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# Active volcanoes guided Tsunamigenic earthquakes from Andaman – Indonesia regions – A tectonic model

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## ABSTRACT

The Indian Ocean Tsunami of Northern Sumatra Great Earthquake disastrous event (Mw 9.3) on 26th December 2004, had initiated release of trains of aftershocks in different directions. The above events resulted in explosions of series of Volcanoes of Andaman and Indonesian Island Arc Belt. After the tsunamigenic Northern Sumatra Great Earthquake of 2004, consecutive many tsunamigenerations were formed from the following regions viz West coast of Northern Sumatra (M 8.7) at quadruplicate junction of Australia, India, Burma and Sunda plates on 28th March 2005; South of Jakarta, Indonesia between Australian plate and Sunda Plate on 17th July 2006; and South Sumatra M 8.5 on 12th September 2007. Similarly, the great Indian Ocean tsunami event of 2004 and its aftershocks have also resulted in an additional pressure at specific locations in Andaman-Indonesian Island Arc system and finally a series of volcanoes were erupted as follows viz Barren Volcano of Andaman on May 2005; Talang volcano of Northwestern Sumatra on 12th April 2005; Merapi volcano of Jawa on 14th April 2006 and volcanoes at West Java adjoining to Merapi volcano. On considering the near past seismic and volcanic active scenario of Andaman and Indonesia Arc region it look more possible for earthquake triggered volcanoes and eruptive volcanoes controlled tsunamigenic earthquakes. Based on the sites of Tsunamigenic earthquakes, locations of activated volcanoes, movement directions of harmonic seismic aftershocks of each tsunamigenic earthquakes, Migrations of Magma and decompression melting due to harmonic seismic tremors resulted in a tsunamigenic earthquakes are highlighted in the tectonic model.

**Keywords:** Tsunamigenic earthquakes, Northern Sumatra, tectonic model, Australian plate, Andaman and Indonesia Arc

## 1. Introduction

Understanding the earthquake process and historical occurrences of earthquake from individual tectonic setting are fundamental to forecast and prediction of earthquakes. The Barren – Narcondam volcanic islands together with the Burmese arc to its north and the Sunda arc to its south forms an important tectonic link between the Himalayan collision zone to the north and the major island arc trench systems of South Asia (Chhibber 1934). The Indian plate up west of this arc, subducts below the Burmese plate to a depth of almost 200-230 km. It is well known that Tsunamigenic events are happened due to submarine earthquakes (M>7), Violent Volcanic explosion at sea and coast, Marine landslides, large body meteoritic impacts on seas and manmade atom bomb testing under sea water.

## 2. Rare phenomenon

The highly destructive, tsunamigenic, the second largest earthquake of the world every recorded [Mw9.3] occurred in Indian Plate, Just north of Simeulue Island (3.70N and 95.00E), off the western coast of Northern Sumatra on 26 December 20042. The generated tsunami struck the coastal regions of Indonesia, Sri Lanka, India, Thailand, Somalia, Port Elizabeth in South Africa, 8000 Km away from epicentre and the death toll was more than 3,00,000 people. The weak tsunamigenic but the second largest earthquake in the world since 1964[M8.7) occurred on 28 March, 2005 in Australian plate at shelf region of western coast of Northern Sumatra (2.0740and 97.0130), roughly between the Islands of Nias and Simeulue. Weak Tsunami of 3-4.5m run up struck at Simeulue, hundreds of buildings were collapsed and reported death toll was 2000 at Nias: but the expected significant tsunami was not generated (USGS NEIC 2005). Two great earthquake of short duration (87 days), that to occur in the same region is the very rare phenomenon in the world. Thousands of aftershocks of 26 December 2004 great earthquake and hundreds of aftershocks of 28 March 2005 great earthquake were released. Based on the different pattern of the aftershocks, 28 March 2005 earthquake (M 8.7) should be considered as either triggered earthquake of 26 December earthquake or of independent status of the great earthquakes of Australian plate and Indian plate respectively [Figure 1].

