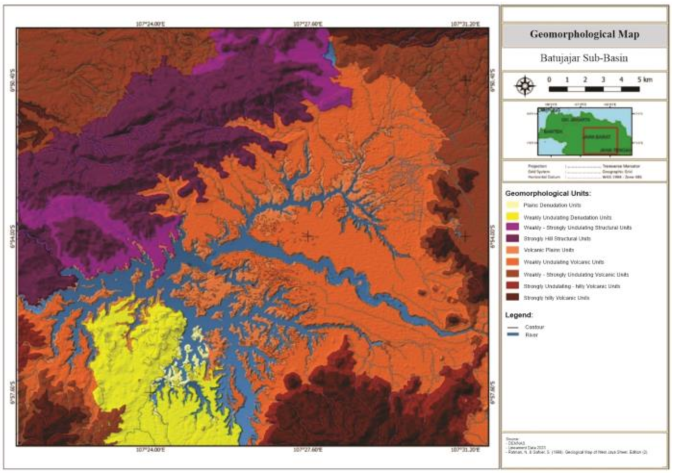

Fig. 3. Geomorphological Map of Batujajar Sub-Basin (Sulaksana et al., 2023)

B. Andesite Rock Unit of Batujajar Sub-Basin

Three rock samples were taken from the diorite porphyry intrusion outcrop in the Batujajar area. Two thin sections were made for each sample for petrographic analysis. This petrographic analysis aims to identify the type of rock based on the characteristics of its texture, mineral composition, and minerals (Figure 3).

In thin sections, additional indications such as alteration by

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hydrothermal or weathering processes are observed, providing insights into the rock's history of solidification. The megascopic appearance reveals that the rock has a fresh part with a gray color, while the weathered parts are brownish-gray and occasionally reddish. It features a mesocratic color index and a porphyritic texture, containing both felsic (light) and mafic (dark) minerals. The dominant felsic minerals are estimated to be plagioclase, while the mafic minerals include hornblende and pyroxene. The groundmass is gray and the structure is massive and very hard, with developing tensional joints filled with secondary minerals such as carbonate (calcite) and some iron oxide (Fe-oxide) minerals.

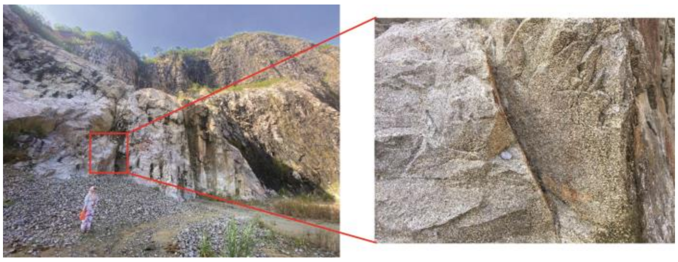

Fig. 4. Andesite Outcrop

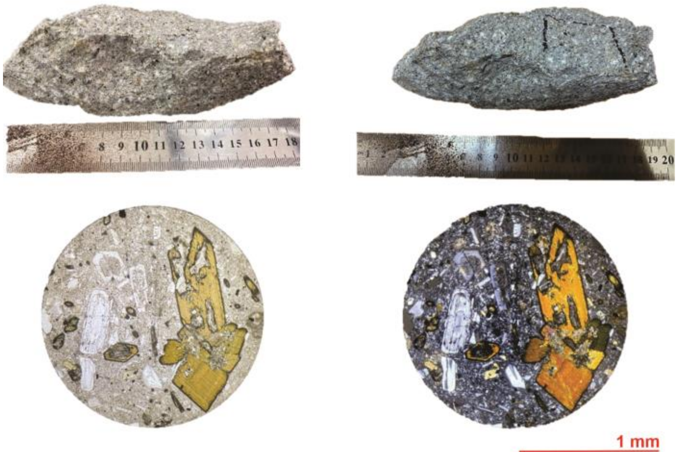

Fig. 5. Andesite Petrography

The results of microscopic observations of six thin sections (RS-1 to RS-6) show a porphyritic granularity, with crystal sizes ranging from 0.3 to 2 mm, micro phenocrysts between 0.1 and 0.3 mm, and groundmass particles measuring less than 0.1 to 0.3 mm. The rock exhibits inequigranular packing, hypo crystalline crystallinity, and euhedral to subhedral prismatic crystal forms, with hypidiomorphic mineral shapes. Its composition includes plagioclase phenocrysts, amphibole/hornblende, pyroxene, and potassium feldspar (k-feldspar), along with minor amounts of opaque minerals, quartz, and carbonate minerals. The groundmass is medium to coarse-grained, consisting of plagioclase microlites, amphibole microlites, and pyroxene microlites, some of which are partially replaced by clay and carbonate minerals (see Figure 4). Based on the mineral composition, the rock is classified as diorite (Streckeisen, 1978). A summary of the petrographic analysis results is presented in Table 2.

