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# ANALYSIS OF LEMBANG FAULT CHARACTERISTICS BASED ON LITERATURES OF GEOLOGICAL STRUCTURE, ROCK FORMATION AND PEAK GROUND ACCELERATION PROBABILISTIC EARTHQUAKE ANALYSIS

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## ABSTRACT

*Earthquakes are a very frequent phenomenon, especially in the territory of Indonesia with a lot of compression pressure from the Eurasian and Indian Ocean tectonic plates. The influence of volcanism activity and the southern part of the Java subduction pathway triggers the formation of faults in Java, one of which is the Lembang fault. How is the geological history process structurally and the calculation of the maximum peak ground acceleration (PGA) to determine the characteristics of the Lembang fault? In this study, the focus is on a literature review with descriptive methods with the aim of collecting reference data information on studies to find out more about the characteristics of the Lembang fault. Based on the results of the literacy study that was collected and the interpretation of the structure that has been carried out, it can be stated that the characteristics of the Lembang fault are very complex through six sections. The majority are normal faults with strike-slip fault variations in several parts. The maximum peak ground acceleration probabilistic earthquake analysis on the Lembang fault depends on the distance and trajectory of the fault and the source of the earthquake and on the type of soft or hard rock formation. The areas that have the highest maximum ground movement acceleration are in the North and East Bandung areas.*
***Keywords:*** *earthquake, sesar Lembang, structure, peak ground acceleration*

## INTRODUCTION

The Lembang Fault is an active fault with an east-west direction along 22 km from Mount Manglayang to Cimahi, which is located approximately 10 km to the north of the city of Bandung by crossing the Lembang City District. From east to west, the height of the fault escarpment due to the magnitude of the fault shift (vertical or dislocation) has changed from about 450 meters at the east end (Maribaya, Gunung Pulusari) to around 40 meters in the west of the Cisarua area, and then its appearance is not visible at the west end. north of Padalarang (Brahmantyo, 2005)

Bandung is a very dense area both in terms of population and infrastructure. It makes a high risk of earthquakes. Even though the geographical position is relatively far from the source of the earthquake, which comes from the subduction route of the Indo-Australian plate with the Eurasian plate, the effect is quite low if the earthquake originates from that source. The existence of the Lembang Fault in the north of the city of Bandung causes the level of earthquake hazard due to fault activity to be considered.

Historical data on the seismicity of this fault activity is considered to be lacking, thus causing a lot of debate among experts. However, in research on the Lembang fault, there is an approach with morphometric analysis and sag pond sediment analysis, namely, to determine the activity of the Lembang fault. The parameters studied are the ratio of the width of the valley floor to the height of the valley (Vf) and the asymmetry of the drainage basin (AF). The micro-earthquake activity monitored by the Geological Survey Center in the Cihideung area in 1999 (Marjiyono et al., 2008) with a magnitude of 3.1 probably originated from the stress level that was still accumulating on the Lembang fault, and it was feared that there would be a potential for a very large earthquake. This fault is capable of producing an earthquake with a magnitude of 6-7 Mw with a repetition time of 170–670 years (Daryono et al., 2019: Handayani et al., 2009).

Based on the history of the formation of the Lembang fault (Bemmelen, 1949, and Tjia, 1968) stated that the movement of the Lembang fault was influenced by volcanism activity, namely Mount Sunda, this was confirmed by a statement in another study by Dam and Nossin stating that the movement produced was not entirely by normal fault movements (dip-slip), but there was also the appearance of a strike-slip (Tjia) shift movement. Reinforced by (Daryono et al., 2019), mentioning the Lembang Fault has a dominant sinistral movement through geomorphic analysis.