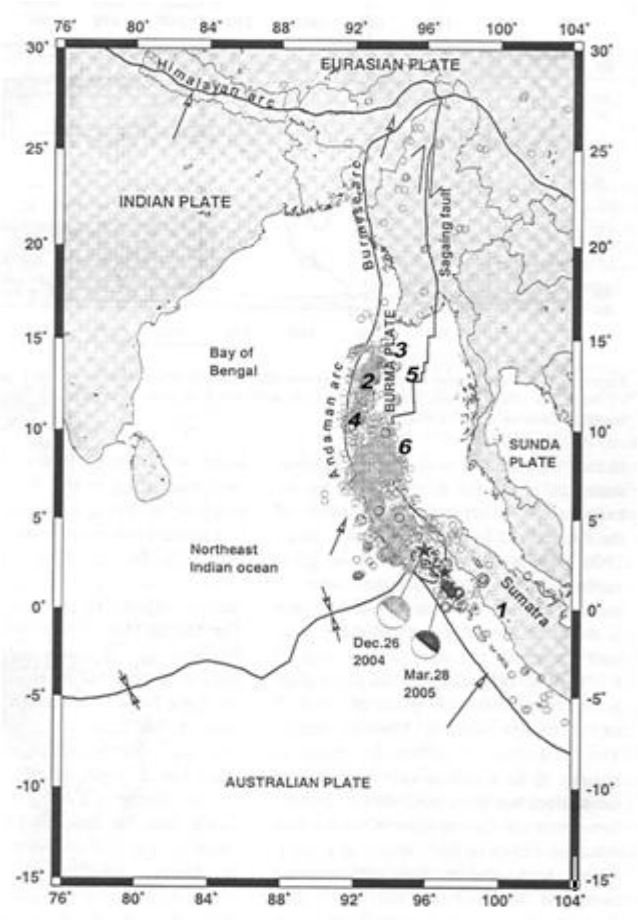


**Figure 1:** Location Map of 26 December, 2004 and 28 March 2005 Northern Sumatra great earthquakes which occurred near quadruple tectonic junction of India, Burma, Australia and Sunda Plates. Location of the volcanoes 1. Talang, 2. Barren 3. Narcondam 4. Invisible bank sea mount 5. Alcock and 6. Sewell are shown (Modified after Purnachandra Rao and Hanumanthachary, 2004).

## 3. Erupting Volcanoes

The volcanism in Andaman, Indonesia has been intermittent in the Oligocene, Miocene periods before being vigorous in the Pliocene due to increased seismicity and heat flow characteristics. More than 140 volcanoes are located in the Andaman-Sumatra – Indonesia volcanic arc belt, and they are located either on inland or submarine or at seashore (Valdiya 1987). Almost all of them have been pouring out fire, ash and molten andesitic material during the Holocene period and most of them have been very violent and their volcanic explosivity index (v) have been ranging between 4-7 (Abbott, 2002). Currently most of them are dormant of centuries. (Figure 1 and 2).

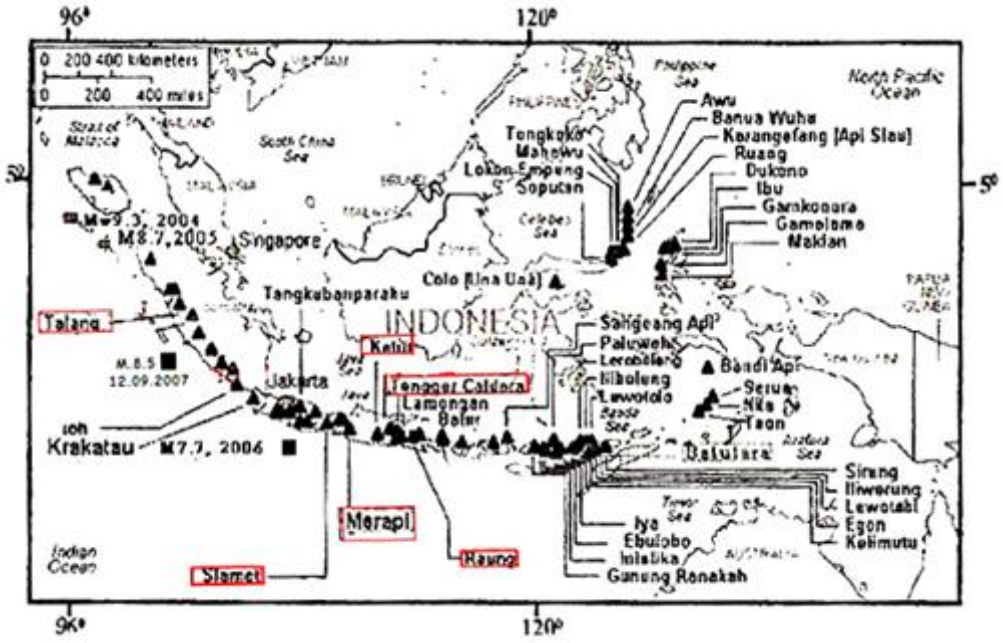


**Figure 2:** Shows epicenters of Tsunamigenic earthquakes of 26th December 2004, 28 March 2005, 17th July 2006 and 12th September 2007 located in Sumatra-Java Arc Region and important volcanoes of Indonesia. Current erupting volcanoes are shown in Boxes (modified after USGS)

