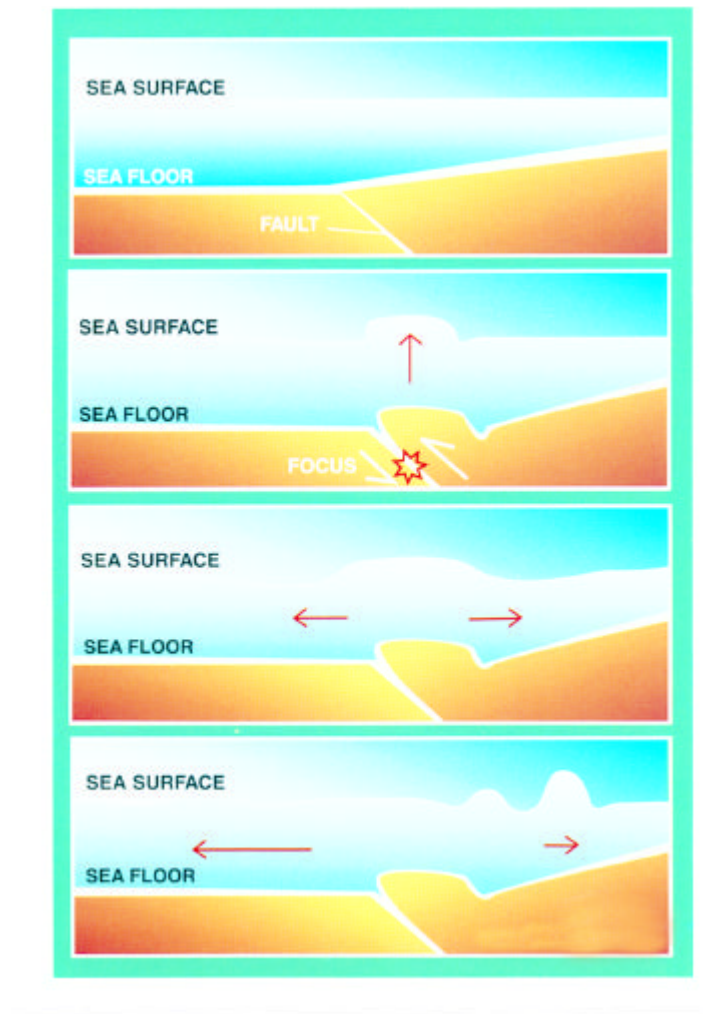


## What causes tsunamis?

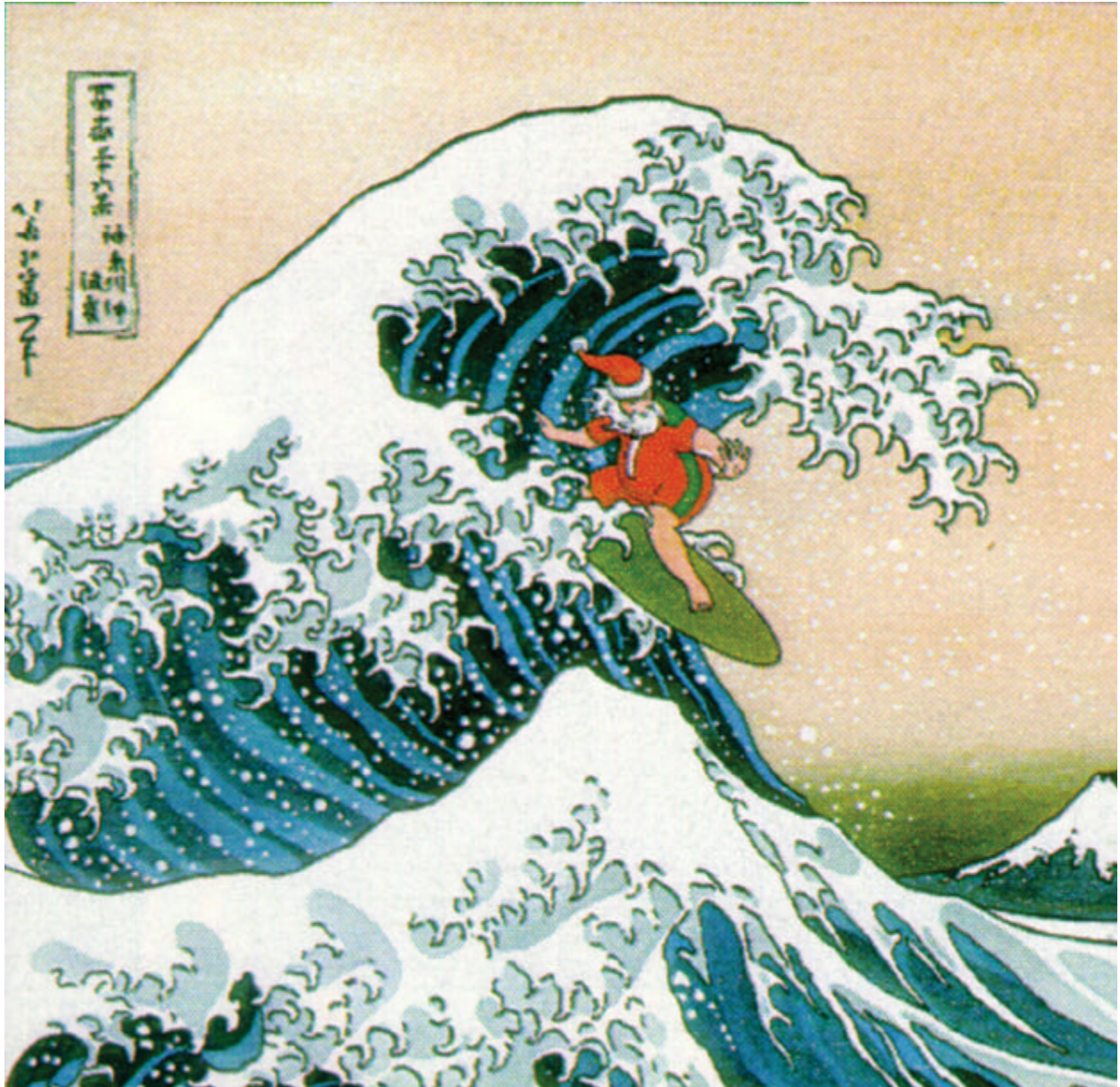
Any movement/displacement of the ocean floor can generate the energy that forms a tsunami. However, tsunamis are usually generated by large, shallow earthquakes, which have epicenters under the ocean floor. These epicenters are usually located on the faults in areas where two crustal plates of the earth are colliding. The fault movements can tilt, offset, or displace areas of the ocean floor up to thousands of square miles in size. When an earthquake moves the ocean floor, the water above it is displaced and a tsunami is formed.

Other, but less common, movements of the ocean floor can result from submarine landslides or undersea volcanic eruptions. A tsunami can even be caused by the impact of a large meteorite in the ocean.



## What are tsunamis?

Tsunamis are a series of large sea waves usually produced by movement of the ocean floor. The word "tsunami" (pronounced tsoo-nah'-mee) is a combination of two Japanese words-"tsu" meaning harbor and "nami" meaning wave. In the past tsunami waves have been called "tidal waves" or "seismic sea waves". However, these terms have been abandoned because tsunamis are not caused by changes in the tides, and are not solely caused by seismic (earthquake) activity.



## What types of tsunamis do we experience in the Pacific Northwest?

In the Pacific Northwest we are part of the "circle of fire" of volcanoes and earthquakes that rim the entire Pacific Ocean. Thus, we can experience two very different types of tsunamis.

