

Chapter 5

Tsunami and Its Effects

5.1 Human Loss

The tsunami caused by this earthquake probably the most disastrous so far and killed more than 200,000 people in a region from Sumatra as far as to South Africa. Approximately 170,000 people of Aceh province were killed by this tsunami. According to UN estimates, 655,000 people are homeless and sheltering in scattered refugee camps across the province. Although the tsunami caused the great damage and the great loss of lives in countries neighboring Indian Ocean, the most severely hit region was the west and north coast of Aceh province. Out of 10,000 original population of Leupung town, the estimated number of survivors was only several hundreds. According to official estimates, 8,000 of the 18,000 population of town Teunom were dead. 40,000 people of Meulaboh city with a population of 120,000 were killed by the tsunami.

5.2 Tsunamigenic Earthquakes Off the West Coast of Sumatra Island

The 26 December 2004 earthquake was not the first tsunamigenic earthquake, which occurred off the west coast of Sumatra Island. Some earthquakes generated tsunamis in past are shown in Figure 5.1. Only 7 people out of 70,000 people of Simeulue Island nearby the epicenter of the earthquake were killed, thanks to the saying of their ancestors "if there is an earthquake run for your life". The experience of the 1907 tsunami disaster was put to good account.

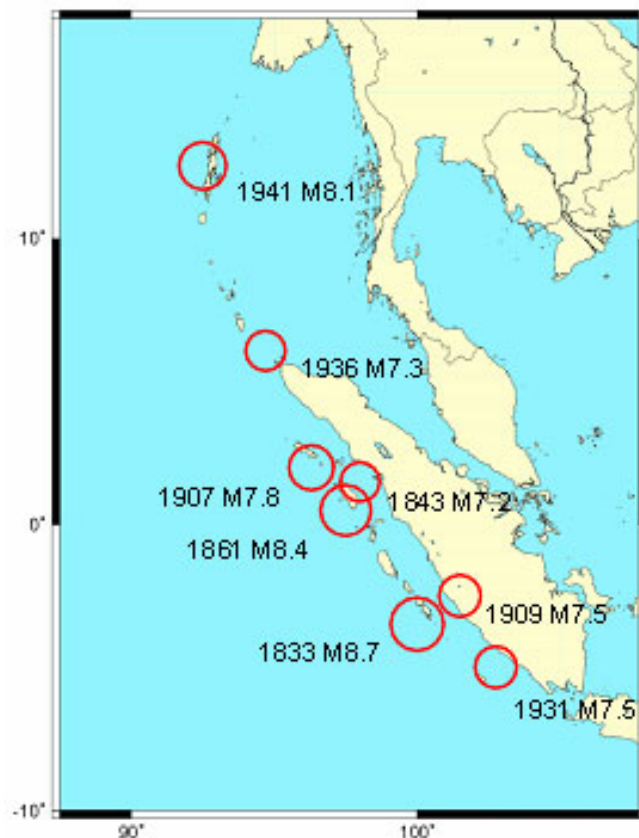


Figure 5.1 Some tsunamigenic earthquakes off the west coast of Sumatra Island (The original figure from BRI)

5.3 Tsunami Simulation

The rupture length of the causative fault was more than 1,000km and at least 2-3m vertical uplift displacement occurred on the continental side (east side). The observations of Prof. Sieh from California Institute of Technology (Caltech) on the shores of Simeulue Island indicated that the island was raised by 70-230cm and these confirmed the initial estimates on the vertical uplift displacement on the Euro-Asian side. The strike of the causative fault plane is about 80-100km from the west coast and the rupture lasted more than 400s. the tsunami waves arrived on the land within 20 minutes following the ground shaking.

The first computational estimations (Figures 5.2 and 5.3) for propagation and wave height of tsunami induced by this earthquake were done by Dr. Kenji Satake of National Institute of Advanced Industrial Sciences and Technology (AIST, Japan) by assuming that seabed was deformed as shown in Figure 5.4. Because of the fault geometry, the tsunami propagating to the East (towards Thailand) begins with a receding wave, which explains why the sea started to retreat minutes before flooding the coast. On the opposite, to the West (towards India and Sri Lanka) a large wave suddenly hit the coast without warning. 10 hours later, the tsunami reached the African coast. Following this first estimation by Dr. Satake, several researchers and institutes did similar type of simulations with better seabed topography and longer computation times. Such a computation result is useful to conduct on-site investigations effectively.

