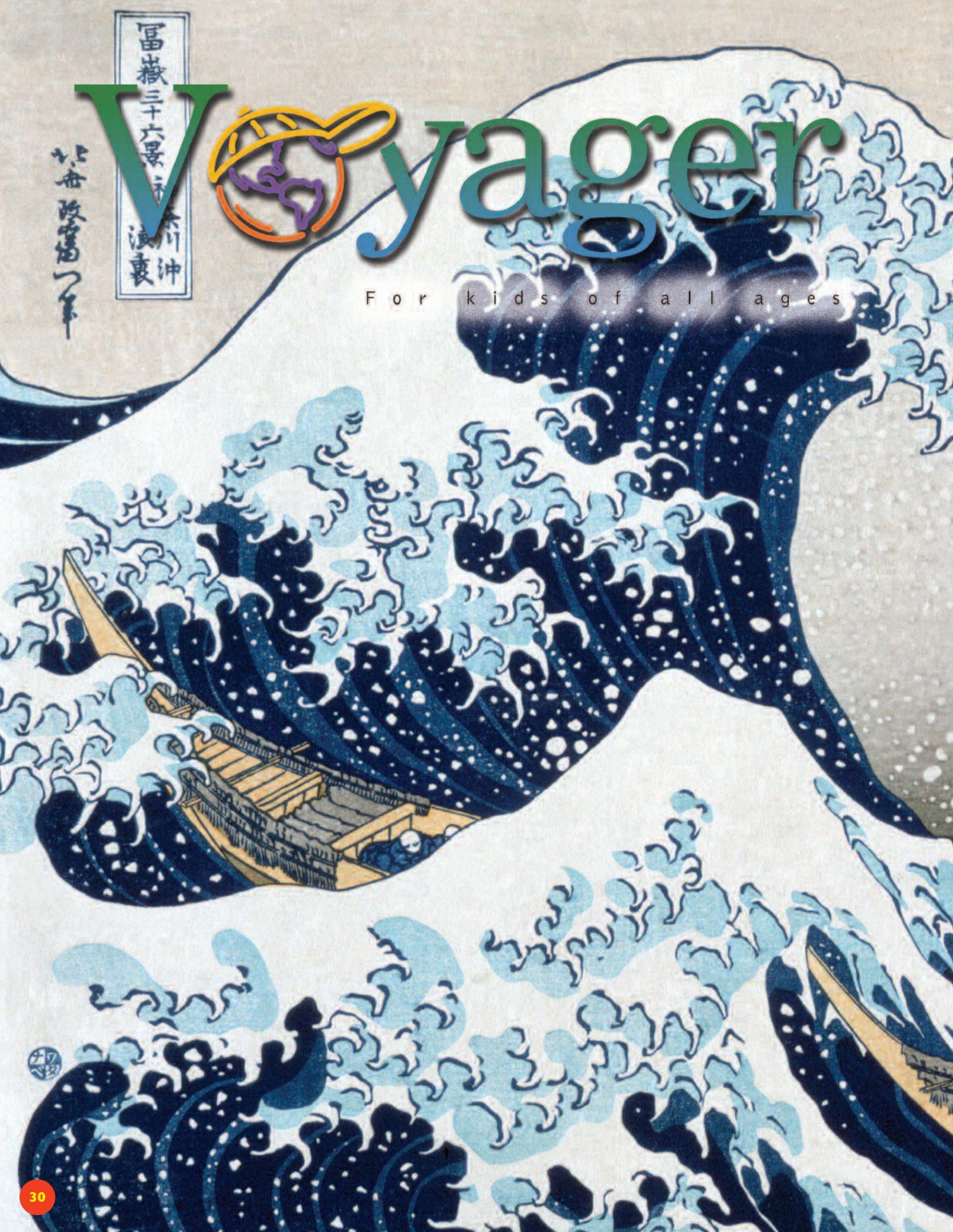


富嶽三十六景  
神奈川沖  
浪裏

大船渡り

# Voyager

For kids of all ages



# T S U N A M I

## OUT OF THE BLUE



It's no ordinary day at the beach when ocean water suddenly pulls out to sea, leaving flopping fish and stranded boats along the shore. When a huge wave hits just moments later, plowing over small buildings and everything in its path, that's not business as usual either.

