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FACIES AND PETROGRAPHIC CHARACTERISTICS OF CILETUH FORMATION IN THE MANDRAJAYA AREA, CIEMAS SUBDISTRICT, WEST JAVA

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ABSTRACT

The Eocene Ciletuh Formation, exposed within the Ciletuh-Palabuhanratu UNESCO Global Geopark, provides a key record of syn-tectonic sedimentation in West Java. While its general submarine fan setting is known, detailed facies and petrographic studies in specific localities are limited. This study aims to characterize the sedimentology of the Ciletuh Formation sandstone in the Mandrajaya area through an integrated analysis of lithofacies, petrography, and their spatial distribution to reconstruct its depositional environment. The methodology involved geological mapping to document outcrop characteristics and collect samples, followed by petrographic analysis of sandstones and conglomerates. Four primary lithofacies were identified: (a) matrix-supported polymictic conglomerate, (b) graded sandstone, (c) parallel-laminated sandstone, and (d) massive sandstone. Petrographic analysis reveals that the sandstones are texturally immature Lithic Arenites, and the conglomerates contain polymictic clasts of gabbro and recycled sandstone within a similar lithic arenite matrix. The spatial distribution of these facies delineates a submarine fan architecture, characterized by channel-fill deposits (conglomerates and massive sandstones) flanked by associated levee and overbank deposits (graded and laminated sandstones). The lithofacies association and petrographic composition confirm deposition within a dynamic submarine fan system sourced from a "Recycled Orogenic" belt, specifically the uplifted Ciletuh mélange complex, within a tectonically active Paleogene fore-arc basin.

Keywords: Submarine Fan, Lithic Arenite, Conglomerate, Fore-arc Basin, Sedimentation, Turbidite, Eocene.

ABSTRAK

Formasi Ciletuh berumur Eosen yang tersingkap di kawasan Ciletuh-Palabuhanratu UNESCO Global Geopark, merekam proses sedimentasi *syn-tectonic* di Jawa Barat. Meskipun secara umum telah diketahui bahwa formasi ini terendapkan dalam lingkungan *submarine fan*, studi rinci mengenai fasies dan petrografinya pada tingkat lokal masih terbatas. Penelitian ini bertujuan untuk mengkarakterisasi batupasir Formasi Ciletuh di daerah Mandrajaya melalui analisis litofasies, petrografi, dan distribusi spasialnya untuk merekonstruksi lingkungan pengendapannya. Metode yang digunakan mencakup pemetaan geologi untuk mendokumentasikan karakteristik singkapan dan pengambilan sampel, yang kemudian dianalisis secara petrografi terhadap batupasir dan konglomerat. Hasil analisis mengidentifikasi empat litofasies utama, yaitu: (a) *matrix-supported polymictic conglomerate*, (b) *graded sandstone*, (c) *parallel-laminated sandstone*, dan (d) *massive sandstone*. Analisis petrografi menunjukkan bahwa batupasir tergolong sebagai *lithic arenite* yang bersifat imatur secara tekstur, sedangkan konglomerat mengandung komponen gabro dan *recycled sandstone* yang terperangkap dalam matriks *lithic arenite* serupa. Distribusi spasial dari litofasies tersebut merepresentasikan arsitektur sistem kipas laut dalam, dengan endapan saluran proksimal berupa konglomerat dan *massive sandstone* yang diapit oleh endapan tepian saluran dan endapan luapan berupa *graded sandstone* dan *parallel-laminated sandstone*. Asosiasi litofasies dan komposisi petrografi mendukung interpretasi bahwa Formasi Ciletuh terendapkan dalam sistem *submarine fan* yang dinamis dan aktif secara tektonik, dengan sumber material berasal dari *recycled orogenic belt*, khususnya kompleks *mélange* Ciletuh yang telah mengalami pengangkatan, dalam suatu cekungan busur muka berumur Paleogen.

Kata Kunci : Kipas Laut Dalam, *Lithic Arenite*, Konglomerat, Cekungan Busur Muka, Sedimentasi, Eosen.

INTRODUCTION

The Ciletuh area, part of the Ciletuh-Palabuhanratu UNESCO Global Geopark, represents a significant and rare exposure of Pre-Tertiary rocks in West Java (Ikhram et al., 2018; Rosana et al., 2006). Geologically, the region is widely known as an outcrop location for a mélange complex associated with a subduction zone, which records the historic convergence between the Eurasian and Indo-Australian plates (Rosana et al., 2006; Satyana et al., 2021). This unique assemblage of ophiolites, metamorphic rocks, and deep-sea sediments makes the Ciletuh area a key natural laboratory for tectonic studies (Ikhram et al., 2018; Patonah, 2011; Rosana et al., 2006).

Within this complex tectonic setting, the Ciletuh Formation is a key stratigraphic unit. While historically linked to the Cretaceous subduction zone, recent studies interpret the formation as a product of mass-flow deposits rather than a tectonic mélange, supported by the lack of significant internal deformation in its matrix and clasts (Hartono et al., 2022). The formation, consisting of polymictic breccias and turbiditic sandstones, is considered the region's earliest basin fill, unconformably overlying the mélange complex (Hartono et al., 2022; Martodjojo, 2003; Satyana et al., 2021; Schiller et al., 1991). Researchers have significantly advanced the understanding of this formation. Geochronological analyses of associated metamorphic rocks have constrained the timing of subduction to the Eocene (55.2 ± 2 Ma to 37.8 ± 1.5 Ma) (Ikhram et al., 2023; Satyana et al., 2021), and palynological studies have further refined the age of the sandstone unit to the Middle Eocene (E6-Zone) (Winantris et al., 2023). The presence of sedimentary structures like Bouma sequences has also confirmed a submarine fan environment shaped by turbidity currents (Hartono et al., 2022; Martodjojo, 2003; Schiller et al., 1991).

