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# Depositional Model of Middle Eocene Ciletuh Formation: New Field Findings from Kunti Island, Ciletuh, West Java

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**Abstract**

West Java stratigraphy is commonly divided based on its tectonic development into two regions, the Southern and Northern Regions. Whilst the stratigraphy in the Northern Region is relatively stable and dominated by carbonate development, the stratigraphy in the Southern Region is quite complex. One of the examples is the deposition during Eocene that is affected by the emergence of the East Java collision to Sundaland creating a complex environment of deposition. Most authors pointed out that the earliest basin fill is the Mid-Eocene Ciletuh Formation with the tectono-stratigraphic position is still under debate whether it is part of tectonic melange, sedimentary melange, or mass flow deposits. Moreover, the occurrence of Eocene volcanism during Eocene deposition is still questionable. This paper presents several key findings during 2022 ITB Field Activities that answer several questions. Commonly, lithological characteristics of the Ciletuh Formation suggest mass-flow deposits that are composed of ultramafic-mafic rocks, chert, limestone, andesite, low degree metamorphic rocks, conglomerate, and turbiditic sandstone. No internal deformation in both matrix and grain are found like in Karangsambung suggesting Ciletuh Formation is not a tectonic melange. Moreover, three turbiditic sandstone sequences were sandwiched between polymict breccia that interpreted as submarine channel facies. It is uncommon features if Ciletuh Formation is sedimentary melange leaving mass flow deposit as the most possible explanation. Furthermore, coal is found suggesting input from the terrestrial, possibly related with fluvio-deltaic facies of the "Pre-Bayah" Formation. Therefore, with the lithological assemblages, there are three major sediment sources during Ciletuh Formation deposition. First, coal and quartz fragments were transported by fluvio-deltaic facies of "Pre-Bayah" from the north, andesite fragments from the "Ciletuh Volcanics" in the east, and the exotic fragments from the accretionary prism in the south. The most suitable tectonic setting for this simulation is the submarine canyon in the fore-arc.

**Keywords:** Ciletuh Formation, Depositional Environment, Eocene, Field Observation, Submarine Deposits

## Introduction

The Paleogene basin fill in Java is quite fascinating to be studied as the depositional system and the tectonic position are still enigmatic due to the tectonic controls during those times. Specifically, in West Java, the earliest basin formation and fill were controlled by the NE-SW subduction of Indo-Australia plates together with the emergence of the East Java Micro-Continent collision (Sribudiyani et al., 2003; Clements et al., 2009). With the complexity, the depositional system and also the tectonic position are still subject to discussion until now. Moreover, volcanism in southern West Java during Eocene has been brought to the attention (Schiller et al., 1991; Clements and Hall, 2007; Clements et al., 2009).

This study focuses on some parts of Eocene intervals, namely the Ciletuh Formation (based on locality; Martodjojo, 2003) or "Ciletuh Beds" (van Bemmelen, 1949 in Satyana et al., 2021), which still opens up some questions that need to be answered. The earliest work intervals have been done by Duyfjes (1940 in Satyana et al., 2021) followed by Lemigas (Thayyib et al., 1977), and the most recent one done by FTG Unpad in 2021 (the results presented on Satyana et al., 2021). In this paper, we brought several field findings from Cikadal Bay, Kunti Island (Figure 1a), Ciletuh that were taken during 2022 ITB Regional Geology Excursion. With these findings, the understanding of the Eocene basin fill in the southern region of West Java is improved.

## Regional Tectonics

In terms of structural and stratigraphic features, West Java has complex geological settings, in which Darman and Sidi (2000 and references therein) divide West Java into five tectonic provinces, from the north to south respectively, Northern Basinal Area, Bogor Trough, Modern Volcanic Arc, Southern Slope, and Banten Block. These tectonic blocks were separated by thrust fault (Martodjojo, 2003). Our research area is focused on the Southern Slope where this block is probably the oldest block in West Java composed of Pre-Tertiary crystalline rock and Eocene-Miocene sediments that were formed by several tectonic episodes.