But it happened on December 26, 2004, when a series of waves appeared out of the blue and killed more than 250,000 people who were living at or visiting coastal areas of the Indian Ocean.

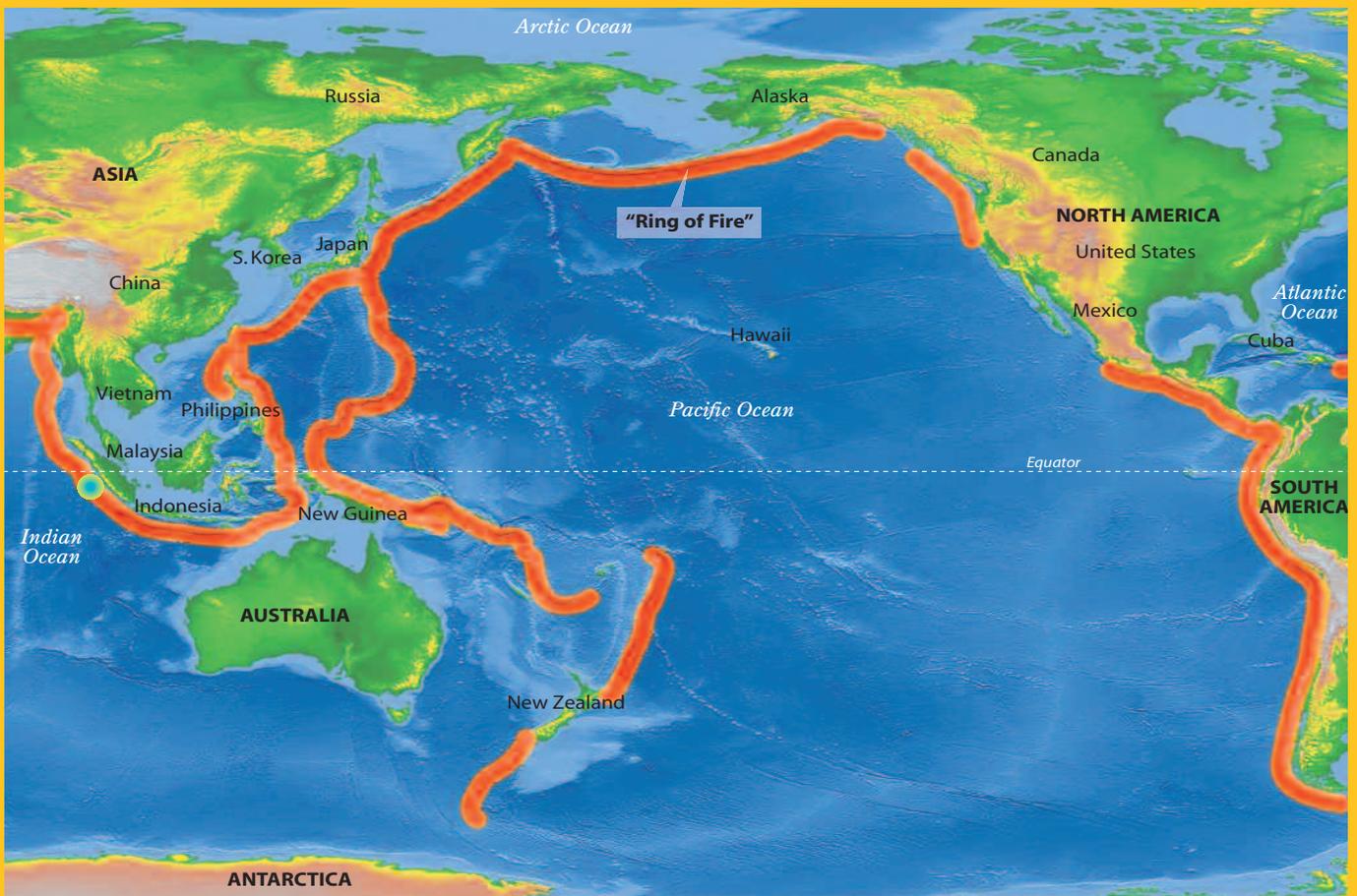
These deadly trains of waves are called tsunamis (tsoo-NAH-mees)—a Japanese word for “great harbor wave.” Tsunamis are capable of moving across entire oceans at speeds greater than 500 miles an hour. That's as fast as a jet airplane. The recent Indian Ocean tsunami, which was triggered by the great Sumatra earthquake, raced around the world from the epicenter of the earthquake and arrived in places as far away as New Jersey 32 hours later.

