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STRATIGRAPHIC ANALYSIS AND DISTRIBUTION OF ROCK UNITS IN THE CIPATAT AREA, WEST BANDUNG REGENCY, WEST JAVA PROVINCE, INDONESIA

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ABSTRACT

Geological mapping of the Cipatat area, West Bandung Regency, West Java Province was conducted at a scale of 1:12,500 to establish the stratigraphic succession, spatial distribution of rock units, and structural configuration of the region. Three rock units were identified spanning the Late Oligocene to Quaternary: the Rajamandala Limestone Unit (TOMBG), the Citarum Sandstone Unit (TMBP), and the Quaternary Volcanic Unit (QV). The Rajamandala Limestone, deposited in a shallow neritic carbonate platform, is biostratigraphically constrained to zones Te3–Tf1 based on larger foraminifera including Lepidocyclina, Operculina, Miogypsina, and Cycloclypeus, while petrographic analysis confirms mudstone to packstone facies. The overlying Citarum Sandstone Unit represents a deep-marine turbidite system characterized by graded bedding, parallel lamination, and load casts defining a Bouma sequence dominated by the Tb facies, with foraminifera assemblages assigning deposition to Middle Miocene zones N5–N9 and reflecting progressive basin deepening from neritic to bathyal conditions. Petrographic analysis of the sandstone further supports classification as volcanic-derived lithic wacke, consistent with a volcanogenic provenance. The Quaternary Volcanic Unit unconformably caps the sequence, marking a shift from marine sedimentation to subaerial volcanism. Structural analysis identified three principal fault systems, namely the Cibuntu, Cibrengkok, and Cilimus River Faults, which formed in response to a northwest–southeast compressional stress regime associated with Sunda Arc convergence during the Miocene to Plio-Pleistocene. This tectonic deformation produced west–east-oriented fold pairs that exert a strong control on the current ridge-and-valley topography and the distribution of lithological units throughout the study area.

Keywords: Geological structure, Rajamandala Formation, Rock unit distribution, Stratigraphy, Turbidite

INTRODUCTION

The Cipatat region is in West Bandung Regency, West Java Province. It is an important geological site with a great variety of rock kinds and formations. The rocks of the Rajamandala Formation in this area are known to have been generated in a marine carbonate platform environment (Gani et al., 2020; Khorniawan et al., 2024) and are carbonate rocks containing limestone. The Cimandiri Fault Zone is one of the most prominent geologic structures in West Java that has played a significant role in shaping the morphology and movement of the surrounding area (Haryanto et al., 2017; Indrajati, 2018). The Cimandiri Fault Zone is one of the major structural features controlling the character of Cipatat. The geomorphology of this area is a result of lithological variety and tectonic activity. This is shown from the presence of several landform units that indicate variations in rock resistance and fault-controlled topography (Sulastri et al., 2024; Setiawan., 2017). The study area is characterized by a structurally complex, fault-dominated landscape that exerts strong control over the distribution of lithological units. Nevertheless, the stratigraphic relationships and subsurface configuration of these rock units remain inadequately resolved. Previous geological studies have largely focused on individual formations or isolated geological features, leaving significant gaps in the understanding of the regional stratigraphic framework. Given the complexity of the Cipatat area, detailed field mapping combined with sedimentological analysis is necessary to constrain the spatial distribution of rock units, establish their stratigraphic relationships, and elucidate their depositional and tectonic history. Such an integrated approach is fundamental for reconstructing the geological evolution of West Java and refining existing geological models for the region.

REGIONAL GEOLOGY

The Cipatat area exposes a stratigraphic succession comprising four principal rock units that reflect a complex interplay of volcanic, sedimentary, and carbonate depositional environments (Figure 1). The oldest exposed units belong to the Rajamandala Formation, which is subdivided into two members: the Limestone Member (Oml) and the Clay, Marl, and Quartz Sandstone Member (Omc). The Oml member is composed of massive to well-bedded, light-coloured limestone with abundant larger foraminifera, deposited within a shallow marine carbonate platform where biological productivity and chemical precipitation governed the accumulation of thick limestone sequences (Michel et al., 2019; Khorniawan et al., 2024). The Omc member, on the other hand, consists of dark grey to black clay, globigerina marl, quartz sandstone, and quartz pebble conglomerate bearing mica flakes, coal streaks, and amber, indicative of a transitional marine-to marginal depositional setting (Rachman et al., 2021; Gani et al., 2020).

