Analysis of Regional and Local Earthquakes in Thailand and Adjacent Areas

Helmut Dürrast
Geophysics Group, Department of Physics, Faculty of Science, Prince of Songkla University, Songkhla 90112, Thailand

ABSTRACT

Although Thailand is often considered as having low seismicity, it is located only a few hundred kilometers from a major active convergent plate boundary, the Sunda subduction zone in the Andaman Sea and its extension north into Myanmar and China. Higher seismic activities are related to this plate boundary. Earthquakes with moderate magnitudes are common in the northern and western parts of Thailand. However, these are not frequent. The position of Thailand in the seismotectonic map of Southeast Asia has implication for earthquake measurements and analysis, especially in terms of location and magnitude determination. Based on the work started in early 2005, a number of issues, experiences, and problems have been highlighted and discussed. There are still open questions for further work.

KEYWORDS: Thailand, seismicity, earthquake location, earthquake magnitude, Sunda subduction zone, fault zones

INTRODUCTION

Before the 26 December 2004 earthquake, Thailand was, and today still is, considered by many as a country having low seismicity. Therefore, the measurements of, and research in, earthquakes has a low priority. Available data show that earthquakes located in Thailand have not occurred often and have had only moderate maximum magnitudes. Figure 1 shows that Thailand's earthquakes are mainly in the western and northern parts of the country (U.S. Geological Survey, 2008). Figure 1 also shows that there have been a large number of earthquakes outside of Thailand, north and west of the country. These earthquakes are related to the Sunda subduction zone, a major convergent plate boundary in the Andaman Sea and in Indonesia. This subduction zone extends into the continental crust of Myanmar and China as complex fault systems.

The Sunda subduction zone is part of the plate boundary between the Indian-Australian plate and the Burma micro-plate and the Sunda plate, as part of the Eurasian plate. The Indian-Australian plate is subducting under the Sunda plate at a rate of about 65 millimeters per year (U.S. Geological Survey, 2005). The Sunda trench is the boundary between these two plates. This interface was also the cause of the devastating magnitude 9.3 earthquake on 26 December 2004 that caused a sudden uplift of the ocean floor and triggered a tsunami in the Indian Ocean. The location of the 26 December 2004 Sumatra-Andaman earthquake is a few hundred kilometers southwest of the Thai peninsula. The Sunda subduction zone is only 500 to 600 kilometers west of the Thai-Andaman region, including the major tourist destination of Phuket.

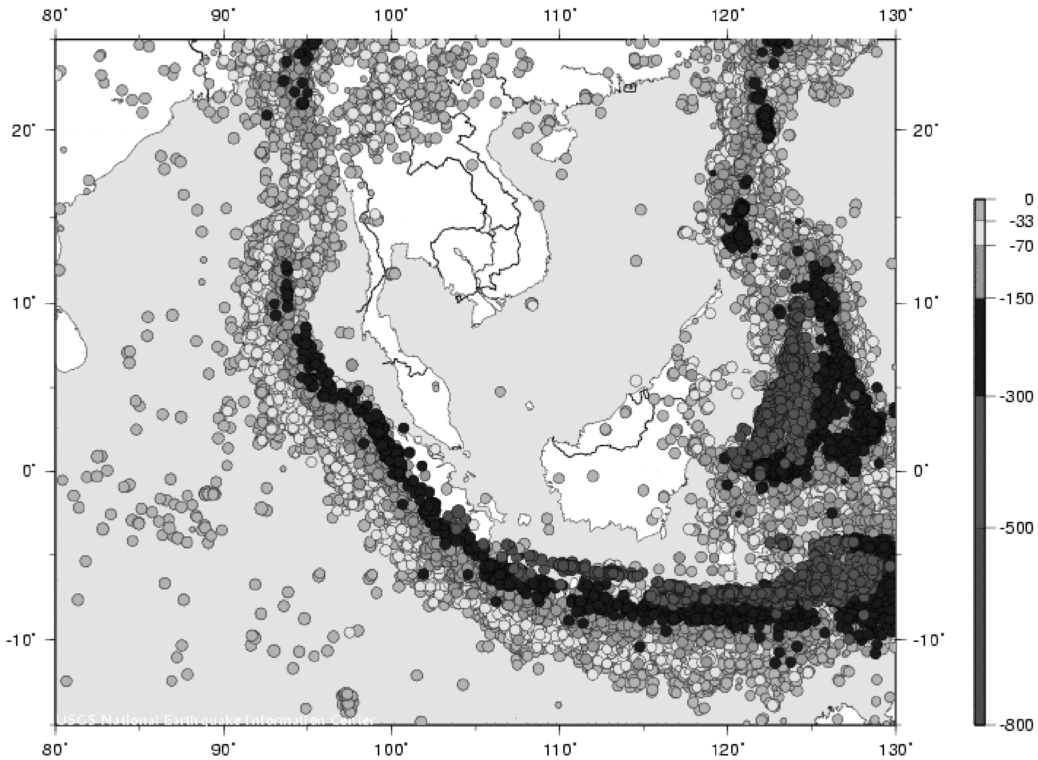

Figure 1. Seismicity in Thailand and adjacent areas based on the U.S. Geological Survey database from 1973 to present; gray colors indicate different earthquake depths in kilometers, as shown in the bar on the right (U.S. Geological Survey, 2008)