### What Is a Tsunami?



Although often called tidal waves, tsunamis have nothing to do with tides and they are not driven by the wind like everyday waves at the beach. They are caused by movements of the earth under the sea—such as earthquakes, undersea landslides, and undersea volcanic eruptions—or by impacts of objects from outer space—such as asteroids or comets. Like a pebble dropped in a pond, these events unleash a series of waves that radiate outward in widening circles. All of these events generate tsunamis by displacing water rapidly.

While out in the open ocean, tsunamis are so small that you wouldn't notice if one crossed your path. They are rarely more than one to two feet tall and the waves are spaced more than 100 miles apart.



Above, The Ring of Fire is an arc made up of volcanoes and undersea trenches located around most of the rim of the Pacific Ocean. The volcanoes and trenches mark areas where subduction takes place. As plates collide at these subduction zones, the seafloor dives underground at the trench and generates earthquakes that in turn can cause tsunamis. Sumatra, Indonesia, where the 2004 Indian Ocean tsunami first hit, is located on the Ring of Fire (as shown by blue-and-green dot).

When tsunamis pass through the ocean, their effects extend all the way down to the deepest parts of the ocean—more than six miles down. Tsunamis carry and transmit a huge amount of energy across entire oceans. They only begin to lose their energy as they enter shallow water and slow down. The path of a tsunami is influenced by the shape of the seafloor below.

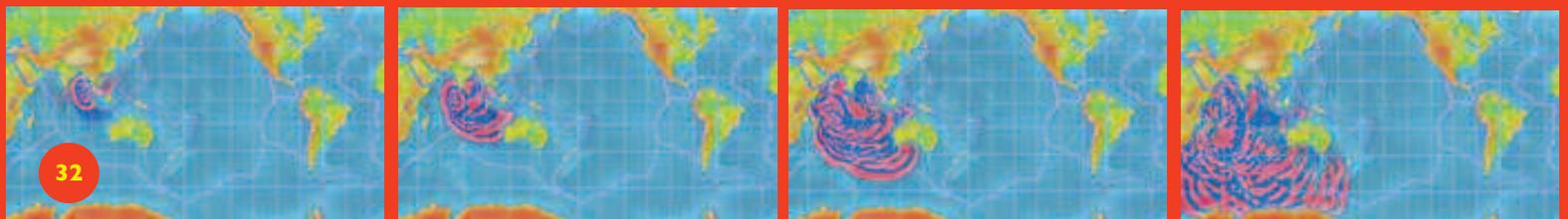
As tsunamis approach the shore they increase in height. Waves of the 2004 Indian Ocean tsunamis reached heights more than 10 meters (30 feet). As they spilled onto land,

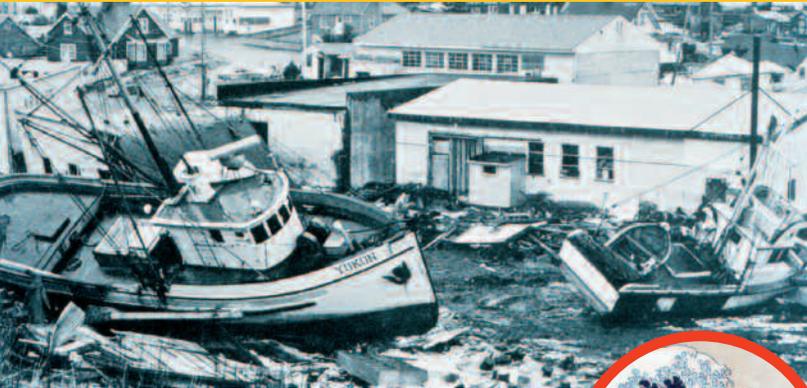


Left, Receding waters from the 2004 Indian Ocean tsunami at Kalutara, Sri Lanka. Center, A 1958 Alaskan earthquake caused a rockslide (A) that slid into Lituya Bay, creating a 1,700-foot tsunami that knocked down millions of trees and stripped the shore to bare rock (B). Bottom, A model



showing waves generated from the 2004 Indian Ocean tsunami as they spread across the world.





