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TSUNAMI

Teacher Notes

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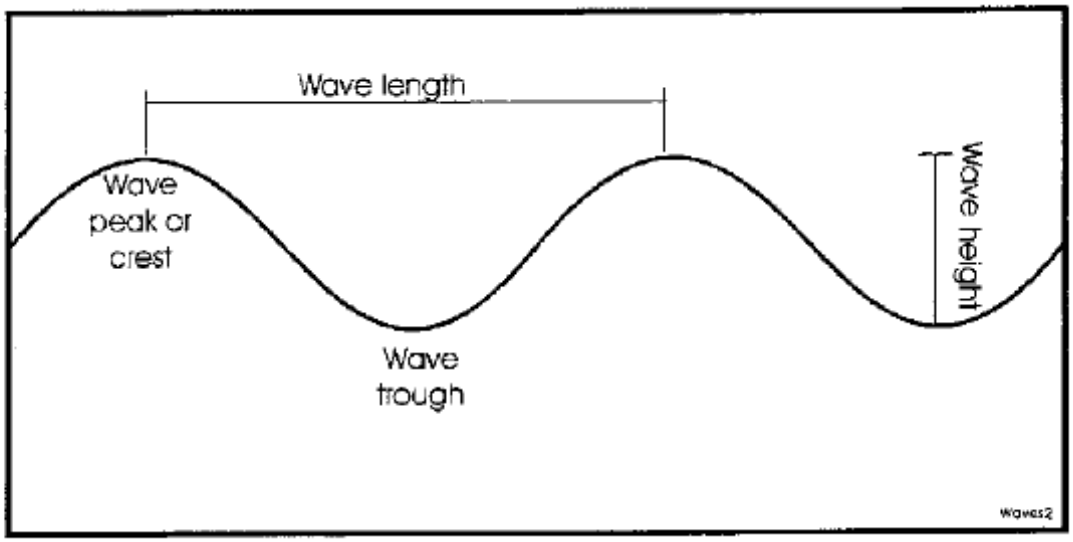
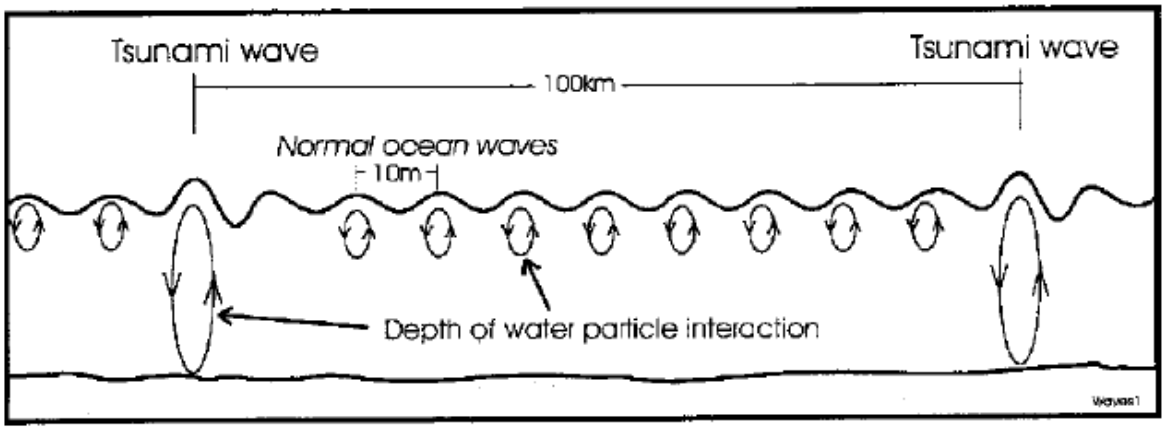
What is a Tsunami?

Tsunamis are a series of waves caused by violent wave movements on or near the sea floor. The generated waves have extremely long wave length and wave period. The wave length in the open ocean is of the order of 100 to 150 km. Tsunamis can travel between 640 and 960 km/h, about the speed of a Boeing 747 (Jumbo Jet). The wave period in a tsunami can be anywhere from 5 to 90 minutes apart. Effects can range from breaking waves, a fast-moving tide to a barely noticeable ripple. The first sign of a tsunami can be either a rise or fall in the water level.