There is another approach in the seismic study of the Lembang fault, namely using the calculation of the maximum peak ground acceleration (PGA = Peak Ground Acceleration) based on the Boore equation (Douglas, 2001) by making an earthquake hazard map model based on the distance of a place from the source of the earthquake and the type of rock formation at Lembang fault area. The study is critical because literacy about earthquakes can reduce disaster risk through understanding and educating the community in the area. Several factors influence the physical vulnerability of an object to an earthquake disaster (Malik, 2010), such as (1) the condition of the rocks covering the deposits resulting from volcanic activity/pyroclastic deposits, namely the Tangkuban Parahu volcano of the Pleistocene age which has consolidated or weak physical properties. If an earthquake occurs, the impact will cause damage because it cannot be suppressed; (2) geological structure where there is a fault lineage pattern as seen in the Lembang fault study area; (3) the morphological form of hills with a gentle - steep slope as shown in Figure 1, where the instability of an area around Lembang against potential earthquake disasters such as the potential for soil movement, landslides, soil, and rock collapse; (4) the magnitude of the earthquake intensity in an area is due to its proximity to the earthquake epicenter in West Java.

It is important to conduct this research to determine the characteristics of the Lembang fault using several approaches in the province of West Java, as part of reviewing references and literature reviews that are mostly carried out by other researchers for the development of studies, especially earthquake disaster mitigation in West Java so that the understanding of literacy characteristics of the Lembang fault can be more informative and comprehensive.

## RESEARCH METHOD

This research was conducted using a descriptive method with a qualitative approach with the object of study being the Lembang fault to find out and collect data and information about the characteristics of the Lembang fault with various studies and approaches from various references, as a theoretical basis for further research and mitigation studies on the potential for earthquake disasters. Earth in West Java, especially the area around the Lembang fault.

## RESULTS AND DISCUSSION

Tectonism only slightly affected the symptoms of increased seismicity, possibly indicating the current lack of plane contact between plates. Variations in earthquakes between large plates along the Sunda arc can be interpreted in the form of models that relate variations in the relationship between plates with the age of the subducted lithosphere.

The characteristics of the Sunda arc, and analogies with the Pacific arc, imply that the entire length of Sumatra has the potential to produce large thrust earthquakes; otherwise, no similar earthquake events have been reported outside Java and the Lesser Sunda Islands. The plate interface near Java and the Lesser Sunda Islands is considered to have low seismic potential (Newcomb, 1987).

Based on the geological structure in Figure 1 which can be interpreted through a combination of the geological map of Lembang Bandung by Van Bemmelen in 1934 accompanied by an overlay of the SRTM digital elevation model (Ar Rahiem, 2021) showing the normal or descending fault structure with the South block as the footwall moving upwards while the North as the hanging wall moves downwards, this is also in accordance with what is shown (Hidayat, 2010) through research to correlate the stratigraphic cross-section of 13 hand drill data in the Panyairan Village area, Parongpong as the location for taking soil drill samples with a maximum depth of 5 m showing swamp deposits that quite thick (sag pond) with silty-clay physical characteristics which are relatively close to the Lembang fault escarpment and are limited by quite a lot of paleosol weathering repetitions with silt characteristics containing lots of wood fragments depending on the drying process of swamps and tuff at the bottom which are the product of erosion (epic sticks) with the appearance of igneous rock fragments and pumice.

The results of both morphometric and sag pond sedimentary analysis show that the Lembang fault is a normal active fault with downward movement and is in accordance with the interpretation of geological structures based on the 3D model.