Although the general depositional context has been established, a specific study that maps the distribution and association of sedimentary facies to reconstruct the depositional architecture in the Mandrajaya area in detail remains limited. Therefore, this research aims to conduct a detailed sedimentological analysis of the Ciletuh Formation sandstone at this location. The objectives of this study are: (1) to identify and describe the sedimentary lithofacies based on outcrop characteristics and petrographic analysis; (2) to analyze the facies associations and their spatial distribution to interpret depositional architectural elements; and (3) to construct a more detailed depositional environment model for the submarine fan system in the study area. The results are expected to provide a higher-resolution understanding of the sedimentary processes within a Paleogene fore-arc basin and contribute valuable scientific insight into the geological heritage of the Ciletuh-Palabuhanratu Geopark.

GEOLOGICAL SETTING

The study area (Figure 1) is physiographically situated within the Southern Mountains of West Java, a zone defined by rugged, hilly topography shaped by intensive tectonic and erosional processes (van Bemmelen, 1949). The region is geologically defined by the Ciletuh Mélange Complex, a rare and significant exposure of a Pre-Tertiary subduction zone in Java. This complex, representing an uplifted accretionary prism, comprises a chaotic mixture of ophiolitic rocks, various metamorphic rocks, and deep-sea sediments, making it a critical area for understanding the tectonic evolution of the Sunda Arc (Rosana et al., 2006; Satyana et al., 2021).

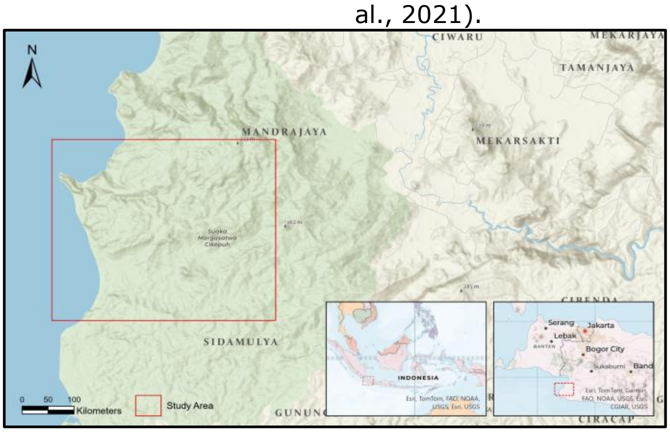

Figure 1. Location map of the study area. The main map shows the topography of the Mandrajaya area, with the study boundary indicated by the red box. Inset maps show the location relative to West Java Province and Indonesia. (Basemap source: Esri, USGS).

The regional stratigraphy, first systematically outlined by Sukamto (1975), is divided into two primary groups: a basement mélange complex and an unconformably overlying Cenozoic sedimentary cover (Figure 2). The basement complex consists of ophiolitic rocks such as peridotite and gabbro (Gunung Beas unit) (Ikhram et al., 2025), metamorphic rocks including schist and phyllite (Pasir Luhur Schist), and associated volcanic rocks like basalt and andesite (Citirem Formation) (Sukamto, 1975). More recent studies and higher-resolution mapping, such as the work by Rosana et al. (2019), have further refined the boundaries and internal complexity of these basement units. Unconformably overlying this entire complex is the Ciletuh Formation, a Middle Eocene sedimentary sequence composed of conglomerate, sandstone, and claystone, which represents the first post-accretion basin fill (Hartono et al., 2022; Winantris et al., 2023). The youngest units are Quaternary alluvial and coastal deposits that cover the low-lying areas (Rosana et al., 2019; Sukamto, 1975). The geological structure of the region is dominated by the legacy of Cenozoic convergence and accretion. The dominant structural grains are characterized by major thrust faults and strike-slip faults, which are generally oriented northwest-southeast and northeast-southwest (Rosana et al., 2006). These fault systems control the block-like exposure of the mélange basement and its juxtaposition against the younger Ciletuh Formation sedimentary rocks. The formation of the mélange itself, with its sheared shale matrix containing blocks of varying lithologies, is evidence of the intense tectonic deformation that occurred within the accretionary prism during the Eocene subduction event (Ikhram et al., 2023, 2025; Satyana et al., 2021). This structural framework is directly responsible for the unique amphitheater-like morphology of the Ciletuh bay and the rugged landscape of the surrounding area.