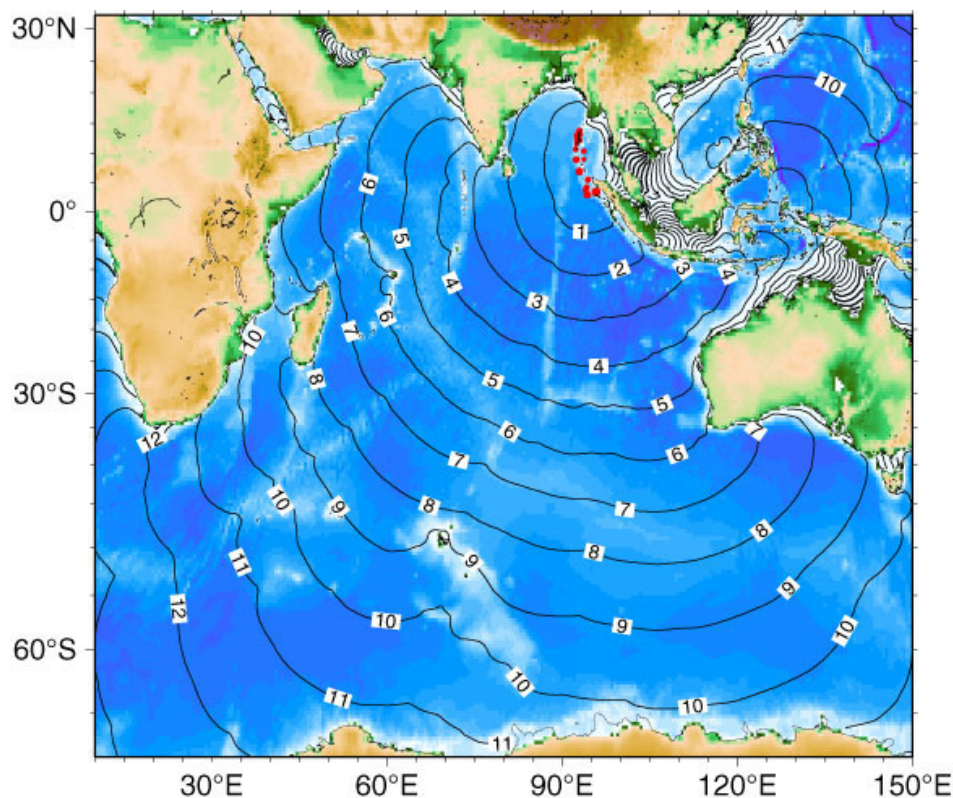


Figure 5.2 Estimated tsunami travel time by Dr. Satake

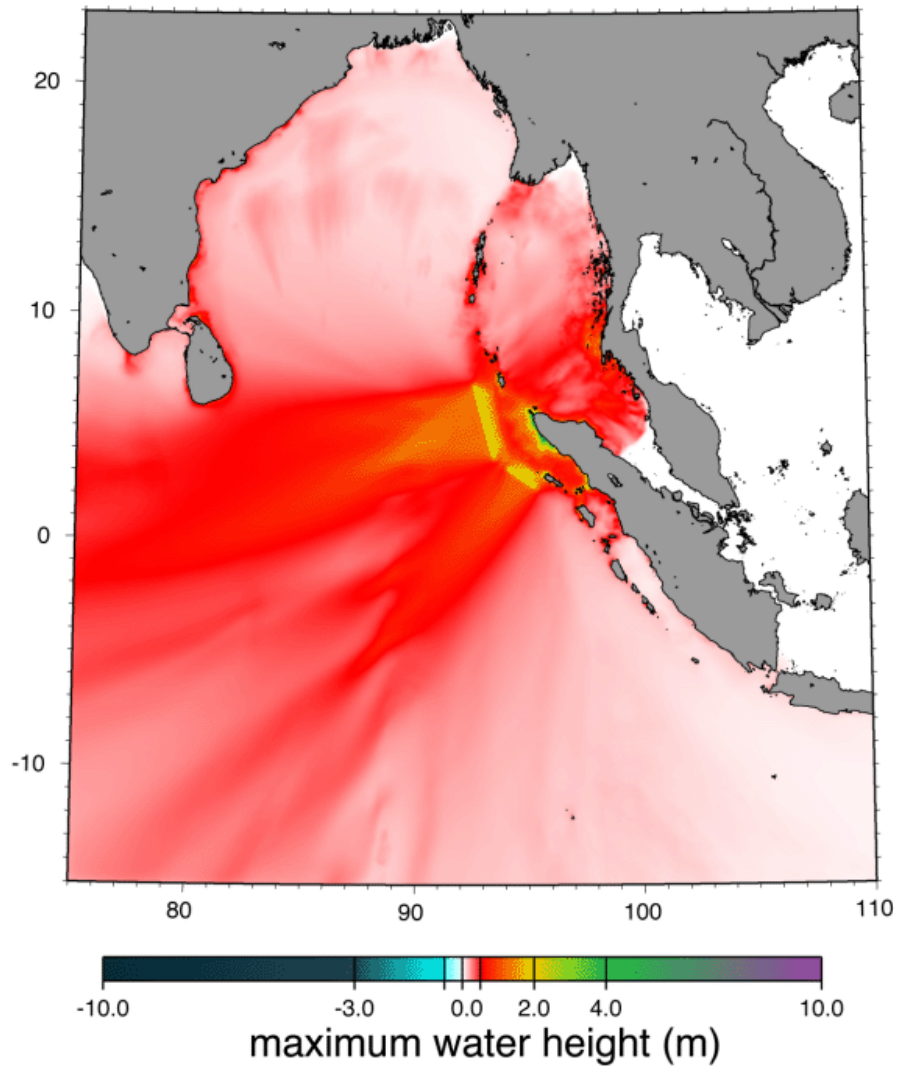


Figure 5.3 Estimated tsunami travel time by Dr. Satake

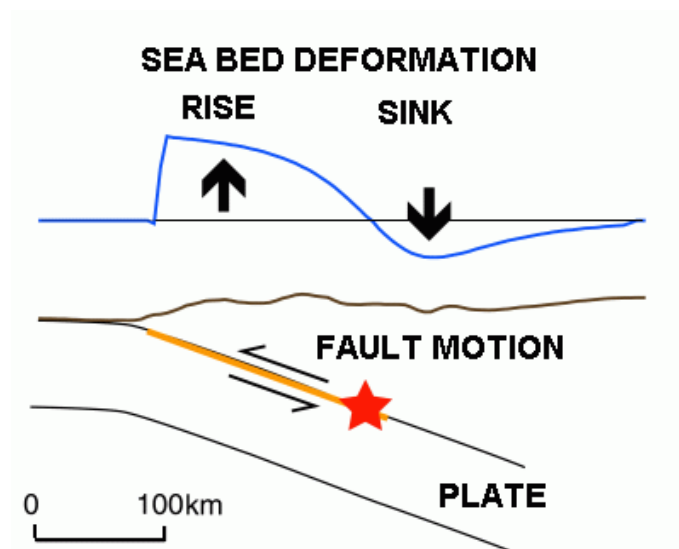


Figure 5.4 Seabed deformation model of Dr. Satake

5.4 Tsunami Trace Height

The tsunami inundated wide coastal areas especially in the west coast of Northern Sumatra and Banda Aceh (Figures 5.5, Photo 5.1 and 5.2).

