Surviving a Tsunami

Lessons from Aceh and Southern Java, Indonesia

United Nations Educational, Scientific and Cultural Organization

Intergovernmental Oceanographic Commission

Jakarta Tsunami Information Centre Unesco Office, Jakarta

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For bibliographic purpose, this document should be cited as follows:

IOC Brochure 2009-1 (IOC/BRO/2009/1): Surviving a Tsunami – Lessons to Learn from Aceh and Pangandaran Tsunamis
ISBN 978 979 19957 3 3

Printed by Jakarta Tsunami Information Centre (JTIC)

Published by the United Nations Educational, Scientific and Cultural Organization on behalf of its Intergovernmental Oceanographic Commission
7 Place de Fontenoy, 75 352 Paris 07 SP, France

This booklet can be downloaded for free, please visit: www.jtic.org

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Lessons from Aceh and Southern Java, Indonesia

Compiled by Eko Yulianto, Fauzi Kusmayanto, Nandang Supriyatna, and Mohammad Dirhamsyah

Examples from eyewitness accounts of Indonesian tsunamis in 2004 and 2006

United Nations Educational Scientific and Cultural Organization
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Jakarta Tsunami Information Centre Unesco Office, Jakarta
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Teteu	**Earthquake**
Teteu amusiat loga	Earthquake, the squirrel is singing
Teteu katinambu leleu	Earthquake, the rumble of thunder is coming from the hills
Teteu girisit nyau'nyau'	Earthquake, there are landslides and devastation
Amagolu' teteu tai pelebuk	Earthquake, the spirits of the seashells are getting angry
Arotadeake baikona	Because the mangroves have been knocked down
Kuilak pai-pai gou'gou'	The Kuilak bird is singing
Lei-lei gou'gou'	Chickens are fleeing
Barasita teteu	Because earthquake is coming
Lalaklak paguru sailet	People are fleeing

An evacuation, probably from a tsunami, concludes this poem from the Mentawai Islands, off the west coast of Sumatra. West Sumatra's history of damaging earthquakes and tsunamis extends in written records back to 1797 and in geologic records back to the middle 1300s. The word "teteu" usually means "grandfather," the usual reading of this poem, but can also mean "earthquake," as in the translation at right.

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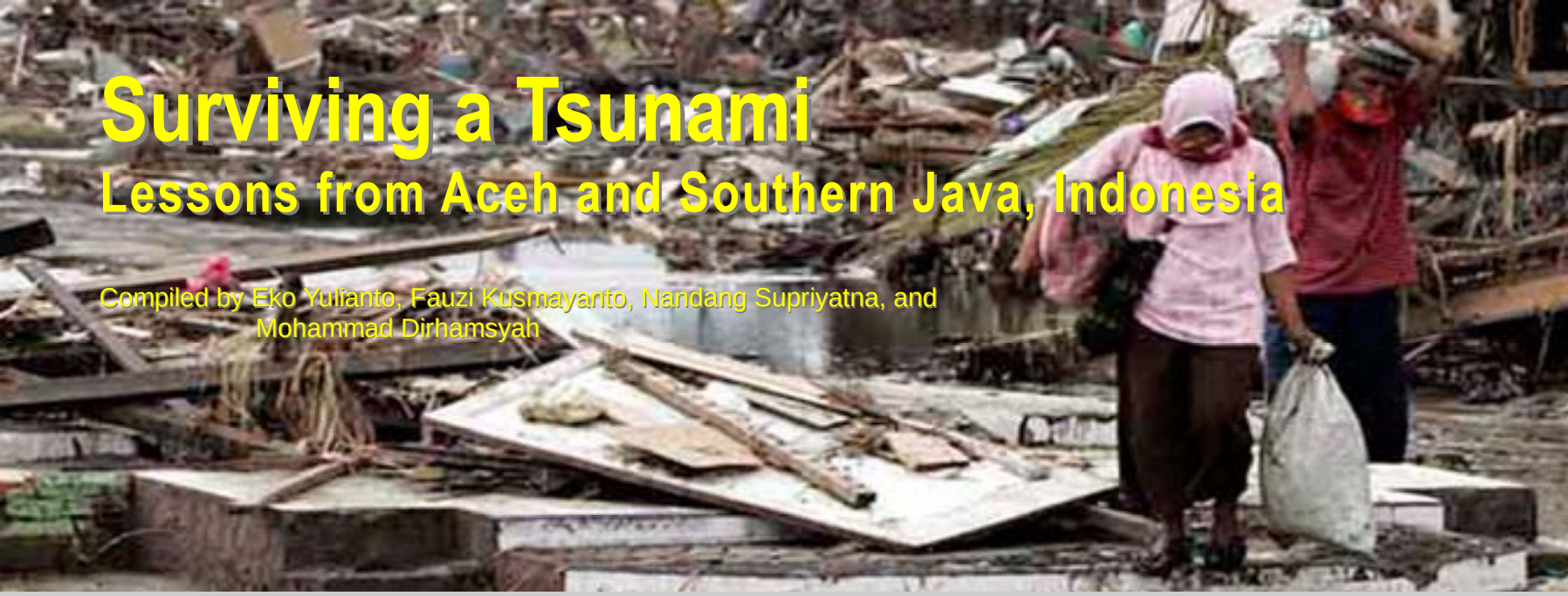

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Compiled by Eko Yulianto, Fauzi Kusmayanto, Nandang Supriyatna, and Mohammad Dirhamsyah

This booklet draws public-safety lessons from eyewitness accounts of Indonesian tsunamis. Above, aftermath of the 2004 tsunami in Aceh.

Introduction

Experience, says the wise man, is the best teacher. Often heard in Indonesia, this saying can mean learning from one's own experience, or it can refer to the experiences of others. Either way, the harder the experience, the more it tends to teach.

Hard experience in Indonesia offers lessons on how to survive, and how not to survive, the sea floods now known worldwide as tsunamis. The lessons in this booklet are drawn from the accounts of eyewitnesses to two Indonesian tsunamis: the catastrophe that took an estimated 160,000 lives in Aceh on December 26, 2004, and a lesser tsunami that left some 700 dead in Java on July 17, 2006.

The booklet originated as a UNESCO publication aimed at Indonesian audiences. Its eyewitness accounts are based on interviews by the compilers in 2005-2008 and on recollections reported in several Indonesian books. Written in Indonesian from an Indonesian perspective, this earlier version was published in print and on the internet as "Selamat dari bencana tsunami" ("Safe from tsunami disaster"). The adaptation here aims to make Indonesian experience more accessible to people who inhabit or visit tsunami-prone shores worldwide.

Hazards of Destiny

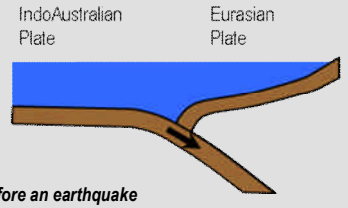
We Indonesians, by God's will, find ourselves on islands that sustain us but also put us in harm's way. The islands yield minerals, oil, gas, and coal. Their soils, enriched by beautiful volcanoes, nourish plants that feed and delight us. The surrounding seas provide fish and ports. But these same lands and waters are also rich in natural hazards. Tsunamis, along with the earthquakes, volcanic eruptions, and landslides at their sources, are part of God's gift for us to contemplate.