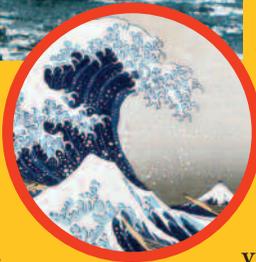
*Left, Fishing boats washed into town by tsunami at Kodiak, Alaska in 1964. Bottom, Illustration shows a tsunami as it approaches the shore.*

## Tsunamis Are Most Common in the Pacific Ocean

the waves looked more like a thick river of ooze than waves with a good curl to surf.

When the crest (highest part) of a tsunami hits land, water rushes inland and pushes against everything in its path. When the trough (lowest part) reaches the coast, water is pulled offshore and carries material and debris out to sea. The first tsunami wave to arrive can cause water to either recede or move landward.

Even though tsunamis slow down when they get close to shore, they still move at speeds of tens of miles an hour, which is much faster than you can run. So a person should never walk out onto the exposed seafloor after the water has receded because another tsunami wave will arrive within minutes. At the time of the 2004 Indian Ocean tsunami, a vacationing 10-year-old British girl saw water rapidly being pulled out to sea and recognized this as the sign of an impending tsunami wave. She was able to alert other beachgoers and save hundreds of lives.

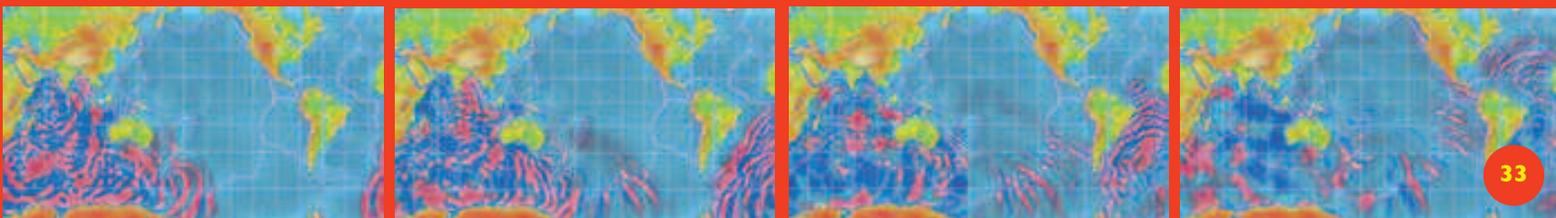
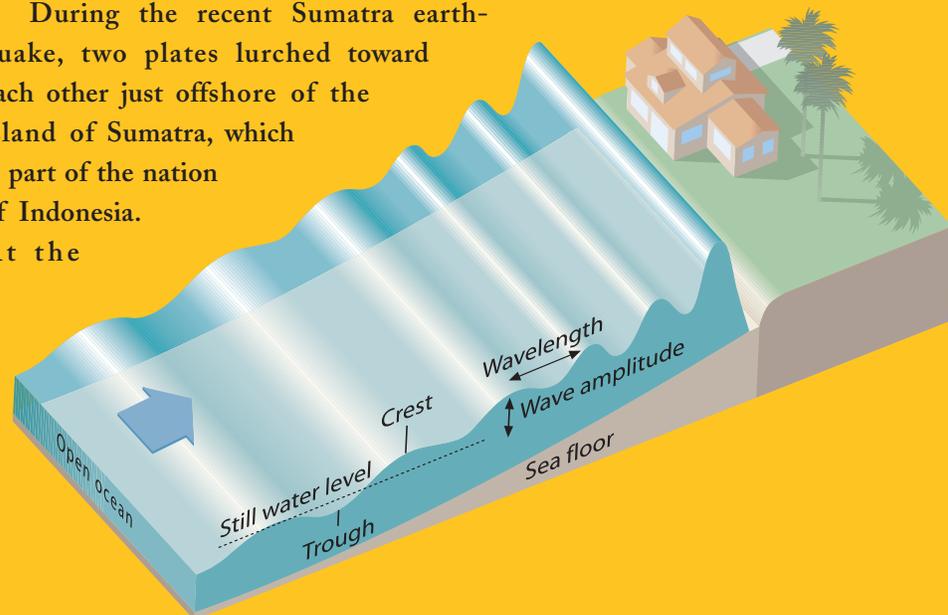


