Yogya earthquake and the dynamics of java trench

by Sutarto Sutarto

Yogya Earthquake and the Dynamics of Java Trench

Carolus Prasetyadi, Sutanto, EkoTeguh P., Sutarto, and Arif Riyanto

Department of Geology, Universitas Pembangunan Nasional "Veteran" Yogyakarta
Email : cprasetyadi@yahoo.com and cprasetyadi@gc.itb.ac.id

Abstract

It has been three months since a tectonic earthquake struck Yogyakarta and its surrounding areas measuring 6.3 on the Richter scale. A question remains, however, on how such devastating earthquake could strike Yogyakarta? Is there any link with the active Merapi volcano? The BPPT (*Badan Pengkajian dan Penerapan Teknologi*/The Agency for Research and Techonolgy Application) team has conducted an initial research to address those questions and concluded that the earthquake in Yogya was a result of the release of build-up strain of Opak fault which was the consequence of the pressure from both the Mt. Merapi from the northern side and the subduction zone of India-Australian plate in Java trench. The conclusion assumes that Mt. Merapi activities have contributed to the earthquake, but the writer of this paper thinks differently. The presently high activity of Merapi and the earthquake have been the result of the Java trench dynamics which led to the movement of India-Australia plate beneath the Java Island, which is part of the Eurasian plate.

Seismic activty resulting from subducting plate is normally of a deep nature of >30km. The one that struck Yoyakarta, on the other hand, occurred at a shallow depth of 10 km, which was indicated by the high level of destruction it caused and the emergence of fault or reactivation of ancient fault it has triggered. Unlike Yogyakarta, which does not comprise of any active fault lines, the active Cimandiri and Lembang fault lines in West Java have made the region naturally more prone to earthquake. Questions remain on the factors contrubuting to the occurence of earthquakes at shallow depth in Yogya instead of in areas with active fault lines. This paper aims at describing the condition and the dynamics of the Java trench that has been considered to originate the earthquake in Yogyakarta. Emphasis will be on the trench of Java, which lies to the north of Central Java and East Java in close proximity with Yogyakarta region, including details on physiography and seismic distribution. Comparison will be made to the Kobe Earthquake 1995 becaues of its similarity with the earthquake occurence in Yogya. It is expected that this piece of writing will shed some basic light on the principles related to the earthquake in Yogyakarta.

THE PHYSIOGRAPHY OF JAVA TRENCH AND SEAMOUNT PHENOMENON

Java Island is part of an arch of islands widely known as the Sunda arc that lies on the edge of Southeast Asia and stretches from Andaman-Nicobar islands in the west to Banda arc (Timor) in the east. Sunda arc is formed by the northward subduction movement of the India-Australian plates beneath the Euarasian plate at the rate of 7cm/year. **(Picture-1 A).** The subduction occurs south of the Sunda arc, forming a trench known as the Java trench. The subduction of the plates also form a volcanic and a non-volcanic arc. The volcanic arc comprises of the chains of volcanoes that make up the main structure of the Sunda arc islands, while non-volcanic arc consists of the chains of islands extending at the oecanic side of the volcanic arc. The islands of Siberut, Simeleu, and Nias at the western part of Sumatra are part of the non-volcanic arc that emerges to the sea surface, while at the southern part of Java, the arc submerges under water. The non-volcanic chain s formed by materials originating from the inland, shallow ocean, deep ocean and part of oceanic plate where compresed and mixing when oceanic plate subductet to trench. This mixed rock in this trench is called melange, forming accretion prism at the inner part of the trench.