Figure 1. Close-up photographs of rock outcrops at the QOB–MTS formation boundary (left) and OML Formation (right).

Overlying the Rajamandala Formation, the Sandstone and Siltstone Member of the Citarum Formation (Mts) represents a deep-marine turbidite sequence characterised by well-bedded sandstone interbedded with siltstone, claystone, greywacke, and breccia. Sedimentary structures including graded bedding, convolute lamination, current ripple lamination, and trace fossils are well-preserved within this unit, consistent with deposition via turbidity current mechanisms (Bouma, 1962). The youngest unit, Old Volcanic Products (Qob), unconformably caps the sequence and consists of volcanic breccia, flow breccia, lahar deposits, and lava with platy and columnar jointing of andesitic to basaltic composition, reflecting a phase of Quaternary volcanic activity that significantly overprinted the pre-existing stratigraphy of the area.

RESEARCH METHOD

In this inquiry the entire geological mapping technique was used including field observation, laboratory inspection and spatial data processing. Pre-field preparation included the production of topographic base maps at a scale of 1:12,500, remote sensing interpretation of satellite imagery, and analysis of the existing regional geological literature. Geological traverses were systematically sampled in the field. This included lithological description, stratigraphic measurement and the collection of structural data including strike and dip readings. Samples of rock were collected from each of the specific lithological units identified for subsequent laboratory study. The petrographic study of thin sections of the rock was done with a polarising microscope to determine the mineral content, texture and classification of the rock. The biostratigraphic examination included the identification of planktonic and benthic foraminifera to assess the age of the deposits and to provide an interpretation of the sedimentary environment. Stereonet analysis was performed using Dips and paleostress tensor inversion using WinTensor. These two programs were used to process the structural data. The stratigraphic columns were produced using Sedlog . The whole geographical data was combined in ArcGIS to make the final geological map at a scale of 1:12,500.

RESULT AND DISCUSSION

The map shows the spatial distribution of observation routes and sampling points over the study area (scale 1:12,500) (Figure 2). The routes were set up based on the principal lithological units exposed in the field traverses. There Are volcanic, clastic and carbonate rock units. Slickenside orientations and strike/dip measures were carefully recorded, in addition to petrographic, paleontological and stratigraphic section data, in order to compile a complete geological framework of the area. Based on the geomorphological classification of Ike Bermana (2006), the Cipatat area may be split into four morphological divisions, namely, plains, low hills, hills and high hills (Figure 3). The research region is dominantly characterised by hilly and high hilly terrain, which is typical a mature erosional landscape with moderate to steep relief, governed by lithological variation and structural elements. The drainage system in Cipatat area has dendritic, trellis and parallel type. The dendritic pattern suggests weak structural control. The trellis and parallel patterns demonstrate the influence of geological formations and topographic gradients on stream development (Davis & Reynolds, 1996).

