Diatom and Geochemical Application Concept for Earthquake Disaster Assessment in Lembang, West Java, Indonesia

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Keywords: Diatom, Geochemical, Lembang Fault.

Abstract: The limitation of clear historical records of the past large earthquake from Lembang fault, West Java, Indonesia, is making the geological records playing the role as the primary information sources. However, weathering and bioturbation are very intensive in this tropical country, and high potentially destruct the geological tracks of the fault on the outcrop. Sedimentation records in the tectonic lake and the other tectonic basins could be the significant alternatives with better preservation. One of the best options for the study of paleoseismology and its effects on the aquatic environment is the sag pond formed by fault movement. This environment and resultant stratigraphy is directly influenced by the fault activity and associated with the weathered profile as the marker of environmental changes. The deformation could be affecting the accommodation space, water level fluctuation, and sedimentary flux, which influence the water chemistry. The diatoms as the sensitive bio-indicator could respond to water level fluctuation and sedimentary flux. This paper highlights and proposed the diatom and geochemical perspective to reveal the records of earthquake movement based on the environmental change of sag pond sedimentation feature.

1 INTRODUCTION

The unavailability of a clear historical record of Lembang fault activity causing the earthquake assessment depends on the scientific research results. However, they might be related to the records in the available disaster catalogue (Harris & Major, 2016) and scientific disaster database (Nguyen, et al., 2015). The information about Lembang fault activity has improved by Daryono et al (Daryono, et al., 2019) which using the high-resolution remote sensing database combine with conventional geological observation and paleoseismological trenching. Their research resulted from the precise location of Lembang fault, geometry, kinematics, slip rate and reoccurrence interval estimation.

The information of Lembang fault enriched with geodetic research improvement. The geology researchers have identified the existence of sag ponds in Lembang fault area (Daryono, et al., 2019), (Hidayat, et al., 2008), (Dam, MAC, 1994). Although the existence of sag pond is also categorized as one of the objects in paleoseismology study to provide the recognizable deformation caused by the earthquakes (in the form of deformed stratigraphic units, displaced landforms, or earthquake-induced sedimentation), there are still few types of research focused on sag pond sediment are found in Indonesia. The stratigraphy records could provide an option when the paleoseismological study also depends on the preservation of surface rupture, which could be limited due to progressive erosion in Indonesia as a tropical country (Daryono, 2016). This review highlights the chance of diatom and geochemical analysis applications to reveal the past great earthquakes from Lembang fault sag pond records.

2 RESULTS AND DISCUSSION

2.1 An Overview of Lembang Fault

Lembang fault is the active fault located in Lembang, 10 km northern part of Bandung, West Java (figure 3). The activity of the Lembang fault is undoubtful after the earthquake from this fault occurred. For example, several earthquakes have been reported in 2011, which triggered by this fault [(Sulaeman & Hidayati, 2011), (Sulaeman, 2011)]. This fault is associated with the Cimandiri fault (Irsyam, et al., 2017), although the other researcher has a different

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result (Madhya & Sanny, 2017). The origin of Lembang fault is volcano-tectonic origin with normal kinematics as the response of collapsing caldera after Sunda Vulcano large eruption [(Van Bemmelen, 1949),(Tjia, 1968), (Dam MAC, 1996), (Nossin, 1996)]. Tjia (Tjia, 1968) identified the change of kinematics movement from vertical to strike-slip, which was confirmed by a recent study [(Meilano, et al., 2012), (Afnimar, et al., 2015), (Daryono, et al., 2019)].

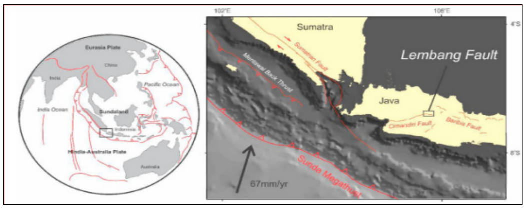

Figure 1: Location of of Lembang Fault (Daryono, et al., 2019).

Geodetic slip rate range from 2-13mm/yr (Abidin, et al., 2009) and 6 mm/yr (Meilano, et al., 2012), and geological slip rate estimation is 1.95- 3.45 mm/ yr (Daryono, et al., 2019). Daryono et al, has suggested this fault could be produced 6.5-7 mW earthquake with reoccurrence interval 170-670 year with comprehensive paleoseismology in Lembang fault. They also identified at least three great earthquakes in 15th Century, 2300-60BC, and around 18000 BC and mapped lithological in Lembang fault surrounding area.