Scientists see tsunamis as predestined by plate tectonics—the motion of giant slabs of rock that form our planet's outer shell. In the simplified view below, Indonesia straddles sloping boundaries among tectonic plates: a continental one that includes most of Europe and Asia, and several that include floors of the Pacific and Indian Oceans. The oceanic plates descend, or subduct, beneath the continental plate. This subduction yields the fault ruptures and explosive eruptions that set off most of Indonesia's tsunamis. The plates themselves are moving about as fast as a fingernail grows. The motion, monitored by orbiting satellites, shows no sign of stopping.

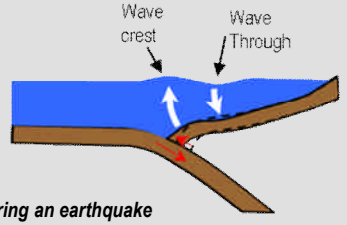
[Plate-tectonic map needed here. Or the reader can be referred to the page of index maps if these include a plate-tectonic map that would fully support the above text.]

Most Indonesian tsunamis originate near boundaries between the pieces of Earth's outer that have become known as tectonic plates. This global map names the main tectonic plates that meet within or beneath the archipelago. See [INDEX MAP PAGE] for a closer view.

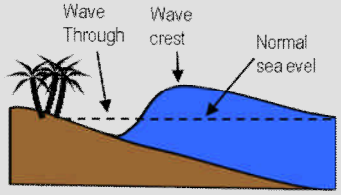
MAKING A TSUNAMI. A typical Indonesian tsunami begins during an earthquake on one of the archipelago's subduction faults. The fault conveys an oceanic part of Australian Plate beneath the overriding Eurasia. Between earthquakes, when the fault is locked, the downgoing oceanic plate drags the Eurasian Plate downward. When the fault breaks during an earthquake, the Eurasian Plate recoils upwards. The recoil suddenly displaces



Before an earthquake
As the Australian Plate slowly descends beneath Eurasia, it drags the leading edge of the Eurasian plate downward.



During an earthquake
Suddenly released, the Eurasian Plate springs back, raising the ocean floor. The water above also rises, setting off a tsunami.



During a tsunami
A tsunami wave grows taller as it approaches shore.

Matter of Minutes

Our country leads the world in tsunami losses. The Indonesian archipelago accounts for two-thirds of the tsunamis fatalities worldwide since the year 1800. Even without our greatest tsunami disasters—an estimated 160,000 deaths in Aceh in 2004, and 36,000 deaths from waves set off by 1883 eruptions of Krakatau— our sum of post-1800 tsunami deaths rivals the total from Japan and exceeds that for all of South America.

These grim superlatives owe much to the large numbers of us on low-lying shores. A recent United Nations report says that five million of us—two percent of Indonesia's population—inhabit places that tsunamis can reach. Many have no other place to live and feel that it may be their destiny to die from a tsunami. Some are ill-informed on tsunamis and how to survive them. Still, our nation's tsunamis pose daunting challenges of their own.

Originating just off our coasts, Indonesian tsunamis give less advance notice and tend to attack with greater force than on the distant shores they reach hours later. A typical Indonesian tsunami begins 100-200 kilometers from the nearest part of the archipelago, close enough for its leading edge to arrive in just tens of minutes. The 2004 tsunami began flooding mainland Aceh in 15-20 minutes and stopped clocks in Banda Aceh in 20-50. The leading edge of the 2006 tsunami took 40-60 minutes to travel from its source to the south coast of Java. By contrast, the 2004 tsunami reached Phuket in 2 hours, Chennai in 2½, Colombo and Maldives in 3, Diego Garcia in 5, Salalah, Oman in 7, Zanzibar in nearly 10. For decades in the Pacific Ocean, recordings of seismic waves and water waves have been triggering the broadcast of tsunami advisories. Such an advisory gives Hawaii 4 hours of advance notice of an Aleutian tsunami and 15 hours of warning of a tsunami from Chile.

Precious minutes from its main tsunami sources, we Indonesians cannot expect the hours of lead time that help make technological warnings effective. Experience in Aceh in 2004 teaches us to search history for forewarning and touse earthquake shaking as an immediate signal that a long-expected tsunami may finally be on its way. Experience in Java in 2006 tells us to heed other natural warnings in case the earthquake is so weak that people scarcely feel it. Whatever the kind of warning, experience teaches us how to behave as a tsunami approaches or arrives. The lessons in this booklet thus focus on warnings that nature provides and strategies for successful evacuation.

Tsunamis since 1800 have taken more lives in Indonesia than anywhere else on the planet. In part these losses result from travel times of several tens of minutes at most, examples of which can be inferred from clocks that tsunamis probably stopped. The clock at left, in Aceh, points to a time a little more than 20 minutes after the 2004 Aceh-Andaman earthquake, which began at 7:58 a.m. [replace with Lavigne photo? pinned to a particular place; if so, the endnote for this page will need a photo credit linked to reference 29]. The clock at right, found in Pangadaran, suggests that the tsunami stopped it 64 minutes after the 2006 earthquake off southern Java, which began at 3:19 p.m. These lags between earthquake origin and tsunami damage, by leaving little time for official warnings, make natural warnings and evacuation strategies key to tsunami survival in Indonesia.

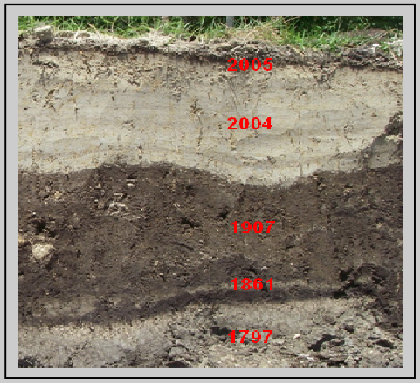
Infrequent Reminders

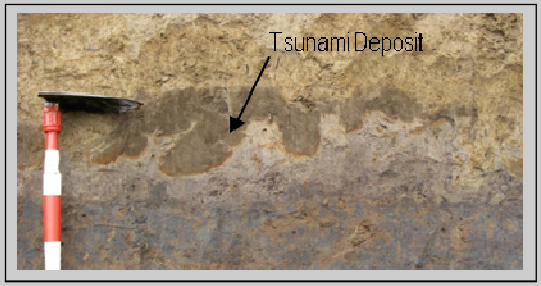
Repeatable history provides the earliest warning of future tsunamis. This warning system depends, however, on geological records that are easily destroyed and on human records that are easily lost or forgotten. Moreover, even a well-remembered past may span too little time to include a catastrophic tsunami, like the one in 2004, that takes many centuries to repeat.

Over 100 tsunamis are known from the last four centuries of Indonesia's written history. On average in the last decade and a half, a tsunami happened somewhere in the archipelago every other year. Yet the time between tsunamis at any one place commonly spans decades or even centuries. Such long times between successive tsunamis contributed to the recent tsunami losses in Aceh and southern Java.

In mainland Aceh the 2004 tsunami seemed without precedent. In 2004 nobody had yet unearthed geological evidence for a probably comparable tsunami between 1300 and 1450 (Thai example, bellow left). Nor did many people pay attention to written records of lesser tsunamis that reached Aceh in 1797, 1861, and 1907. And because Aceh had gone without a damaging tsunami since 1907, generations of mainland Acehnese lacked first-hand tsunami experience as a teacher. Such limited knowledge of the past helps explain why the waves in 2004 took so many by complete surprise.