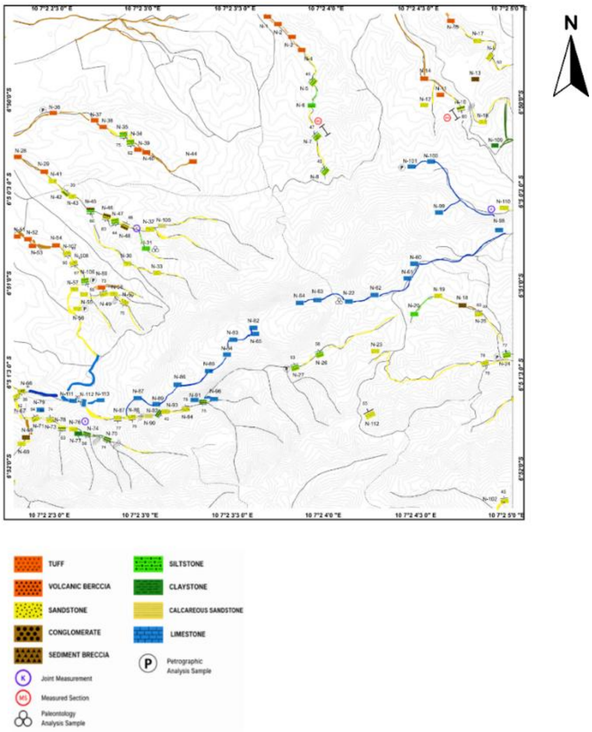

Figure 2. Map of route and sample collection locations (Scale 1:12,500), showing nine lithological units from volcanic to carbonate rocks with polyphase structural deformation.

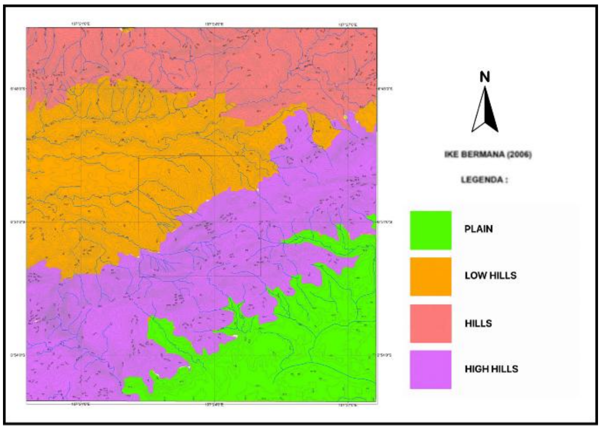

Figure 3. Morphological map of the Cipatat area, classified based on the geomorphological classification of Ike Bermana (2006).

The slope gradient map illustrates that the Cipatat area is mostly moderate-to-steep terrain with slope values of 0° to 140° (Figure 5). The dominant slope class is 20–55°, which suggests a significant lithological and structural control on topography development in the research area (Anfasha et al., 2016). Steeper slopes are associated with resistant rock units such as limestone and volcanic products; whereas gentler gradients are associated with more erodible lithologies along structurally controlled drainage corridors.

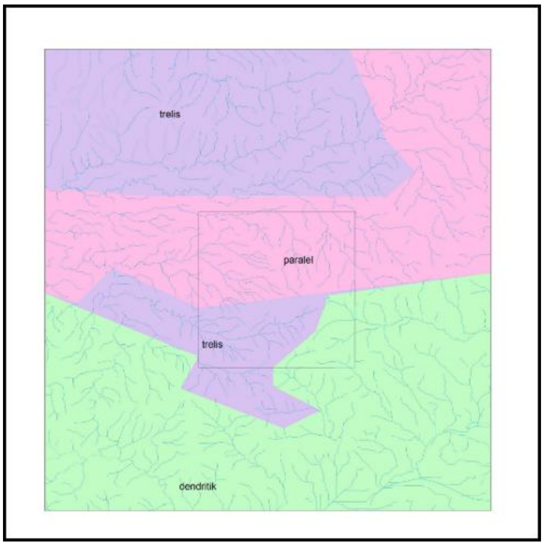

Figure 4. Drainage pattern map of the Cipatat area. The distribution of these patterns reflects variations in lithology, topography, and structural controls within the study area.