2.2 Sag Pond and Earthquake History Assessment

Sag ponds are the low regime sedimentary environment, form when divergent movement associated with transtensional or extensional faulting creates a topographic depression (example model and sag pond in figure 1, and local hydrologic conditions maintain water levels in the depression (Simpson, et al., 2014). The existence of sag ponds is also categorized as one of the objects in paleoseismology study to provide the recognizable deformation caused by the earthquakes (in the form of deformed stratigraphic units, displaced landforms, or earthquake-induced sedimentation) (Dam, MAC, 1994). The most improved study of sag pond sediment is Lembang fault sag pond. It could be related to the availability of High-resolution geomorphological identification, which is very powerful to determine the existence of sag ponds even the land use has been changed. This review highlights the chance of diatom and geochemical analysis applications to reveal the past great earthquakes from Lembang fault sag pond records. The form should be completed and signed by one author on behalf of all the other authors.

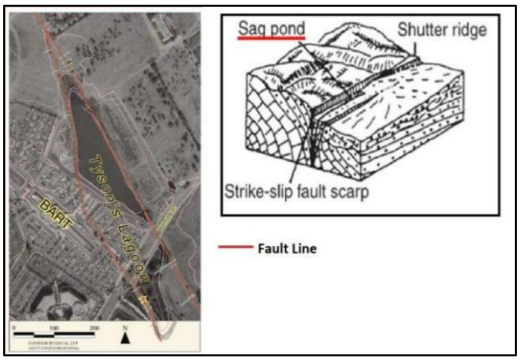

Figure 2: (Left) Tyson's Lagoon, the example of one sag pond in the San Andreas fault zone, the fault line maks with a red line (from Lienkaemper et al (Lienkaemper, 2002). The cartoon model (right) shows sag pond development in strike-slip fault zone (Dam, MAC, 1994).

The sag pond is suitable for preserving paleoearthquake evidence because they are relatively low-energy environments where sediments accumulate episodically in thin strata, separated by weathering profiles, organic soils, or peats. Sagpond is one of the "Recurrence sites" which has the best condition to preserve datable material for earthquake events (Dam, MAC, 1994). Well stratified and thinly bedded sediment of sag pond also noted as the suitable object for high-resolution seismic reflection (Zilberman, et al., 2005).

The example of the sag pond stratigraphy records for earthquake events has been conducted by Hubbert-Ferrari et al (Hubbert-Ferrari, 2012), with a combination of sedimentology, isotope and geochemical approach in Aşağıtepecik Lake, which identified as a sag pond. They identify four sediment records. Three confirm historical earthquakes related to the North Anatolian Fault (NAF) and one as a local earthquake (figure 3).

The map (upper right) of in Aşağıtepecik Lake and its stratigraphy (left). The stratigraphy marker unit 1 representing three historical earthquakes in 1939 (unit 1-SEQ-1), 1668 (unit 1-SEQ-2) and 1254 (unit 1-SEQ-4) related to the North Anatolian Fault (NAF). Unit 1 in SEQ-3 is interpreted as the local earthquake.

The sag pond stratigraphy was also studied for Late Cretaceous normal fault in Utah to understand local seismicity and surface rupture in the study area

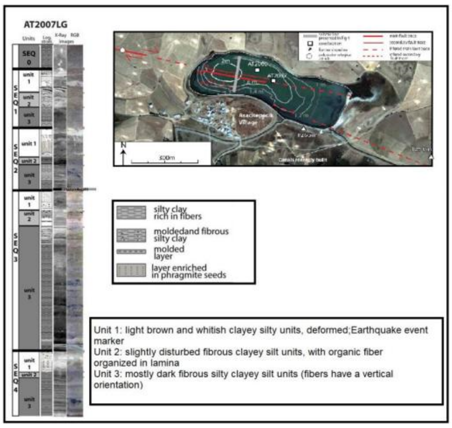

Figure 3. Composite picture from Hubbert-Ferrari et al (Hubbert-Ferrari, 2012).