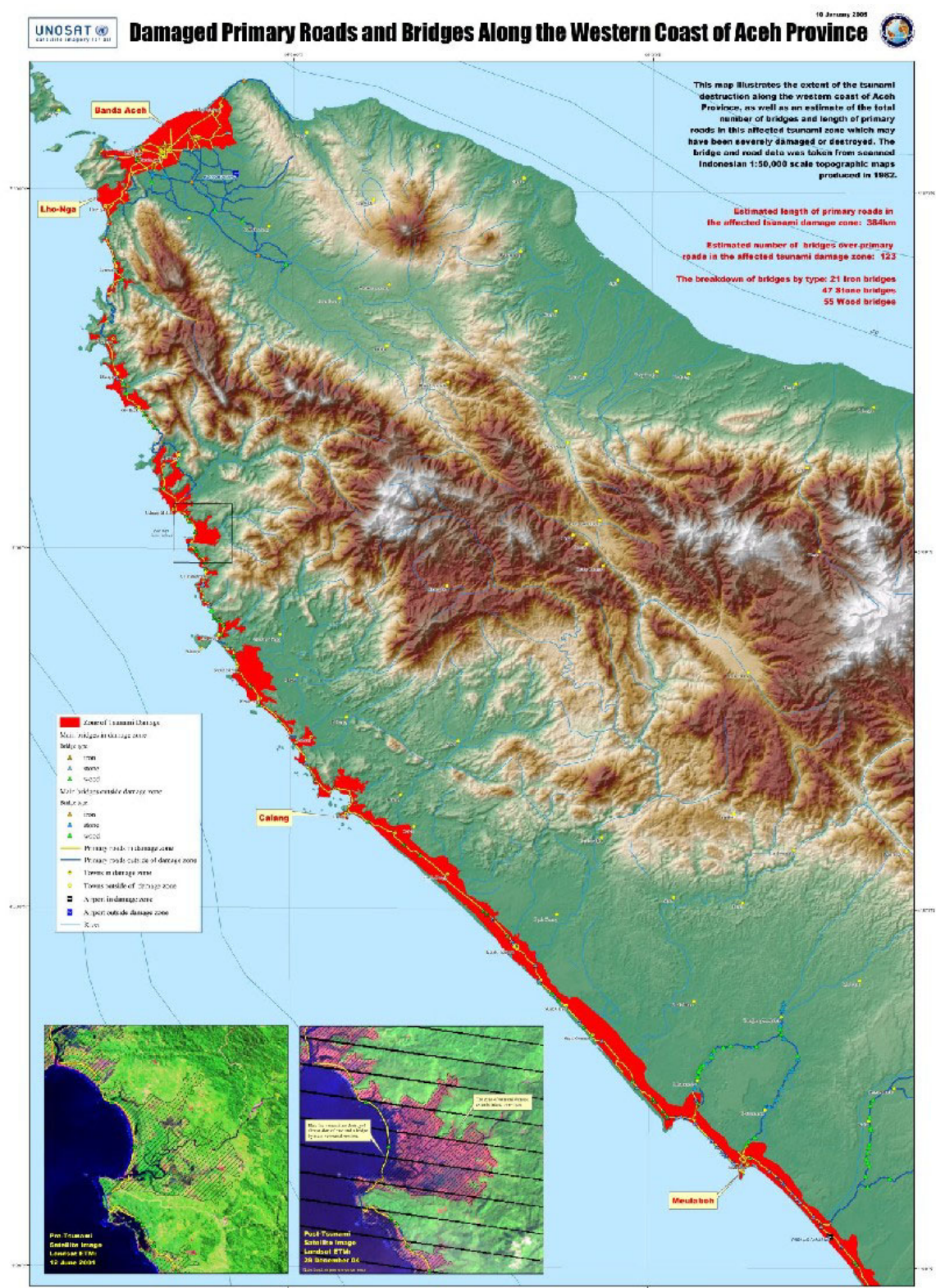


Figure 5.5 Inundated areas (red zone) in Aceh Province (UNOSAT)



QuickBird Browse Image: 28 December 2004



Photo 5.1 A satellite and aerial view of Banda Aceh City (US navy)



(a) Before the tsunami (on June 23, 2004)



(b) After the tsunami (on December 28, 2004)

Photo 5.2 Two satellite views of tsunami-affected areas in Aceh province (From DigitalGlobe)

The tsunami trace height and inundation distance measured by several local and international groups in the tsunami-affected regions neighboring Indian Ocean. The group led by Prof. Tsuji of ERI of University of Tokyo measured the maximum run-up height as 34.5m at Lhonga in Aceh Province (Figure 5.6), and the maximum inundation distance was about 7km according to UN reports. The run-up height was 6m in Sabang Island to the North of Banda Aceh.