Similarly before the 2006 tsunami in Java, tsunamis seemed to pose little threat to the coast near Cilacap and Pangandaran. The area's geological history includes a tsunami from centuries past, but its traces would not be found until after the 2006 tsunami had struck (photo below). A tsunami in the area's written history occurred in 1921, several generations before 2006. It still remains to be learned whether Java is subject to infrequent tsunamis as enormous as the one that took Aceh by surprise in 2004.





On most coasts, a damaging tsunami happens so rarely that a coastal family may escape this kind of disaster throughout the lifetimes of its grandparents, parents, and children—only to have the next generation caught unawares. Earth's own extended memory of its tsunami history, shown here as sheets of sand, can help remedy such amnesia. The Thai example, at left, shows the sand sheet from 2004 (light-colored layer at top) and three earlier sand sheets from the last 2,500-2,800 years, the youngest of these from the 14th or 15th century C.E. The middle example, from Simeulue, may extend as far back as a documented tsunami in 1797 and includes, at top, tsunami deposits from 2004 and 2005. The dark sand layer at right, exposed in a river bank near Pangandaran, probably represents a tsunami that has not been linked to written history in Java.

Surviving Traditions

Simeulue Island, off Aceh's west coast, offers lessons on surviving a near-source tsunami without technological warnings. Generated near the earthquake epicenter just 50 km from the island's north end, waves meters high reached most the island's shores a few tens of minutes after the shaking began. The islanders received no advance notice from radios, sirens, cell phones, or tsunami warning centers. Yet just seven people died. What saved thousands of lives was a combination of natural and traditional defenses: the island's coastal hills and the islanders' knowledge of when to run to them.

Islanders had passed along this knowledge, most commonly from grandparent to grandchild, by telling of *smong*—a local term that covers this three-part sequence: earthquake shaking, withdrawal of the sea beyond the usual low tide, and rising water that runs inland. Smong stories filled free time, taught good behavior, or provided perspective on a fire or earthquake. The teller often concluded with this kind of lesson: "If a strong tremor occurs, and if the sea withdraws soon after, run to the hills, for the sea will soon rush ashore."

Smong can be traced to a tsunami in 1907 that may have taken thousands of Simeulue lives. Interviews in 2006 showed islanders familiar with tangible evidence of the 1907 tsunami: victims' graves, a religious leader's earlier grave that the 1907 tsunami had left unharmed, stones transported from the foundation of a historical mosque, coral boulders in rice paddies.

Langi, barely 50 km from the epicentral area where the tsunami began, evacuated in 2004 with astonishing speed and success. The tsunami is said to have started coming ashore there 8 minutes after the earthquake.

The waves, reaching heights of 10-15 meters, swept houses off their concrete foundations. Yet none of the village's 800 residents died.

When Simeulue's system for early warning saved thousands from the 2004 tsunami, its only hardware consisted of reminders of a preceding tsunami, such as the mosque foundation, graves, and coral boulders pictured here. Storytelling reinforced by these reminders had taught the islanders to use earthquake shaking as a natural signal to run to nearby hills.

Earthquake Shaking

The astonishing success of Simeulue's evacuations in 2004 offers hope for any coast where a typical tsunami comes ashore in tens of minutes. Worldwide, and in Indonesia as well, a vast majority of tsunamis originate during earthquakes that can be felt on the coasts they will attack soonest and hardest. The earthquakes provide natural warnings to go to high ground, or inland, or into a tall building or tree.

In Banda Aceh, during the minutes between the earthquake and tsunami of 2004, people who gathered to look at collapsed buildings were probably unaware that a tsunami was about to enter the city.

At Simeulue it has become a kind of standard procedure to run to the hills whenever a strong earthquake is felt. The islanders especially take this precaution at night, when they cannot easily confirm a smong by watching for its next sign, recession of the sea. At Simeulue, a strong earthquake is sufficient reason to expect a tsunami.

By contrast in mainland Aceh, few heeded the giant 2004 earthquake as a tsunami warning. The shaking could not have gone unnoticed, for it damaged buildings, knocked people off their feet, and was said to have lasted ten minutes. When it was over, many people went outdoors, fearing further damage from aftershocks or just looking at buildings that had collapsed (see photos). Others just carried on with what they had been doing. Meanwhile the tsunami's clock was ticking—a countdown, from the initial earthquake shock, of just 20 minutes for mainland Acehnese coasts facing the tsunami source and a comparatively generous 45 minutes for downtown Banda Aceh.

The south coast of Java faces a more insidious tsunami threat. Twice in recent decades – in 1994 and again in 2006 – tsunamis were generated about 200 km offshore during large earthquakes that people on the nearest shores scarcely felt. The 1994 tsunami took 238 lives in East Java; the 2006 tsunami, described in this booklet, claimed more than twice that number. Another such a tsunami, in 1896, caused 22,000 deaths in northeast Japan, that country's greatest tsunami disaster. Confoundingly, tsunamis in south Java and northeast Japan can also follow earthquakes that are strong enough to serve as a natural warning that is unmistakable as well as immediate. In 1921, for instance, a tsunami attacked Java after an earthquake that was centered 250 km offshore yet was felt as far west as southern Sumatra and eastward to Sumbawa, a distance of nearly 1500 km.

Receding Waters

On many shores the first direct sign of the 2004 Indian Ocean tsunami was rapid withdrawal of the sea, or the draining of rivers near their mouths. Most of these shores are east of the tsunami's source, a mainly offshore area extending from Aceh northward to the Andaman Islands.

Rizal Seurapong didn't think tsunami as he watched the sea recede from Lambaro Beach, Aceh Besar, outside the city of Banda Aceh. He and his friend Anwar were amazed to see the water ebb away for a distance he reckoned as four kilometers. They watched fish flop on the exposed seabed. Not long after he heard the sound of an explosion from that direction—another natural warning of an incoming tsunami (next page). Rizal briefly glimpsed a giant black wave in the distance. He tried to flee but the wave caught up with him.

In the city itself, Katiman was carrying logs at a sawmill at the end of Krueng Cut Bridge, Krueng Raya. The earthquake threw Katiman and his coworkers to the ground. When the shaking stopped, they all ran out of the mill, heading towards the main Banda Aceh-Krueng Raya highway. There they saw the waters of the Krueng Lamnyong River suddenly drain away. Katiman decided to run to Alue Naga Beach, where the tsunami would catch him. At the beach the seawater had also receded, stranding fish.

Another who watched the seawater recede was Teuku Sajidin bin Teuku Ibrahim of Suak Timah, a neighborhood in the Samatiga sector of western Banda Aceh. He guessed that the water went out a kilometer and a half. It left fishing boats stranded on coral reefs.

Armanaidi saw river water ebb away moments after the shaking stopped. At the time he was about five hundred meters inland in Kuala, a neighborhood in Aceh Jaya district outside the city of Banda Aceh. Later, when Armanaidi returned to his house, he saw a man running, shouting that the sea was rising.

The 2006 tsunami also began, in Java, with withdrawal of the sea. Many people in Pangandaran saw the seawater recede after the earthquake and before the tsunami came ashore.

Loud Noise and a Looming Wave

Sharla Emilda binti Muhammad is one of many Acehnese survivors of the 2004 tsunami who reported hearing a booming sound, like an explosion, not long after the shaking caused by the earthquake had stopped. Sharla, who lived near the coast in Alue Ambang village, Aceh Jaya, thought she was hearing gunfire between an Indonesian army unit and separatists of GAM. The conflict had been going on for 28 years, since her childhood, so she paid no attention to the sound. But several minutes later she saw an ocean wave as high as a coconut tree. The wave was closing fast on the shore.