2.3 Previous Lembang Sagpond Stratigraphy Research

The study of Lembang sag pond is significantly correlated with the high-resolution LIDAR and IFSAR imaging. Based on the analysis, several sag basins have been identified in Lembang Fault Segment. The sag pond is located in the basin area, which consisted of lake sediment (figure 4).

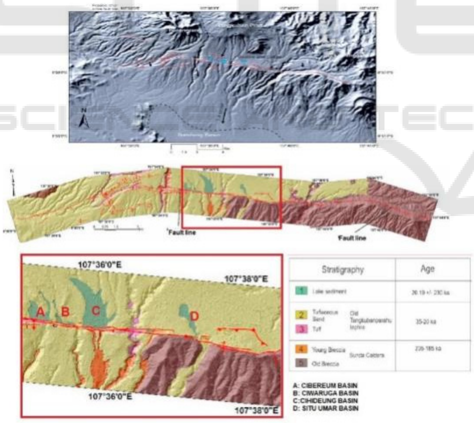

Figure 4: Map of Lembang fault location and geological formation along lembang fault area (upper).

The sag pond took place in the basin area which consists of lake sediment (lowest). The geological map is based on Daryono et al.(2019). Hidayat et al, (2008) made some hand-bore drilling activity in Cihideung and Cibereum sag ponds. They identified the paleosoil layer and sag pond sediment intercalation as the records of deepening and shallowing processes related to the fault movement (figure 5).

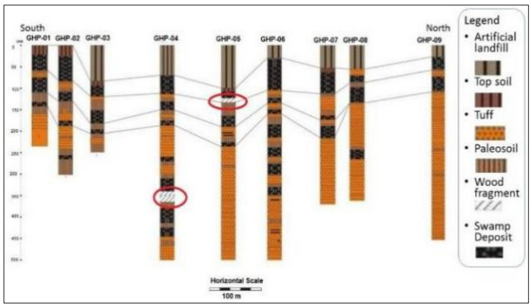

Figure 5: Stratigraphy of Cihideung (Hidayat, et al., 2008) shows the intercalation of paleosoil layer, tuf and swamp deposit, which could represent the shallowing and deepening process in sag pond.

An unpublished master thesis from Sundari (Sundari, 2009) revealed at least nine pollen succession and assuming seven of them indicating the earthquake event. She used a palynological succession of the high plant, aquatic, herbs and grass taxa to detect vegetation changes related to the Lembang slip event (Figure. 5).

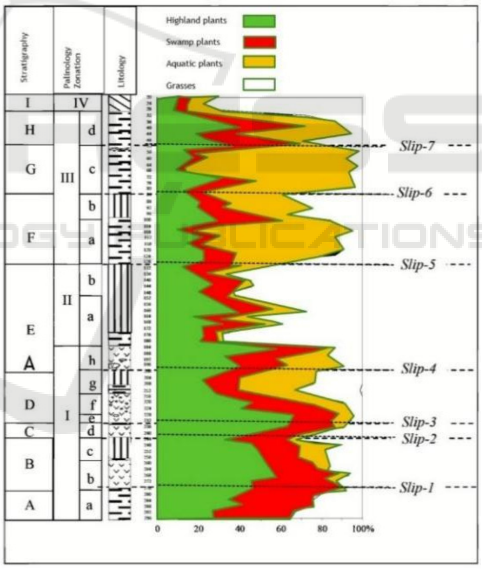

Figure 5. Modified graph from Sundari (Sundari, 2009), which only show four from five pollen type. The seven slip events were identified as the significant change of vegetation surrounding the sag pond area.

The large wood fragment depth in sag pond stratigraphy (Hidayat, et al., 2008) could be the stratigraphic marker representing some destructive event in the past (red mark in figure 5). The palynological signal study also represents the environmental changes that are reflected by the vegetational change in Cihideung Basin (Sundari, 2009). However, the slip event might be separated in more detail based on the whole sedimentary features, which reflect the coseismic slip event (large earthquake) or some smaller slip event in the interseismic phase. Although this result could be a beneficial clue, this result should be compared by other methods which could improve the accuracy and resolution. Suitable dating methods should complete another thing because the seven reported slip events could also include three major earthquakes by Daryono et al.

