On the Geomorphology and Tectonic Position of Ciletuh-Jampang Area, West Java, Indonesia

Iyan Haryanto, Adjat Sudradjat*

Faculty of Engineering Geology, Padjadjaran University, Bandung, Indonesia

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Abstract The Ciletuh-Jampang area is located in the western tip of the Southern Mountain of West Java, Indonesia. The area is presently well publicized in an effort to bring the unique geological characteristics exposed in this particular place to become the Global Geopark Network (GGN) of UNESCO. Ciletuh area exhibits a rare mega-amphitheater morphology. Stratigraphically West Java composed of clastic sediments of continental and volcanic island arc origin with the interruption of sub-aerial volcanic rocks and the coastal reefs banks developed along the coasts both in the north and the south. The age of the rock ranges between Eocene to Recent. The analysis of regional structure shows that a set of deep seated faults was recognized dominating the area in NNW-SSE and NNE-SSW directions. The released faulting occurred in E-W direction. The low angle shallow upthrustings facing north of skin structure in E-W direction dominate the upper part of the rock sequence. The structural analysis revealed the continuous prevailing stress field in SSW-NNE direction since Eocene time. The advancing landslides are readily observable in the rim of the amphitheater of Ciletuh. This phenomenon seems to demonstrate the initial stage (*primarumpf*) of the geomorphologic cycle taking into account the flat surface of Jampang area in the surroundings. Further investigations revealed the geomorphologic evidences of the formation of plateau, namely the erosion surface, old terraces, mountain tables, old beach ridges and the characteristics of drainage pattern. Two remnants of main plateau were recognized in Ciletuh-Jampang area, namely Bentang Plateau and Jampang Plateau. Further investigations show that at least five locations of plateau were identified in western part of Java Island, namely Dieng Plateau (+ 2,000 m), Pengalengan Plateau (+1,300 m), Bentang Plateau (+ 1,000 m), Jonggrangan Plateau (+ 850 m) and Jampang Plateau (+ 700 m). A rough estimation reveals the annual rate of lifting in Java Island since Pliocene time ranges most likely between 5.0 and 5.4cm.

Keywords Amphitheater, Initial Stage, Plateau,

Uplifting, Skin Tectonics

1. Introduction

Ciletuh-Jampang area is located in southern part of West Java. Geographically it extends from the longitudes of 106°20' to 107°00' East and the latitudes of 07°00' to 07°45' South (Figure 1). To the west the area is bounded by Banten Province, to the South by the open sea of Indian Ocean, whilst to the North and East it has common boundaries with Bogor and Cianjur Residencies respectively. The area is located about the same distances from Jakarta, the capital city and from Bandung the Province city, namely 125 kilometers away.

The investigated area is covered mainly by rubber and tea plantations. Recently the coconut palm replaces the old rubber plants. Due to the difficult access the area remains relatively virgin. The rare turtle of the Indian Ocean used to lay their eggs in the white sandy beaches in the investigated area. Fishermen live in the embayment of the coastal area. The arable land is limited to the valleys in the vicinity of the coast.

The off-road vehicle is the mode of transportation from Pelabuhan Ratu a local fisherman's harbor located about 25 kilometers NNE of the investigated area. The other access is by fishing boat directly from Pelabuhan Ratu. In the rough sea at the western monsoon however, the sea transportation might be inconvenient.

The terrain mostly consists of rugged topography, geologically known as Southern Mountains. At the crest of the mountain, a rather flat topography however exists. The Southern Mountain composes of Miocene volcanics with the interruptions of clastics sediments deposited in the shallow marine environment. An escarpment of Cimandiri fault bounds the topography from the relatively smooth Quaternary volcanic terrain in the North.

Ciletuh-Jampang area is intensively investigated to obtain the recognition as the candidate of the Global

Geopark Network (GGN) of Unesco. Although it is at a very initial state, many institutions including local government, supporting the proposal, taking into account the beautiful panorama available in the area. A mega-amphitheater, surrounded by waterfalls, presents an impressive view rarely found. Furthermore, from the geological point of view, the typical rocks of oceanic crust exposed in this area indicate the boundary between the continent and the ocean in the Eocene time or 50.1 ± 2.1 Ma ago (Schiller et al., 1991)[1]. The melange assemblages strongly support the evidence of the ancient subduction in this area. Hence the delineation of tectonic boundary between Eurasian continent and the Indian oceanic crust might be located. The rocks date back to Eocene time represents the basement of Java Island, where a pile of younger rock sequences of Upper Tertiary age laid on. The oldest rock in West Java area based on the borehole's sample indicated the age of 213 ± 11 Ma or

Triassic (Haryanto, 2014)[2].