Emirza, on his boat off the coast at Ulee Lheu when he felt the quake, quite possibly witnessed the source of the explosion that Sharla and others heard. The first unusual wave lifted his boat onto its crest. There he was astonished to find himself looking at exposed bottom of the sea. The wave then crashed down on the sea floor, making a sound like an explosion.

A loud noise noticed at Pangandaran had a somewhat different cause. There, several people reported hearing the sound of an explosion when the tsunami wave crashed into the limestone cliffs.

Many of those who heard explosions also observed, minutes later, a giant wave on the horizon. In both Aceh and southern Java, all the tsunami survivors who witnessed a giant wave on the horizon ended up being swept away it, except for those having a nearby refuge.

If the wave is visible on the horizon, it may already be too close to escape by going inland or to high ground. The best course of action then may be to seek safety in a tall building, water tower, or tree (p. 13, 14, and 15).

Frightened Birds

A disaster can elicit stories in which creatures sense pending trouble before people do. Such accounts of the 2004 tsunami in Aceh often mention birds.

The morning of 26 December 2004 found Brigadier General Suroyo Gino, Deputy Commander of Civil Emergency Operations in Nanggroe Aceh Darussalam on his way from a military base in Banda Aceh to the city's main port, Malahayati. There he was to attend a farewell ceremony for 700 soldiers of Battalion 744 Kupang, who were that day finishing their tour of duty. On the way he saw a flock of white birds flying towards Banda Aceh. He turned back toward the base, thinking this unusual sight a warning something bad. He was already out of harm's way when the tsunami hit Banda Aceh minutes later. The soldiers of Battalion 744 Kupang also survived because they had not yet boarded the ship and were able to run to safety.

That same morning Surya Darma bin Abdul Manaf was at work in his *perahu*, a wooden canoe, a half kilometer off the Banda Aceh neighborhood of Deah Raya. He was pulling up fish traps he had set the day before. When rocked by a wave that felt unusual, he thought that an earthquake had just occurred. A couple of minutes later he saw a flock of cranes fly out of mangroves and head towards the hills, as if being pursued. Figuring something more was about to happen, he abandoned his fish traps and paddled the perahu to shore. A few minutes later, when he was about to start pulling crab traps from a pond, a thundering wave attacked the mangroves. He took refuge in a nearby tree, which withstood the first wave but was swept away by the second. Surya survived by clinging to a jerry-can that kept him afloat until the current carried him towards another tree, where he stayed through the rest of the tsunami.

Abandon Belongings

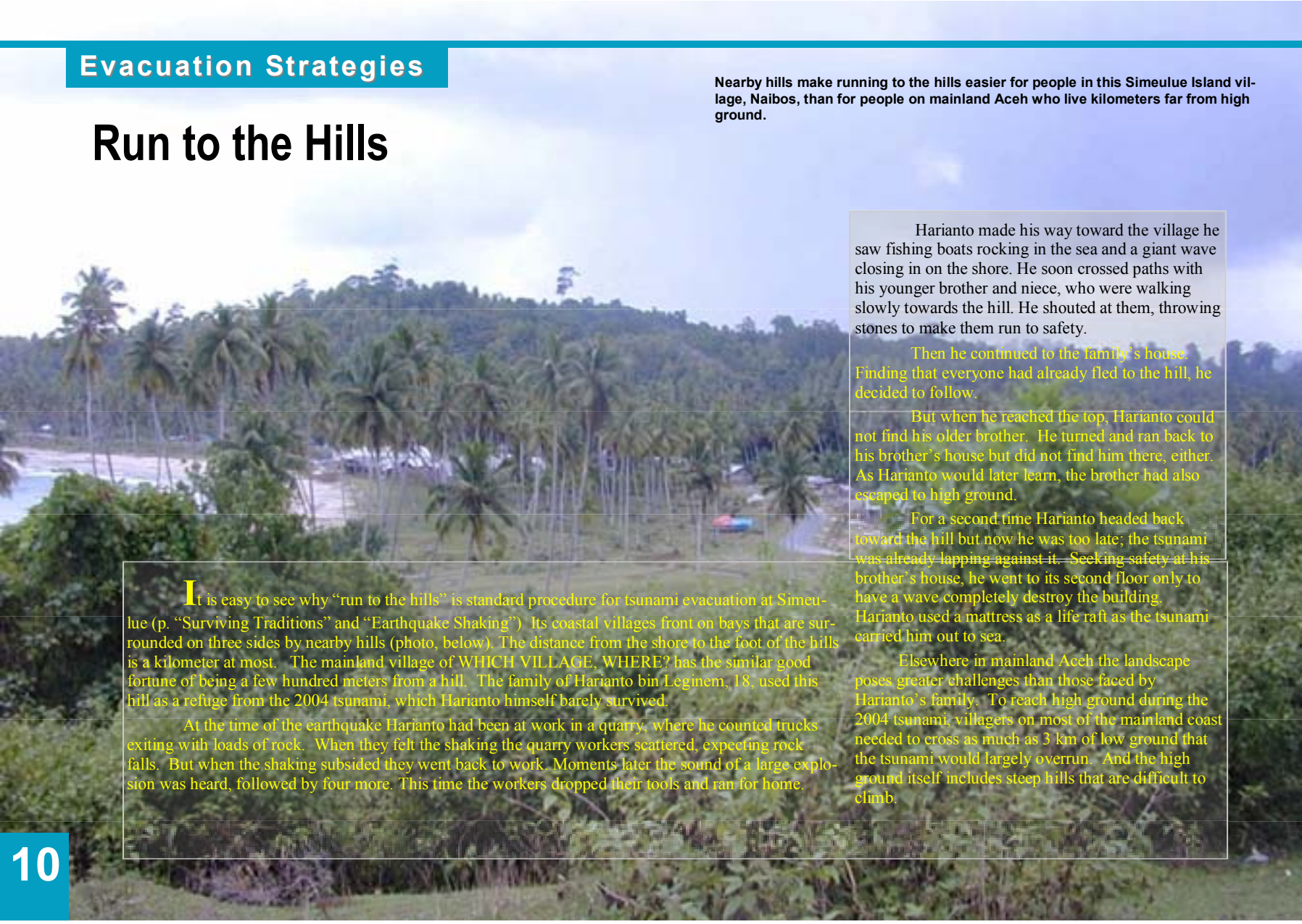
One of the seven tsunami victims on Simeulue Island was Lasamin, a 60-year-old man who knew to use an earthquake as a tsunami warning and evacuated accordingly. His fatal mistake was to value belongings more than his life.

Lasamin, a life-long resident of Sinabang, felt the ground shake strongly on 26 December 2004. Schooled in smong (p. 5), he and his wife got on their motorcycle and sped towards the hills. They reached the hills safely.

When waters of the first wave receded, Lasamin told his wife that he was going to retrieve some important documents left in their house. Perhaps he thought that there would be no more waves, or maybe he believed that if the water did rise again, he would be able to get there in time to save the documents and escape back to the hill. So he turned his motorbike back in the direction of the house.

On the way, he met his friend Sukran, 25. He asked Sukran to come with him. Both men doubted there would be enough time to get the documents before the next wave arrived. Sure enough, an incoming wave toppled the motorbike and Lasamin was flung to the asphalt. Sukran survived by swimming to and climbing a nearby tree, but Lasamin was later found dead.