The relationships among these properties vary depending on the nature of the mechanism creating the wave, the intensity of this generating mechanism and the environment in which the wave exists.

Ordinary wind waves affect only the surface of the ocean; the water movement rarely exceeds 150 m below the surface. They are caused when wind blows over the surface of the water and causes the water particles to move. Tsunamis, because of their long wave length, involve the movement of water all the way to the ocean floor and, as a result, their speed is controlled by the depth of the sea.



Tsunami is a Japanese word, “tsu” means harbor and “nami” means wave- harbor wave. The term ‘harbor wave’ is misleading though as tsunamis occur outside harbors as well. Tsunamis have also been referred to as tidal waves. This is incorrect as tsunamis are unrelated to the tides, although tsunamis can be more destructive if they occur at high tide. Some scientists have called them seismic sea waves, suggesting it is an earthquake-related event. But a tsunami can also be caused by volcanoes, landslides or meteorite impact.

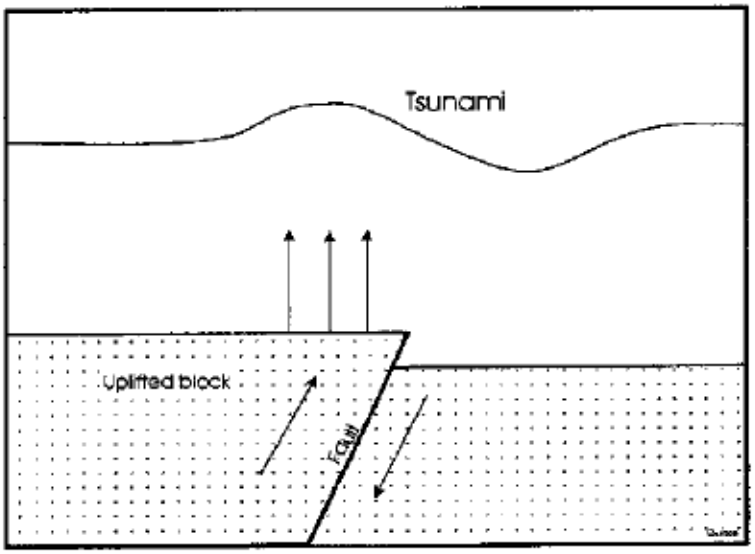
What Causes a Tsunami?

Tsunamis are caused through violent actions of the Earth. These actions may be earthquakes, landslides, volcanoes, or even from meteorite or asteroid impact.

A. Earthquakes

Most tsunamis occur due to large earthquakes under the ocean. An earthquake occurs when slabs of rock are forced to move past each other. The interaction between the large tectonic plates, which make up the surface of the earth, causes the majority of the earthquakes.

When the sea floor moves suddenly during an earthquake, it can displace the overlying water. When large areas of the sea floor are elevated or subside, a tsunami can be created. Fault movement that is horizontal causes little or no displacement of water and therefore such earthquakes do not generate tsunamis.