Many authors among others Martodjojo et al. (1978) [3], Noeradi (1997) [4], Thayib et al. (1977)[5] published the papers about the geology and geomorphology of the investigated area. A tectono-stratigraphy study was carried out by Hakiki (2012) [6] to reveal the tectonic position of melange assemblages under the Tertiary volcano-clastic sediments. Earlier, Suparka (1996) [7] focused the investigation on the petrology and chemical composition of the volcanic rocks in Ciletuh and its vicinity as the key to uncover the tectonic evolution of West Java. Detailed petrographic descriptions of the rock exposed in Ciletuh area were presented by Abdurrahman & Rosana (2014) [8] in their recent publication. The results of those investigations pointed out the strong indication of the ancient subduction zone occurring in Ciletuh-Jampang area.

Figure 1. Index map of the investigated area (shown in quadrangle)

2. Methodology

The previous studies and the systematic geological maps of Ciletuh and Balekambang quadrangle with the scale of 1:100,000 prepared by Sukanto (1975)[9] has provided the ground truth information for the present authors in the interpretation of the geomorphology and tectonic position of Ciletuh-Jampang area. The RSTM satellite image outlines the synoptic view reflecting the clear picture of the geomorphologic and structural phenomena. The field work particularly carried out by the first author collected detail information on the geological evidences.

For the seek of regional analysis concerning the tectonic activities, the investigated area was extended as far as the entire zone of West Java. The evidence of plateau features was compiled from the localities in western part of Java Island, namely from West Progo in the east and Pelabuhan Ratu in the west. The extended investigation in the area further North of West Java gave a better understanding of the regional tectonics taking place in the period of Eocene to Recent.

The fracture patterns and micro-tectonic structural features are the main objects of data collection in the field. The strike and dip measurement was plotted in the rosette diagram and upper hemisphere projection. The result is presented in graphical method showing the general direction of regional structure in the sequence of time. The measurement on topographic map and satellite images provide the information on the position of the slope and altitude of the plateau. The available data based on deductive method determining the age of the rocks involved in the formation of the plateau resulted in the estimation of the uplifting rate of the plateau since

Pliocene time.

3. Results and Discussions

The lithology of Ciletuh-Jampang area consists of the oceanic crust and the assemblages of melange deposits. The K-Ar determination revealed the age of Eocene about 50.1 ± 2.1 Ma (Schiller et al., 1991)[1]. It is therefore concluded that the ancient subduction of Eocene age took place in this region. The rocks resemble that of Lok Ulo area in Kebumen, Central Java. Sukendar (1974)[10], speculated that melange of Lok Ulo strongly correlated with that of Meratus Mountain in South East Kalimantan. Hence the boundary of Ancient Eurasian continent extended from Ciletuh and Lok Ulo to Kalimantan. The open sea existed southeast of the boundary and the ancient continent located in the north. Hall, et al. (2007)[11] was in the same opinion. Haryanto (2014) [2] proposed the skin tectonics above the continental crust basement in western part of Java.

The stratigraphic sequence of the rocks in the investigated area started with the formation of melange of Eocene age frequently known as Ciletuh Formation (Table 1). It consists of clastic sediment with fragments of schist, quartz, mica and tourmaline. It is strongly folded and partly metamorphosed. The basement composes of schist and metamorphosed ultra-basaltic rocks. The age was determined by Schiller et al. (1991)[1] showing the age of 134.0 ± 3.0 or Cretaceous. The formation is followed by Bayah Formation consisting of quartz, sandstone, marl, clay, tuff and thin coal seams. It contains *Assilina pelatispira*, *Discocyclus* and *Camerina* indicating the age of Oligocene.