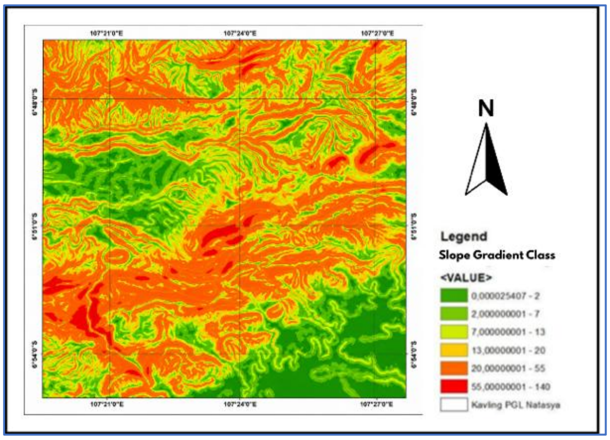

Figure 5. Slope gradient map of the Cipatat area.

The geomorphological map of Cipatat area exhibits four unique morphological units: moderately steep volcanic hills, softly sloping low volcanic hills, steep high structure hills and very gently sloping denudational plains (Figure 6). The distribution of these units is governed by the interplay of lithological composition, structural control, and erosional processes within the study area (Table 1). Steep High Structural Hills dominate the middle to southern region, most likely controlled by fracture and fault systems, with volcanic hill complexes in the northern sector assumed to be products of Quaternary volcanic activity. Denudational plains in the southeast indicate a well-developed erosional stripping of pre-existing rock units under prolonged weathering conditions.

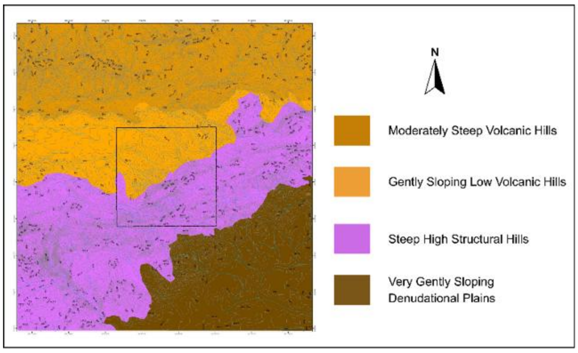

Figure 6. Geomorphological map of the Cipatat area showing four morphological units (Scale 1:12.500).

GEOMORPHOLOGICAL UNIT	COLOR SYMBOL	GEOMORPHOLOGICAL ELEMENTS							
		Morphography				MORPHOMETRY		MORPHOGENETIC	
		DELTA H	LAND FORM	VALLEY FORM	DRAINAGE PATTERN	SLOPE	SLOPE CLASS	ENDOGEN	EXOGEN
Moderately Steep Volcanic Hills		200-500	Hills	V	Trellis–Parallel	Moderately Steep	14-20%	Volcanic	Weathering and Erosion
Gently Sloping Low Volcanic Hills		50-200	Low Hills	U	Parallel	Gentle	8-13%	Volcanic-Structural	Weathering and Erosion
Steep High Structural Hills		500-1000	High Hills	V	Trellis, Parallel, Dendritic	Steep	21-55%	Structural	Weathering and Erosion
Very Gently Sloping Denudational Plains		<50	Plains	U	Dendritic	Very Gentle	3-7%	Denudational	Weathering and Erosion

Table 1. Geomorphological classification of the Cipatat area based on morphography, morphometry, and morphogenetic parameters.

Stratigraphy of the Study Area

The rock units in the Cipatat area range in age from Oligocene to Quaternary, representing the depositional evolution of the southern Bogor Basin. The Cianjur Regional Geological Map specifies three stratigraphic units, from the oldest to the youngest, namely the Rajamandala Limestone Unit (TOMBG), the Citarum Sandstone Unit (TMBP) and the Quaternary Volcanic Unit (QV). The Citarum Formation was deposited in a volcanogenic marine environment (Figure 7). The Rajamandala Limestone Unit (TOMBG) is composed of large to well-bedded limestone in mudstone and packstone facies deposited in a shallow marine carbonate platform (neritic zone) during the Late Oligocene-Early Miocene. The size of the foraminifera taken from station N-22 (Lepidocyclina, Operculina, Miogypsina, Cycloclypeus) confines the age to zones Te3-Tf1. These assemblages are characteristic of shallow marine carbonate platform settings where the carbonate building was controlled by biological productivity (Michel et al., 2019; Khorniawan et al., 2024). The Citarum Sandstone Unit (TMBP) is composed of interbedded sandstone and siltstone with graded bedding and parallel lamination, indicative of turbidite deposition (Bouma, 1962). Planktonic foraminifera (*Globigerinoides trilobus*, *Globorotalia mayeri*) and benthic foraminifera (Bolivina robusta, *Uvigerina proboscidea*) from station N-31 suggest an outer neritic to bathyal environment and belong to Middle Miocene zones N5-N9, indicating a progressive basin deepening in the Miocene (Gani et al., 2020).