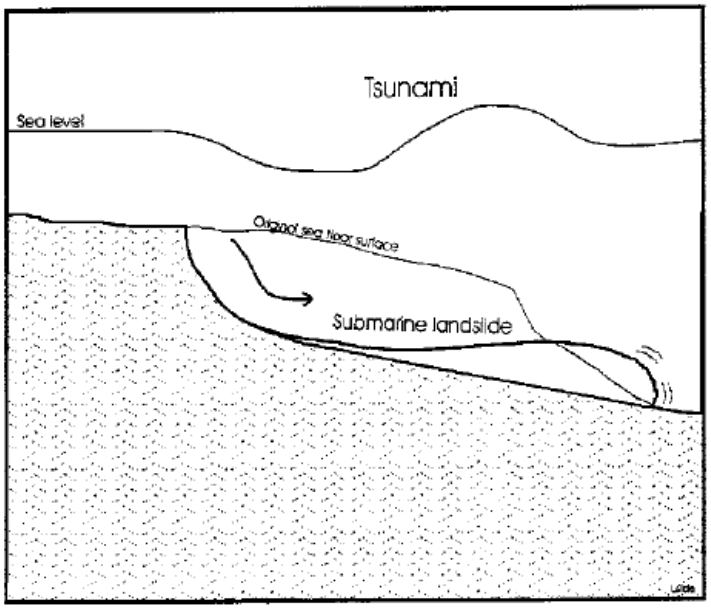


Case study: Papua New Guinea (PNG)

On July 17, 1998 an earthquake measuring 7.0 in magnitude, occurred off of the north coast of PNG. This was 20-30 kilometres offshore from the village of Aitape. The ground and homes shook so violently that people could hardly stand and water tanks collapsed. Within 10 minutes or so the earthquake created a deadly local tsunami. Three tsunami waves were generated and reached heights of 7 to 12 meters. This was sufficient to complete destroy the coastal villages of Arop and Warapu and several damage Sissano and Malol. Approximately 3,000 people were killed. The exact death toll is not clear as some bodies were never recovered, and some villagers left the area and never returned. The earthquake was quite small for the tsunami that was generated. Some scientists suggest that the earthquake caused the sea floor to drop vertically and then rebound creating a 'hump' in the water.

B. Landslides

A landslide that occurs underwater, or land that moves from above sea level into the ocean, can disturb the overlying water and generate a tsunami. Landslides are produced when the slopes or deposits of sediment become too steep and the material fails from the influence of gravity.



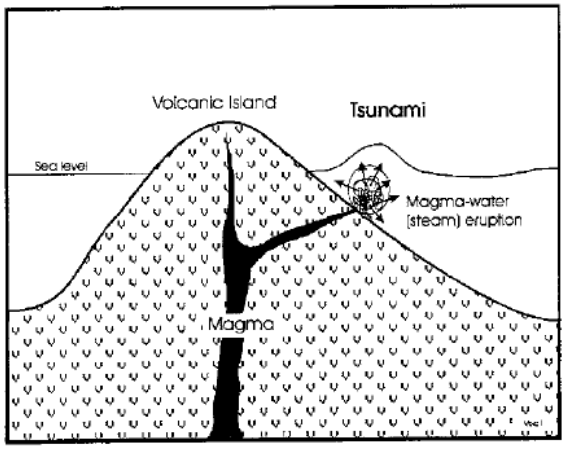
Large portions of islands which make up the Hawaiian island chain have, in recent geological time, slumped into the Pacific Ocean. Some scientists believe that these events caused massive tsunamis, which may have reached the east coast of Australia.

C. Volcanic Activity

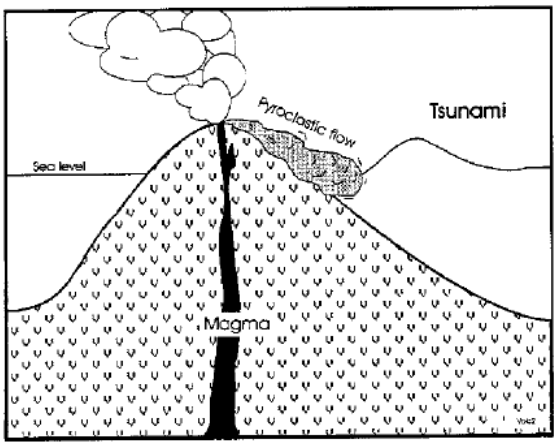
Tsunamis associated with volcanoes are less common than those from earthquakes, but can still be as destructive. Of the casualties that occur from volcanic eruptions, approximately one-quarter result from the volcano-generated tsunami.