Table 1. Simplified stratigraphic column of the investigated area (compiled from various sources)

Age	Formation	Description	Fossils content
Upper Miocene	Bentang Formation	Sandstone, lignite, gravel, titano-magnetic sands	<i>Globigerina</i> , <i>Cycloclypeus sp.</i>
	Beser Formation	Volcano-clastics, conglomerate, clay	<i>Turritella annulata cramatensis</i> MARTIN
Middle Miocene	Cimandiri Formation	Reef limestone, sandstone, clay	<i>Miogyssina indonesiensis</i> TAN, <i>Cycloclypeus annulatus</i> MARTIN
Late Oligocene – Early Middle Miocene	Jampang Formation	Tuff, marl, sandstone, breccia, calcareous tuff, limestone	<i>Trillina howchini</i> , <i>Miogyssina thecidaeformis</i> RUTTEN, <i>Cycloclypeus annulatus</i> MARTIN
Oligocene (unconformity)	Bayah Formation	Quartz, sandstone, marl clay, tuff, thin coal seams	<i>Assilina pelatispira</i> , <i>Discocyclus</i> , <i>Camerina</i>
Eocene (unconformity)	Ciletuh Formation	Clastic sediments with fragments of schist, quartz, mica, tourmaline, partly metamorphosed (melange assemblage)	---
Mesozoic	Basement	Schist and metamorphosed ultrabasic rocks (oceanic crust)	---

Overlying this formation laid Jampang Formation consisting of tuff, marl, sandstone and breccia. Pumiceous tuff, calcareous tuff, volcanic breccia and limestone are also present. The rock contains *Trillina howchini*, *Miogyssina thecidaeformis* RUTTEN and *Cycloclypeus annulatus* MARTIN indicating the age of Late Oligocene to Early Middle Miocene. Cimandiri Formation overlay that sedimentary sequence. The sediments show the clear sea water environment with the presence of reef limestone containing *Miogyssina indonesiensis* TAN and *Cycloclypeus annulatus* MARTIN.

Those fossils indicate the age of Middle Miocene.

Finally, Beser Formation laid upon the sequence of Cimandiri Formation. The formation is characterized by fluvial deposits indicating the beginning of the uplifting. It consists of volcano-clastics, conglomerate and clay containing *Turritella angulata cramatensis* MARTIN of Upper Miocene. The formation is closely associated with the overlying Bentang series consisting of sandstone, lignite, gravel and titano-magnetic sand indicating the erosion commencing the peneplanation process. Marly tuff contains *Globigerina*. In the clay lenses *Cyclochypus sp.* were found indicating the age of Upper Miocene. The uplifting and peneplanation took place by the end of Miocene or the beginning of Pliocene until Present day.

The rocks of oceanic crust compose of basalts and peridotites in intimate relation with deep marine deposits. The pillow lava structure appears in some places at the beach cropping out due to the sea water abrasion. Red chert layers alternated with fine sandstone commonly expose. The strong tectonics of the area produced the steep dip of the layers. In some places the angle reaches almost vertical. Such structural position creates a beautiful alternation of hard red chert and white soft sandstone found in many places in Ciletuh area. Local people identify the rocks as the back of the sea dragon. The beautiful surface exposed by the rocks might be one of the unique geomorphologic phenomena in the area (Figure 2).

Figure 2. The alternation between soft white sand and hard red chert exhibits the unique morphology of the rock

The regional stratigraphy of West Java shows the rock composition dominated by clastic materials alternating between fine and coarse grain size. The volcanic materials are embedded in the clastic sediments. Marl and calcareous fine grain sandstone alternating with clays and mudstone commonly present. In general it shows the characteristics of flysch facies. Martodjojo (1984)[3] described the rock sequence in detail and found out that the rocks were deposited under the sea in fan-like environment. Dam (1994)[12] on the other hands concluded that the rock sequence might have been deposited in the elongated narrow basin south of the Eurasian continent. The materials initially came from the continental crust in the north at the Eocene age and with the existence of the volcanic arc in the south by the end of Eocene and Early Oligocene, the materials came from both sides. Volcanic activity took place at the volcanic arc and formed the presently known Southern Mountain. The rocks consist of andesite and in

some places intruded by dacite and basaltic rocks. The sub-aerial volcanic rocks were deposited in the island arc and supplied materials to the narrow basin in the north. In shallow sea off the ancient continental coast developed coral reefs. In the south, the reef grew earlier before the sea water condition contaminated by the volcanic materials produced by the island arc.

The present study on the measurements of the dip and strike in the sequence of time from Eocene to Pliocene reveals the succession of tectonic events in the area. The dip of the sediment seems to be very flat or almost zero in Bentang and Beser Formations which is in contrast with the situation in older sediments (Table 2). The average dip of Cimandiri Formation is 36.2° in Beser Formation is 9.8° and in the youngest Bentang Formation is 3.2° . It was interpreted that the intensity of tectonic activity diminished toward the end of Miocene. The erosion surface of Beser Formation suggests that the uplifting began and the

peneplaination commenced to took place.