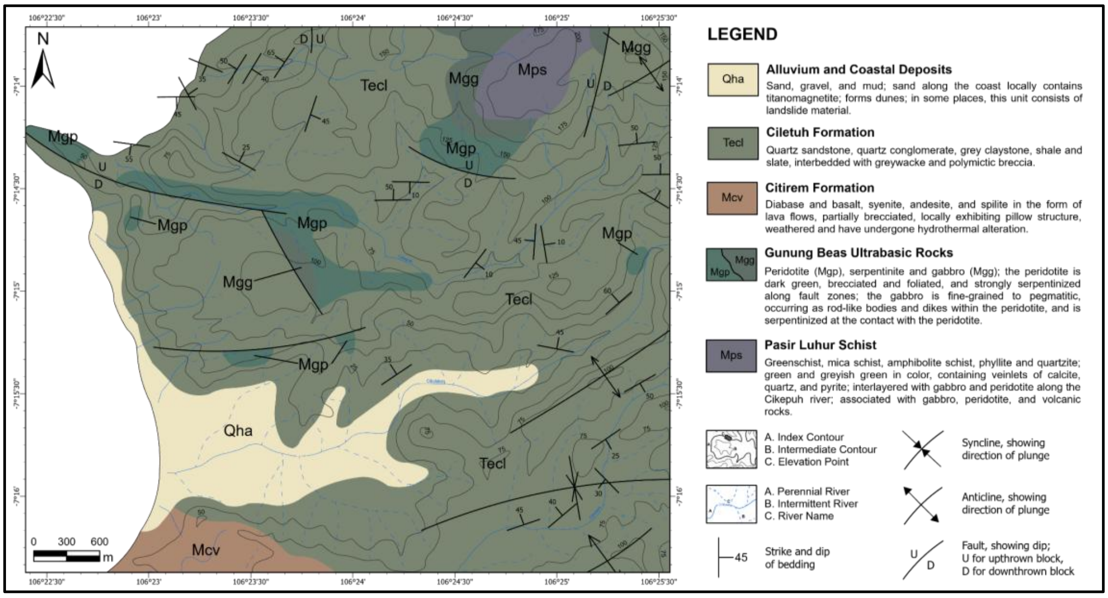

Figure 2. Regional geological map of the study area, modified from the geological map of the Jampang and Balekambang Quadrangles (Sukamto, 1975).

RESEARCH METHOD

This study integrates field-based geological mapping, laboratory petrographic analysis, and facies analysis to characterize the sandstone unit of the Ciletuh Formation. The field investigation was conducted in the Mandrajaya area to systematically document the characteristics of the Ciletuh Formation sandstones at numerous outcrops. This process involved detailed descriptions of lithology, texture (grain size, sorting), and primary sedimentary structures. The spatial position of each outcrop was recorded using GPS to construct a geological map showing the distribution of different rock types. Representative rock samples were collected from each distinct lithology for subsequent laboratory analysis.

In the laboratory, selected sandstone samples were prepared as standard thin sections for petrographic analysis using a polarizing microscope. The modal composition of the framework grains (quartz, feldspar, and lithic fragments) and matrix was determined semi-quantitatively through visual estimation using standard comparison charts. The sandstones were subsequently classified based on Pettijohn (1975).

Lithofacies were defined based on sedimentological characteristics observed in the outcrops. Due to the discontinuous and structurally complex nature of the outcrops in the study area, a continuous vertical stratigraphic succession could not be reliably constructed. Therefore, facies associations were primarily interpreted based on their spatial relationships, as shown on the facies distribution map (Figure 3). Interpretation of these spatially distributed facies was conducted at two scales. Internal structures in individual turbidite layers were analyzed and compared to the classic Bouma (1962) sequence to understand the depositional processes of single gravity-flow events. Subsequently, the full spectrum of observed lithofacies was compared with the comprehensive deep-water facies model proposed by Walker (1978). This framework was used to link individual facies to specific architectural elements of a submarine fan system. The depositional environment was then reconstructed by synthesizing the characteristics of each lithofacies and their observed spatial distribution patterns across the study area.

RESULT AND DISCUSSION

Based on detailed field observations and subsequent analysis, the sandstones and associated deposits of the Ciletuh Formation in the Mandrajaya area can be grouped into distinct lithofacies. The spatial distribution of these facies and their relationship with the underlying basement rocks are shown in the geological map of the study area (Figure 3). Each facies is described below, followed by an interpretation of its depositional process and significance within the broader submarine fan system.