Sribudiyani et al. (2003) proposed four tectonic episodes, the Pre-Late Cretaceous, Late Cretaceous-

Eocene, Eo-Oligocene, and Oligo-Pliocene episodes. The first and second episodes play a critical role during the early basin formation and filling of West Java so this study mostly discussed those episodes. The latter events were responsible for the uplift of the Southern Java stratigraphic intervals. Before Late Cretaceous, West Java was an active continental margin with subduction of the Indo-Australian Plate to Eurasian Plate in the NE-SW direction (Meratus Trend; Sribudiyani et al. 2003; Hall, 2013). During the subduction event, several microcontinents (e.g. East Java, Argoland, and Paternosfer) were drifting relatively to the north, possibly until Paleogene (Hall and Morley, 2004; Hall, 2013).

Moreover, it is hypothesized that Bentong-Raub Suture and Medial Sumatra Tectonic Zone (MSTZ) created a shear zone resulting in the formation of extensional structures (Sribudiyani et al., 2003; Clements and Hall, 2007) that formed basins with N-S trendings (Sunda Trend), such as Sunda-Asri Basin and Northwest Java Basin. The fluvial system brought the sediments from Sundaland in the north through the N-S basins to the south (Schiller et al., 1991; Martodjojo, 2003; Clements and Hall, 2007; Clements et al., 2009; Septama et al., 2021). Latter, East Java Micro-Continent collided in the Late Eocene terminating magmatism in Java (Sribudiyani et al., 2003) and also responsible for the uplift of the Pre-Tertiary basement (Martodjojo, 2003).

**Regional Stratigraphy**

With the episodic tectonic events, stratigraphy of Southern West Java could be divided into three groups deposited above Pre-Tertiary basement (Martodjojo, 2003; Satyana et al., 2021). Several authors (Thayyib et al., 1977; Martodjojo, 2003; Satyana et al., 2021) suggest that the basement in the area is melange composed of native and exotic blocks similar to those in Jiwo Hill and Karangsambung. Moreover, Thayyib et al. (1977) divide the Pre-Tertiary basement into ophiolite, sedimentary, and metamorphic. These three groups are mixed with each other (no visual contact between each block) in sheared and scaly clay matrix (Thayyib et al., 1977; Satyana et al., 2021).

The first episode marks the deposition of terrestrial, fluvio-deltaic, to deep marine sediments from Mid-Eocene to Early Oligocene (Martodjojo, 2003; Clements and Hall, 2007; Koesoemadinata, 2020). Ciletuh Formation is deposited unconformably above the melange complex (Satyana et al., 2021 and references therein) in deep marine settings. Schiller et al. (1991) divides the Mid-Eocene intervals into two facies, the Ciemas Formation composed of quartzose sandstone that represents fluvio-deltaic facies, and the Ciletuh Formation composed of polymict breccia that represents submarine fan facies. Moreover, volcanic materials are also incorporated during Mid-Eocene deposition (Schiller et al., 1991; Clements and Hall, 2007; Clements et al., 2009). Later, Late Eocene Bayah Formation is deposited conformably above the Mid-Eocene interval in terrrestrial deposits with diverse settings from fluvial (Walat Formation in Sukabumi) to lacustrine settings (Septama et al., 2021). The latter episodes of deposition in southern region of West Java are dominated by volcano-clastic deposition with gravity mass flow (GMF) manner from Early Miocene (old andesites) to Quaternary (Martodjojo, 2003).

**Results and Discussion**

Our field observation in Cikadal Bay, Kunti Island, Ciletuh gives similar results with previous studies (Schiller et al., 1991; Martodjojo, 2003; Clements et al., 2009). Ciletuh Formation within the area could be divided into two main groups (Figure 1), The polymict breccia and brecciatic sandstone and sandstone units. The lithology has dipping to the south with strike and dip N90E/65.