Run to the Hills



Nearby hills make running to the hills easier for people in this Simeulue Island village, Naibos, than for people on mainland Aceh who live kilometers far from high ground.

It is easy to see why "run to the hills" is standard procedure for tsunami evacuation at Simeulue (p. "Surviving Traditions" and "Earthquake Shaking") Its coastal villages front on bays that are surrounded on three sides by nearby hills (photo, below). The distance from the shore to the foot of the hills is a kilometer at most. The mainland village of WHICH VILLAGE, WHERE? has the similar good fortune of being a few hundred meters from a hill. The family of Harianto bin Leginem, 18, used this hill as a refuge from the 2004 tsunami, which Harianto himself barely survived.

At the time of the earthquake Harianto had been at work in a quarry, where he counted trucks exiting with loads of rock. When they felt the shaking the quarry workers scattered, expecting rock falls. But when the shaking subsided they went back to work. Moments later the sound of a large explosion was heard, followed by four more. This time the workers dropped their tools and ran for home.

Harianto made his way toward the village he saw fishing boats rocking in the sea and a giant wave closing in on the shore. He soon crossed paths with his younger brother and niece, who were walking slowly towards the hill. He shouted at them, throwing stones to make them run to safety.

Then he continued to the family's house. Finding that everyone had already fled to the hill, he decided to follow.

But when he reached the top, Harianto could not find his older brother. He turned and ran back to his brother's house but did not find him there, either. As Harianto would later learn, the brother had also escaped to high ground.

For a second time Harianto headed back toward the hill but now he was too late; the tsunami was already lapping against it. Seeking safety at his brother's house, he went to its second floor only to have a wave completely destroy the building. Harianto used a mattress as a life raft as the tsunami carried him out to sea.

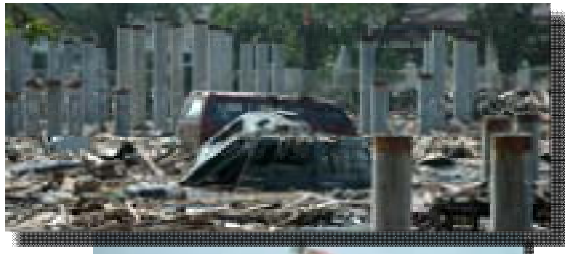
Elsewhere in mainland Aceh the landscape poses greater challenges than those faced by Harianto's family. To reach high ground during the 2004 tsunami, villagers on most of the mainland coast needed to cross as much as 3 km of low ground that the tsunami would largely overrun. And the high ground itself includes steep hills that are difficult to climb.

Stay out of Cars

An automobile is a death trap for its occupants and for others in an evacuation from a tsunami generated nearby. The earthquake minutes before is likely to have severed the road with fissures or blocked it with landslides. Even without such damage, the roads can become clogged by people on foot, and moving cars may injure these people and impede their progress. The tsunami itself may trap motorists inside their cars, as in these accounts of family tragedies in the city of Banda Aceh.

When Bukhari bin Abdullah, 45, in the neighbourhood of Alue Naga, heard people shouting that the seawater was rising, he ordered his wife and one of their sons into the family car. He drove them a few hundred meters before a wave turned it upside down and dumped it in a river. Bukhari managed to escape through a broken window, then stayed afloat by hanging on to a tire. But his wife and son remained trapped with the car, sinking with it to the river bottom.

Sujiman bin Abdullah, 57, some three kilometers inland in the neighbourhood of Jeulingke, also heard shouts that the sea was rising. Parked outside his house was his younger brother's car. He and his wife and their children got in. The car could barely move among the throngs of people on the road. An incoming wave 6 m high, sounding like the roar of an approaching aircraft, slammed into the car. The car began to fill with tsunami water. Sujiman tried to break open the doors and windows but was unable to do so. Meanwhile the water inside the car rose toward the ceiling. Sujiman and his wife managed to escape but one of their childen drowned inside the car.



The tsunami drowned the wife and child of Bukhari bin Abdullah, LEFT, by trapping them in a car that the tsunami had deposited in a river. The other photo shows another of the thousands of cars that became tsunami debris in Banda Aceh.

Avoid Rivers and Bridges

A river can be highway for a tsunami. Its smooth surface admits the incoming water more readily than does the roughness of houses and mangroves. Buildings beside the river tend to be swept away before those farther from the river banks. Bridges that cross the river may get swept away or, if strong enough, may dam up waterborne debris that can crush the people among it (photos, below). Boats and ships on the harbour would also be swept by ths wave and-would eventually hits and possibly destroyed bridges crossing the river (photo, lower middle).

Suwardi, farming in Widarapayung, East Cilacap, witnessed the deadly assistance that a river gave to the 2006 tsunami in Java. In Widarapayung there is a swale, parallel to the coast, that a sandy ridge separates from the sea. The swale contains a river flanked by fields of rice, fruit, and vegetables.

Suwardi was working one of these fields at the time of the 2006 tsunami. He did not notice the weak earthquake beforehand, and he had no chance to see a wave looming on the horizon because the sandy ridge blocked his view of the sea. When the tsunami took him by surprise it came from two directions—from across the ridge and from the river. He avoided getting swept away by pressing his feet against a stout coconut tree and by clutching, with his hands, a smaller tree beside it (photo, lower right). From this position, with the water rising to his nose, Suwardi watched the tsunami rush from the river into other farmed fields, where it carried people away.

The 2004 tsunami in Aceh destroyed some bridges and made others into dam for debris that probably crushed some of the victims found within it.

Braced in this position, against fast-flowing water up to his nose, Suwardi saw the 2006 tsunami near Cilacap carry people away along a river.

Climb a Tall Building

If, as on the coastal plains of Aceh, there are no hills nearby, a high part of a building may save your life from tsunami.

The 2004 tsunami trapped Mochtar A.R., Hasbi, Ibrahim, and Rohani on such a plain, in the Kajhu neighborhood of Banda Aceh. Mochtar heard three explosions just before seeing a wall of black water on the horizon. People jammed the road, blocking any traffic.

The first wave to reach Kajhu ran only knee deep but flowed fast. Children at first screamed happily, wanting to play in the water. Mochtar and Hasbi ordered them to run to the building of a newspaper, the Serambi Indonesia Daily, about 150 m distant.

Fifty-two people survived the 2004 tsunami by climbing up the stairs of the Daily building. Most took refuge on the second floor. Ibraham climbed higher, to just below the roof, afraid that the water would reach the second floor. The second wave was indeed higher than the first, and debris it was carrying caused the building to shake, but the building remained standing, and everyone who had made it to the second floor survived.

The Daily building allowed what has come to be known as vertical evacuation. Engineers have been sizing up buildings in the city of Padang, West Sumatra, for use in vertical evacuation from a tsunami expected there. Mosques in Aceh and water towers in Pangandaran offer lessons for designers of vertical evacuation structures. The 2004 tsunami caused little damage to many of the mosques in Aceh as its waters passed through the open structure of their ground floor. Likewise in Pangandaran, the 2006 tsunami passed harmlessly between the stilt-like supports of water towers while knocking down the walls of nearby houses (p. 14).