Most tsunamis are caused by large undersea earthquakes. These earthquakes generally take place in areas where a geologic process called “subduction” occurs. Subduction zones are the places where thick, mostly horizontal slabs of the earth’s crust, called tectonic plates, dive under neighboring plates. Subduction is similar to the way rubber conveyor belts disappear under the edge of a grocery store check-

out counter, though it doesn’t operate quite as smoothly. The subducting tectonic plates often stick to the overriding plate as it moves downward. This activity causes the buildup of stress until the subducting plate is eventually released and lurches forward, generating earthquakes and releasing tremendous amounts of energy. When the earthquake causes a vertical displacement of the seafloor, a tsunami results, with the magnitude and extent of the tsunami waves depending on the size of the vertical displacement and the length of the fault rupture. The earthquake displacement effect can be thought of as similar to suddenly tilting the floor of a bathtub, generating a wave that travels to the edges of the basin.

During the recent Sumatra earthquake, two plates lurched toward each other just offshore of the island of Sumatra, which is part of the nation of Indonesia.

At the





subduction zone, colliding plates slipped 35 feet past each other across a large surface area 750 miles long by 100 miles wide, ripping rock from south to north and occurring over nine minutes. The earthquake released the energy of a magnitude nine earthquake and caused the Indian Ocean tsunami. In Sumatra, such earthquakes occur every several hundred years. Similar activity takes place in an area between northern California and Washington state called the Cascadia Subduction Zone.

## How Do We Know if a Tsunami Is Approaching?

Tsunamis do not occur after every large earthquake. If they did, there would be tsunami warnings regularly, because sizeable earthquakes happen almost daily somewhere on Earth. Generally, only earthquakes that rupture the oceanic crust generate tsunamis, and only those that produce significant vertical displacements generate large tsunami waves.

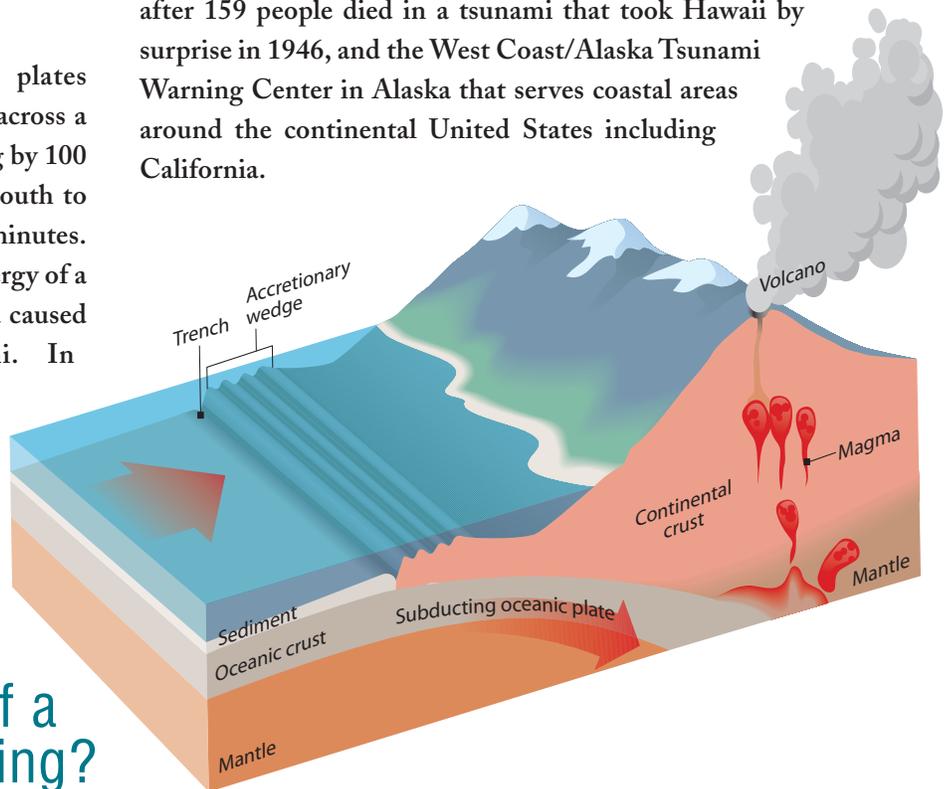
So all earthquakes do not generate tsunamis, and people generally do not

want to evacuate unless they are certain that a tsunami is coming.