Table 2. The significant dip discrepancies between Bentang Formation, Beser Formations and Cimandiri Formation

Bentang Formation (youngest)		Beser Formation (Younger)		Cimandiri (older)	
Strike	Dip	Strike	Dip	Strike	Dip
70	2	135	13	275	50
90	3	135	10	215	45
90	3	125	1	300	20
90	3	130	17	85	20
80	4	115	5	100	54
90	3	125	8	90	48
85	5	115	13	130	70
90	2	130	3	110	20
115	4	5	18	290	20
45	3	90	10	310	25

For the stratigraphic position refers to Table 1

From the measurements of the dip and strike of the sediments in the course of the age from Upper Eocene to Pliocene resulted in the consistent movement of the dip axis toward the center of the upper hemisphere projection (Figure 3). It might be interpreted that the uplifting continuously occurred leaving the younger formations of Bentang and Beser remained flat. During the deposition tectonic activity took place and continued from Oligocene to present times.

The strike of the sediments remain at the same azimuth which was interpreted that the tectonic pressure was consistent in the direction of N5-25E. The first phase produced a set of faulting in Early Miocene which at present appear as deep seated faults (Haryanto, 2005)[12]. The second phase of tectonic activity resulted in shallow folding and faulting. The deep seated faults dominated the NNW-SSE and NNE-SSW directions. The strikes are dispersed in Pliocene rock formation due to the horizontal nature of the layers. This tectonic activity characterized the uplifting in Ciletuh-Jampang area. On the other side of the crest, Java anticline showed totally different situation, where the younger formations tend to slide down forming the upthrusting. The structure involved the upper part of the sequence, therefor skin tectonics was introduced (Haryanto, 2014)[2].

Figure 3. The result of strike and dip measurements shown in rosette diagram and upper hemisphere projection

The North-South cross section across Java Island through Ciletuh shows the geomorphologic position of Ciletuh Jampang area at the south flank of the major anticline with the axis trending E-W (Figure 4). The area is relatively stable during the tectonic uplifting. Timely the activity ceased and provides sufficient time for the peneplain process to take place. Based on topographic and satellite image interpretation, the remnant of peneplains was readily identified. Field verification particularly based on the geomorphologic map prepared among others by Pannekoek (1946)[13] found out the remnant of the peneplains. The diminishing tectonic activities started from Upper Miocene. The uplifting took place in Pliocene age. The activity continues from Pliocene and Recent (Sulaksana, 2011)[14] and uplifted the peneplains in various altitudes, hence the plateau came into being.

Figure 4. Schematic N-S cross-section of Java Island

Those plateaus locate at various altitudes. Dieng plateau lies at the altitude of 2,000 meters, Pengalengan 1,300 meters, Bentang 1,000 meters. Jonggrangan 850 meters and Jampang 700 meters (Table 3). In Jampang Plateau at least five rows of old beach ridges containing iron sand were identified. Terraces are also found among others in the river banks of Cikaso demonstrating the recent uplift. Table mountains in Jampang Plateau represent the remnant of peneplain surface (Figure 5). Based on the age of the rocks involved in the uplifting of Pliocene age, it is interpreted that the annual rate of the lifting most likely between 5.0 to 5.4 centimeters.

Table 3. The location and altitudes of the plateau

Name	Altitude (m)	Location
Dieng	2,000	Central Java
Pengalengan	1,300	West Java
Bentang	1,000	Ciletuh-Jampang
Jonggrangan	850	Central Java
Jampang	700	Ciletuh-Jampang

Ciletuh-Jampang Plateau occupied the southern part of the investigated area. It thus locates in the southern flank of the anticline. Bentang plateau locates almost at the crest of the anticline. The intensive eroded valleys delineate both the plateaus. At the west edge of Jampang Plateau the initial stage (*primarumpf*) of the erosion takes place. It expresses the beginning of the new geomorphologic cycle after the formation of Jampang Plateau in Pliocene time. The erosion activity produced mega-amphitheater feature of Ciletuh area. The upstram erosion can be easily observed in the beds of the rivers draining into the amphitheater.