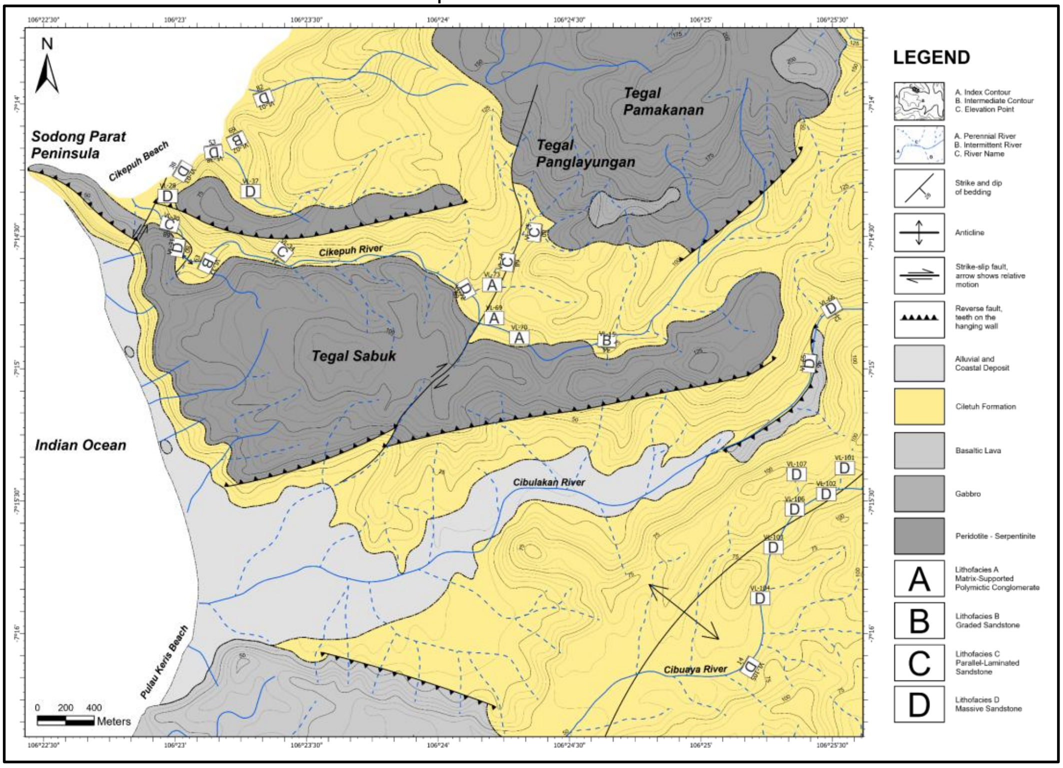

Figure 3. Geological and Lithofacies Map of the Mandrajaya study area. The map shows the spatial distribution of the identified sedimentary lithofacies of the Ciletuh Formation, the associated basement rocks (ophiolite complex), quartenary deposits, and mapped geological structures.

LITHOFACIES

Lithofacies A: Matrix-Supported Polymictic Conglomerate

This facies is characterized by poorly sorted, matrix-supported conglomerates (Figure 4A), observed at stations VL-69, VL-70, and VL-73. The unit is typically massive and lacks any internal stratification. The framework clasts are diverse (polymictic), ranging in size from pebbles to fine boulders (4−512 mm) with sub-rounded to well-rounded shapes. The clasts consist of various rock types, including pre-existing sedimentary rocks (sandstone) and igneous rocks (gabbro), as well as quartz minerals. These clasts are chaotically dispersed within an open-fabric framework, supported by a matrix of fine-to-medium grained sandstone.

The massive, disorganized nature, matrix-supported fabric, and poor sorting of this facies are characteristic of deposits from a high-concentration sediment gravity flow, most likely a cohesive debris flow (Nichols, 2009). In such flows, the sediment moves as a single, viscous mass where the strength of the matrix supports the larger clasts, preventing significant sorting and the formation of tractional structures (Boggs, 2014).

These characteristics correspond well with Facies A1.1 (Disorganized, matrix-supported gravel) or Facies F (Chaotic Deposits) from the classic deep-water facies scheme by Walker (1978). The findings are also highly consistent with observations by Hartono et al. (2022) in the nearby Kunti Island area. They described a similar polymict breccia unit that was poorly sorted and matrix-supported, which they interpreted as a product of a high-energy, mass-flow mechanism (Hartono et al., 2022).

In a submarine fan architectural model, this coarse-grained, chaotic facies is interpreted as a channel-fill deposit (Walker, 1978). The presence of this facies, particularly its close association with levee and overbank deposits (Lithofacies B and C), indicates that it occupies a major channel within the Middle Fan environment. These channels act as the primary conduits for transporting high-concentration, coarse sediment from a proximal source down into the deeper basin (Nichols, 2009). The occurrence of this facies in the study area is therefore direct evidence of these primary sediment transport pathways.

Lithofacies B: Graded Sandstone

This facies consists of medium- to coarse-grained sandstone beds, typically ranging in thickness from 0.7 to 2 meters, as observed at stations VL-02, VL-15, VL-32, and VL-35. The most distinct characteristic of this facies is the presence of normal graded bedding, where the grain size fines upwards from a coarse or very coarse sandy base to a medium or fine sandy top (Figure 4B). The basal contacts of these beds are often sharp and erosional. Petrographic analysis reveals these sandstones are lithic arenites, composed predominantly of quartz and lithic fragments.

The pronounced graded bedding in this facies is the classic signature of deposition from a decelerating, high-density turbidity current (Bouma, 1962). The initial, high-energy phase of the current deposits the coarse-grained base, while subsequent waning of the flow results in the progressive deposition of finer material. This structure corresponds directly to the Ta division of the Bouma sequence (Bouma, 1962; Nichols, 2009).

In Walker (1978) deep-water facies model, Lithofacies B is classified as Facies C: Classical Turbidites. The coarse-grained nature and the dominance of the Ta interval suggest these are "proximal" turbidites, deposited relatively close to the source of the flow. The presence of this facies is consistent with the findings of Hartono et al. (2022) and Schiller et al. (1991), who also identified Bouma sequences in the Ciletuh Formation sandstones, confirming deposition by turbidity currents.

Architecturally, this facies is interpreted to represent deposition in a sub-environment directly associated with a major submarine channel. More specifically, these graded beds are interpreted as levee or overbank deposits, formed adjacent to the main channel conduit when turbidity currents spill out from the channel confines (Walker, 1978). The close proximity of Lithofacies B to the channel-fill deposits (Lithofacies A and D) signifies that it is a component of a well-developed channel-levee system within the Middle Fan environment (Boggs, 2014; Nichols, 2009).

Lithofacies C: Parallel-Laminated Sandstone

This facies consists of fine- to medium-grained sandstone, observed at outcrops such as stations VL-30, VL-34, VL-74, and VL-75. The beds are typically well-sorted and display prominent, well-defined parallel laminations throughout their thickness (Figure 4C). These beds are generally thinner than those of Lithofacies B, ranging from 30 cm to over 1 meter. The base of these units is typically sharp and non-erosional, and they are often found overlying finer-grained deposits or other turbidite beds.