***Polymict Breccia Unit***

The polymict breccia units are poorly sorted, grain-supported, and composed of fragments that commonly appeared in melanges such as low-degree metamorphic rock (slate, phyllite, and schist), metasedimentary rock, peridotite, basalt, chert, turbiditic sandstones, conglomerates, chert, and limestones (Figure 1b). The size of the fragments ranges from pebble to cobble. In some parts, basalt with pillow lava and lava flow structures (in Breccia Unit C) have a boulder size. Not restricted to melange materials, andesitic rocks together with quartz and coal fragments (Figure 1b) are also found within the breccia. These fragments are sub-rounded to angular and distributed in a non-calcareous greenish-gray matrix (Figure 1b). No internal matrix deformation is found. Generally, the breccia displays massive and disoriented structures. However, in the upper part (Breccia Unit A), reverse graded bedding is observed. Local imbrication of the fragments is also noted in the middle part of Breccia Unit B. The interesting part of this polymict breccia is that laterally, the fragment size changes.

The poorly sorted and immature textural maturity of polymict breccia indicates that the sediment is deposited in the proximal area with GMF mechanism (Walkers, 1992; Nichols, 2009). We doubt that the textural immaturity is the result of huge sediment transport but rather the consequence of depositional position. This reason is also supported by a boulder of pillowed lava (> 10 m) as a fragment that shows an indication of a sliding mechanism (Figure 1b; Shanmugam, 2006) which is typical in the proximal part. With this understanding, this characteristic confirms the previous statement that suggests Ciletuh Formation is deposited near and/or in the slope

created by a fault scarp (Schiller et al., 1991; Clements et al., 2009)

***Brecciatic Sandstone and Sandstone Units***
The contact between breccia and sandstone units is mostly gradual with localized erosional contact (Figure 1b). All sandstone units have brownish-grey color, are medium to poorly sorted, and grain supported. The grain size ranges from coarse to medium sand (even some interval could be referred to as brecciatic sandstone) in a non-calcareous matrix.

The Brecciatic Sandstone and Sandstone Units also display GMF-related sedimentary structures. Bouma sequences (normal graded bedding [Ta] and parallel lamination [Tb), and convolution (Figure 1b) were almost observed in Sandstone Units. Sole marks were also found between the Breccia and Sandstone Units. Genetically, the Breccia Units are deposited above the unlithified Sandstone Units resulting in these features. As additional information, it should be noted that each sandstone units "sandwiched" by polymict breccia units display different characteristics of the sedimentary structures. To be detailed, in the lowest part, Sandstone Unit D is composed of sandstones intercalated with shale (Figure 2). Sandstone Unit C and B. is characterized by massive sandstones with rip-up clast features (Figure 2), while Sandstone Unit A and B in the upper part display a brecciatic sandstone with local imbrication of fragments. All of these features are related to the mass-flow mechanism, especially low to medium density GMF (Walkers, 1992; Shanmugam, 2006). The different characteristics of the Sandstone Units are related to the different positions of deposition.

Further south from Sandstone Unit D, basaltic rocks were found. These basalts are aphanitic and have a vesicular and pillow lava (Figure 2) structures. Additionally, calcite veinlets are frequent in these pillow lava outcrops. However, direct contact is absent between the pillow lava and the sedimentary units.

***Depositional Environment***
With the combination of our field observations confirmed by biostratigraphic studies conducted by Schiller et al. (1991), we conclude that the Ciletuh Formation is indeed deposited in the deep marine environment. Additionally, with the nature of the rocks that are related to mass-flow deposits, we believe that the deposition of the formation is related to the submarine fan environment.

Coal fragment (not as a layer as previously suggested by van Bemmelen, 1949 in Schiller et al., 1991) in the polymict breccia unit indicates the occurrence of the deltaic system in the north of Ciletuh. Coal fragment is typical for the terrestrial environment and is transported to the deep marine environment by a great deltaic system. This deltaic system is assumed to be similar to Late Eocene Bayah Formation so we refer to this source for the coaly materials as the "Pre-Bayah" Formation (equivalent to Ciemas Formation; Schiller et al., 1991; Clements et al., 2009). Koesoemadinata (2020) has also already put information regarding the transportation of terrestrial material to the deep marine system during Mid Eocene.