The photograph above shows the Serambi Indonesia Daily building. Fifty-two people survived by escaping to the second floor of this building. Among them were Mochtar, Ibrahim, Hasbi and Rohani (back row, right to left) and Rohani's children, Intan, Muhajirin and Magdalena (front, right to left).

Several two-storey buildings withstood the 2004 Aceh tsunami even though they were close to rivers.

A mosque and minaret survived the tsunami even though all the buildings around it were flattened.

Climb a Water Tower

The 2006 tsunami destroyed about 2000 buildings but spared most water towers. The towers were constructed on tall 'legs' or piles with the space in between left open. This construction allowed the water to pass through.

Had the towers been equipped with steps or ladders, they could have served as vertical evacuation structures. Most are taller than a two-storey building—above the heights where many people survived the 2004 and 2006 tsunamis by just getting to a building's second floor.

Water towers commonly survived the 2006 Pangandaran tsunami where adjoining houses were flattened.

Climb a Tree

People caught by a tsunami sometimes survive it by reaching and climbing trees. Some steer themselves toward the nearest tree, while others have the good fortune of drifting there by accident. Once in a tree, many people manage to hang on for the tsunami's duration.

Like so many others in Banda Aceh, Wardiyah could not help but notice the 2004 earthquake. Although her house in Kajhu stood 300 m from the shore, she heard none of the explosion-like sounds reported by others (p.8). She did, however, hear a sound like the roaring of a wind just before the tsunami washed over her. She was carried inland by the first wave, then out to sea by its backwash. Along the way she managed to grab a piece of wood that helped keep her afloat. The next wave moved her back onshore to a place near a kedondong tree (photos bellow). There she found herself standing in water just knee deep. But soon more water surged in, carrying her closer to the tree. She grabbed a branch and climbed to the tree top. Fearful of more waves she stayed in the tree several hours longer along with a man who had also taken refuge there.

Wardiyah and the kedongdong tree that saved her life in Banda Aceh during the 2004 tsunami

The 2006 tsunami found Teguh Sutarno on the beach east of Cilacap, in Widarapayung, collecting little clams to feed to his ducks. It was the season for that type of clam. Seeing something like a large swell on the horizon, he wondered what it could be. He waited, watching, until realizing it was a big wave. By then it was too late for an escape. The water first carried him into some bushes, where he remained until the second wave moved him to a group of tree stumps. During the third wave Teguh remembered hearing how people had survived the 2004 Aceh tsunami by climbing trees. He aimed for one of the many coconut trees nearby. Managing to reach and climb one, he held on while the tsunami flowed harmlessly beneath him. This strategy might not have worked in the parts of Aceh where the 2004 tsunami ripped out coconut trees by the roots.

Teguh Sutarno, carried inland by three waves of the 2006 tsunami near Cilacap, eventually found safety in a coconut tree.

Use Floating Object as a Life Rafts

Many of the survivors in Aceh, though caught by the tsunami and not necessarily able to swim, saved themselves by clinging to lumber, tree trunks, mattresses, refrigerators, jerry-cans, plastic bottles, tyres, and boats. Some drifted out to the open sea with their makeshift flotation devices, while others used them as ferries to trees or buildings. Many of those who survived had managed to climb atop the floating object. Merely holding on to it exposed the floating person to injury or death by other debris.

On the morning of the Aceh tsunami, eleven-year-old Taha bin Ilyas was helping his father plant mangroves along the shore in the Alue Naga sector of Banda Aceh. When the shaking stopped he headed home, his father staying behind to chat with friends. Not long after rearching home Taha heard a thundering sound coming from the direction of the sea, followed by shouts that the sea was rising. Taha, his brother, and mother rushed out of the house and joined the throng on the road. A giant black wave closed in, swallowing up all in its path.

This first wave moved Taha but a short distance before bringing him to a tree. He held on tight until the next wave broke his grip. This second wave submerged Taha beneath debris it was carrying. He struggled to the surface, saw a pillow, and clutched it.

This pillow kept Taha afloat through the rest of the second wave and through a third as well. After the backwash of the second wave carried him out to sea, the third wave sent him landward, only for its backwash to return him to the sea. All the while, Taha cast about for a better life raft, the now-soaked pillow having lost much of its buoyancy.

Now expecting to drown, Taha noticed a thick book among other, smaller debris. He grabbed it but kept hold of the soggy pillow, too. With both the book and the pillow his body felt lighter. Though still hoping to find something better, he managed to stay afloat until the sea ended his odyssey by washing him ashore some two hours later. Taha unsteadily made his way up the beach.

Expect more than One Wave

A tsunami is a wave train. Often, though not always, the first wave is not the biggest. And it is never the last. The 2004 tsunami reportedly contained five waves on Simeulue and around ten in Banda Aceh. The 2006 tsunami included three consecutive waves a few minutes apart.

Forty-year-old Nurdin bin Ahmad escaped one wave after the next during the 2004 tsunami. He lived in the Banda Aceh neighborhood called Peunaga Pasi. He and a companion, Amir bin Gam, were elsewhere in the city at a market, Simpang Empat Jeram, when the giant earthquake struck. After strong shaking ended Nurdin and Amir headed back toward Peunaga Pasi on a motorbike. Along the way they saw many buildings that the shaking had brought down or damaged. They were still a few kilometers from home when a chest-high wall of water knocked them over. Amir and his motorbike were swept away by the wave. Nurdin managed to stand up briefly but then he too was carried along. The water still rising, he grabbed hold of a block of peat about 2 m on a side and climbed on top of it. The block drifted towards a mangrove swamp and lodged in the trees.

Nurdin did not know that there were more waves to come. Some thirty minutes after the water subsided he climbed down from the peat block into chest-deep water of the swamp. He started home, jumping over fallen trees as he went. But he had not gone far before another wave approached. He climbed a tree and stayed there until its waters receded. He hopped down and walked on a bit only to climb again when another wave approached. Only after three such ups and downs did he manage to reach a main road. And even then the wave train kept coming, sending him up a coconut tree for one final climb.

Multiple waves also reached Asep on the eastern shore at Pangandaran as he tried to save his boat from the 2006 tsunami. He and his brother were making a fishing platform a hundred meters offshore when they felt the tremor. Soon they saw a wall of sea water approached. They could see three waves, one after the other. When the first wave smashed into the fishing platform they jumped into their boat. Asep cut the mooring rope, started the engine, and turned the boat around in hopes of slicing through the oncoming waves. As they tried to head south into deep water they battled waves reflected from shores to their east and west. They also nearly ran out of fuel. Their battle went on about two hours, until they headed safely back to shore around six o'clock in the evening.

Asep and his brother, in a boat off Pangandaran, won a two-hour battle against multiple waves of the 2006 tsunami.

If Offshore, Go Farther Out to Sea

As a tsunami approaches shore its great speed and wavelength get converted into height. So it is not surprising that fishermen, already at sea when the 2004 and 2006 tsunamis bore down on them, found safety by going farther seaward.

Emirza, a fisherman from Banda Aceh, found safety during the 2004 tsunami by working his boat into deep water and staying there. He barely escaped death from tsunami backwash that took him by surprise when he eventually returned to the port.

One of them, however, nearly fell victim to tsunami backwash and another lost a friend who had sought safety at the shore.