2.4 Chance for Diatom and Geochemical Approach

This paper offered the diatom and geochemical perspectives comparable to environmental changes study of sag pond area related to fault movement. The diatom is one of the powerful bioindicators for environmental change, especially in the aquatic environment. They are slightly sensitive to water level changes, which correlate with another change of geochemical and physical parameters (Smol J P. 2008). In low water levels, the ratio of benthic taxa is dominated by planktonic taxa. When the water level is higher, the planktonic taxa could be increased(Smol J P & Chuming B F, 2000). Some correlation between eutrophication and diatom taxa to infer the water level is also reported by Heinsalu et al (Heinsalu, et al. 2008) in Estonian Lake. They saw eutrophic taxa has a negative correlation to planktonic taxa presentation. It is related to the higher nutrient concentration in low water levels (Moss B, et al., 2009). The change of pH is considered as the function of water level change and controlling the diatom colony. The acidophilic taxa could be increased in the low-level water phase (Bunting M j, 1997) and decreased with higher water level conditions, accompanied with more alkalophylous taxa colony (Krabbenhoft & Webster, 1995). The challenge of the diatom approach is the limitation of datasets of tropical diatom. Diatom is very applicable for peatland environments [(Kienel, et all., 1999), (Brigham & Swain, 2000)].

Another perspective is geochemical analysis. The distinctive δ13C values of organic carbon and C/N ratios of algal and land-plant tissues can be used together to assess the sources of organic matter in the lake sediments (Meyers, 2003). Generally, terrestrial plants can be divided into C3, C4, and CAM types according to their photosynthesis characteristics and carbon atomicity. C3 plants have a δ13C value from -40‰ to -20‰, while C4 plants have a δ13C value varying between -19‰ and -9‰, with an average range value of -27‰ and -12‰, respectively [(Smith & Epstein, 1971), (Oleary, 1981)]. On the other hand, lacustrine algae have an average δ13C value of -28‰ (Farquhar, et al., 1989). Based on C/N Ratio, endogenous lower organisms like aquatic algae, phytoplankton, and zooplankton have low C/N ratios ranging between 4 and 10 submerged. FLoating aquatic macrophytes or mixed sources of organic matter have C/N ratios between 10 and 20, whereas organic matter derived from exogenous terrestrial plants have C/N ratios greater than 20 [(Meyers, 2003), (Pu Y, et al., 2013)]. The combination could confirm the vegetational change in sag ponds with higher resolution (Wang G, 2019). The results should be bonded with suitable dating methods to result in chronological interpretation. AMS radiocarbon dating and luminescence dating are suitable for the sag pond sediment (Dam, MAC, 1994). The high organic material is suitable for radiocarbon dating, including the large tree fragment in the strata. Luminescence dating is applicable for fine grain size material and volcanic material.

2.5 Challenges of the Offered Perspective Application

The paleolimnology application for earthquake assessment study in Sapanca Lake, Turkey (Shcwab, et al., 2009), including the diatom parameter as bioindicator to find the chemical flux of hydrothermal fluids seepage from the fault and nutrients from sediment. However, the diatom does not provide the species succession, although they also indicate rapid depositional processes in the strata and show the nutrient change in the lake water. This study shows that the diatom signal could have limitation and should have considered the other paleolimnology parameters. The other challenge faced for diatom application is relevant datasets of diatom taxa and the present condition of Lembang fault sag ponds almost unpreserved from their original form. However, the diatom analysis at a closer region could be constructive. Rawa Danau, West Java, represents the bog condition in Western Java which also changes and represents water level change.

The palynology from Van der Kaars (Van der Kaars, et al., 2001) in Rawa Danau could provide a reference study for diatom and palynology in the bog environment. Rawa Danau study, which used Lignin Phenol Vegetation Index and Bulk organic carbon analysis (Tareq, et al., 2004) to determine the significant vegetation change (LPVI) in the mid-Holocene, could be a reference for geochemical analysis. However, Situ Lembang is not like a bog or swamp that connects with peat deposits and explains the diatom explicitly. The water level change at this shallow lake is represent by the benthic diatom domination ratio from all phytoplankton colonies (Sulastri, 2011).

3 CONCLUSION

The diatom and geochemical analysis is the promising alternative method for enhancing previous researches about the environmental changes of Lembang fault Sagpond. However, the best approach for diatom analysis should improve by the transfer function in the existing sag pond for the best result. The concept of the water level and diatom community analogue based on the lake study might be wide open to applying a similar approach to the tectonic lake scale. The concept is not only applicable to the preserved lake or swamp but also the paleolake.

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