The parallel laminations in this facies are indicative of deposition under upper flow regime conditions, where rapid sedimentation from a turbidity current allows sand grains to settle and align with the flow direction (Nichols, 2009). This structure is characteristic of the Tb division of the Bouma sequence and is a key indicator of turbidite deposition (Bouma, 1962). The absence of the coarser, graded Ta division suggests that these deposits were formed either from the distal reaches of a turbidity current where energy had diminished, or from a less concentrated, lower-energy flow event from the outset.

This facies directly corresponds to Facies D (Laminated Sandstones) in (Walker, 1978) model. Facies D is commonly found in more distal settings compared to the channelized and proximal lobe deposits. The interpretation of a distal marine setting is consistent with the findings of Winantris et al. (2023), whose palynological analysis of samples from the Ciletuh Formation suggested a depositional environment

transitioning towards a more distal marine setting.
Architecturally, Lithofacies C is interpreted as a component of the overbank deposits directly associated with the main submarine channels. The fine-grained nature and parallel laminations suggest deposition from the more dilute, upper portions of turbidity currents that spilled out from the primary conduits during large flow events (Nichols, 2009). The presence of this facies, often found in close proximity to the main channel-fill deposits, indicates a relatively low-energy environment adjacent to the primary axis of sediment transport. This setting is characteristic of a levee or interchannel area within a well-developed channel-levee system in the Middle Fan environment (Walker, 1978).

Lithofacies D: Massive Sandstone
This facies is characterized by thick beds of medium- to coarse-grained sandstone that appear homogenous and lack significant internal stratification (Figure 4D). These beds, observed at numerous locations: VL-01, VL-03, VL-28, VL-31, VL-37, VL-38, VL-65, VL-66, VL-67, VL-72, VL-101, VL-102, VL-103, VL-104, VL-105, VL-106, and VL-107, are generally poorly sorted and can appear disorganized. While they lack clear grading or lamination, some beds contain floating, outsized clasts or occasional rip-up clasts of mudstone. The basal contacts are typically sharp, and in some cases, clearly erosional. Petrographically, these sandstones are also classified as lithic arenites.
The massive, structureless appearance of this facies suggests deposition from highly concentrated, rapid sediment gravity flows where sedimentation was too swift for tractional structures to develop (Boggs, 2014). This can occur in several types of flows, including high-density turbidity currents where the suspension fallout is so rapid that the flow "freezes," or in sandy debris flows where grain-to-grain interactions and a high-concentration matrix prevent the formation of internal layering (Nichols, 2009). This lithofacies corresponds to Facies B1.1 (Structureless Sandstones) in the Walker (1978) model. Facies B is often considered a proximal deposit, forming in similar settings to graded beds (Facies C) but resulting from flows with higher sediment concentration (Walker, 1978). The presence of this facies further supports the interpretation of a dynamic submarine fan environment, where various types of gravity flows were active. The massive nature of these beds indicates periods of particularly energetic and sediment-laden flows, likely occurring within the main depositional lobes or as the fill of shallower, less-confined channels in a Middle Fan setting.

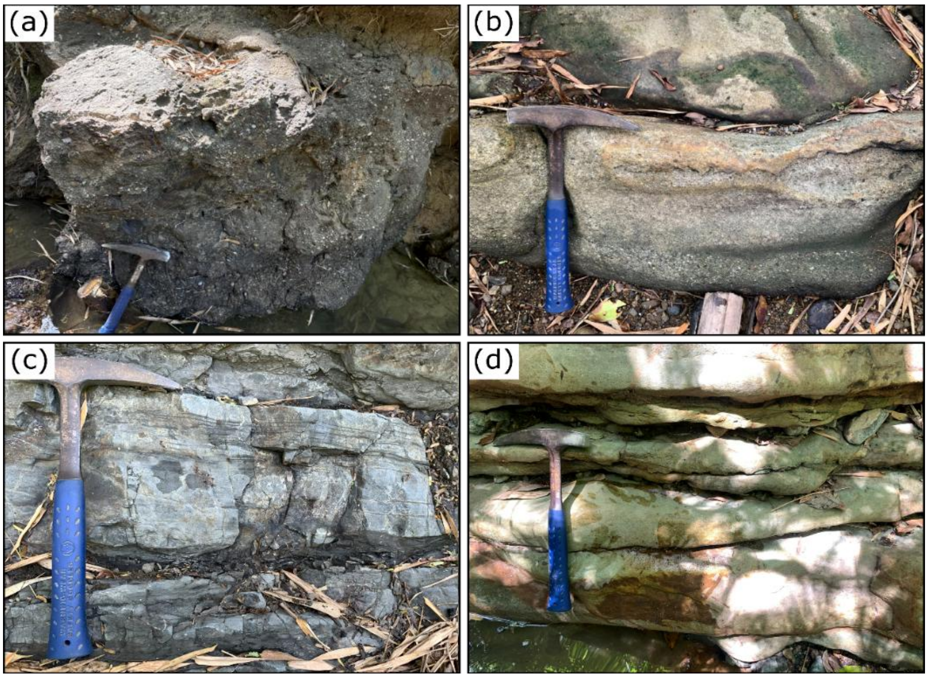

Figure 4. Field photographs of the representative lithofacies of the Ciletuh Formation in the study area. (A) Lithofacies A: Matrix-supported, polymictic conglomerate showing poor sorting and large, rounded clasts. (B) Lithofacies B: Thick bed of graded sandstone showing a fining-upward sequence. (C) Lithofacies C: Well-sorted, fine-grained sandstone exhibiting distinct parallel lamination. (D) Lithofacies D: Thick, massive sandstone bed lacking internal stratification.