Regional geology and tectonics show a number of fault zones related to the subduction zone and/or the collision between the Indian Subcontinent and the Eurasian Continent. Thailand has fault zones in its southern part, mainly between Ranong, Surat Thani, and Phuket, in its western part in Kanchanaburi Province, and further north, mainly in Chiang Mai and Chiang Rai Provinces. Any movement and subsequent seismic activity might be related to the overall seismotectonics.

Thailand might be labeled as having low seismicity, but Thailand is located very close to an active major plate boundary, resulting in neo-tectonics plate movements with significant and extensive seismicity. This can have an indirect effect on Thailand, like through the tsunami, or this can have a direct effect, like seismicity on fault zones located in Thailand (Dürrast and others, 2007).

Besides the analysis of geological and tectonic structures, the analysis of earthquakes is quite important for understanding the regional geology and neo-tectonic movements. Earthquake analysis is also necessary for the evaluation of seismic hazards and it is essential for any Indian Ocean tsunami warning system. The earthquake parameters of primary importance are location, depth, magnitude, and origin time. Of further importance is information about movement, direction, orientation of the fault plane, and slip vector. Earthquake monitoring in Thailand is the duty of the Seismological Bureau of the Thai Meteorological Department (Thai Meteorological Department, 2008).

EARTHQUAKE MEASUREMENTS

Earthquakes are usually measured using a seismometer, which in principal consists of a mass attached to a fixed base. During an earthquake, the base moves and the mass does not. The motion of the base with respect to the mass is commonly transformed into an electrical voltage. The electrical voltage is recorded. This record is proportional to the motion of the seismometer mass relative to the Earth, but it can be mathematically converted to a record of the absolute motion of the ground, the movement of the Earth's surface. Since a seismic wave can come from any direction inside the Earth and in order to record as much of the wave as possible, most seismometers today are equipped with sensors in three perpendicular directions, north-south, or n-component, east-west, or e-component and vertical, or z-component. The amplitudes of seismic waves are recorded over time, thus, forming seismograms. Time is usually recorded using the global positioning system and given in universal time coordinates, UTC. Thai time is UTC + 7 hours.

For Thailand, the following issues, problems, and questions arise:

- Is the seismometer calibrated and, if necessary, how is it done?
- How to find a good place for a seismometer, especially since the near subsurface layer is often highly weathered? A good place should have low seismic noise and low near-surface attenuation. It must have electricity, safety, and security.
- How much is the effect of ocean wave noise in seismic records in Thailand? How low should the noise be for a low noise station?
- In southern Thailand, seismic noise is an important issue since most of the region is more or less populated.
- Blasting in quarries can be easily recorded by seismometers. However, it is often difficult to get accurate records about blasting activities.

DETERMINATION OF EARTHQUAKE LOCATION

The determination of an earthquake location makes use of the fact that an earthquake generates compressional P waves and shear S waves. The compressional P waves travel the fastest and arrive first at seismic stations. They are called primary waves. The velocity of shear S waves is less than that of the compressional P wave velocity. Therefore, these shear S waves arrive later at seismic stations. They are the secondary waves. As the Earth is a sphere, the ray paths are at larger distances and not direct. When they approach density boundaries, reflection and refraction occur. By using the time difference between the arrival of S waves and P waves, this being the delta time, or delta t, Δt, the distance between the seismic station and the earthquake location can be determined. The velocities of seismic waves depend on the density of material in the Earth and they change with different layers. Seismologists have developed an Earth model from past data that has velocities of the different layers of the Earth (Bormann, 2002). Using these velocities and with distance data from more than three or four seismic stations, the location and depth of an earthquake can be determined.