The first type is called a "local" tsunami. This type of tsunami is caused by earthquakes with epicenters close to the Oregon coast. The earthquakes are the result of the opposing movements of the North American and Pacific Ocean crustal plates. The Pacific and Juan De Fuca plates are colliding with, and being overridden by the North American plate. The area where the two plates collide is called the Cascadia Subduction Zone. Thus, earthquakes that result from movements on the faults that bound the plates are known as Cascadia earthquakes.

Even though the epicenters for these types of earthquakes are deep below the ocean floor, subduction zone earthquakes of the type associated with the Cascadia Subduction Zone have been known to cause earthquakes with magnitudes of 8.0 to 9.0. The movements of the ocean floors that result from earthquakes of those magnitudes displace large amounts of water and cause very large tsunamis. These tsunamis come ashore within minutes of the earthquakes that generated them.

The second tsunami type is called a "distant" tsunami. It is the result of an equally large magnitude earthquake that occurs anywhere within the Pacific Ocean basin. In the historical past earthquakes in the areas of Japan, Chile, and Alaska have generated tsunamis that have hit the coast of Oregon. In the deep parts of the ocean the tsunami waves from these earthquakes can travel at speeds up to 600 miles per hour. However, with the great distances across the Pacific Ocean basin, these tsunamis generally take four hours or more to arrive at the Oregon Coast.





