A Preliminary Result of an Investigation of Crustal Properties Underneath Thailand from Earthquake Data Using a Refraction Technique

P. Pananont*, B. Wechbunthung, P. Putthapiban***, T. Lerkwieng*** and Capt. S. Ekmahachai RTN******

** Department of Earth Sciences, Faculty of Science, Kasetsart University, Bangkok, Thailand.*
Previously Department of Physics, Faculty of Sciences, Mahidol University, Bangkok, and Geoscience Program, Mahidol University, Kanchaburi Campus, Kanchanaburi, Thailand.
*** Thai Meteorological Department, Bangkok, Thailand.*
**** Geoscience Program, Mahidol University, Kanchaburi Campus, Kanchanaburi, Thailand.*
***** Royal Thai Navy Seismic Research Station, Chiang Mai, Thailand.*

ABSTRACT

Ten permanent seismograph stations recorded seismic waves, both compressional P and shear S waves, from two shallow moderate earthquakes that occurred in the northern Thailand. One earthquake was a magnitude 4.7 event on 12 December 2006 in Chiang Mai and the other earthquake was a magnitude 6.3 event on 16 May 2007 near the Thai-Laos border. The seismic stations that recorded these two events were spread throughout Thailand, though most of these were generally aligned in a north-south direction and were in the western part of Thailand. A two-layer crustal model explains the first and later prominent seismic phases. The compressional P wave velocities range from 5.87 kilometers per second in the upper crust to 6.27 kilometers per second in the lower crust. The shear S wave velocities vary from 3.48 kilometers per second in the upper crust to 3.57 kilometers per second in the lower crust. The boundary between the upper and lower crusts is about 34 kilometers underneath Thailand, as calculated from travel time curve of shear S waves. Poisson's ratios of the upper and lower crusts underneath Thailand are 0.23 and 0.26, respectively, thus, suggesting slightly rigid upper crust and typical lower crust material.

KEYWORDS: Earthquake data, crustal properties, northern Thailand

INTRODUCTION

Most studies of seismic crustal properties in the Southeast Asia are concentrated in the whole of Southeast Asia or in the north of Thailand (Li and other, 2006; Zhou and others, 2003). There have been no studies of crustal seismic properties specifically underneath Thailand. Most oil industry seismic reflection surveys in Thailand have been in sedimentary basins (Polachan and Sattayarak, 1989; Kornsawan and Morley, 2002; Morley, 2007) that occur only in the uppermost part of the crust. Therefore, crustal properties underneath Thailand, which are part of the main fundamental knowledge for tectonics study, remain unresolved.

Seismic body waves from two moderate earthquakes, the magnitude 4.7 earthquake that occurred on 12 December 2006 in Chiang Mai and the magnitude 6.3 event that occurred on 16 May 16 2007 near the Thai-Laos border (Table 1) were recorded by most seismic stations in Thailand and were used to analyze the crustal property underneath Thailand. Figure 1 is a map of the locations of the seismograph stations and the location of these two earthquakes used in this study.

Table 1. Earthquake information used in this study (National Earthquake Information Center).

Event Date	Origin Time (UTC)	North Latitude	East Longitude	Depth (km)	Magnitude (Mw)	Location
16 May 07	08:56:15	20.5°1N	100.74°E	20	6.3	Near Thai-Laos border
12 Dec 06	17:02:29	18.91°N	98.93°E	8.5	4.7	Chiang Mai, Thailand

Figure 1. Map of Thailand and surrounding area showing location the earthquakes and seismic recording stations used in this study.

CRUSTAL STUDY USING EARTHQUAKE DATA WITH REFRACTION METHOD

Most seismic stations used in this study are operated by the Thai Meteorological Department. The seismometers are broadband type with frequency response from 1/40 and 1/120 to 50 hertz (Table 2).