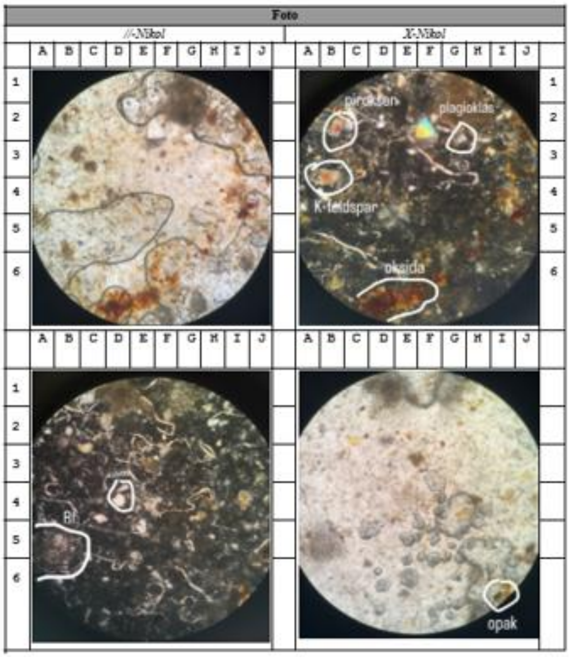

Figure 7. Photomicrographs of Citarum siltstone under PPL and XPL, showing pyroxene, plagioclase, K-feldspar, bioclast (Bi) fragments, and oxide minerals, reflecting volcanogenic marine deposition of the Citarum Formation.

Petrographic studies of the Citarum sandstone show a poorly sorted framework of rock fragments, quartz, plagioclase, K-feldspar, pyroxene, and oxide minerals indicating the classification as volcanic-derived lithic wacke (Figure 8).

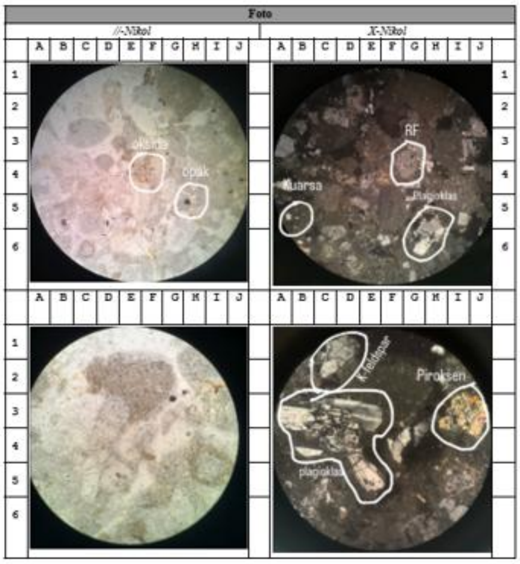

Figure 8. Photomicrographs of Citarum sandstone under PPL and XPL at two magnifications, showing rock fragments (RF), feldspar, plagioclase, pyroxene, and magnetite, confirming classification as volcanic-derived lithic wacke.

The associated siltstone, on the other hand, is characterised by a fine-grained matrix with bioclastic components and disseminated opaques, indicating the volcanogenic marine deposition of the formation. Field data from measured sections in stations N-10 and N-7 confirm this idea. A deep-marine turbidite system is defined by regularly interbedded extremely fine sandstone, siltstone and mudstone. Sedimentary structures such as graded bedding, parallel lamination and load casts define a Bouma sequence with the Tb facies dominant indicating moderate energy turbidity current deposition with a subordinate Tc component indicating progressive flow competence loss during submarine gravity flow deceleration in a bathyal environment.