***Volcanism during Eocene***
Similar to the previous studies (Clements et al. 2009; Satyana et al., 2021 and reference therein), our field observation also support the occurrence of volcanism during Ciletuh deposition based on the appearance of andesitic rocks as a fragment in the polymict breccia unit. Although there is volcanism during Eocene, we proposed a different model to the previous studies, in which the previous concept pointed out that the volcanism is the result of basaltic magmatism that manifest via fissures in a similar fashion to Izu Bonin magmatism (Clements and Hall, 2007; Clements et al., 2009). We do believe that the andesitic rocks are most likely a product of calc-alkaline magmatism. With assumption, Eocene volcanic chain has a NE-SW trend following the Meratus trend (Sribudiyani et al., 2003; Hall, 2013), other Eocene volcanic product should be found in the northwestern part of Java. This assumption is then true by the discovery of Jatibarang volcanic in Northwest Java Basin, where the rocks also have calc-alkaline affinities that are related to the active continental margin (Hutabarat, 2016).

***Tectonic Reconstruction***
Ciletuh Formation have been attributed to be deposited in an accretionary prism by the early work (Thayyib et al., 1977) which is tectonically active. Consequently, the matrix and grain must be internally deformed, in which the evidence is absent in our research area. Clements and Hall (2007) proposed that the deposition of Ciletuh Formation occurred in the fault scarp related to extensional faulting. The extensional faulting is assumed related to basaltic volcanism through fissures. However, as previously discussed, the volcanism during Eocene in Java is interpreted to be subduction-related to the calc-alkaline affinities (Hutabarat, 2016). Satyana et al. (2021) interpreted that Ciletuh Formation was considered as olisostrome, which it was sourced from uplifted melange. Consequently, the terms olisostrome means that Ciletuh Formation are deposited in the subduction trench slope.

Our interpretation is most likely similar to Schiller et al. (1991), which pointed out that Ciletuh Formation is deposited in the fore-arc or intra-arc. Specifically, we interpret that Ciletuh Formation is deposited in

the piggyback basin where the melange complex is thrusted in the south to southeastern part (Figure 2 and 3). The uplifted basement act as the source of sediment for the exotic block found in the polymict breccia unit such as peridotite, pillowed lava, etc. The volcanic vent is possibly situated in the northern part as the source of andesite. Coal and quartz fragment are transported by a large river system from Sundaland (Figure 2 and 3). The dynamic of the thrusting is observed in the vertical facies changes where in the early Mid Eocene, the tectonics are relatively stable and changes into a frequent thrusting in the upper Mid Eocene.

## Conclusions

Several key findings during ITB Regional Geology Excursion 2022 have answered some questions regarding the deposition of the Ciletuh Formation during Mid Eocene. After all, Ciletuh Formation is a mass flow product deposited in a submarine fan environment. Tectonically, the interval was filling a piggyback basin with multiple sources of sediments. Further research such as petrographic analysis for detailed provenance study and/or organic petrography of the coal fragment should be continued to support our hypothesis. Moreover, the research opens up the possibility for petroleum geology study in South West Java as coal fragments in Ciletuh Formation could indicate the occurrence of Mid Eocene mature organic-rich source rock within the area.