TABLE II. Petrographic Analysis of Batujajar Sub-Basin

No	Sampel Code	Composition										Rock Name
		Pl	Amf	Px	Kf	K	Op	Kb	Lmp	Kl	Md	(Streckeisen, 1978)
1	1A	40	10	5	7	3	3	5			35	Diorite
2	1B	35	12	3	7	3	3	5			37	Diorite
3	2A	40	12	3	7	3	3	5			32	Diorite
4	2B	46	7	3	7	4	3	4			30	Diorite
5	3A	30	8	4	7	2	4	5	10	2	45	Diorite
6	3B	35	6	2	6	2	4	10		1	45	Diorite

The mineral composition found in the thin sections is generally as follows:

- Plagioclase (30-45%): Colorless, euhedral to subhedral, low relief, no pleochroism, with cleavage in one and two directions, albite twins, Karlsbad, albite-Karlsbad, strong to weak zoning, yellowish-gray interference colors in the first-order range, Andesine plagioclase type. Opaque inclusions and amphibole/hornblende mineral inclusions are present. Some of them have turned into clay minerals with carbonate and albitite. They range in size from 0.1 to 2 mm, occurring as phenocrysts, in the groundmass as microlites, and as inclusions within amphibole/hornblende minerals.
- Amphibole/hornblende (7 – 12%): Greenish-brown and light green color, ranging in size from 0.1 to 1.3 mm, with a dominant size of 0.4 mm, occurring as phenocrysts and in the amphibole microlite groundmass. They are anhedral to subhedral, prismatic to elongated/needle-like, and hexagonal shape, with high relief and weak to moderate pleochroism. Cleavage is present in one and two directions. Interference colors are secondary, yellow to orange. The crystals exhibit intense fractures, some of which are filled with groundmass and glass. Corona and corroded textures are present, with occasional weak zoning, simple twinning, and penetration twinning. Some crystals have changed to mud and carbonate minerals with opaque inclusions exposed. The amphiboles are clinoamphiboles, specifically hornblende.
- K-Feldspar (5-7%): Colorless, ranging in size from 0.1 to 0.3 mm, occurring as phenocrysts and microlites. They are anhedral to subhedral in shape, with low relief and no pleochroism. Simple twinning is present, with ash-colored interference in the first order. The crystals exhibit fragments, opaque inclusions, and occur in association with plagioclase stacks.
- Pyroxene (3-5%): Light green to green-brown color, ranging in size from 0.2 to 0.9 mm, occurring as phenocrysts and microlites. They exhibit high relief and weak to moderately weak pleochroism. The crystals are small to tetrahedral, prismatic and show cuts in one direction. Twinning is present along with fractures, and the interference color is gray in the first order. Opaque inclusions, as well as amphibole/hornblende inclusions, are observed. Some crystals have altered into amphibole, carbonate minerals, or clay minerals. The types present include both clinopyroxene (augite) and orthopyroxene.
- Quartz (2-3%): Colorless, anhedral shape, with low relief and no pleochroism. Displays wavy extinction and

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first-order gray interference colors.

- Opaque (3-4%): Black color, anhedral shape, with cubic mineral form and high relief. The crystals size from <0.1 to 0.2 mm, occurring as phenocrysts, in the groundmass, and as inclusions within plagioclase, amphibole, and pyroxene.
- Carbonate (2-5%): brownish-white in color, with moderate relief, is a secondary mineral altered from phenocrysts and plagioclase groundmass, amphibole, and pyroxene, and partly fills fractures.
- Chlorite (1-2%): brownish-green color, anhedral, and altered from amphibole/hornblende.
- Clay minerals: as a result of the alteration of phenocrysts and groundmass, including amphiboles, pyroxenes, and plagioclase.
- Groundmass (30-45%): medium to coarse sized; consists of plagioclase microlites, amphiboles, pyroxene, k-feldspar, quartz, opaque, glass, carbonate minerals, and clay minerals.

V. CONCLUSION

The Batujajar Basin is a geomorphological feature resembling a basin surrounded by hills or mountains. The Batujajar area is characterized by a group of andesite intrusion hills resulting from volcanic and magmatic activities in the western part of the Bandung Basin. These intrusion hills separate the Bandung Basin from the Batujajar Basin, also known as the Batujajar Sub-Basin. The magmatic activity is estimated to have occurred during the Pliocene epoch, approximately 4 to 2 million years ago, with a north-south trend. This activity led to the formation of a cone-shaped geomorphological structure, resulting in the name Batujajar. The Batujajar Sub-Basin features geomorphology ranging from plain to very steep terrain, with moderate to strong undulating hills, V-shaped valleys, and steep slopes. The surface is characterized by a series of hills forming a relief path. The area has volcanic lithology dominated by andesite diorite and tuff rocks, indicating significant potential for non-metallic mining resources.

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