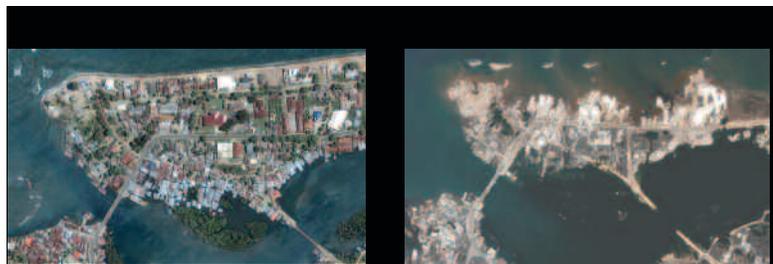
Today, sophisticated sensors detectors check continually for tsunamis, particularly after a major undersea earthquake. Instruments located on the seafloor all around the ocean detect changes in the pressure of seawater as a result of passing tsunami waves. The instruments are connected to buoys at the surface that relay information to satellites.

When a tsunami is detected, a warning is sent through an emergency network. The network must then pass this information along to people who are in danger, something that took too long during the recent tsunami. As a result, better warning systems are being planned and built in the Indian Ocean region today.

For areas around the Pacific Ocean, two centers provide warnings: the Pacific Tsunami Warning Center, established in Hawaii after 159 people died in a tsunami that took Hawaii by surprise in 1946, and the West Coast/Alaska Tsunami Warning Center in Alaska that serves coastal areas around the continental United States including California.



Above, This illustration shows a plate undergoing subduction.



Above, Banda Aceh Shore, Indonesia, before (left) the 2004 Indian Ocean tsunami and after (right).



## PUBLIC EDUCATION

As in any other kind of emergency, it's good for everyone to know what to do in case no one else is around to help and there are no instruction signs.

If you suspect a tsunami is coming, run uphill! If the sea suddenly goes out unusually far, be suspicious and run the other way back onto land. Many times, it is quick action and just a small distance that make all of the difference.

Because subduction zones are almost always close to shore, there is little time to get the tsunami warning to nearby beaches. Scripps scientists Fred Spiess, John Hildebrand, and David Chadwell have studied the motion of plates in areas such as the Cascadia Subduction Zone. What they learned may help people who are at the most risk of a tsunami.

Even where no subduction occurs, in areas such as southern California, undersea earthquakes and undersea slides may trigger rare tsunamis very close to shore. Images of the seafloor mapped by Scripps scientists such as Neal Driscoll reveal areas that may be prone to undersea slides.

Sometimes there's no way to outrun a tsunami, but if there's enough advance warning there could be time for people to escape. Although tsunamis are rare occurrences, they will continue to take place. Technology and education are continuing to improve and will help provide early warnings and help to save more people in the future. 🌐

## How Can We Prepare for a Tsunami?

Preparation for a tsunami is like getting ready for a test. Your strategy may depend on how much time you have to prepare.



## Research

Long before an event, you might try to avoid tsunamis altogether. You could choose to avoid tsunami-prone areas such as places near subduction zones or far from the coast, but that may not be practical or desirable. Or you might learn about where the most tsunami-prone regions are and then make your choice about where to live.

## Warning Systems

If you live near the coast, a warning system is useful because most tsunamis take hours to arrive. If the warning travels quickly enough, you may not be able to save your property, but you could save your life.

Some areas are hit harder by tsunamis than others, so it is important to figure out where to focus warning efforts. Scientists are working on computer models that can figure out where tsunami waves will end up based on information about the initial earthquake and the shape of the seafloor as well as the coastline. The hope is for the model to make the tsunami forecast map more accurate in estimating when the tsunami will actually arrive, just like we already do for weather. 🌐



*A tsunami wave carried this schoolhouse 200 feet before it got caught in surrounding palm trees (July 1998, Papua New Guinea).*