PETROGRAPHIC CHARACTERISTICS

Sandstone Petrography

Petrographic analysis of the Ciletuh Formation sandstones reveals a composition that provides critical insights into the sediment's origin and transport history. Microscopically, the sandstones are texturally immature, characterized by angular to sub-rounded grains and moderate to good sorting. The framework is typically grain-supported with a clay matrix content of approximately 10%, classifying them as arenites (Pettijohn, 1975) (Figure 5).

The framework grains are composed of a diagnostic mixture of quartz, feldspar, and a high proportion of lithic fragments. Based on the analysis conducted in this study, the modal composition shows some variability, with quartz content at 35%, feldspar ranging from 9% to 20%, and lithic fragments ranging from 34% to 45% of the framework grains (Figure 5). The most significant components are the lithic fragments, which are abundant and diverse. While this study identified clasts of pre-existing sedimentary rocks, other researchers have documented a wider array of clasts in the Ciletuh Formation, including fine-grained volcanic rocks (andesite, basalt) and low-grade metamorphic rocks (Hartono et al., 2022; Satyana et al., 2021).

Based on the modal composition, where lithic fragments are a dominant component, the sandstones are consistently classified as Lithic Arenite following the scheme of (Pettijohn, 1975). The high abundance of chemically unstable grains, particularly the volcanic and metamorphic rock fragments reported in the literature, indicates that the sediment was derived from a source area with significant relief undergoing rapid mechanical erosion (Nichols, 2009). This process allows unstable fragments to be preserved by minimizing the duration of chemical weathering and transport (Boggs, 2014).

This petrographic signature is consistent with provenance studies in the Ciletuh area, which also identified the sandstones as lithic arenites sourced from a "Recycled Orogenic" belt (Sudithio et al., 2017). A recycled orogen provenance denotes a source from uplifted terrains, such as suture zones or accretionary prisms, where a mix of sedimentary, metamorphic, and igneous rocks is exposed and eroded (Dickinson & Suczek, 1979). The detrital modes observed in this study, combined with the comprehensive clast assemblages reported by (Hartono et al., 2022), strongly point to the Ciletuh mélange complex itself as the primary source terrain, confirming that it was actively being uplifted and eroded during the Middle Eocene deposition.

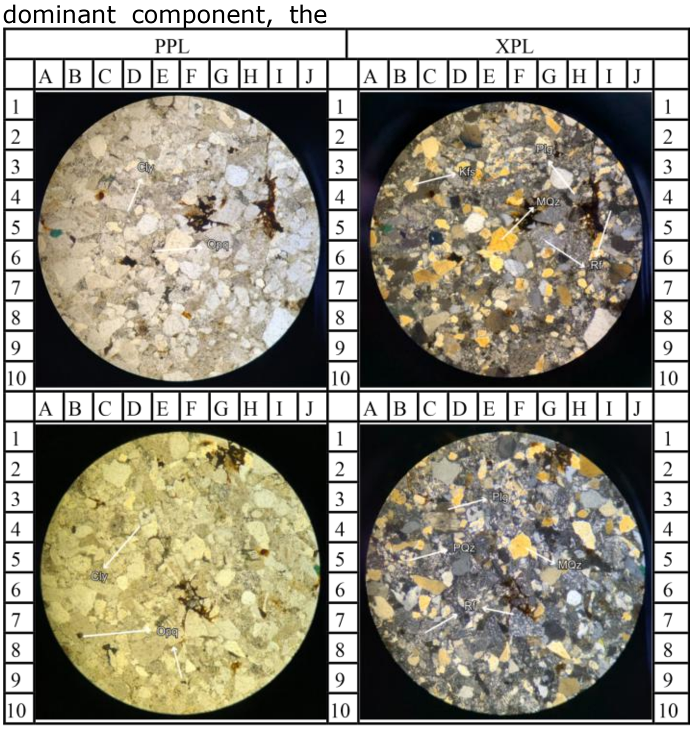

Figure 5. Photomicrographs of sandstone from the Ciletuh Formation (Sample VL-04), classified as lithic arenite. The figure shows two different fields of view from the same thin section to illustrate the general composition. Each view is presented in plane-polarized light (PPL, left) and cross-polarized light (XPL, right). Abbreviations: Mqz = monocrystalline quartz; Pqz = polycrystalline quartz; Plg = plagioclase; Kfs = K-feldspar; Rf = rock fragment; Cly = clay minerals; Opq = opaque minerals.

Conglomerate Petrography

The conglomerate units of the Ciletuh Formation are polymictic and poorly sorted. Megascopic observation reveals that the clasts range in size from fine pebbles to fine boulders (4–512 mm), are sub-rounded to well-rounded, and are set within an open, clast- to matrix-supported fabric. The clasts are composed of diverse lithologies, including igneous rocks (gabbro), sedimentary rocks (sandstone), and individual quartz minerals.

Microscopic analysis was conducted on the sandy matrix that binds the larger clasts. Petrographically, this matrix is nearly identical to the sandstone beds described in the previous section. It is a Lithic Arenite, with a framework composed of quartz (~42%), feldspar (~15%), and lithic fragments (~30%) (Pettijohn, 1975) (Figure 6A). The clasts themselves are also revealing; petrographic analysis of igneous clasts confirms they are altered gabbro (Figure 6C), while the sedimentary clasts are identifiable as pre-existing lithic arenites (Figure 6B).