There are three main volcanic processes that cause a tsunami:

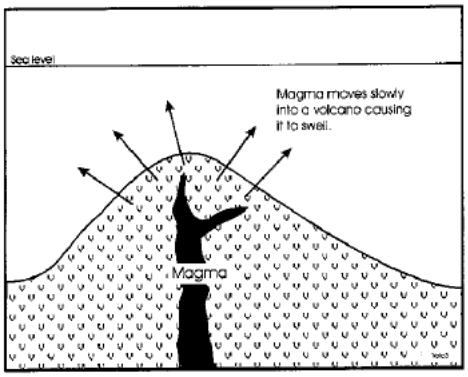
1. Submarine volcanic explosions occur when the cool seawater comes in contact with hot magma. It can react violently and produce steam explosions.

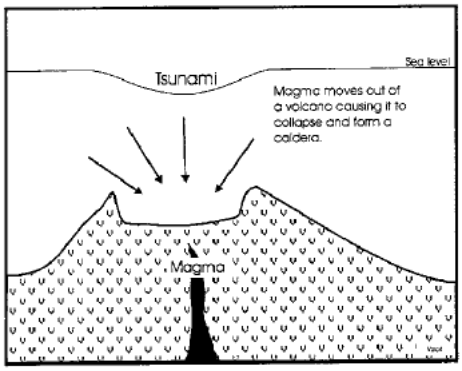


2. Pyroclastic flows are the flow of volcanic debris down the flank of a volcano as part of the eruption process. When these flows move rapidly into the ocean they displace water, which may result in a tsunami.



3. Collapse of a caldera can occur when the magma beneath a volcano is withdrawn back deeper into the earth. The sudden subsidence displaces water causing a tsunami.





Case Study: Krakatau, Indonesia

The island of Krakatau is situated in the Indonesian archipelago, between Java and Sumatra. The massive volcanic eruption that occurred on Krakatau, August 27, 1883, was the culmination of three months of smaller eruptions

On August 26th, a series of eruptions created tsunamis 1-2 meters high. As the eruptions became more sever, so did the tsunamis. On the morning of August 27, an eruption caused a tsunami 10 meters high. This was followed by another explosion sending ash to a height of 25,000 meters and an explosion that could be heard 2,000 km away- it was even heard in central Australia. At one point the tsunamis generated reached heights of 40 meters and tossed coral reef blocks weighing approximately 100 tons onto the shore. A boat was carried 9 meters above sea level, 3 km inland. The tsunami travelled across the Pacific and Indian Oceans and was even recorded in the Atlantic. In Australia, a 6-metre tsunami was observed along the north west coast of Western Australia. The tsunami waves had destroyed 300 coastal towns and villages. The official death toll was 36,417, however many bodies were washed out to sea and never found. A death occurred in Sri Lanka as a result of the tsunami created by Krakatau.

D. Meteorites and Asteroids

As the two-thirds of the earth is covered by water, chances are that when an asteroid or a meteorite actually hits the earth it will land in the ocean. This would be devastating for the most coastal areas due to a devastating tsunami, but the same impact on land would create a dust cloud, which could possibly block the sun for many months.

Case Study: Chicxulub meteorite

At the end of the Cretaceous period, 65 million years ago, the 10 kilometer wide Chicxulub meteorite slammed into the area that now forms the Yucatan Peninsula on the northern coast of Mexico. A huge 180 kilometer wide crater was formed when massive quantities of dust and rock were blasted into the atmosphere by the impact. Vast vapor clouds also billowed out as water turned instantly to vapor. In addition, the shock waves generated by the meteorite would have travelled out from the site of the impact, creating massive tsunamis in nearby oceans.

Huge numbers of living creatures were devastated by the immediate effects of the meteorite's impact and the associate tsunamis. In fact, scientists estimate that more than half of Earth's plant and animal species (including the dinosaurs) became extinct at this time.

Where do Tsunamis Occur?

Most tsunamis occur in the Pacific Ocean because the Pacific basin is surrounded by the most tectonically active zone. Often referred to as the Pacific Ring of Fire, the Pacific basin is bounded by the edges of tectonic plates. These interact to form seismically active belts dotted by active (often explosive) volcanoes. Tsunamis also occur elsewhere including the Mediterranean Sea and Indian and Atlantic Oceans. One of the most devastating tsunamis occurred as a result of the "Great Lisbon Earthquake" of 1755.