Geological Structure

The structural study of the three major faults in Cipatat area was performed based on the fault-slip data processed in WinTensor software. The results of the analysis are presented in the form of projections of equal-area lower-hemisphere stereonet and stress tensor solutions.

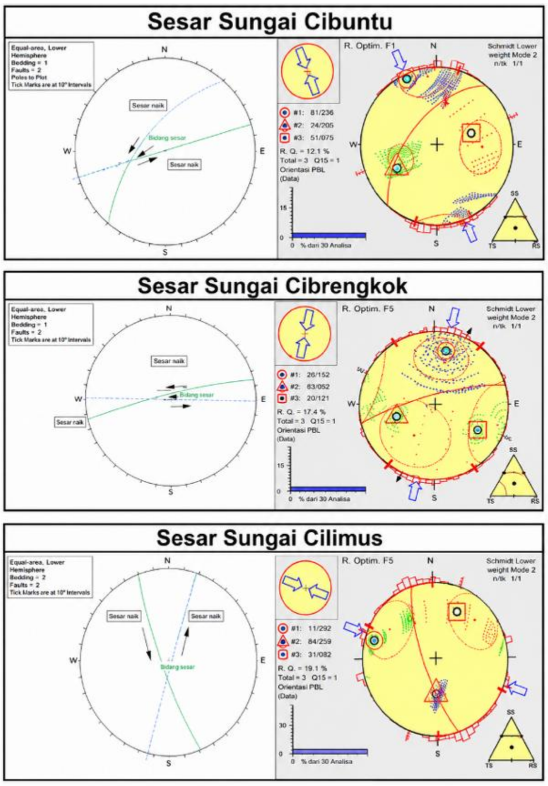

Figure 9. Stereonet plots and stress tensor solutions using dips and wintensor for the Cibuntu, Cibrengkok, and Cilimus River Faults derived from WinTensor analysis.

The Cibuntu River Fault is made up of three fault planes, i.e. 81/236, 24/295 and 51/075 with a stress ratio R = 12.1% showing an oblique reverse (reverse left-slip) mechanism under a compressional to transpressional regime with an orientation of σ_1 north-south to northwest-southeast. The Cibrengkok River Fault is interpreted as a left lateral strike-slip fault with a little vertical component acting as a tear fault to accommodate the differential displacement between neighbouring reversal segments (Davis & Reynolds, 1996) with planes 26/152, 63/060 and 20/121 (R = 17.4%). The primary compressional structure that produced Tertiary rock uplift and structural ridges in the examined area is the Cilimus River Fault with fault planes at 11/292, 84/259, and 31/082 with R = 19.1%. This fault is characterised by a prominent reverse slip component, indicating that the main kinematic driver is not lateral translation but horizontal shortening, which directly controls the exposure at the surface of older Rajamandala limestone along structural highs. The stress tensor solutions of the three faults all reveal a sub-horizontal σ 1 in a northwest-southeast direction, perpendicular to the west-east running fold axes seen in the area (Davis & Reynolds, 1996). The geometric association of fault kinematics with fold orientations indicates that both structures were produced during the same stress field and not during separate episodes of deformation. The parallelism of all fold axes to the regional Java Pattern indicates a single compressional regime probably related to Miocene-Pliocene convergence throughout the Sunda Arc.

The joint measurements at stations N-10, N-110 and N-87 are consistent with the data from the surrounding faults and suggest that they originated as secondary fractures within the same deformation system. In summary, these structural data indicate that the folding, faulting, and fracturing in the Cipatat area are part of a cohesive compressional event that controlled lithological distribution, ridge morphology and the present-day structural framework of the examined area.

