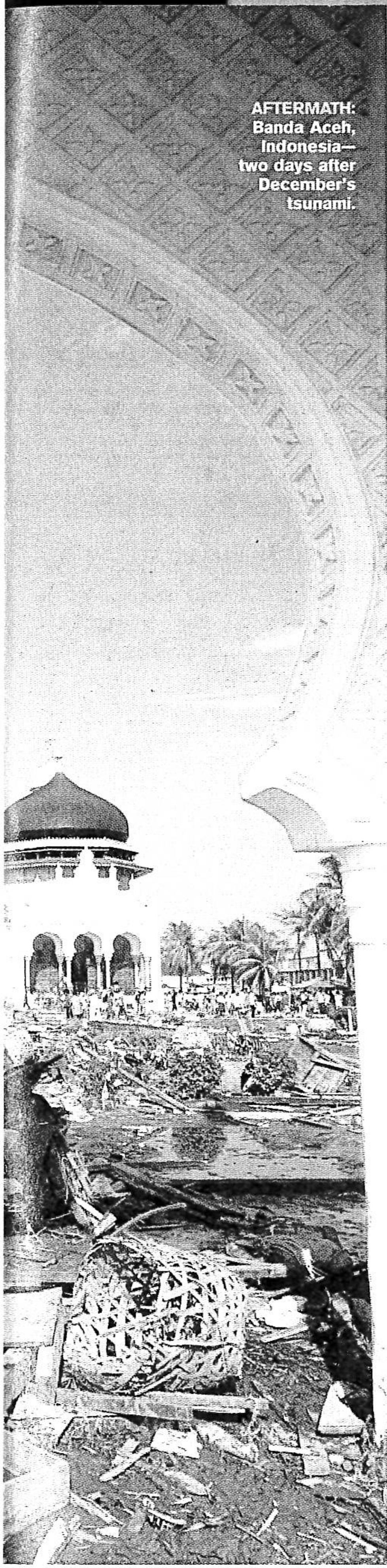
HOW DID THIS HAPPEN?

By Ken Kostel

Scientists try to unravel what caused the devastating tsunami last December



AFTERMATH: Banda Aceh, Indonesia—two days after December's tsunami.

December 26, 2004, showed signs of being a pleasant day in Sumatra, Indonesia. The tropical skies were clear, and the Indian Ocean surrounding the island was warm. But at 8:00 a.m., the seafloor off Sumatra's northwest coast suddenly buckled, generating a massive earthquake—the largest in 40 years. The quake triggered a *tsunami*, or a series of powerful ocean waves, that flooded the coastline of a dozen countries in Southeast Asia, South Asia, and parts of East Africa. When the water receded, the devastation surfaced: Many coastal communities had been destroyed. More than 280,000 people were dead or missing.

"Something like this is unparalleled in recent history," says Emile Okal, a *seismologist* who studies earthquakes, at Northwestern University. In the last century, only seven tsunamis are known to have resulted from earthquakes beneath the Indian Ocean. None of these rare events were very large or caused significant damage. That's why no one anticipated last year's tsunami—and the severe devastation that it brought. "The bottom line is we can't predict tsunamis," says Okal.

UNPREDICTABLE EARTH

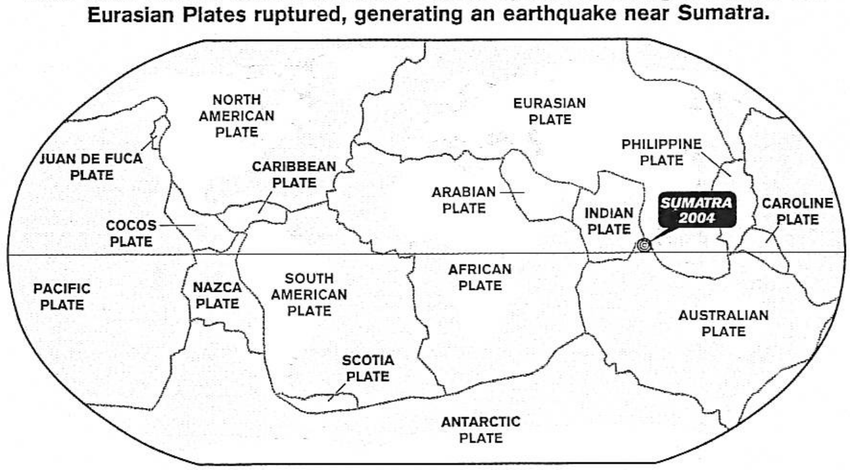
Tsunamis are difficult to predict because they mainly form after an extremely strong underwater earthquake. Since quakes happen out of sight, deep within Earth, scientists have yet to find a method to pinpoint when or where one will occur.