Case Study: Lisbon, Portugal

On November 1, 1755, an earthquake that reportedly lasted for 5 to 8 minutes and would have measured approximately 8.75 in magnitude, occurred in Lisbon, Portugal. Almost immediately after the earthquake a tsunami was generated. Waves destroyed coastal towns in Spain, North Africa and as far afield as Barbados in the Carribean. The greatest devastation was in Lisbon where 30,000-50,000 people were killed.

When Tsunamis Approach Land

As a tsunami gets nearer to land it is transformed. The speed at which a tsunami travels is related to the depth of the water. When the tsunami is approaching land, the water depth shallows and the tsunami speed slows. As it slows its height increases. The front of the wave slows first and the effect is like the car pile-up on a freeway, with the rear of the wave catching up with the front. The tsunami continues to increase in height from this bunching effect. This is why you cannot feel a tsunami at sea aboard ships, but it may grow several meters or more as it nears land. Tsunamis 30-40 meters high have been known to take place but most of the waves are much smaller. Tsunamis tend to be smaller on small, isolated islands where the bottom drops away quickly into deep water and bigger where there is a long, gradual shoaling to shore with sufficient time to interact with the bottom.

When tsunamis reach the land, the size of the wave and extent of destruction depends on the shape of the coastline and the depth of the ocean floor (bathymetry). Areas most at risk are funnel-shaped bays and harbors, such as Hilo Harbor, Hawaii. The effects of a tsunami can be further exacerbated by the Seiche effect. The Seiche effect is the sloshing of water in any basin. The time in which the water continues to oscillate depends on the physical size and shape of the basin. E.g. bathtubs may have a Seiche period of 2-3 seconds, a swimming pool 8-12 seconds and natural harbors or bays from a few minutes to hours.

Waves may also be focused onto particular parts of the coast by submarine canyons or valleys, so the amplitude varies in a complex way along the coast.

How Do You Measure the Size of a Tsunami?

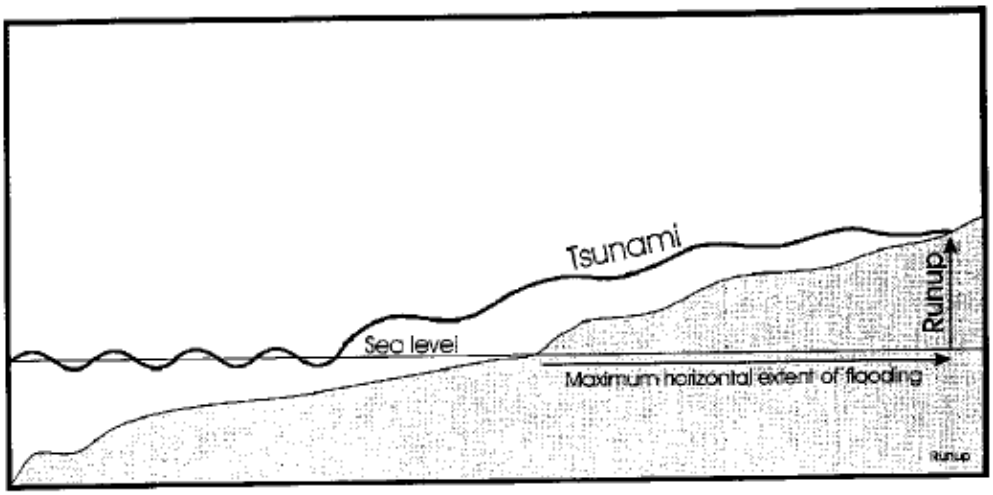
The term used to describe the hazard potential of a tsunami is tsunami magnitude. The magnitude measures the 'run-up' height- the maximum height above sea level reached by the tsunami.

Tsunami magnitude	Run-up height (meters)
0	1-1.5
1	2-3

2	4-7
3	8-15
4	16-31
5	32 and greater

High- magnitude greater than 2
Moderate- magnitude 0-1
Low- this is where no tsunami waves have been reported or, if they have been, very little damage has been reported.