## What are the signs of an approaching tsunami?

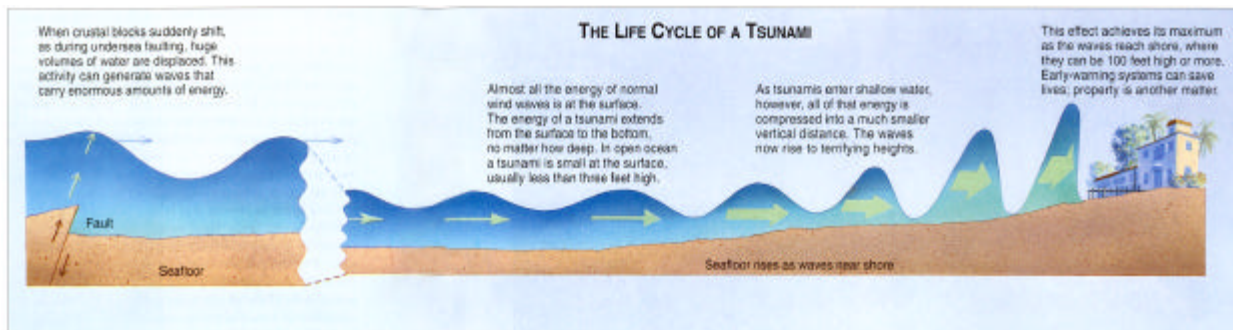
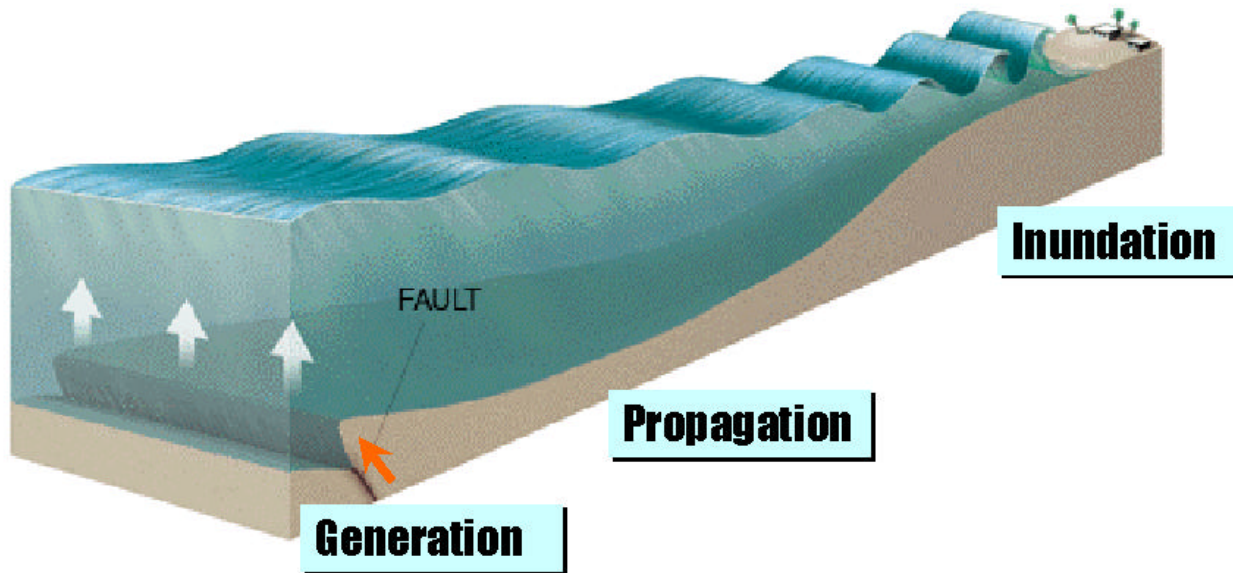
Tsunami waves are generally imperceptible in the open ocean. In some cases a sudden withdrawal or surge of water from the shore can signal the approach of a tsunami. In the case of the local tsunamis, the shaking of the large magnitude earthquake that precedes the tsunami is the most obvious warning that a wave will strike within minutes. Many communities have developed siren and other warning systems to signal to the approach of a distant tsunami.