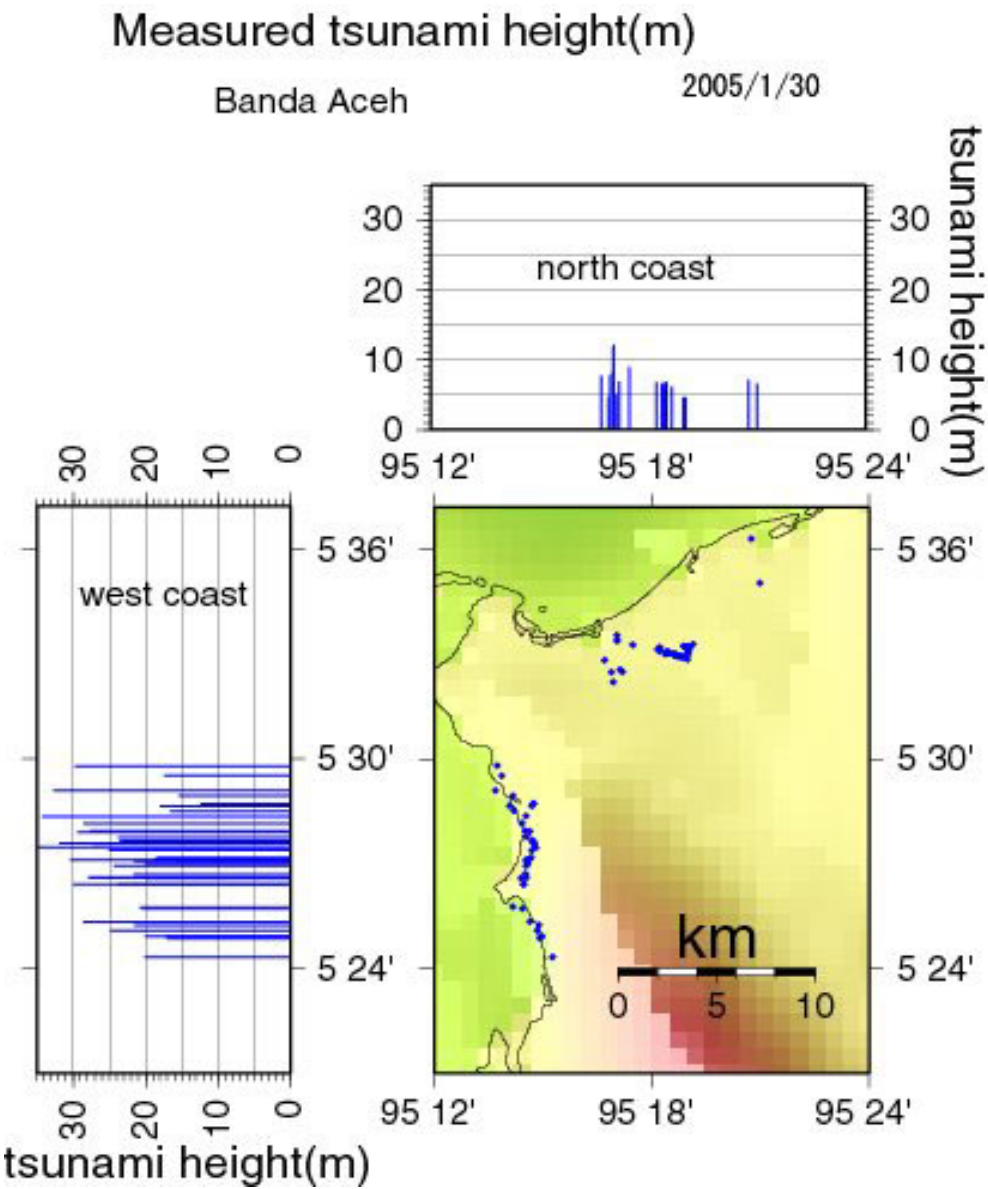


Figure 5.6 Tsunami trace heights measured by the group led by Tsuji of ERI

Figure 5.7 shows the height of tsunami traces measured in our field survey. The green numbers are the height of tsunami traces, and the yellow numbers are the elevation of the ground. The tsunami height was measured with respect to the sea surface level at the arrival time of the first tsunami. The numbers in the parentheses is the trace heights above the ground.