The petrography of the conglomerate provides powerful evidence for the depositional processes and provenance. The composition of the matrix, a lithic arenite similar to the main sandstone beds, suggests that the fine-grained component of the debris flows was derived from the same sediment source that supplied the turbidity currents, indicating a shared provenance.

More importantly, the polymictic nature of the framework clasts confirms a "Recycled Orogenic" source (Sudithio et al., 2017). The presence of gabbro clasts points directly to the erosion of the local ophiolitic basement complex, which was exposed during the Eocene (Satyana et al., 2021). The inclusion of sandstone clasts, which are themselves lithic arenites, is compelling evidence of a "cannibalistic" depositional system. This indicates that previously deposited and semi-consolidated submarine fan sediments were being actively eroded, ripped up, and incorporated into later, higher-energy gravity flows (Nichols, 2009). Such a process is characteristic of tectonically active settings, such as the fore-arc basin proposed for the Ciletuh Formation, where slope instability and faulting can trigger large-scale mass flows that rework older deposits (Hartono et al., 2022).

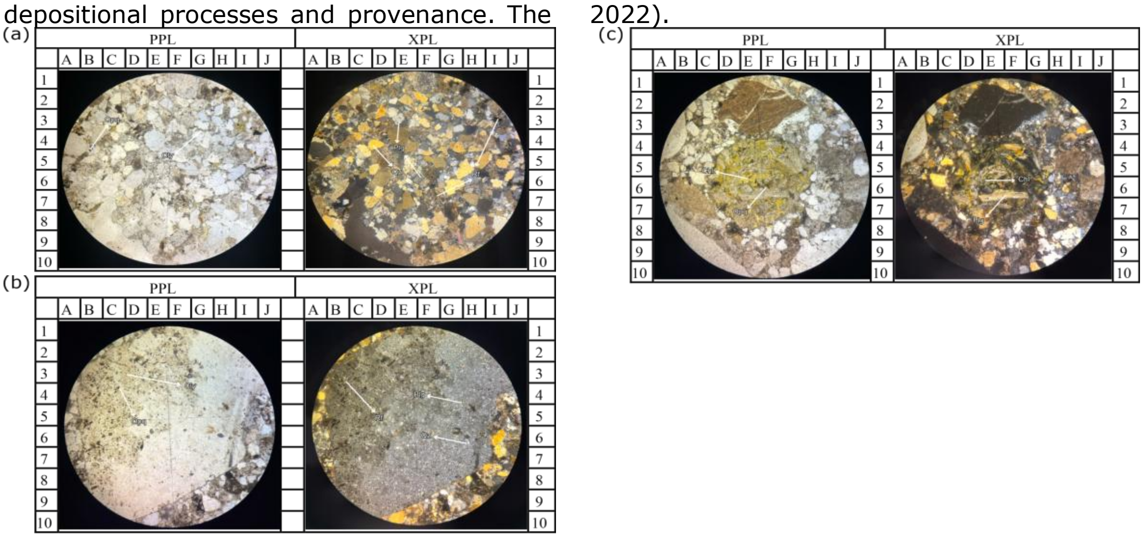

Figure 6. Photomicrographs of polymictic conglomerate from the Ciletuh Formation (Sample VL-70). (A) Sandy matrix of the conglomerate under plane-polarized light (PPL, left) and cross-polarized light (XPL, right). (B) Recycled sedimentary clast, identified as lithic arenite (PPL, left; XPL, right). (C) Altered gabbro clast of igneous origin (PPL, left; XPL, right). Abbreviations: Qz = quartz; Plg = plagioclase; Rf = rock fragment; Cly = clay minerals; Chl = chlorite; Opq = opaque minerals.

DEPOSITIONAL ENVIRONMENT SYNTHESIS

The integration of lithofacies characteristics, their spatial distribution, and petrographic data allows for the reconstruction of the depositional environment for the Ciletuh Formation in the Mandrajaya area. The evidence strongly points to a submarine fan system that developed within a tectonically active basin. This interpretation aligns with the conclusions of multiple previous studies that identified the formation as a product of mass-flow deposition (Hartono et al., 2022; Schiller et al., 1991).

The spatial distribution of the identified lithofacies (Figure 3) reveals a coherent depositional architecture. A significant observation is that Lithofacies A (Conglomerate), the coarsest deposit, is found exclusively in the central part of the study area. This central zone is interpreted as the main feeder channel or the most proximal part of the fan system captured in the study area. Flanking and distal to this central channel are areas dominated by other facies. The northwestern area contains a mix of Lithofacies D (Massive Sandstone), which is dominant, alongside Lithofacies B (Graded Sandstone) and C (Parallel-Laminated Sandstone). This association is interpreted as a channel-overbank complex, where massive sands filled a secondary channel while the finer-grained, classical turbidites were deposited as adjacent overbank or levee deposits. The southeastern area, composed entirely of Lithofacies D, likely represents another persistent, high-energy channelized environment. This spatial arrangement, from a central conglomerate-filled channel to outboard sandy channel and overbank complexes, suggests a primary sediment transport direction originating from the central region and dispersing outwards.

This architectural model, conceptually illustrated in Figure 7, is strongly supported by the nature of the facies. The channel-fill deposits (Lithofacies A and D) represent high-concentration sediment gravity flows, such as debris flows and sandy density flows, typical of the Middle Fan environments (Walker, 1978). The associated levee and overbank deposits (Lithofacies B and C) are characterized by classical turbidites showing features of the Bouma (1962) sequence, indicating deposition from less-concentrated portions of turbidity currents that spilled from the main conduits.