The three pictures below show the arrival of a tsunami generated by the May 26, 1983 magnitude 7.9 earthquake in Akita Prefecture, Japan. In the upper left, water is drawing away from the shore as the trough of the tsunami arrives at Oga Aquarium. The upper right photo shows inundation at its maximum level. The lower photo shows the area of inundation after the complete withdrawal of the wave. The tsunami destroyed 700 boats and 59 houses for a total of \$800 million (1983 dollars) in property damage. One hundred and four people drowned in Japan and three drowned in Korea. Photo credit: Takaaki Uda, Public Works Research Institute, Japan



## Why are the tsunami waves larger near the shore than they appear in the middle of the ocean?

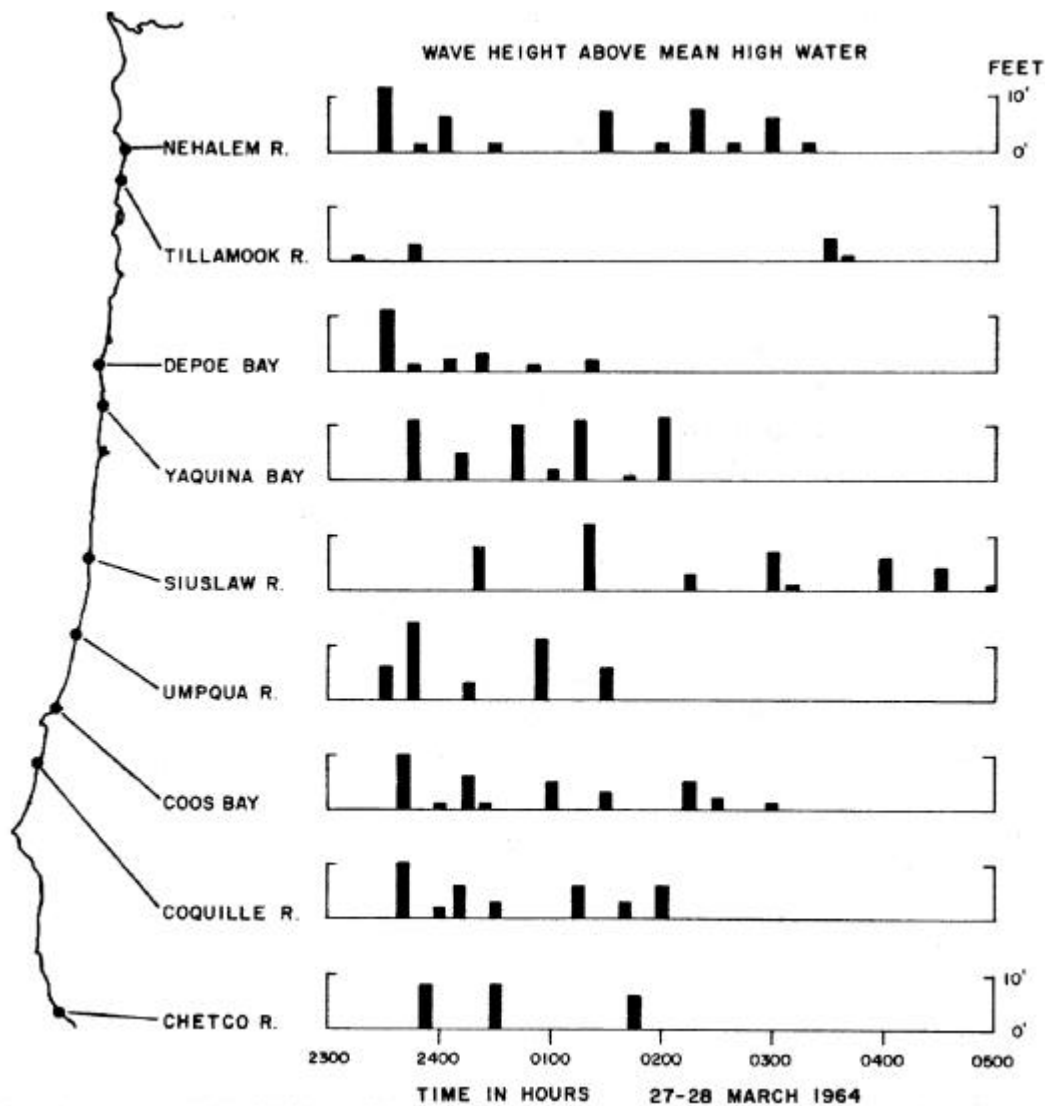
The energy of the wave near the shore is concentrated by the shallowing of the ocean floor. Thus, tsunami waves that are barely perceptible in the open ocean, where their energy is dispersed, generate walls of water that may become higher as they move closer to the shoreline.