Photo 5.3 Watermark on the first high school in Banda Aceh



Photo 5.4 A hole by collision of an obstacle and watermark

Banda Aceh City has developed on a flat area facing the sea. In the area 2km away from the near coast, the ground elevation was about 1m above the sea level when the tsunami arrived. Such a low-lying flat area was severely inundated and the seawater reached the inland areas several kilometers away from the coast.

5.5 Tsunami Damage

The expected all forms of damage from a tsunami were observed in this event. A wide band of the coastal zone was inundated and eroded by seawater, the impact and drag force of tsunami waves destroyed buildings, towns, cities, forests, fish farms, agricultural areas, infra-structures, industrial facilities, harbors and roadways, and killed both humans and animals. Although no nuclear or thermal power plants utilize seawater as cooling agent in Sumatra Island, the nuclear power plant in the east coast of India utilizing seawater as cooling agent source had to be stopped manually due to receding seawaters due to tsunami draw-down.

In coastal areas of Banda Aceh City where the 10m tsunami attacked, and the west coast of Sumatra Island where the 20m tsunami attacked, almost buildings were destroyed. However, some rigid buildings like mosques remained. The rigid and high buildings are useful as tsunami shelters especially in wide low-lying areas like Banda Aceh City in order to save human lives.

The tsunami swept away large bodies like a power plant barge and oil tanks. The power plant which generated 7,500 KW (Photo 5.5) was moored in a new ferry port of Banda Aceh, and was washed away by the tsunami action. Finally it reached the inland town 3km away from its original site. The watermark left in the inland town was 3m above the ground. The barge can easily drift if the water depth is greater than 3m.



Photo 5.5 Power plant barge (1,700 weight ton) removed in to inland area

In the vicinity of Krueng Raya, a port of Northern Sumatra, three oil tanks, which were almost empty, were displaced by the tsunami (Photo 9.2). A big tank was moved to the neighboring town 314m away from its original site. It had the diameter of 17.5m and the height of 11.0m. From the watermarks on the tanks, which were not swept and still remained at their original position, the tsunami higher than 4m attacked the tanks.

The tsunami eroded severely the north coast of Banda Aceh (Photo 5.2). Although there were protection measures by stones in this area before the tsunami, the protection works were completely destroyed and the reclaimed areas behind the protection works were eroded more than 1.5m in height (Photo 5.6), and then the topography was changed. The topographic change is also seen in the Thailand where a sandbar was eroded by the tsunami.



Photo 5.6 Eroded sandbar in the north coast of Banda Aceh

5.6 Tsunami Warning

No tsunami warning was issued in any country neighboring Indian Ocean although the scale and possibility of the tsunami was estimated by US Pacific Tsunami Warning Center, Japan and Australia. The officials at US Pacific Tsunami Warning Center seem that they tried to get in touch with authorities in the countries to be affected by the possible tsunami. However, they could not find anybody to inform. It seems that the seismograph of National Earthquake Center of Indonesia at Padang nearby the earthquake epicenter recorded the event. However the geophysicist on duty could not get in touch with the center in Jakarta. Although there could be no or very limited time for such a warning for Aceh Province, it is unbelievable that some warnings could not have been issued to other countries in spite of the availability of advanced communication options of this century. It is really a big SHAME for all people involved with the tsunami warning locally and internationally.

Reference

- Satake, K. (2005): December 26 Tsunami in Indian Ocean. Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology.
<http://staff.aist.go.jp/kenji.satake/Sumatra-E.html>
- UNOSAT (2005): Damaged primary roads and bridges along the western coast of Aceh Province. http://www.disasterscharter.org/graphics/dis/CALLID_079/
- Tsuji, Y. et al. (2005): Distribution of the Tsunami Heights of the 2004 Sumatra Tsunami in Banda Aceh measured by the Tsunami Survey Team led by Dr. Y. Tsuji.
<http://www.eri.u-tokyo.ac.jp/namegaya/sumatera/surveylog/eindex.htm>

(Author of this chapter: T. Tomita)