Geological History of the Cipatat Area

The Cipatat area has a stratigraphic record from Late Oligocene to Quaternary. The oldest exposed unit is the Rajamandala Limestone (TOMBG) that reflects deposition in a shallow neritic carbonate platform during the Late Oligocene–Early Miocene when carbonate production was higher than clastic intake. The presence of larger benthic foraminifera in this unit provides reliable biostratigraphic constraints on the paleoenvironmental circumstances and depositional age (Novita et al., 2023). Deep-marine siliciclastic sedimentation in the Early to Middle Miocene and a continuous deepening of the basin are reflected by the main stratigraphic transition at the conformable contact between the Rajamandala Formation and the underlying Citarum Formation (TMBP). The geological elements of this transition have been recognised on prior mapping studies of the Cipatat and neighbouring regions (Gunawan, 2017). The preserved turbidite structures of the Citarum Formation reflect ongoing deposition of submarine gravity flows in a bathyal environment. The youngest active phase is represented by the Quaternary Volcanic Unit (QV) which overlies the earlier sedimentary succession in an irregular way. The current structural configuration of the region, such as the formation of structural ridges, and the current distribution of rock units on the surface are the result of compressional deformation that overprinted the stratigraphic succession, and have wider implications for land use and geohazard considerations as evidenced by the west-east trending fold axes and reverse fault kinematics (Sukiyah & Khoirullah, 2020). These structural constraints also have direct relevance to foundation and subsurface engineering in the Cipatat area (Wicaksana et al., 2020).