An underwater earthquake begins below the seafloor, in a part of Earth's hard *crust*. This outer layer of the planet is composed of a jigsaw puzzle of rocky slabs called *tectonic plates* (*see map, below*). "Earth is like a hard-boiled egg with a cracked shell, except that the pieces [of Earth's shell] are moving," says Steven Ward, a geophysicist who studies the physics of the earth, at the University of California, Santa Cruz. These tectonic plates float on the *mantle*—a layer of hot, gooey rock—and rub against each other along boundaries called *faults*.

Earth's plates move about 8 centimeters (3 inches) per year. But this

EARTH'S MOVING PLATES

Earth's crust is composed of *tectonic plates*. These rocky slabs push against each other at *fault* boundaries. Last December, the fault along the Indian and Eurasian Plates ruptured, generating an earthquake near Sumatra.



BANDA ACEH: DIMAS ARDIAN/GETTY IMAGES; MAP: JIM MCMAHON FOR SCHOLASTIC INC.

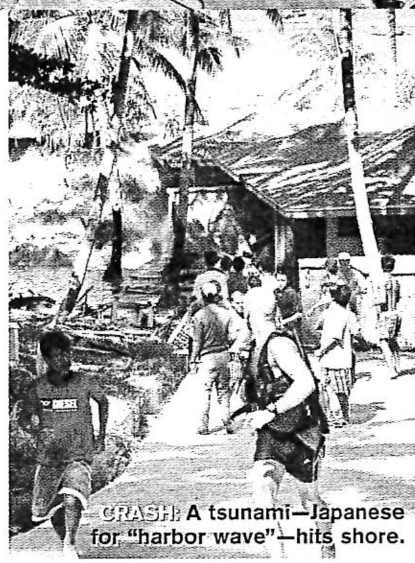
AWASH: December's tsunami raced through a Sri Lankan village.

movement creates *stress* (force that acts on rock, causing it to bend) along the tightly locked faults. When the stress becomes too intense, the faults rupture. The rocks on either side of the fault violently move by each other.

Starting at the *focus*—or the point where the rocks first break—then moving all along the fault, *seismic waves* are released. These vibrating energy waves travel in all directions through the earth. The Indian Ocean quake registered a staggering magnitude of 9.3 on the *Richter scale*, a measure of the strength of the earthquake's seismic waves. "Earthquakes like last December's cause a lot of shaking," says Ward. "But it's not the shaking that makes a tsunami."

WAVE MAKER

What makes a tsunami? The Indian Ocean earthquake occurred between the Eurasian and Indian plates along a *subduction zone*, an area where one plate tries to dive beneath another. When this *thrust fault* ruptured, it caused the plate on top to snap upward. A piece of the Eurasian Plate—about 1,000 kilometers (600 miles) long and 100 km (60 mi) wide—was pushed up as much as 10 meters (30 feet). "If you have that much vertical movement in the [seafloor], you are going to move a lot



CRASH: A tsunami—Japanese for "harbor wave"—hits shore.

of water," says Okal. "And that water has to go somewhere."

The displaced seafloor pushed the column of water above it upward, but the attractive force of *gravity* quickly pulled the bulged ocean surface back to sea level. That jolt pushed waves outward in all directions (*see diagram, p.15*). The waves raced along the depths of the Indian Ocean at nearly 800 km (500 mi) per hour. Then the waves met the sloping incline of the seafloor, known as the *continental slope*, and approached shallow water near shore. This caused the waves to slow down, and their peaks to scrunch together and get taller. When the tsunami hit shore, eyewitnesses in Southeast Asia saw walls of water towering as high as 12 m (40 ft).

UNCOMMON WAVES

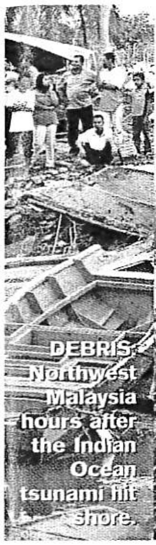
But not every strong underwater quake produces a massive tsunami, which makes predicting tsunamis even more difficult. Just two days before the Indian Ocean tsunami occurred, a magnitude 8.1 earthquake—the strongest of the year at the time—rumbled through the seafloor of the Southern Ocean.

As powerful as that quake was, all it did was shake the ground of desolate Macquarie Island approximately 400 km (250 mi) away, startling a few resident penguins. It also produced a 20 cm (8 in.)-tall tsunami in New Zealand—which is located approximately 1,100 km (700 mi) away.

Why such a small wave? The quake occurred along a *strike-slip fault*, where two plates grind against each other in opposite directions. "Strike-slip faults are much less efficient at making tsunamis than thrust faults," says Ward. When the fault ruptured in the Southern Ocean, the two plates suddenly jolted sideways in opposite directions. There was very little vertical movement in the crust, so little water was displaced. Most of the energy just went into shaking rocks.

LIFEGUARD

Scientists routinely use *seismometers* to monitor for seismic waves



DEBRIS: Northwest Malaysia hours after the Indian Ocean tsunami hit shore.