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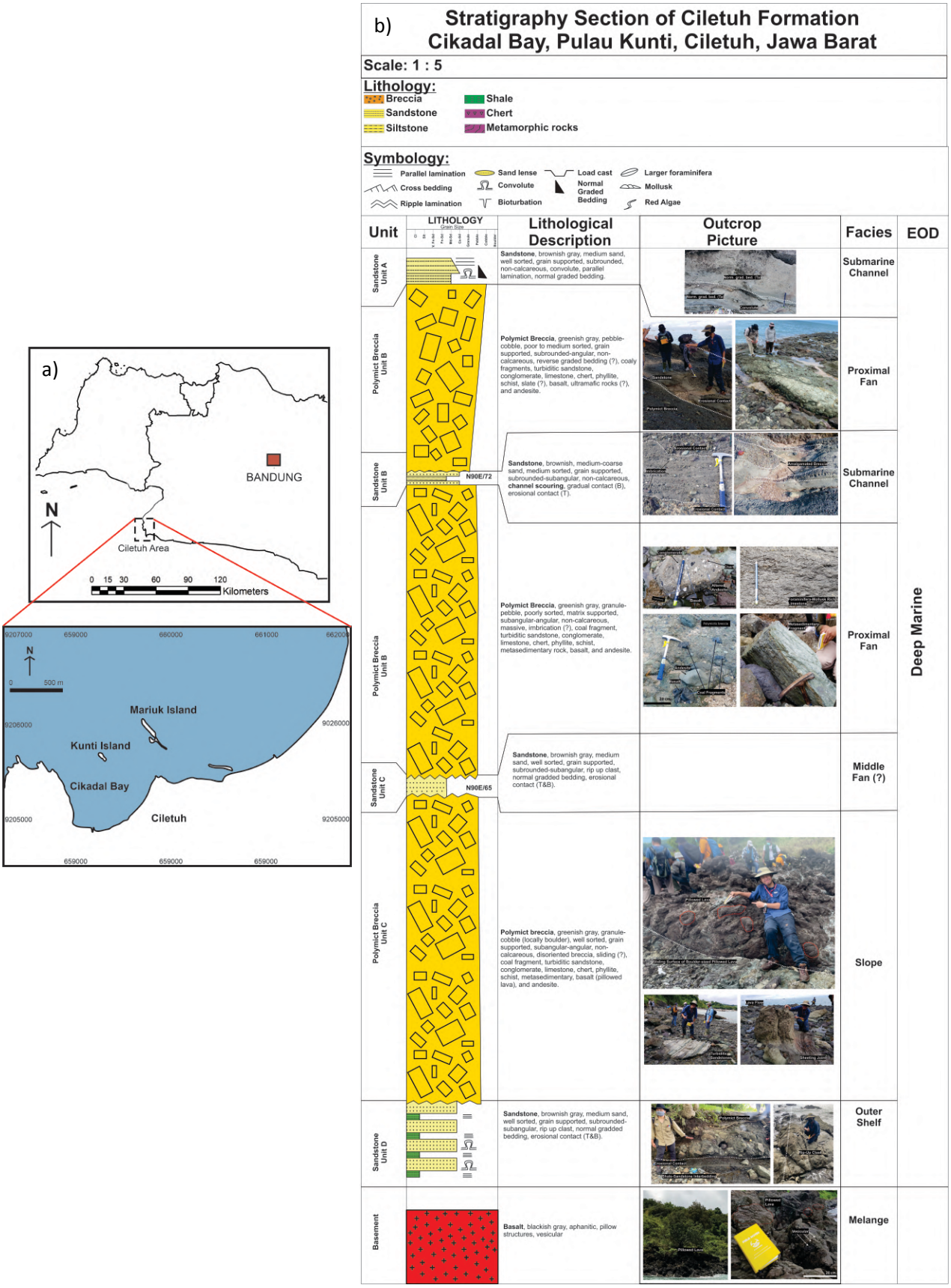


Figure 1: (a) Overview location map of Ciletuh Area; (b) Stratigraphic section of Ciletuh Formation together with lithology description and outcrop pictures. Based on the lithological characteristics, the interval in Pulau Kunti could be divided into two main groups, Polymict Breccia and Sandstone Units. Clearly, Ciletuh Formation is a mass-flow deposit in deep marine settings deposited unconformably above the Pre-Tertiary melange complex.