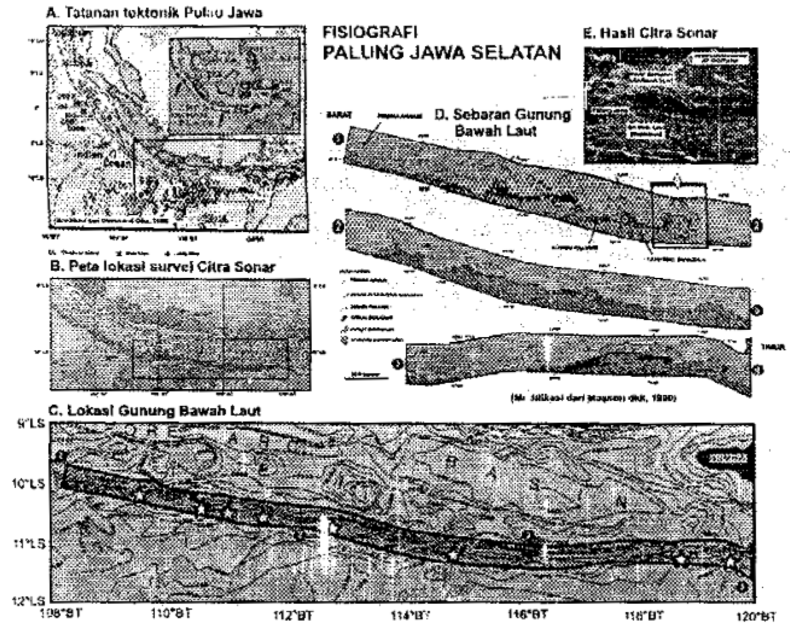

Fig. 1. The Physiography of Java Trench and the distribution of Seamounts

The Java trench, which extends 5600 km long from the Andaman-Nicobar islands in the west to Sumba in the east, has various features as a result of the different direction and velocity of subduction. Minster and Jordan (1978, in Ghose and Oik,e 1988) estimated that the rates of subduction at the northern tip of Sumatra and near Sumba island are respectively 6cm/year and 7.8 cm/year. The nearly perpendicular motion of the subduction to the east of Java has resulted simpler variety of plate subduction. It strikes differently than the one in Sumatra., which forms the horizontal Semangko fault resulting from oblique motion and even nearly parallel motion of subduction in Andaman islands. To the northen tip of Java trench in part of Sumba and Timor, a more complicated system of tectonic has developed, where collission between Banda arch and the northwestern part of the Australian continent occurs. Dimension of accretion prism and the depth of the trench also varies from the west to the east along with the decrease of the thickness of sediments at the subducton zones.

The Sunda Strait, which separates Sumatra and Java, becomes a significant geodynamic boundary where striking dip angles occur between the eastern and the western part (Zen, 1983). To the west of Sunda Strait, seismic activities normally occur at a depth not excedding 200 km, while at the eastern part, they occur at increasing depth of up to 350-500 km. Other geodynamic feature that influence the dynamics of the trench is the morphology of the surface of the oceanic plateau. The sea floor can be relatively smooth or coarse as a result of humpy part of seamounts, mid oceanic ridges, and basaltic plateau. As a result, subduction of oceanic plate has undoubtedly dipped seamount and other submerged morphological features into the trench. The southern part of Java trench is characterised among others by a number of seamounts. This striking phenomenon has been researched into by the *"Java Trench" Indonesia-Japan Deep Sea Expedition team* in 2002 (Kompas, 13 October 2002) and mapped by Mason *et al* (1990) using

GLORIA long-range sidescan sonar swath to cover an area of 45x1300km at longitude 108° – 120° E **(Figure-1 B-E)**. Its main morphological feature at the sea floor is the *Roo Rise*, a gigantic submerging plateu which rises 2000m from the ocean floor. The front end of Roo Rise lies in the Java trench area at 112° – 115° N, marked by the shallow depth of the trench in the area **(Figure-1 B)**. Apart from Roo Rise, other gigantic seamounts have also been identificed with a diameter of more than 10km and in different stages of subduction from medium subduction to full subduction into the trench**(Figure-1 D, and E)**. The depth of the trench ranges between <5600 km and > 7000 km with the deepest point lies in the north at 111° E and between 115° -119° E.

Figure-1 D shows the result of the map on the trench route. Ten seamounts have been identified with dimensions ranging from <10 km to 60 km. One of the seamounts **(Figure-1 E)** rises 1500 m from the ocean bed with flat summit and slopes of approximately 10°. This seamount is within a progressing stage of subduction with accretio prism. The dip forms a collision scar with steepy slope facing the seamount side. Penekukan lempeng samudera ke dalam palung has created dipping faults normal fault of 5-20 km at the ocean bed bordering with the trench. The formation of collision scar indicates evidence of displacement of accreticn prism material to more intensive thrusting formation in the direction of the inland. At the same time, the sudducted plate has caused seamount rupture at similar scale with the surround ocean bed. A 3-dimension section shows the presence of seamounts in the southern part of Java trench. **(Figure-2 A).**