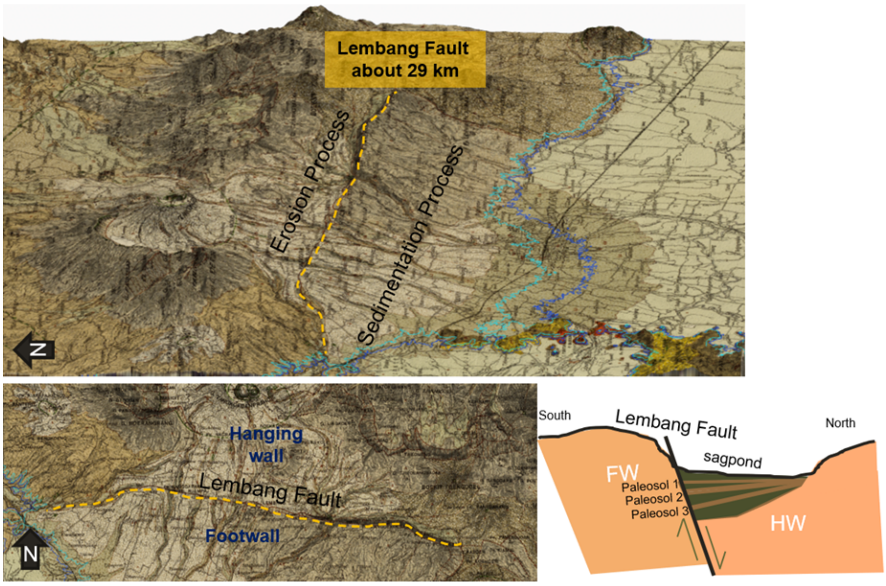


**Figure 1.** 3D Model Geological Map Sheet Bandung Van Bemmelen 1934 (modified by Ar Rahiem, 2021)

From (Afnimar, 2017) stated in his research that the Lembang fault has left-lateral kinematic characteristics influenced by the pressure vector's movement that develops from the Australian plate to the NNE. The 1-D velocity modelling shows the interpretation of the stratigraphic configuration model based on Vp and Vs and the poison ratio Vp/Vs around the fault, which consists of three layers: the upper layer is a quaternary volcanic layer, the middle and lower layers are tertiary sedimentary layers.

Another study used the P and S wave re-picking arrival time parameters through the

BMKG network (Supendi, 2018). The hypoellipse method and the hypocenter double-difference method can show the location of the hypocenter better in the seismic pattern in West Java. The earthquake cluster at a depth of 30 km is associated with the Cimandiri, Lembang and Baribis faults. The results show the source of the Lembang fault mechanism is a left-lateral strike-slip, which has similarities with research by (Daryono et al., 2019).

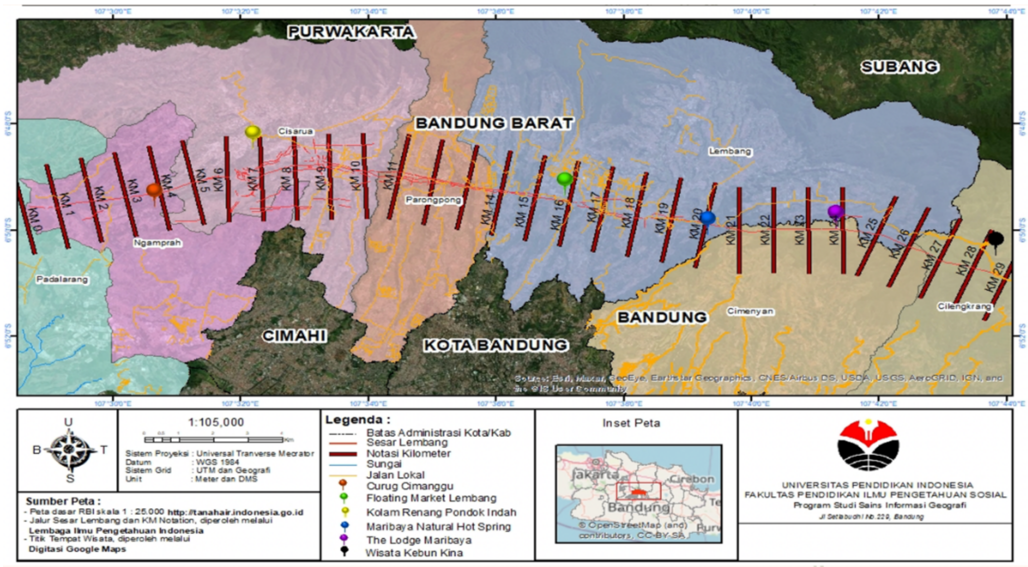


**Figure 2**. Lembang fault line details

The Lembang fault line shown in Figure 2 has a complex structure from the west end. There are six segments or sections, namely the Cimeta segment with strike-slip faults (kilometers 0 to kilometers 6), Cipogor normal faults (kilometers 5 to kilometers 11), Cihideung with faults oblique faults (kilometers 10 to kilometers 16.5), Mount Batu with normal faults (kilometers 16.5 to kilometers 21.5), Cikapundung with strike-slip or horizontal faults (kilometers 21.5 to kilometers 25), and Batu Lonceng with a strike-slip fault (kilometer 25 to kilometer 29), which is at the eastern end. Based on evidence from geomorphic analysis, it is stated that the Lembang fault has a dominant sinistral shift with a slip rate of 1.95–3.45 mm/year (Daryono et al., 2019). The Lembang Fault accommodates the parallel trench slip motion due to the Java subduction slope according to the conclusions of the analysis of the earthquake focus mechanism (McCaffrey, 1991) and geodetic data modeling (Koulali et al., 2017).