Now the most important is the two consecutive great earthquakes have triggered the many volcanoes of Andaman and Indonesia Regions i.e.(i). Talang Volcano of Padang city at Western Coast of Central Sumatra, started eruption on 12 April after a continuous four aftershocks on 11 April 2005. Hot ashes and gaseous eruption are still going on (Figure 2). The Volcano of Barren Island, 225 Km Northeast of Port Blair of Andaman is emitting hot glowing gases with lava particles intermittently from the month of May 2005 onwards (Figure 1). The Barren-Narcondam active volcanic arc continues up to the Simenko rift in Sumatra (Rudolfo 1969). In the past the barren erupted in two phases, one between April-September 1991 and the other around January-July 1995. The Cuire Isotherm Depth (CID) along the Andaman Volcanic arc was found to vary from 5 to 10 Km depth from Mean Sea Level which indicates 2 Km from the basement and may act as a potential zone of volcanic arc formation in future (Sengupta et.al 2005)

The inland volcano, Merapi of Indonesia started gaseous eruption on 14th April 2006 onwards and violently erupted on 15th May 2006.

It is inferred that the lava pouring Volcanoes, the Merapi of West Java and the Talang Volcano of Central Sumatra might have developed cone of depression in Magma at their bottoms. The Migration of magma towards the above volcanoes may initiate harmonic tremors in between them. As a result the lateral redistribution of magma may occurred in region between Merapi and Talang volcanoes and due to enhancement of stress the tsunamigenic Java earthquakes (M 7.7) was released in between the Talang and Merapi Volcanoes on 17th July 2006 (Figure 2).A small tsunami was generated through a powerful great earthquakes of magnitude 8.5 occurred on 12.09.2007 at off the coast of South Sumatra. During the time slot between 17.07.2006 and 12.09.2007 the following volcanoes of Indonesian Arc regions were erupted as follows:

1. The Semeru volcano of Java on 6th Feb-4th March 2007.
2. The Slamet volcano of Java on March 2007.
3. Bromo Volcano of West Java on June 2007.
4. The Talang volcano of Sumatra on 18th June 2007.
5. The Raung volcano of West Java on August 2007.
6. The Kelut Volcano of West Java on August 2007.
7. The Merapi Volcano of West Java between August 2007-June 2008.

On considering the location of South Sumatra Tsunami between the erupting volcanoes of Talang of Central Sumatra and the above other volcanoes of Java Clearly reveal a possible link between the tsunamigenic earthquake and active eruptive volcanoes of Indonesian Island Arc. To know the facts behind the above idea a plot (Figure 3) for seismic focus data between 28th March 2005 Northern Sumatra Tsunami and 17th July 2006 Java Tsunami are plotted in their respective GPS locations. The earthquakes more than M 4.5 are plotted with Seismic focus range (depth) symbols.