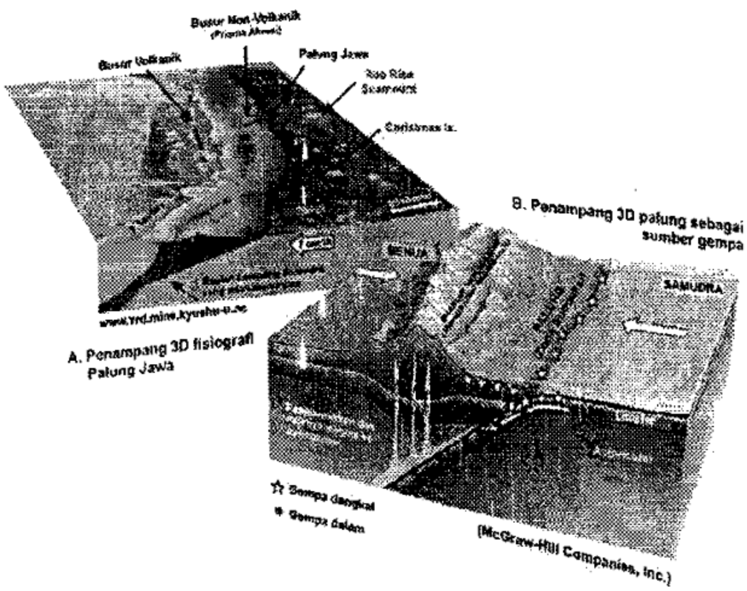

Fig. 2. A 3-dimension section shows the presence of seamounts in the southern part of Java trench and the distribution of spatial and temporal seismic activity on the dynamic trench.

THE DYNAMICS OF JAVA TRENCH

Trench is locatin where oceanic plate subducted. During the subduction, oceanic plate to collision to other upper plate. The pressure results in seismic activity or tectonic earthwuake originating at the surface of the subducted plate. The depth of the earthquake source depends on its horizontal distance to the trench axis; more distance away from the trench towards the inland will create deep earthquake, while shallow earthquake is characterised by shorter distance to the trench. **(Figure-2 B).** Therefore, distribution of spatial and temporal seismic activity of a region depends on the dynamics of its trench.

Using two basis of data, namely the NOAA hypocenter data file (from January 1900 to May 1981) and ISC data file (from January 1971 to December 1983), Ghose and Oike (1988) evaluated the distribution of spatial and temporal seismic activiy along the Sunda arc. Based on the seismic distribution map **(Figure-3A)**, we can identify locations with high occurence of earthquake (shown by the high density of earthquake points). These points are distributed in the northern tip of Sumatra, north of Simeuleu island, southeast of Nias, southern tip of Siberut island, south of West Java, south of Java between 107°-110° E, and in southwest of Sumba. Interestingly, trench-originated shallow seismicity found in Sumatra does not cause high occurence of earthquake in the inland, while overall island of Java are exposed to high occurences of shallow earthquake. Two likely causes are: firstly, the origin of shallow earthquake in Sumatra is associated with lateral fault in Sumatra; on the other hand, lack of main fault system in Java has caused the occurence of shallow earthquake to be associated with plate subduction activity in the trench that it allows transmission to the overall island. Secondly, there is greater distance of the trench to the indland in Sumatra in comparison to that in Java. Meanwhile, volcanic lines (which is normally linked with the depth of subduction zones of around 100km) in Java lie in the centre of the island, while in Sumatra they extend at the western side near the Indian Ocean. This explains shallower seismic activity in the continent of Java rather than in Sumatra.

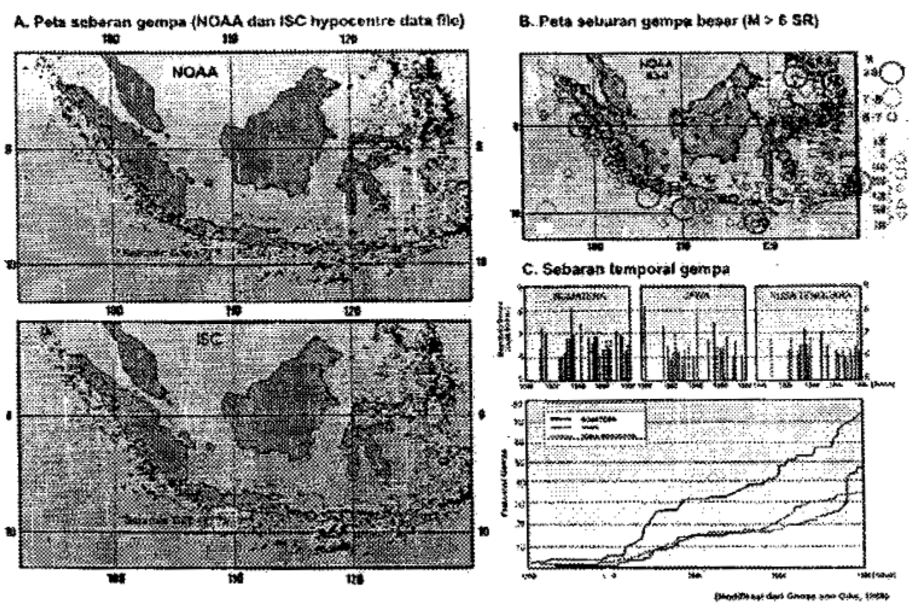

Fig. 3. The distribution of spatial and temporal seismic activiy along the Sunda arc

Other remarkable feature from **Figure-3A** is the silent zone or seismic gap in the south of Java at around 110° E. This seismic silent zone stretches 75km wide north-south of Java trench. Seismic activity of small intensity might also occur in the silent zone, but absence of earthquake of >4 magnitude (even at the trench axis region) is a phenomenon worth exploring.