**Figure 3.** Peak Land Movement Acceleration Map of the Indonesian Territory (www.openquake.org)

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The PGA map shown in Figure 3 depicts the geographical distribution of Peak Ground Acceleration with a 10% probability of being exceeded within 50 years, calculated based on rock characteristics reference (Vs30 shear wave velocity between 760-800 m/s). This probabilistic seismic hazard map is a basic display through the modelling of the Global Earthquake Model version 2018.1 (PUSGEN, 2017) to calculate the risk of damage or loss that occurs in Indonesian territory over a certain period of time that can be caused by earthquake shocks both structurally and non-structurally. Based on the earthquake fault source data and parameters for West Java and its surroundings, it can be described that the Lembang fault is a segmentation of the Lembang area with a length of 29.5 km, with a sense of the mechanism of a horizontal fault type (Strike-slip), which has an average slip movement of 2.0 mm/year (GPS Slip-rate measurement result).

Based on the calculation of the maximum peak movement acceleration of the Bandung Basin with the case of the Lembang fault (Handayani et al., 2009) utilizing the speed of S waves (shear) for the top 30 meters of the soil layer with the assumption that the response is considered important on the type of soil through which seismic waves pass because of their effect on damage. That might happen. Velocity Vs30 categorization is done by classifying geological formation units, which are converted into seismic velocity values S. By interpreting the characteristics of geological formation units by comparing formation units in the research object area (Wills et al., 2000). By referring to the geological map of the Bandung Sheet (Silitonga, 1973), the characteristics of the S wave velocity can be interpreted as follows:

**Table 1**. Interpretation of S Wave Velocity Characteristics on Geological Formation (Modified from Wills et al, 2000)

| Symbol | Formation Geology | Category of rock in Vs30 | Estimated Velocity S (m/s) |
|---|---|---|---|
| Qvu | Volcanic rocks are irreversible | B | >760 |
| Qob | Breccia, lava product of G. Api Sunda | B | >760 |
| Qmt | Tufa and lava of Mount Malabar | BC | 555-1000 |
| Qmm | Tufa and breccia G, Thunder, Base and Kendang | BC | 555-1000 |
| Qyu | Volcanic rocks that cannot be decomposed M. Tangkuban parahu | BC | 555-1000 |
| Qyt | Tufa and pumice product of G. Tangkuban parahu | BC | 555-1000 |
| Qyd | Tuff of sand from G. Tangkuban parahu | BC | 555-1000 |
| PB | Tufa breccia, sandstone lava, conglomerate | CD | 270-555 |
| Ql | Lake sediment | D | 180-360 |

Referring to (Meilano, 2012) in the geological map of the Bandung basin, we can synchronize with table 1 and the PGA map formulated in the attenuation equation to get the PGA value not explained in the study, only interpreting the processing results in the form of a map of maximum peak ground acceleration (Handayani, 2009), due to the lack of seismic data at the research location, the approach used is a geological map of the surface and its relationship to S wave velocity. Based on the Wills approach, the geological