CLEANUP: Elephants help clean up the devastation in Thailand.

WEB EXTRA
For more on the science of tsunamis, visit: www.pmel.noaa.gov/tsunami

released by earthquakes. Although some scientists detected the Indian Ocean quake, no one saw the tsunami coming—and no one warned people to evacuate the shores.

Tsunami scientists usually focus their attention on the Pacific Ocean. That's because the area that borders the ocean, dubbed the "Ring of Fire," contains most of Earth's subduction zones. That is where 90 percent of all tsunamis occur. In fact, that is why the Pacific Ocean has the only network of sensors that detects and warns scientists of the changing water levels and pressures associated with a tsunami.

Scientists are now studying records of how the Indian Ocean tsunami traveled through the water and exactly where it hit. They hope the information will help them design a tsunami detection and warning system for the Indian Ocean, and make last December's tsunami the final one to claim so many lives.

It's Your Choice:

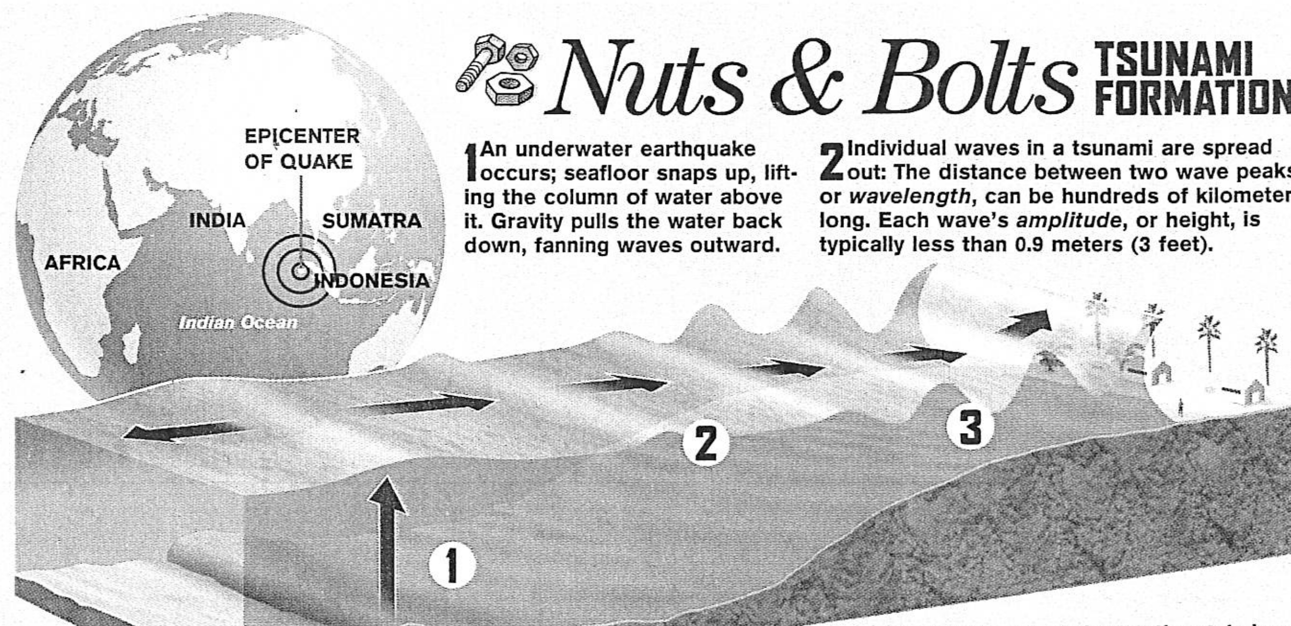
1 Earth's crust floats on the
- Ⓐ mantle.
- Ⓑ core.
- Ⓒ subduction zone.
- Ⓓ tectonic plates.

2 Last December's Indian Ocean earthquake occurred along a _____ fault.
- Ⓐ subduction
- Ⓑ thrust
- Ⓒ strike-slip
- Ⓓ tectonic

3 When a strike-slip fault ruptures, plates on either side of the fault
- Ⓐ snap upward.
- Ⓑ dive under each other.
- Ⓒ jolt sideways in opposite directions.
- Ⓓ spread far apart.

4 Tsunami sensors located in the Pacific Ocean do NOT monitor
- Ⓐ water pressure.
- Ⓑ water level.
- Ⓒ tsunamis.
- Ⓓ algae count.

Nuts & Bolts TSUNAMI FORMATION



1 An underwater earthquake occurs; seafloor snaps up, lifting the column of water above it. Gravity pulls the water back down, fanning waves outward.

2 Individual waves in a tsunami are spread out: The distance between two wave peaks, or *wavelength*, can be hundreds of kilometers long. Each wave's *amplitude*, or height, is typically less than 0.9 meters (3 feet).

3 As waves meet the continental slope and shallower water, wavelength decreases and amplitude rises.