Activity: See "Run-up on Llewellyn" activity



Calculating the velocity, wave height and destructive force of a tsunami for any stretch of coastline is complicated by several factors. For example, the shape of the sea bed can produce effects that might not be predicted by a simple equation. Harbors and headlands also cause the waves to reflect, diffract and refract, changing their direction- some tsunami have been known to 'bend' around islands, eventually engulfing the coast on what was supposedly the protected side. Other factors include the effect of backwash from ove wave on the waves that follow, and the exact nature of the disturbance that generated the tsunami in the first place.

To accurately assess tsunami risk, scientists need information on the likely occurrence and location of a tsunami-generating event, the expected magnitude

of the event, the shape of the sea bed, and the topography of the affected coastal area. Rarely is all this information available, complicating the identification of potentially vulnerable areas. Nevertheless, as more information on recent, historical and prehistorical tsunamis is collected, the identification of vulnerable regions using computer aided analysis should become increasingly accurate. This could assist town planning- for example, in vulnerable regions it may be necessary to restrict development on low-lying areas, or to build walls to protect dwellings from inundation.

Tsunamis in Australia

Australia on average has a tsunami recorded once every two years. Fortunately for Australia, most of the tsunamis that reach the shore are too small to be noticed, only close observation of the tidal record will indicate a tsunami has reached Australia's shore. Most of the Australian coast has 'low' or 'medium' threat of tsunami reaching the shore, but there may be some areas with a 'high' threat.

Activity: "Time and Tide"

Since European colonization there hasn't been a large tsunami; however, there is evidence to suggest that the Australian coastline has been impacted by tsunamis- large ones. Large boulders, shells, corals, have been found 20-30 meters above sea level and several kilometers inland. Carbon dating of these deposits show that they were placed during the last millennium, but the cause has not been unequivocally determined.

Warning Systems

The Pacific Tsunami Warning Center in Hawaii is the headquarters for the Operational Tsunami Warning System. It works closely with other regional centers to monitor seismic and tidal instruments to evaluate and issue warnings for potential tsunamis.