Finally, the petrographic signature provides a correlation link between the fan deposits and their source. The classification of the sandstones as Lithic Arenite and the polymictic nature of the conglomerate clasts confirm a "Recycled Orogenic" provenance (Dickinson & Suczek, 1979; Sudithio et al., 2017). This indicates that the fan was fed by the rapid erosion of a tectonically active, uplifted terrain composed of a mix of rock types. The presence of gabbro and recycled sandstone clasts points specifically to the Ciletuh mélange complex itself as the primary source. This aligns perfectly with regional tectonic models, which establish that the mélange basement was actively uplifted during the Eocene (Satyana et al., 2021).

The Ciletuh Formation in the Mandrajaya area records deposition within a dynamic submarine fan during the Middle Eocene (E6-Zone) (Winantris et al., 2023). This fan was situated within a tectonically active fore-arc basin. This interpretation is not only supported by regional models but is demonstrated directly by the data presented in this study. The petrographic classification of the sandstones as texturally immature Lithic Arenites, rich in unstable fragments, points to a high-relief source area undergoing rapid erosion with minimal transport, a hallmark of a tectonically active setting (Dickinson & Suczek, 1979; Nichols, 2009). Furthermore, the presence of coarse, poorly sorted debris flow deposits (Lithofacies A) signifies deposition on or at the base of steep, unstable slopes, consistent with a fault-bounded basin margin (Walker, 1978). The most compelling evidence for syn-tectonic activity is the discovery of recycled sandstone clasts within the conglomerates, which indicates that the basin floor itself was being uplifted and eroded during deposition (Boggs, 2014). This fan system was directly supplied by the erosion of its adjacent accretionary prism, providing a textbook example of syn-tectonic sedimentation.

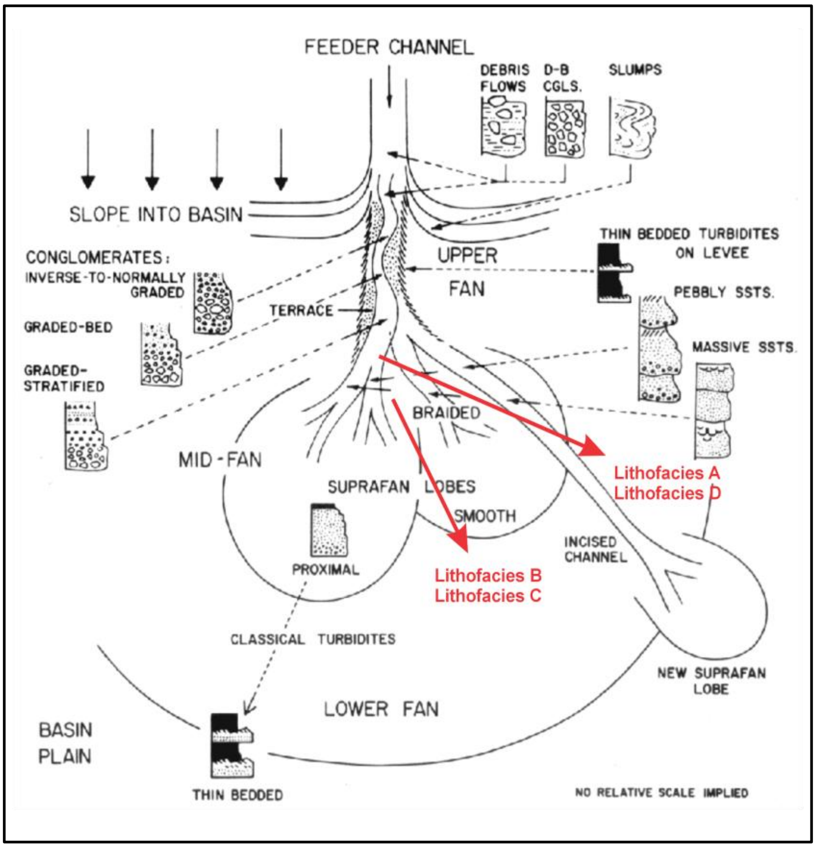

Figure 7. Schematic depositional model for the Ciletuh Formation submarine fan, illustrating the interpreted depositional setting for the lithofacies identified in this study. Arrows link each facies (A–D) to its corresponding architectural element within the Middle Fan environment (Base model modified from Walker, 1978).

CONCLUSION

The sedimentology and depositional environment of the Middle Eocene Ciletuh Formation in the Mandrajaya area have been characterized through an integrated analysis of field observations and petrography. Four distinct sedimentary lithofacies were identified: Matrix-Supported Polymictic Conglomerate, Graded Sandstone, Parallel-Laminated Sandstone, and Massive Sandstone. The spatial distribution of these facies allows for the reconstruction of a submarine fan depositional system, where conglomerates and massive sandstones represent the channel-fill deposits, while the graded and laminated sandstones signify the associated levee and overbank elements of a channel-levee complex. Petrographic analysis confirms that the sandstones are texturally immature Lithic Arenites, and their composition, rich in fragments from the underlying ophiolitic and mélange basement, indicates a recycled orogenic provenance. This study demonstrates that the Ciletuh Formation in the Mandrajaya area preserves the remnants of a dynamic submarine fan system that developed within a fore-arc basin setting during the Middle Eocene, driven by syn-tectonic sedimentation adjacent to an actively eroding and uplifting subduction complex.

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