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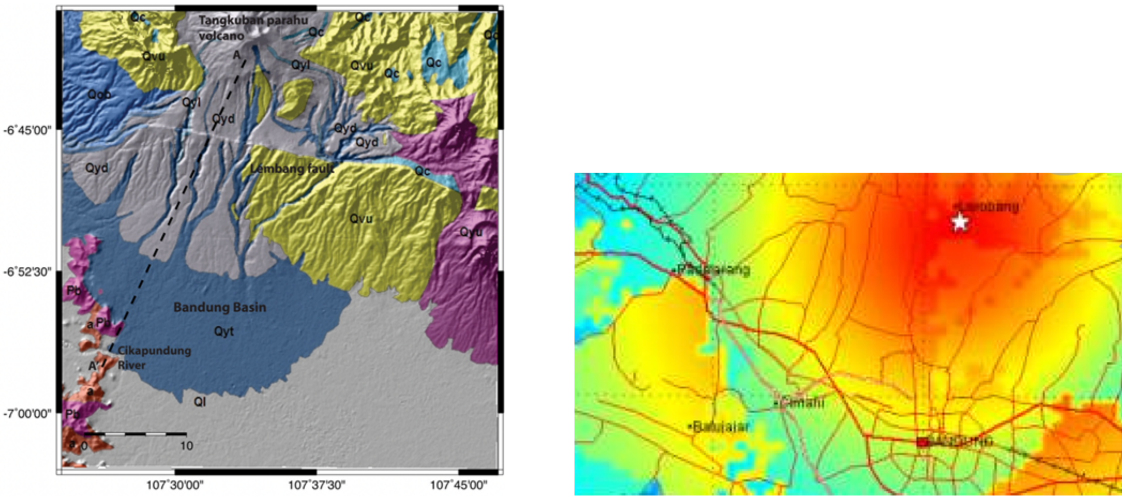
formations in the Bandung sheet are interpreted into three groups: hard rock (category B, Hardrock, metamorphic rock, and volcanic rock). Softrock (category C, softrock, sedimentary rock) and alluvial deposits (category D). Meanwhile, igneous rocks with relatively younger ages are categorized as BC, and sedimentary rocks of Miocene age are categorized as CD.



*(a)* *(b)*

**Figure 4** (a) Geological map of the Bandung basin (Meilano, 2017; Silitonga, 2003); (b) Map of maximum ground movement acceleration in Bandung and its surroundings with the epicentre of the earthquake at the Lembang fault (Handayani, 2009)

According to the interpretation of the PGA map explained from Figure 4(b) for a scale of 0.2 g, it is a criterion for high peak ground acceleration with an indication of a reddish-orange color with a value > 0.2 g in the north, namely Lembang, West Bandung Regency and Dago, on the north side. The east of Bandung city, which is around Cicadas-Ujungberung-Kiaracondong, has high criteria with a PGA value of 0.13–0.2 g, for moderate criteria, it is shown in the Padalarang-Batujajar area, while the criteria are low with a PGA value below 0.1–0.05 g in the area around the mountains surrounding the Bandung Basin of Quaternary age with volcanic lithology forming solid igneous rocks. The area outside the city of Bandung, namely Cimahi-Padalarang-Cicaheum, has fairly high criteria with a value of 0.1 because it is close to the earthquake source and is in a volcanic deposit zone.

## CONCLUSIONS

From various approaches and reference studies that examine the characteristics of the Lembang fault, it can be concluded that the Lembang fault is an active or normal type of fault with variations in strike slip (shear) in the Cimeta, Cikapundung, and Batulonceng segments. The maximum peak ground acceleration on the Lembang fault depends on the distance and trajectory of the fault and the source of the earthquake and on the type of soft or hard rock formation. The areas that have the highest maximum peak ground acceleration are in the North and East Bandung areas.

## RECOMMENDATIONS

This research is expected to be continued with the approach of earthquake hypocenter determination, relocation, and focal mechanism analysis, as well as the effect of volcanism on earthquakes in the Lembang fault, for further research in determining the micro zonation of earthquake-prone areas and earthquake susceptibility in West Java. Another urgent research topic with earthquake disaster mitigation from analysis of social activities characteristics in Lembang (Zakaria,

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2011) and earthquake simulation activities in areas and for local community and tourist as spatial educating the public to be aware of earthquake disasters.

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## DATA AVAILABILITY

Earthquake data visualisation were accessed from the OpenQuake Map Viewer catalog (https://maps.openquake.org/map/global-seismic-hazard-map/) and 3D visualisation geology map of Bandung we used to interpretation from the Ar Rahiem website catalog (http://www.malikarrahiem.com/petabemmelen/). All websites were last accessed in January, 2022.

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