Table 2. Seismic recording stations used in this study

Station Name	North Latitude	East Longitude	Elevation (m)	Sensor Type (Nanometrics)
SRDT	14.3945^{o}	99.1212^{o}	122	Trillium 120
KRDT	14.5905^{o}	101.8442^{o}	266	Trillium 40
SKNT	16.9742^{o}	103.9815^{o}	254	Trillium 40
PBKT	16.5733^{o}	100.9687^{o}	8	Trillium 120
CMMT	18.8128^{o}	98.9476^{o}	400	Trillium 120
MHMT	18.1764^{o}	97.9310^{o}	164	Trillium 40
MHIT	19.3148^{o}	97.9632^{o}	270	Trillium 120
RNTT	9.3904^{o}	98.4778^{o}	38	Trillium 40
SURT	8.9700^{o}	98.8090^{o}	20	Trillium 40
SKLT	7.1735^{o}	100.6188^{o}	15	Trillium 120

The epicentral distance and the travel time of compression, P, and shear, S, waves between the epicenters of the earthquakes and each seismic recording station were measured and plotted to produce travel time curves. The waveforms of each earthquake recorded at the seismic stations are shown in Figures 2 and 3.

Fourteen compression P wave and 15 shear S wave arrival times from two earthquake events were used to construct travel time curves. Assuming horizontal layers with constant velocities, the travel time curves shown in Figure 4 were interpreted to have a relatively simple seismic velocity structure. Linear regression analyses as used in refraction methods were performed on the P and S wave arrivals to obtain crustal velocity estimates. Using arrival times from all stations, the linear best fit P wave velocity is 5.87 kilometers per second for the near epicentral distance and 6.27 kilometers per second for the far epicentral distance. The linear best fit of the S wave velocity is 3.48 kilometers per second for the near epicentral distance and 3.57 kilometers per second for the far epicentral distance.

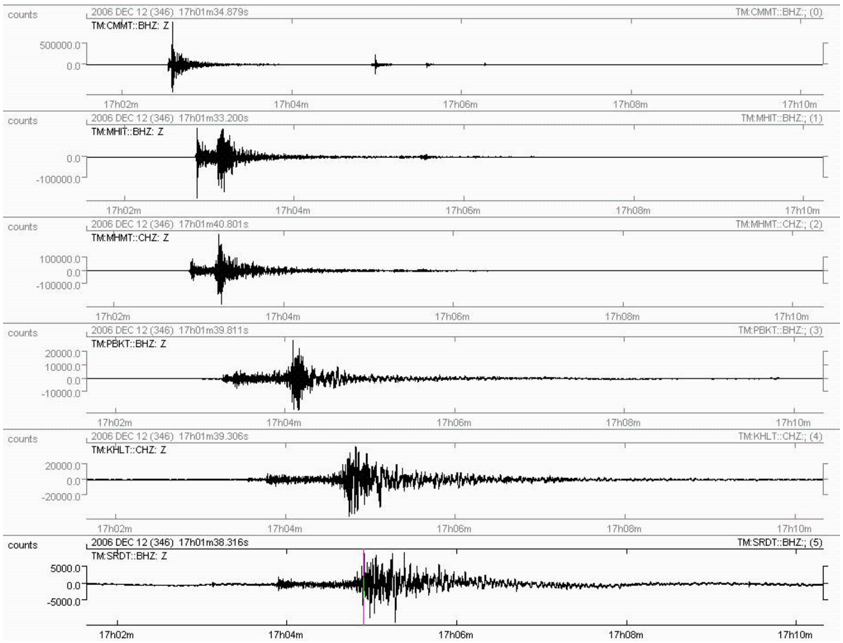

Figure 2. Seismic waveforms recorded at each station from the 12 December 2006 magnitude 4.7 earthquake in Chiang Mai.