For Thailand, the following issues, problems, and questions are pertinent:

- All earthquakes located in Thailand might be called local earthquakes since their distance from most seismic stations is less than 500 to 600 kilometers. The majority of the earthquakes related to the Sunda subduction zone are further than 600 kilometers and are regional earthquakes. Regional and local earthquakes can be easily separated by distance.
- It can be difficult to separate local earthquakes from blasting events in seismograms; experience makes this achievable.
- For Sunda subduction zone earthquakes, the S wave arrival is often in the ongoing P wave train and, therefore, quite difficult to determine. This is especially so for earthquakes with long duration. Any uncertainty in the S-wave determination has direct implications for the distance determination.
- What Earth model should be applied for Andaman Sea earthquakes and are there any corrections necessary because of the back arc structure? Reasonable results have been obtained using the AK135 model (Kennett, 2005).
- What Earth model is appropriate for Thailand since no model is available? What is the depth of the Moho discontinuity and what are the velocities for the subsurface layers? In previous and current work, the Jeffreys and Bullen (1967, 1970) model was used.
- There are no data concerning the thickness and related velocities of the continental and oceanic crusts in the Andaman Sea area.
- The proximity of the Sunda subduction zone earthquakes provides an almost linear relationship of distance versus travel time for the seismic waves, with refraction at the Moho discontinuity. This makes data processing relatively easy and straightforward.
- If data from only one seismic station with three components are available, the back azimuth method provides reasonable results for location determination. However the quality of the

results depends on the earthquake location in relation to the seismic station (Bormann and Wylegalla, 2002).

- The depth resolution can be quite challenging for local earthquakes due to the uncertainty from the S-wave arrival determination. This because the depth is considered quite shallow, from a few kilometers down to 25 kilometers (Dangmuan, 2008).

DETERMINATION OF EARTHQUAKE MAGNITUDE

The magnitude is a number that characterizes the relative size of an earthquake. Magnitude is a logarithmic measure of the size of an earthquake or explosion based on instrumental measurements of the maximum motion recorded by a seismograph. Several scales have been defined, but the most commonly used are local magnitude, commonly referred to as Richter magnitude, surface-wave magnitude, and body-wave magnitude. The moment magnitude, Mw, scale is based on the concept of seismic moment. All magnitude scales should yield approximately the same value for any given earthquake. Magnitudes are derived from ground motion amplitudes and periods or from signal duration measured from instrument records. Nowadays, highly sensitive instrumentation close to the source may record events with a magnitude smaller than zero.

For Thailand, following issues, problems, and questions arise:

- For earthquakes in the Andaman Sea, the body-wave magnitude can be used, since the distance from seismic stations in Thailand is generally more than 500 to 600 kilometers, or about 5 degrees. However, the U.S. Geological Survey is not using the body-wave scale for epicentral distances less than 20 degrees.
- Recent work from Setapong and others (2008) has shown that it is possible to determine a reasonable body-wave value for distances of about 5 to 7 degrees using the *Q* given by Gutenberg and Richter (1956). *Q* is the correction function of the body wave phase, depending on the focal depth, *h*, and the epicentral distance, *D*.
- Setapong and others (2008) determined the body wave magnitudes from the highest amplitude, A, of the whole P-wave train, but before the S-wave arrival, and from the period, T, of the highest amplitude, following Gutenberg and Richter (1956). The U.S. Geological Survey usually uses only a maximum twenty seconds after the P-wave arrival. This difference in procedure needs to be taken into account for any data comparison.
- Higher magnitude values experience saturation. Is it then possible to use the cumulative body wave magnitude, Σm_B? Srattakal (2007) followed Bormann and Wylegalla (2005) and showed that it is possible to get reasonable values for the 26 December 2004 earthquake recorded at the PSU station in HatYai. This might be an option for fast and more reliable magnitude determination of tsunami generated earthquakes.

- For local earthquake magnitudes from earthquakes located in a fault zone, attenuation might be different in different directions having anisotropic conditions. This might also apply in the same way to the seismic velocities in a fault zone.
- In recent studies, local earthquakes with zero and minus magnitudes were determined in southern Thailand (Dangmuan, 2008). This is physically possible and explainable (Joswig, 2007). However, for Thailand the following issues need to be discussed: Are local magnitudes with zero or minus magnitude values real and realistic? Is the sensitivity of the equipment sufficient to achieve this? Is the noise level low enough to see this? What is the geological significance of these earthquakes?

CONCLUSIONS

For evaluating the seismic hazards in Thailand, earthquakes located in Thailand and in adjacent areas, such as in the Sunda subduction zone, have to be considered. For the analysis of these local and regional earthquakes in terms of location and magnitude, general issues and questions arise. These are also specific general issues and questions, depending on the unique situation of Thailand in the seismotectonic map of Southeast Asia. Since early 2005, research and work in and about earthquakes in Thailand has provided not only more data, but also more answers to open questions. However, many questions still remain unanswered. For example, questions about the recent earthquakes in the Gulf of Thailand, which caused damage to communities in Chumpon and nearby areas, need to be discussed further, especially what was the cause. Finally, several important issues concerning the analysis of earthquakes are highlighted in this paper as a base for further research and work.

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