Figure-3B is a plot of earthquake events of >6 magnitude based on NOAA Data File. The map shows a number of earthquake occurences in Sumatra trench, which in general show much greater magnitude as opposed to those in Java. It shows that the compression among plates is considerably higher in Sumatra. However, two eartuquakes of huge magnitude >8 that also occured in the south of Java indicated a high compressive zone in the region. In order to identify whether plate subduction in Sumatra, Java and Nusa Tenggara is dominated by local or regional tectonic factors, Ghose and Oike (1988) evaluated the temproral variety of seismicity in the three regions. **Figure-3 C** shows the temporal distribution of earthquakes of >6 magnitude within a span of 100 years (from 1990 to May 1981). The figure shows that the link between the frequency of earthquake occurences of >6 magnitude (N) with time in overall shows similar trend in the three tectonic zones of Sumatra, Java and Nusa Tenggara. Between 1935-1940, there was high frequeny of earthquake occurences. In the span of 20 years between 1940 and 1960, earthquake of high magnitude occured in low frequency. From 1960 to May 1981, however, the activity was on the rise again. The similarity of seismic temporal pattern gives evidence that there is similar variation of tectonic stressing (compressive strength resulting from Indian-Australian plate subduction beneath Southeast Asia) by time in the three segments of Sunda arc and controll an overal long-term temporal pattern. Within this longer span of time, subduction dynamics have affected differently at the local level, depending on the interaction between plates in each segment. For instance, as shown in **Figure-3D,** within the same period of time from 1900-1981, there were greater number or frequency of earthquakes in Sumatra in comparison to that in Java or Nusa Tenggara. It can be concluded that despite its varied geodynamic conditions in spatial manner, the overall frequency of seismic activity in Sunda arch does not depend on its spatial feature (or location).

CAUTION TOWARDS SEISMIC GAP IN SOUTHERN OF JAVA

The description on the dynamic of Java Trench and seismic distribution above has generated a number of issues for caution in relation to the nature of seismic activity or earthquake originating from southern Java trench. In principle, tectonic earthquake occurs as a result of release of strains build-up at the earth crust caused by the interaction of litospheric plates (continental and oceanic plates). The higher the built-up strains, the greater magnitude of the possible occurence of earthquake.

The physiographic features of southern Java trenc allows high level accumulation of strains as a result of uneven oceanic plateau characterised by a number of seamounts (with diametre of 10-60 km) subducting in the trench, as well as the presence of Roo Rise as the hugest seamount in the south. The classification of Cloos (1993) on the presence of lithospheric in the subduction zones mentions that potentially generates orogenic collision and disturb subduction process mentions that a seamount as big as Hawaii (height >8km) would be the ideal size to stop the speed of subduction, but a seamount of >1-2 km like Roo Rise can also cause permanent disturbance to subduction process and contribute to high accumulaton of strain in the trench.

Sumatra experience higher frequency of earthquake occurences in comparison to Java. Seismic activity in Java is relatively lower that Ghose and Oike (1988) identify the presence of silent zone or seismic gap aroun 110° E around southern Java trench in close proximity with Roo Rise. Low activity in areas with seismic gap should receive attention because there is much greater likelihood that building-up of strain is occuring in the trench axis due to the slowing down of oceanic plate by the under water morphology like the seamount. Once this strain is released, the resulting earthquake will be of high magnitude and shallow depth (close to the trench depth).

Question remains on whether the earthquake occurence in Yogya is linked with this seismic gap phenomenon. More accurate answer would need an in-depth and thorough research on earthquake characteristics in Yogya. This description aims at providing initial information on the possibility of seismic gap symptom in southern Java to enable changes of practice in anticipating the nature of seismic activity in Java in general and Yogya in particular. The recent Yogya earthquake has teached us a invaluable lesson that will be of no avail if we are unwilling to pay attention to the following:

- Merapi volcano activity and Yogya earthquake are related with the dynamics of plate interaction in Java trench.
- The earthquake in Yogya has devastating effect as a result of soil condition that consists of fragile volcanic deposit as well as its high magnitude (6.3 at Richter Scale) and its depth (at 10km.)
- The presence of seamount that interacts with Java trench needs more thorough attention as it might increase build-up of strain in the trench.
- Low seismic activity in Java in comparison to the one in Sumatra indicates possibility of silent zone or seismic gap around 110° E around southern Java trench, in close proximity with Roo Rise, the biggest seamount in Java southern sea.
- While current priority is on rehabilitation of the areas affected by the earthquake, it is necessary to carry out intensive socialisation to the general public on the origins of earthquake occurance and volcanic activity in order to raise the awareness that we are living in areas prone to tectonic earthquake disaster and volcanic hazard.

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