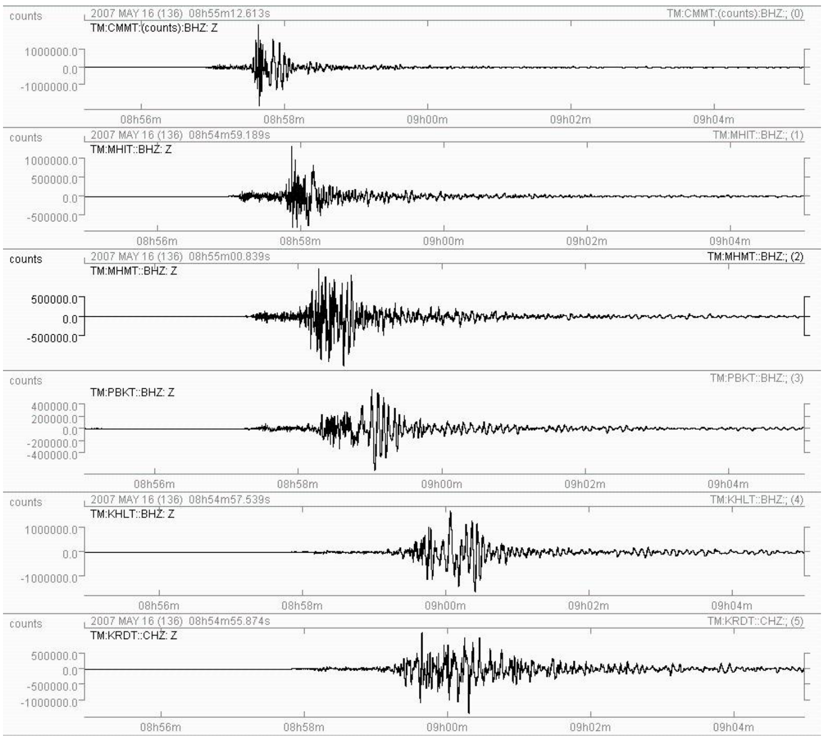

Figure 3. Seismic waveforms recorded at each station from the 16 May 2007 magnitude 6.3 earthquake near the Thai-Laos boarder.

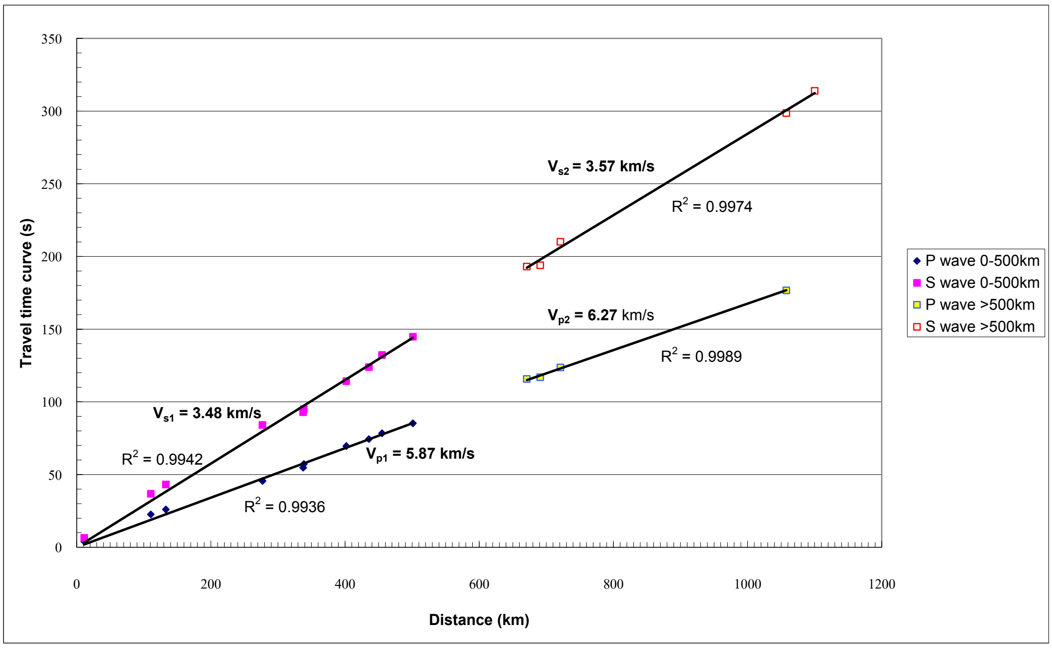

Figure 4. Travel time-distance curves of P and S waves from the earthquakes arriving at each seismic station.