Emirza survived most of the 2004 tsunami while off Banda Aceh's Uleuleu shore. It was in those waters that the tsunami's first wave lifted his boat. Three more waves did the same thing. Each time Emirza struggled to keep the bow pointed at the incoming wave, and all the while he sought to get farther out to sea. Eventually he got there, waited for the sea to calm, and decided to head home to find his family. But just before he reached the harbor a torrent from the land drove the boat seawards and capsized it. Emirza survived by grasping an electric cable and climbing up a power pole. He stayed there until sea water had receded completely.

Budiyono and a friend were fishing about five hundred metres off the shore at Pangandaran when the first wave of the 2006 tsunami loomed on the horizon. At first Budiyono did not see it because he was facing toward land. The friend noticed the wave, but by the time Budiyono turned to see it the wave was fast approaching. The friend, in a separate boat, raced towards the coast. Budiyono headed out to sea even though it took all his strength to fight the incoming waves. Budiyono survived but the friend who had turned back to land did not.

Heading farther out to sea similarly helped Budiyono outwit the 2006 tsunami, which took the life of a fellow fisherman who had instead headed to shore.

Notes

A popular story in Java tells of a queen, Nyi Roro Kidul, who from time to time sends ashore a large wave that carries people out to sea. Occasionally the queen returns a few of them alive to tell of her existence. Similar stories are told elsewhere along the Sunda Trench, westward in the Mentawais and eastward to Flores. Do the legends have their origins in ancient Indonesian tsunamis?
(image source: http://javagodin.multiply.com/photos/album/8/Carriage_Javanese_Ratu_Kidul)

Frontispiece

The poem and a translation from Mentawai into Indonesian were provided by SUSPENSE [Eko will supply name, credentials, affiliations].

An earthquake and tsunami on February 10, 1797, begin the documentary history of earthquakes and tsunamis off West Sumatra[20, 37]. Natural records found in corals have helped to clarify and extend this history; the corals show the size and extent of the ruptures on the subduction thrust beneath the Mentawai Islands[35] while telling also of earlier breaks on this fault[46].

Maps that face the table of contents

SOURCES TO BE CITED

INTRODUCTION

According to EM-DAT[56], an international database on disasters, Indonesia's deaths from the 2004 tsunami total 165,708. The tsunami database maintained by the National Oceanic and Atmospheric Administration (NOAA)[12] gives a similar death toll, 165,659. (A global risk assessment published by the United Nations International Strategy for Disaster Reduction Secretariat (ISDR)[53], on its page 25, cautions against treating death tolls as exact, or even approximate in some cases, for disasters that preclude accurate counts.)

Notes

For the 2004 tsunami the NOAA database also lists fatalities from eleven other countries: Sri Lanka, 35,322; India, 18,045; Thailand, 11,029; Somalia, 289, Maldives, 108; Malaysia, 75; Myanmar, 61; Tanzania, 13; Seychelles, 3; Bangladesh, 2; and Kenya, 1. EM-DAT gives similar numbers except for India, 16,389, and Thailand, 8,345.

The 2006 tsunami probably took about 700 lives, all of them in Indonesia. Figures from Indonesia's Ministry of Health, tabulated in a 2007 analysis by geodesists from Indonesia and Japan[21], sum to 668 dead and 65 missing. Other estimates of the total number of deaths: 373 according to the NOAA database[12]; at least 600, according to a international post-tsunami survey team[16]; and 802 according to EM-DAT[56]. The total of 414 died in Pangandaran and vicinity, the area where most of the fatalities occurred, according to a detailed list provided by local authorities to a joint New Zealand – Indonesia post-tsunami survey[11].

In content and format the booklet is modeled on a collection of eyewitness accounts of the 1960 Chilean tsunami[2]. The booklet's Indonesian version, "Selamat dari bencana tsunami", was first published in 2008 by UNESCO's Jakarta Tsunami Information Center (JTIC)[14]. The version here, based on an English translation by Eko Yulianto, contains editing and provisional endnotes by Brian F. Atwater of the U.S. Geological Survey, prepared in 2009 while he was in Indonesia as a Fulbright Scholar. It also contains text editing by Sally E. Wellesly and layout by Ardito M. Kodijat of JTIC.

Eleven of the eyewitness accounts from Aceh were adapted from a provincial archive office's collection of survivors' stories[5]: Rizal, Katiman, Teuka, and Armandi (p.8), Sharla (9), Surya (10), Harianto (12), Bukhari and Sujiman (13), Taha (18), and Nurdin (19). Eko Yulianto further interviewed Katiman, Teuka, Bukhari, and Sujiman. The booklet also draws on a separate collection of dozens of essays and stories from Aceh[8] (Suroyo, p. 10), and on a collection of newspaper accounts of the 2006 tsunami in southern Java[15].

Previously unpublished material in the booklet comes from interviews by Eko Yulianto and Nandang Supriatna at Simeulue Island and mainland Aceh in 2005, 2006, 2007 and 2008, and in Pangandaran and Cilacap in 2006, 2007 and 2008. Most of the photos were taken by Muhammad Dirhamsyah (cover and p. [old 1, 6, 9, 13]) and Eko Yulianto (p. [old 3, 5, 7, 8, 10-14, 16-19]).

Hazards of Destiny

The ISDR report[53] ranks Indonesia first in number of people exposed to tsunamis. The report also places Indonesia among the six nations facing the greatest losses of life from the combination of tropical cyclones, floods, earthquakes, and landslides (the others are Bangladesh, China, Colombia, India, Myanmar). The report relates these risks of death not just to the natural hazards but also to population, standard of living, governance, environmental quality, and climate change.

Standard references on Indonesia's plate-tectonic hazards include a journal article on historical earthquakes in Sumatra and Java[37] and a monograph on the 1883 Krakatau eruptions and the tsunamis they spawned[47]. A new book in Indonesian provides a well-illustrated overview of the country's earthquake and tsunami hazards[50]. Scientific journals provide frequent updates on Global Positioning System measurements of Indonesian plate motions[48], which include contortion of the eastern part of the archipelago[49] and extraordinary displacements that occurred during and soon after the giant 2004 Aceh-Andaman earthquake[51].

Often misrepresented as radiating from this earthquake's epicenter, the 2004 tsunami resulted instead from sudden warping of the ocean floor in an area extending 1,500 km northward along the trench from northern Sumatra to the Andaman Islands and beyond (map facing the table of contents)[9]. This enormous rupture length, greater than any other in the last 100 years or more, helps explain why the 2004 Aceh-Andaman earthquake approaches the greatest of all instrumentally recorded earthquakes, giant Chilean mainshock of 1960, on the "moment magnitude" scale that seismologists now use to express earthquake size[27].

Matter of Minutes

Death tolls from Indonesia's tsunamis after 1600 were tabulated a decade ago by Indonesian and Japanese researchers[20]. The comparisons with fatalities in other parts of the world is based on figures in the NOAA database[12]. The travel times for the 2004 and 2006 tsunamis in Indonesia are from reports of post-tsunami surveys in mainland Aceh[7,29], on Simeulue Island[30], and in Java[16]. Stopped clocks and tsunami videos give evidence for a roughly 45-minute travel time in central Banda Aceh according to a French and Indonesian group that reconstructed the tsunami's chronology from comprehensive field observations[29].

Sea-level gauges[32] and computer simulations[52] show how the 2004 tsunami spread across the Indian Ocean, continued into the Atlantic, and leaked into the Pacific. It registered on tide gauges as distant as Valparaíso (24 hours after the earthquake), Hilo (27 hours), Bermuda (28 hours), and Kodiak, Alaska (39 hours). The 1946 Aleutian tsunami, which spurred the first efforts to provide advance warning of tsunamis generated on the Pacific Rim, took about 5 hours to reach Hawaii[45]. The 1960 Chilean tsunami reached Hawaii in 15 hours[13] and Japan in just under a full day[2].