Water falls indicate the edge of the plateau. Here the rockfalls accumulated at the foot of the waterfalls might easily observed (Figure 6). The curvilinear scars indicating the initial stage of the mass movement, predominated the outer boundary of the amphitheater. The upstream erosion were also observed by Sukiyah (2009)[15] at the the edge of Pengalengan Plateau. The erosion is very intensive bringing a large amount of materials which causes flood and heavy siltation at the downstream of Citarum river. The phenomenon indicates the initial stage of the new cycle. The erosion might cause the negative impacts to the water instalation such as Saguling, Cirata and Jatiluhur dams located in Citarum river.

Figure 5. The Table Mountains of Ciletuh-Jampang and the old beach ridges

Figure 6. The intensive rock falls indicate the upstream erosion

4. Conclusions

In the investigated area the remnant of the plateaus are identified, namely Jampang and Bentang. Such a plateau also occurs in Pengalengan, Dieng and Jonggrangan at various levels of altitude. The phenomena indicate the interrupted uplifting of Java Island which provided opportunity for peneplanation.

The tectonic position of Ciletuh-Jampang area is at the southern flank of the E-W trending main anticline of West Java. Based on the position of the plateau the annual rate of uplifting was estimated between 5.0 and 5.4 cm since Pliocene time. The unique Ciletuh amphitheater reflects the initial phase of the geomorphologic cycle, hence the sliding and the circular extension of the rim might continue in the future.

Further investigation is needed to carefully examine the occurrence of the plateau in entire parts of Java. The information would significantly contribute to the understanding of the tectonic development of Java Island.

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REFERENCES

- [1] Schiller, D.M, Garrard, R A and Prasetyo, L, Eocene submarine fan sedimentation in Southwest Java, Indonesia, Petroleum Association Proceedings, 20th Annual Convention, p. 125-182, 1991
- [2] Haryanto, I, Tectonic evolution of Western part of Java Island, during Cenozoic, Dissertation, Padjadjaran University, repository, 2014
- [3] Martodjojo, Sujono, The evolution of Bogor Basin, West Java, Dissertation, ITB, repository, 1984
- [4] Nuradi, N, The evolution of Paleogene basin in Ciletuh area, southern part of West Java, Bulletin of Geology. V. 27, n. 1/3, ITB, 1997
- [5] Thayib, E S, Said, E L, Siswoyo and Priyomarsono, S, The status of melange complex in the Ciletuh area, South West Java, Indonesian Petroleum Association, Proceedings 6th Annual Convention, p. 242-254, 1977
- [6] Hakiki, G F, Tectonostratigraphy of Ciletuh and its vicinity, thesis, Padjadjaran University, repository, 2012
- [7] Suparka, M E, Petrology of chemical pattern characteristics of volcanic rocks in Citireum Formation: a key to refine the synthesis of the tectonic development in West Java, Research Institute, ITB, 1996
- [8] Abdurrahman, Oman and Rosana, Mega Fatimah, The tune of the earth: Ciletuh-Jampang, Geological Agency, 171 p., 2014.
- [9] Sukanto, R., Geologic map of Jampang and Balekambang Quadrangles, Java, scale 1:100,000, Geological Research and Development Center, 11 p., 1975.
- [10] Sukendar, Asikin, The geologic evolution of Central Java and adjacent areas with reference to the New Global Tectonic Theory, Dissertation, ITB, unpublished, 1974
- [11] Hall, R., Clements B, Smyth, H R, & Cottam, M A, A new interpretation of Java's structure, Proceeding, Indonesian Petroleum Association, 31rd Annual Convention, p. 125-181, 2007
- [12] Haryanto, I., The collided tectonic plates of Java Island: A review on the position of subduction in Java, Bulletin of Scientific Contribution, Geology, Padjadjaran University, 2005
- [13] Pannekoek, A.J., The geomorphologic reconnaissance of Jampang Plateau, West Java, TKNAG, 63,3, The Netherlands, p. 340-367, 1946
- [14] Sulaksana, Nana, Tectonic control of the morphometry on the Tertiary sediments and Quaternary volcanics of Sunda volcano in Subang and Purwakarta regencies, West Java, Dissertation, Padjadjaran University, repository, 243 p. 2011, 2011
- [15] Sukiyah, Emi, The erosion model of Quaternary volcanic terrain in Southern part of Bandung Basin, Dissertation, Padjadjaran University, repository, 2009