As the quality of the S wave arrival picks is better than that of the P waves because of some noisy stations, the S wave arrivals were used to calculate the depth of the discontinuity in the crust. The cross-over distance of the S wave arrivals is about 580 kilometers and yields the depth of the discontinuity in the crust to be about 34 kilometers. This discontinuity is probably a boundary between the upper and the lower crusts underneath Thailand. The 34-kilometer discontinuity identified in this study agrees with the result of the study from Zhou and others. (2003), who suggested that there is at least one discontinuity at 34 to 35 kilometers underneath the IRIS' CHTO station underneath Chiang Mai, Thailand.

The calculated P and S wave velocities yield Poisson's ratios of 0.23 and 0.26 for the upper and lower crust, respectively. This indicates slightly rigid upper crust and typical lower crust material underneath Thailand (Rudnick and Fountain, 1995).

CONCLUSION AND RECOMMENDATION

Seismic waves from two shallow moderate earthquakes that occurred in northern Thailand and near the Thai-Laos border were used to analyze the crustal property underneath Thailand. These seismic waves were recorded by seismic stations in Thailand. These data suggest a simple two-layer crustal model in which the compressional P wave velocities range from 5.87 kilometers per second in the upper crust to 6.27 kilometers per second in the lower crust and the shear S wave velocities vary from 3.48 kilometers per second in the upper crust to 3.57 kilometers per second in the lower crust. The depth of the boundary between the upper and lower crusts is about 34 kilometers, calculated from the travel time curve of the shear S wave. The Poisson's ratios of the upper and lower crusts are 0.23 and 0.26, respectively. This suggests a slightly rigid upper crust and a typical lower crust underneath Thailand.

As very few moderate to large earthquakes have occurred in or near Thailand, the amount of the data that can be used for crustal studies using the refraction method is very limited. This lack of data makes any crustal calculations not too reliable. The result in this study is, therefore, only preliminary. Better and more reliable results of crustal properties underneath Thailand should be obtained by using more available earthquake data and, also, from ongoing receiver function method study.

ACKNOWLEDGEMENT

We thank the Thai Meteorological Department and the Royal Thai Navy's seismic research station for providing the earthquake data for this study.

REFERENCES

Li, X., Kind, R., Yuan, X., Sobolev, S.V., Hanka, W., Ramesh, D.S., Gu, Y. and Dziewonski, A.M. 2003. Seismic observation of narrow plumes in the oceanic upper mantle. *Geophysical Research Letters.* **30(6),** 1134, doi:10.1029/2002GL015411.

Kornsawan, A. and Morley, C.K. 2002. The origin and evolution of complex transfer zones (graben shifts) in conjugate fault systems around the Funan Field, Pattani basin, Gulf of Thailand. *Journal of Structural Geology* **24**, 435-449.

Morley, C.K. 2007. Variations in Late Cenozoic-Recent strike-slip and oblique-extensional geometries within Indochina: the influence of pre-existing fabrics. *Journal of Structural Geology* **29**, 36-58.

Polachan, S. and Sattayarak, N., 1989. Strike-slip tectonics and the development of Tertiary basins in Thailand. In:.International Symposium on Intermontane Basins; Geology and Resources (Eds. by Thanasuthipitak, T. and Ounchanum, P), Chiang Mai Univ, Chiang Mai.

Rudnick, R. L. and Fountain, D.M. 1995. Nature and composition of the continental crust: a lower crustal perspective, *Review of Geophysics* **33,** 267–309.

Zhou, Y., Nolet, G. and Dahlen, F.A. 2003, Surface sediment effects on teleseismic *P* wave amplitude, *Journal of Geophysical Research* **108(B9)**, 2417, doi: 10.1029/2002JB002331.