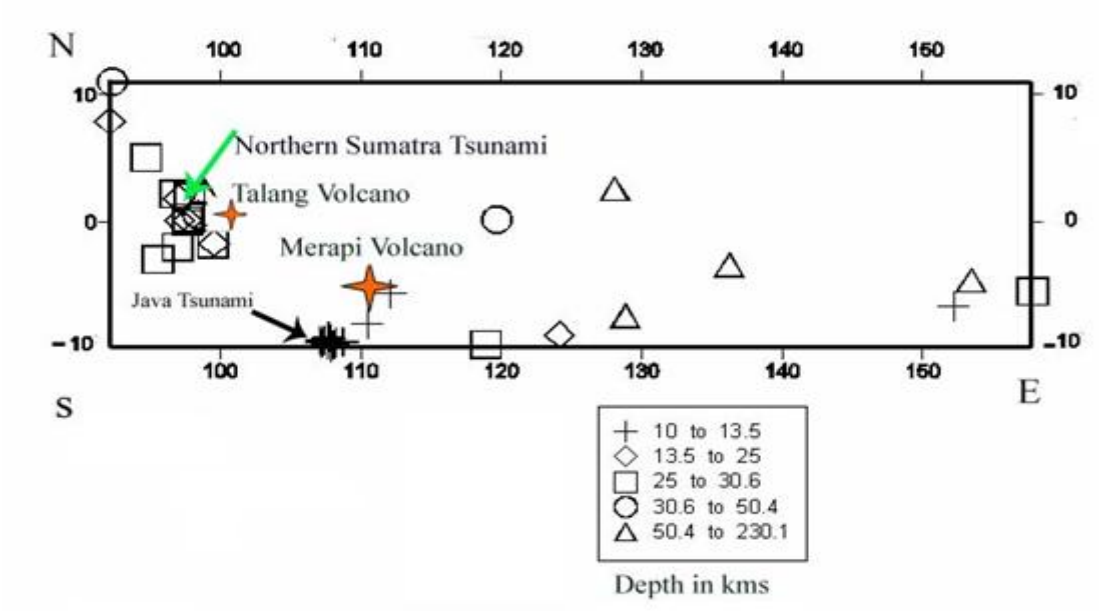


**Figure 3:** Seismic focus data in-between 28 March 2005 Tsunami and 17 July 2006 Java Tsunami are plotted. The generation of Java Tsunami well located between active Talang volcano erupted on 12.04.2005 and Merapi volcano erupted on 14th April, 2005.

The figure 3 shows generation of Java Tsunami at same shallow focus foreshocks overlapping each others and at location between erupting Talang volcano and Merapi Volcano. Likewise the epicenter of Northern Sumatra Tsunami (28th March 2005), Southern Sumatra Tsunami (12.09.2007) and Java Tsunami (17.07.2006) and the guiding erupted volcanoes after the Java tsunami and before the Southern Sumatra Tsunami are plotted (Figure 4).The figure 4 shows the generation of Southern Sumatra Tsunami in the midway between the erupting Talang volcano at Northwest and West Java Volcanoes, ie., Slamet, Bromo, Kelut, Raung, and Merapi at South East certainly reveal the influence of erupting volcanoes over the Tsunamigenic earthquake.

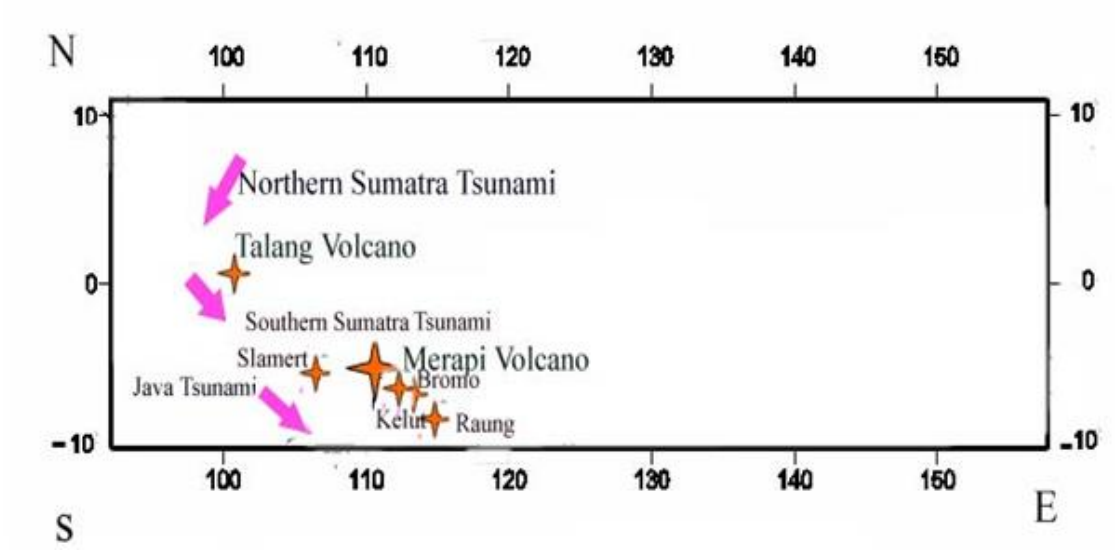


**Figure 4:** Southern Sumatra Tsunami generations between the guiding volcanoes Talang, Slamet, Merapi, Bromo, Kelut and Raung volcanoes of Indonesian Arc.

## 4. Volcanoes guided Tsunamigenic earthquake tectonic model

The styles of Subduction between the Indian-Burma plates and Australian – Sunda plates are quite distinct, with earthquake distribution reaching down to only about 230 km in the former, while it is found upto 700km in the latter i.e., depth of penetration of subducting Indian and Australian plates are different (Purnachandra Rao and Hanmantha chary 2005). A 15m subduction during 26th December 2004 earthquake and 3m subduction during 28th March 2005 earthquake has been reported (Manimaran and Antony Ravindran 2007).