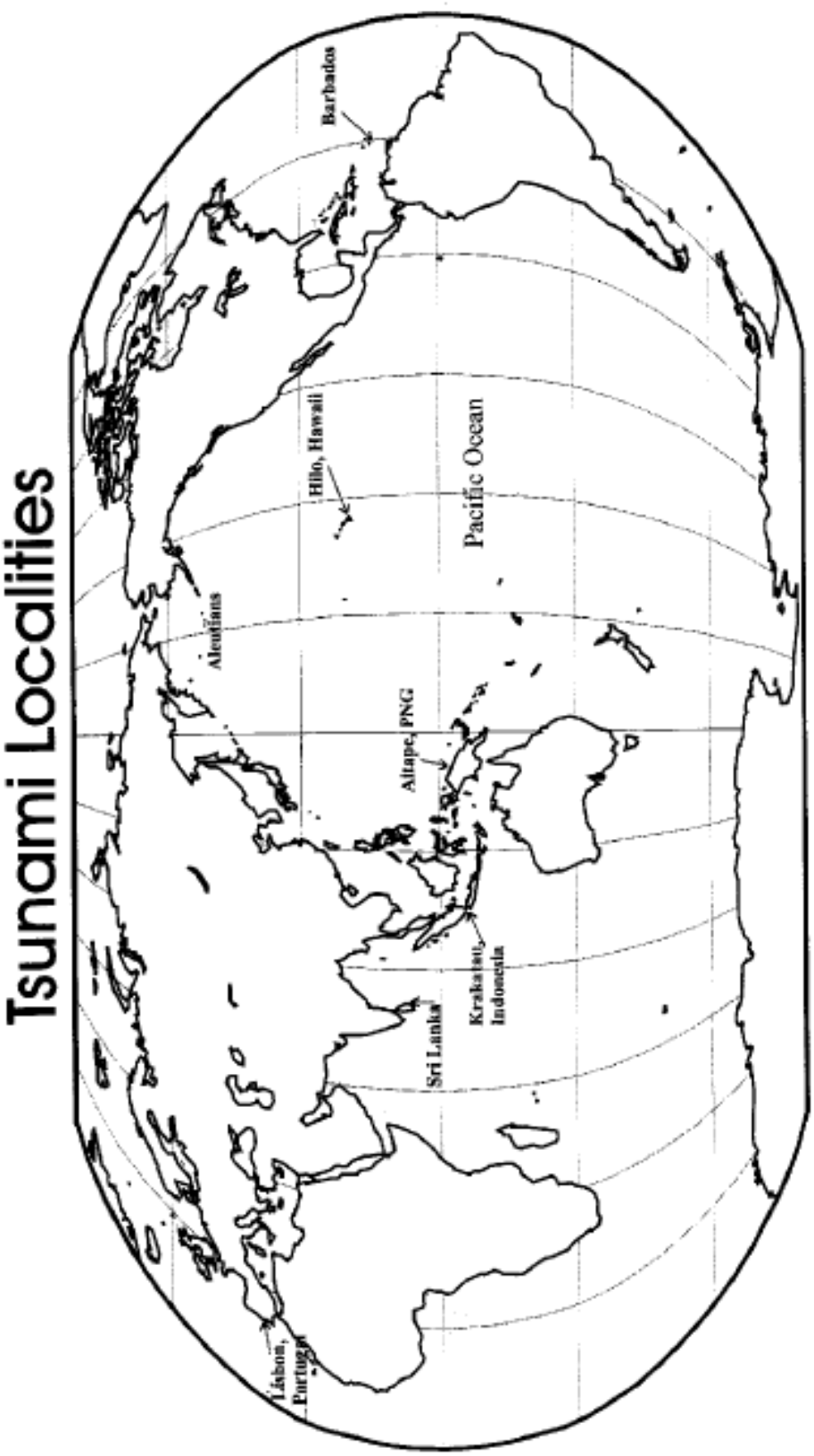
The Pacific Tsunami Warning System was a result of the Aleutian earthquake and the death and destruction it caused in Hawaii in 1946. Tsunami Travel Time maps

have been produced by observing the relationships between earthquakes, depth of ocean floor and wave arrival times from previous tsunamis. At present the Pacific Tsunami Warning System consists of a series of seismic monitoring stations and a network of gauges that measure sea levels. When a seismic disturbance is detected, its location and magnitude are computed. Warnings are issued in areas that are susceptible to abnormal changes in sea level. If a tsunami is detected, coastlines lying in the predicted path of the tsunami are warned of the approaching wave train. Deep ocean sensors, that can pick up changes in water pressure as a tsunami passes, are being trialed and could make an even more significant advance in tsunami warnings. These warnings are relevant for Pacific-wide tsunamis, but are not effective against a tsunami caused by local or regional events.

<u>Activity:</u> See "Hawaii Wave"

Case Study: Laupahoehoe, Hawaii

In April, 1946, the south of the big island of the Hawaiian coast was affected by a devastating tsunami. The tsunami was the result of an earthquake 3700 km away in the Aleutian Islands, Alaska. In the town of Laupahoehoe, five teachers and sixteen students were swept to their deaths. The first warning of the coming tsunami was a small wave, which was followed by the disappearance of these from the shore. Rather than making an attempt to get to higher ground the class stayed to watch the event. A generation of students an teachers had passed through Laupahoehoe School since tsunamis had killed anybody so the teachers and students didn't know about tsunamis. Some simple knowledge could have saved their lives. The same event killed an additional 138 Hawaiians. In 1960 an earthquake in Chile caused a tsunami that reached the island of Hawaii, killing 61 people in Hilo. In Hawaii today there are warning sirens on the beaches and low lying areas.


Tsunami Localities
Barbados
Hilo, Hawaii
Pacific Ocean
Aleutians
Aitape, PNG
Krakatau, Indonesia
Sri Lanka
Lisbon, Portugal

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