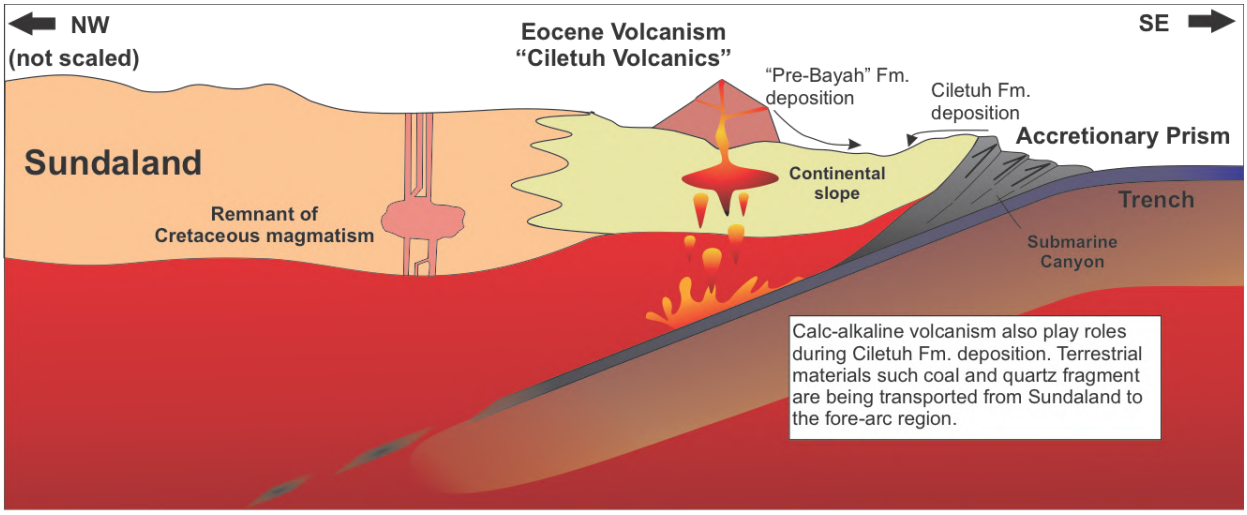


Figure 2: Tectonic cross-section of South West Java during Mid Eocene which is interpreted based on field observation and several publications (Schiller et al., 1991; Martodjojo, 2003; Sribudiyani et al., 2003). Ciletuh Formation was deposited in fore-arc, specifically in the piggyback basin, in which the ophiolitic and metamorphic fragments are sourced from the thrusted melange complex in accretionary prism in the south, intermediate volcanic rock from Eocene magmatic arc, and coal and quartz fragments from Sundaland in the north as a continuation of Pre-Bayah delta deposition.

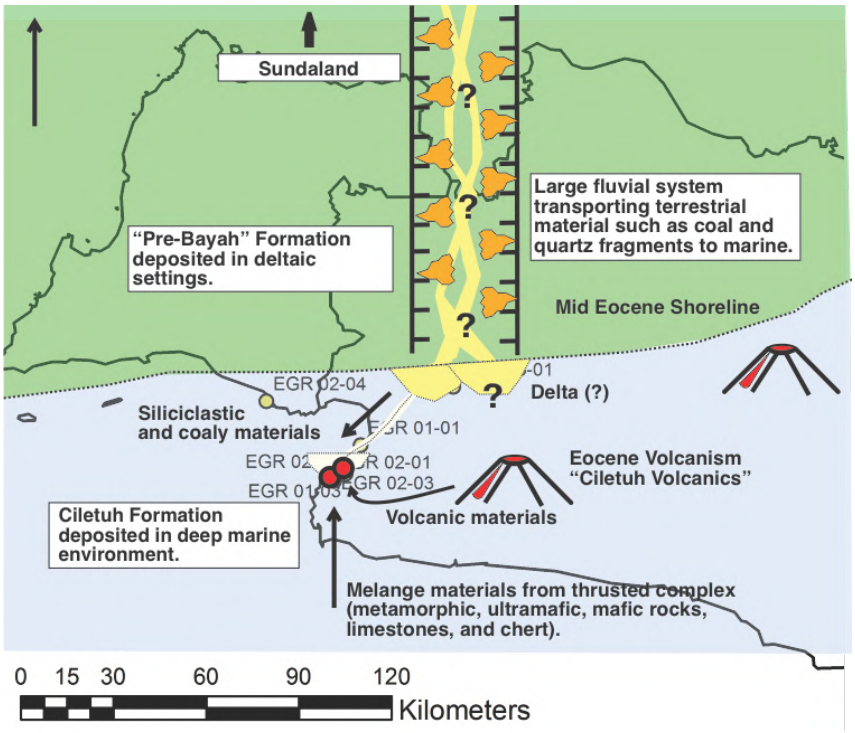


Figure 3: Paleo-Geographic reconstruction of West Java during Mid Eocene was interpreted from field observation and several publications (Martodjojo, 2003; Sribudiyani et al., 2003; Clements and Hall, 2007; Clements et al., 2009; Koesoemadinata, 2020). Large fluvial system brought terrestrial organic matter such as coal and quartz fragments from Sundaland via N-S trending basins and deposited as deltaic sediment of Pre-Bayah Formation and transported further to Ciletuh Formation in the deep marine settings.