This two stage consecutive subduction certainly initiated the decompression melting under Andaman-Indonesian volcanic arc region. As the result, there is upwelling of magma and increase in volume resulting new fracture zone formation below the volcanic arc. The fracturing may initiate further decompression melting, rise of volatile rich magma and abnormal volume increase so as to trigger the violent explosion of a series of Volcanoes (Manimaran 2007, Manimaran and Renuga 2007).

The release of couplet of tsunamigenic great earthquakes on 26th December 2004 (Mw 9.3) and 28th March 2005 (M 8.7) and their respective trains of aftershocks moving northerly direction upto Burma border and southeasterly direction upto Java from their respective epicentres (Figure 1) The above aftershocks have triggered the eruptions of Barren volcano on May 2005 and Talang on 12th April 2005. The Southeasterly moving aftershocks have

volcano of West Java and it started gaseous eruption on 14th April 2006 onwards. On 15th May 2006 it erupted violently and expelled ashes into the atmosphere and white solfatara fumes raising 400m and lava avalanches were started. The volcanoes guided tsunamigenic model figure 5 clearly depicts the locations of Talang and Merapi Volcanoes.

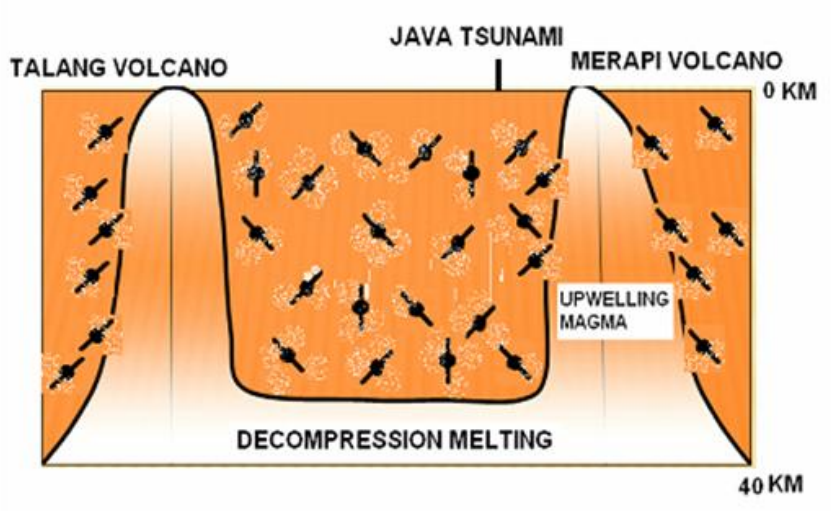


**Figure 5:** Aftershocks seismic bombs of 28th March 2005 Tsunamigenic earthquake initiated decompression melting and additional stress between Talang and Merapi volcanoes resulted in generation of java Tsunami.

The seismic energy released by the northerly moving and southeasterly moving harmonic aftershocks of different depths in Andaman-Indonesian arc, there has been remarkable enhancement in the upwelling of magma (rise of Curie Isotherm Depth) due to the opening of new fissure and reopening of old fissures below the arc and also might develop a cone of depression in magma between their bottoms of these volcanoes. The migration of magma towards the above volcanoes (ie., Talang and Merapi) might have initiated the harmonic seismic bombs in between them. The event was resulted in networks of new fractures formation and further residual, residential decompression melting at various tremors sites. As a result the volume increase in magma and stress increase between the erupting volcanoes and lateral redistribution of magma was occurred in region between Talang and Merapi volcanoes. The enhancement of stress beyond the critical limit was attained in a place, normally between the two erupting volcanoes (ie. Merapi and Talang Volcanoes) or a two sets of volcanoes of adjoining locations i.e. Talang volcano of Central Sumatra on one side and other volcanoes of Semeru, Slamet, Bromo, Raung Kelut and Merapi of West Java on the other side resulted in Tsunamigenic earthquakes of Java Tsunami and southern Sumatra Tsunami of Indonesia regions respectively. Hence it looks more possible for earthquake triggered volcanoes and eruptive volcanoes controlled/ guided tsunamigenic earthquakes.

## 5. Conclusion

In Indonesian Island Arc system, through initially the tsunamigenic earthquake triggered a series of volcanoes, the later formed tsunamigenic earthquake epicenters were known to be controlled by the locations of erupting volcanoes. Their related connective phenomena like networks of new fractures formation due to harmonic seismic quakes, decompression melting and upwelling of magmas, stress developed critically between two or two sets of erupting volcanoes so as to develop a tsunamigenic earthquake is more probable

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