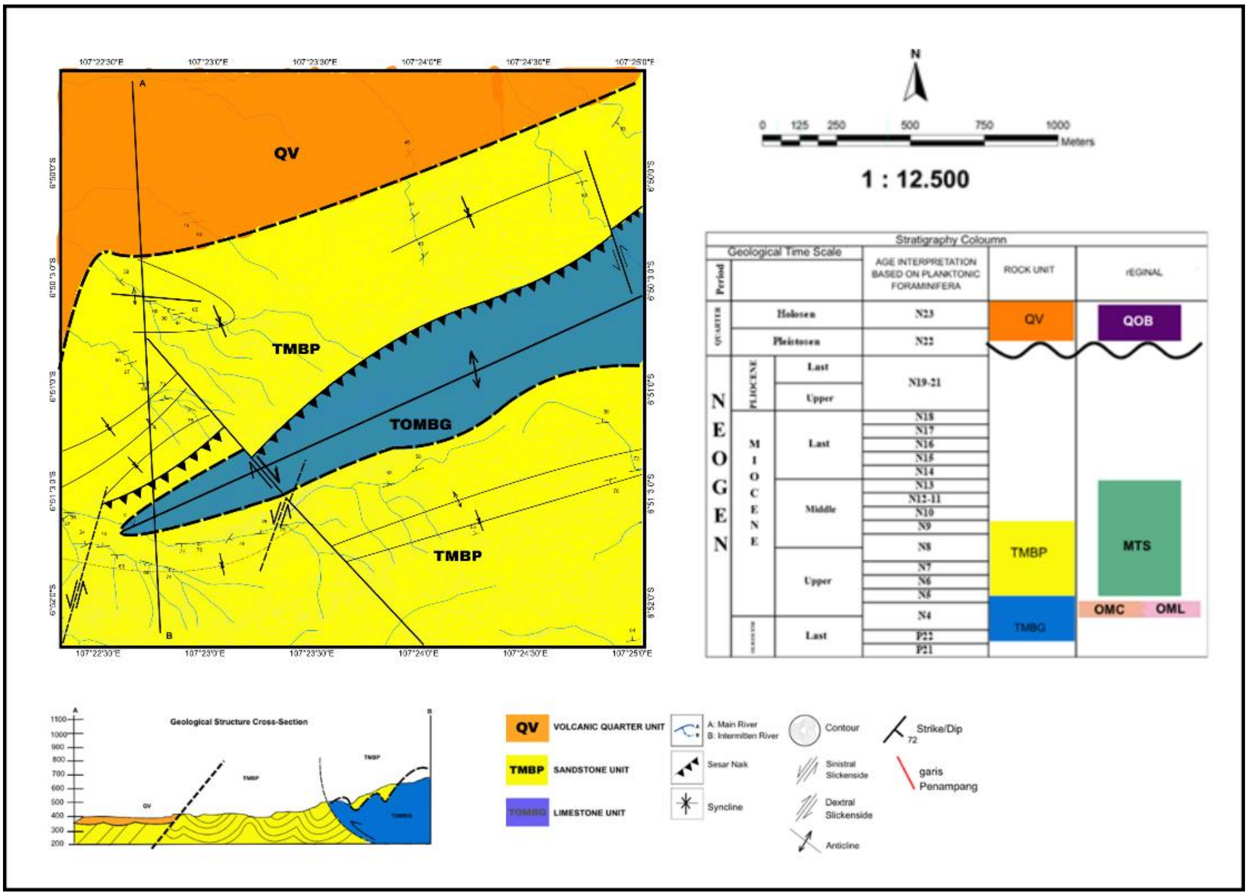

Figure 10. Geological map of the Cipatat Sub-district, West Bandung Regency (scale 1:12,500), showing the distribution of three rock units (QV, TMBP, TOMBG) and structural elements, supported by a stratigraphic column and A–B cross-section

Late Miocene, producing west–east-trending fold pairs — including the Ciparang, Cibarengkok, Cisaat, and Cilimus anticline–syncline structures — consistent with the regional Java Pattern, with initial topographic differentiation into ridges and valleys. Deformation reached its climax during the Pliocene, when continued shortening tightened existing folds to close-to-upright geometries, exemplified by the Cibarengkok and Cilimus anticlines, and drove propagation of the Cibuntu and Cilimus River faults as oblique reverse structures and the Cibrengkok River Fault as a tear fault accommodating differential displacement between reverse segments. During the Pleistocene, contractional deformation gave way to Quaternary volcanism. Tuffs and tuffmatrix breccias of the Quaternary Volcanic Unit (QV) were emplaced unconformably over the deformed Tertiary sequences, marking the end of the principal folding phase. However, the Miocene-Pleistocene structural framework still controls the primary characteristics of the present-day ridge-valley morphology, directions of drainage and lithological distribution in Cipatat region. The landscape has been altered over time in the Holocene via weathering, river erosion, mass wasting, and alluvial deposition.

CONCLUSION

Geological mapping of the Cipatat area at 1:12,500 scale defines three rock units spanning the Late Oligocene to Quaternary. The Rajamandala Limestone (TOMBG) records shallow neritic carbonate deposition, succeeded by the turbiditic Citarum Sandstone (TMBP) reflecting basin deepening during the Middle Miocene, and capped unconformably by the

Quaternary Volcanic Unit (QV) marking the onset of subaerial volcanism. The stratigraphic change from carbonate to siliciclastic sedimentation is associated with progressive subsidence and increased volcanic input as shown by the petrographic classification of the sandstone as volcanic-derived lithic wacke. Biostratigraphic data from larger and planktonic foraminifera restrict the depositional dates of the Tertiary layers and the Citarum Formation is interpreted to have had an outer neritic-bathyal environment. The Sunda Arc shows tectonic activity in the Miocene-Pliocene-Pleistocene time, illustrated by the west-east trending folds and reversal fault systems. The compressional stress field is NW–SE orientated. The structural framework controls directly the ridge-valley shape, drainage patterns and the present distribution of rock types in the examined area directly.

These findings improve the current regional geological map and provide a more detailed stratigraphic and structural framework for the Cipatat area, with immediate implications for subsurface investigations, carbonate resource evaluation of the Rajamandala Limestone, and future active fault studies along the Cimandiri Fault system. The combined technique of biostratigraphy, petrography and structural analysis as demonstrated in this study may be a replicable approach for the geological description of comparable difficult sites in West Java.

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