Indonesia officially inaugurated a national tsunami-warning system in November 2008 (http://www.thejakartapost.com/news/2008/11/11/new-system-give-nearimmediate-tsunami-warnings.html). As with such systems in Japan and the United States, the initial cue is an undersea earthquake detected by seismometers[55]. The seismic waves, by traveling tens of times faster than tsunami waves, make possible initial warning messages within several minutes. Water-level gauges on the coast and offshore are then to show whether a tsunami has been generated, after time lags still under evaluation.

Infrequent Reminders

The sand beds in the Thai photo further suggest that a total of four Indian Ocean tsunamis like the one in 2004 have occurred since 2,500-2,800 years ago, for an average recurrence interval of 800-900 years or less[25]. Geologic evidence for predecessors to the 2004 tsunami has also been reported from West Aceh near Meulaboh[33] and from India in the Andaman and Nicobar Islands[41, 42] and south of Chennai[40]. The sand beds in the photos from Simeulue and Pangandaran await dating and intepretation in scientific publications.

Multiple centuries typically separate back-to-back earthquakes recorded geologically at several other subduction zones including Sumatra[46], south-central Alaska[39], Cascadia[3, 18, 36], Hokkaido[34, 44], and south-central Chile[10]. At these zones, unknown fractions of the centimeters per year of motion between tectonic plates becomes, eventually, seismic slip in the zones' largest earthquakes. The motion, like money put in a savings account every payday, can take centuries to yield the average slip of 10 or 20 meters that is typical of giant earthquakes.

For the subduction zone that slants beneath Java it is an open question whether earthquakes the size of 2004 Sumatra-Andaman, magnitude 9.1-9.3, can happen there at all[31]. The zone's largest earthquakes measured by seismology[6,37] are the ones that led to an estimated 250 tsunami deaths in East Java in 1994 and the roughly 700 deaths farther west in 2006. At moment magnitude 7.8 and 7.7, respectively, these earthquakes had less than 1/1000th the size of the 2004 earthquake (each whole number increase in the logarithmic scale of earthquake magnitude corresponds to a nearly 32-fold increase in seismic moment, a linear measure of earthquake size[26]).

Surviving Traditions

The saving of thousands of lives by tsunami education at Simeulue has been documented most thoroughly by Indonesian researchers[23]. A brief account of the remarkably fast evacuation of Langi appears in a collection of scientific and engineering papers on the 2004 tsunami[30]. The same collection contains an analysis by geologists and psychologists of natural warnings of the 2004 tsunami in Thailand[19].

In a widely known celebration of traditional knowledge about tsunamis, a Greek-American journalist fictionalized an evacuation by Japanese villagers well-practiced in using an earthquake as their cue to go to high ground. In the journalist's dramatic retelling[22], none of them know to take this cue except for an elderly man steeped in traditional knowledge. Too far away to be heard, the man lures the clueless villagers to high ground by torching all of his freshly harvested rice. The earthquake that he notices is weak, like the real earthquake whose stealth tsunami killed 22,000 people in northeast Japan in 1896. The story, published soon after that disaster and known in Japanese as "Inamura no hi" ("The rice-sheaf fire"), brought the word "tsunami" into the English language[4].

Durable monuments, a common reminder of past tsunamis in Japan[4], now tell of the height, extent, and swift arrival of the 2004 tsunami in mainland Aceh[24]. The monuments consist of reinforced concrete poles at 85 places in Banda Aceh and vicinity. The height of each pole gives the estimated maximum height of the tsunami. A plaque at the base of each pole gives the time of the earthquake and an estimate of the time of the tsunami's arrival.

Earthquake Shaking

The combination of feeble shaking from the 1994 and 2006 Java earthquakes poses a challenge for official tsunami warnings as well as for natural ones. Tsunami-warning centers make rapid estimates of earthquake size as a first clue to tsunami potential. Earthquake size is estimated most readily by measuring what Emile Okal calls "treble notes", the high-frequency waves that people feel. The 1994 and 2006 earthquakes, however, contained a lot of "bass notes." For much the same reason that people scarcely felt these earthquakes, a seismologist could underestimate their size by neglected their low-frequency content. Seismologists have come up with work-arounds that tsunami-warning centers are evaluating[28, 54].

The widely felt 1921 earthquake off Java resulted from faulting within the Australia plate seaward of the Sunda Trench[37]. Unlike the 1994 or 2006 Java earthquakes, and also unlike the 2004 Aceh-Andaman earthquake, it did not result from sudden slip on the boundary between this plate and the overriding Eurasian plate.

Notes

Receding Waters

The initial withdrawal in Aceh, uncommon to the west in peninsular India and Sri Lanka, resulted from the tsunami's initial shape: an elongate ridge a few meters high flanked on its east by a parallel trough[17]. This ridge and trough at the sea surface mimicked warping of the sea floor, a warping produced by the fault slip that also produced the earthquake itself. The sea floor raised the sea surface where the leading part of the overriding tectonic plate ran up the rupture on the sloping fault plane. The sea floor lowered the sea surface where this sudden slip stretched, and consequently thinned, the trailing part of the overriding plate. The downwarp included the northwest coast of Aceh[29].

The pairing of uplift over the shallow part of a thrust fault and subsidence over the adjoining, deeper part was first mapped 40 years ago on shorelines raised and lowered during the great 1964 Alaska earthquake[38].

Loud Noise and Looming Wave

After hearing the explosive sound, Emirza found his boat nearly dragged under by the wave. Four later waves nearly prevented him from steering to safety farther offshore.

Climb a Tall Building

A reconnaissance study of structures damaged in Banda Aceh blamed tsunami-related damage on water pressure from the tsunami and on the impact of debris that the water carried. The report[43] concluded that "the damaging effects of the tsunami were most pronounced in unreinforced masonry walls, nonengineering reinforced concrete buildings, and low-rise timber-framed buildings". Regarding the city's mosques, the same report described them as supported by circular columns of high-quality reinforced concrete that resisted seismic loads. These columns limited the damage that the mosques sustained before the tsunami attacked them.

Recommended designs for vertical evacuation structures in the United States are intended to allow a tsunami to pass through ground floors without damage to supporting columns, braces, or walls[1]

Climb a Water Tower

"A report by the National Coordination Agency for Disaster Mitigation of Indonesia on property damage issued on August 1st, 2006 [two weeks after the 2006 tsunami], stated that 1,986 buildings (including hotels, residential and government buildings) were destroyed..."[21]

Climb a Tree

A tsunami in 1611 carried a boatload of fishermen and samurai end into a pine tree, according to an account that includes the earliest known use of the word "tsunami" in Japanese. The account appears in a January 1612 entry in "Sumpuki," a diary attributed to an aide to the founding Tokugawa shogun[4].

Expect More Than One Wave

After getting down from the coconut tree after walking through knee-deep water along the remains of the road to his village, Nurdin bin Ahmad eventually met up with fellow survivors from Peunaga Pasi. Fifty of them passed Sunday night in the forest. The next day they went back to their destroyed neighborhood to search for corpses.

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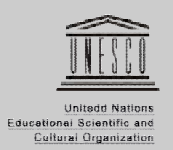

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