## Have we ever had destructive tsunamis on the Oregon Coast?

Both the geological record and the historical record contain evidence for major destructive tsunamis hitting the Oregon Coast. Geological evidence suggests that the most recent major Cascadia Subduction Zone earthquake occurred in January, 1700. Some oral historical traditions from Pacific Northwest Indian tribes strongly suggest the occurrence of large magnitude earthquakes and tsunamis, but are not specific as to time and place. However, written historical data in Japan strongly suggest that a damaging tsunami came ashore at that time on the eastern Japanese coast.

During historical times distant tsunamis from earthquakes in Alaska and Chile struck the Oregon coast in 1960 and 1964. The tsunami from Alaska killed 4 people at Beverly Beach and caused damage in many Oregon coastal communities. Below is a graph of the wave heights at the Oregon coast generated by the 1964 Alaskan quake.



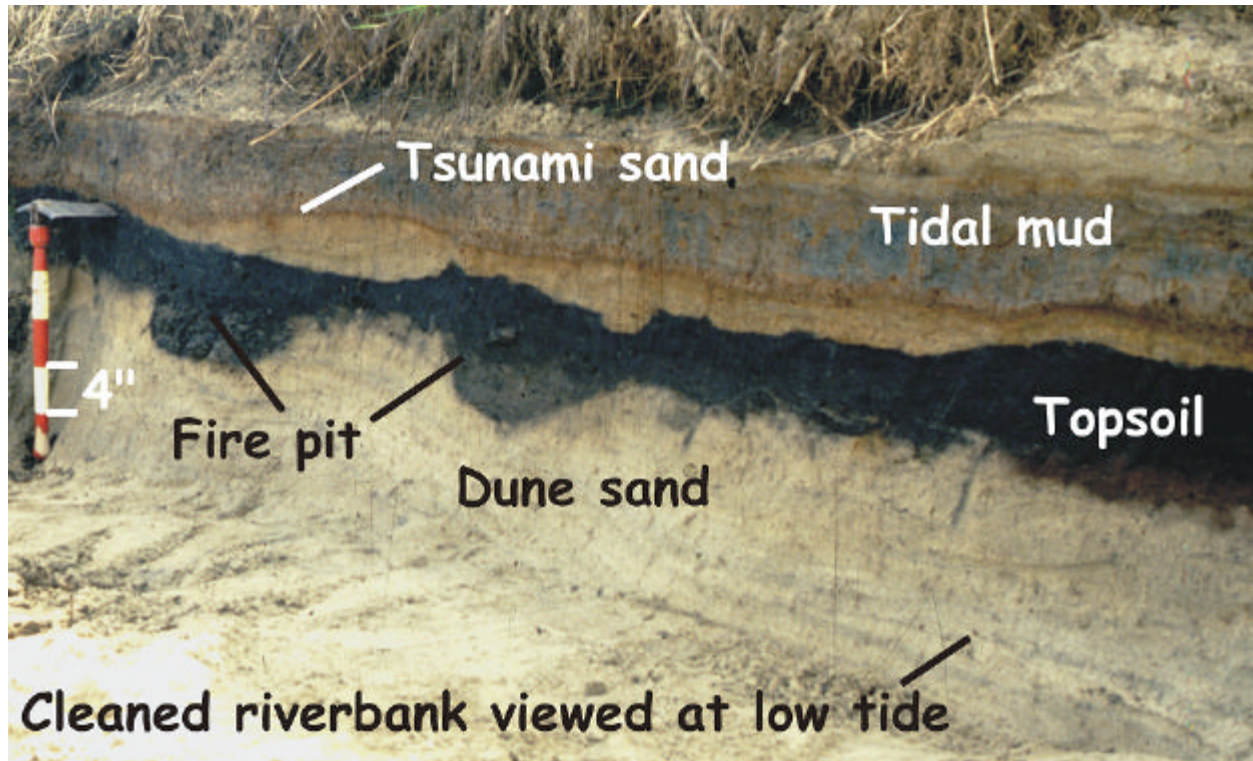


## How often can we expect major tsunamis to strike the Oregon Coast?

During the last 200 years twenty-four tsunamis have caused damage in the U.S. and its territories. Since 1946 six tsunamis have killed more than 350 people and caused a half billion dollars of property damage in Hawaii, Alaska, and the West Coast.

Recent geological research in coastal marsh areas of Washington, Oregon and northern California suggests that 11 Cascadia Subduction Zone earthquakes and tsunamis occurred during the period between 300 and 5,400 years ago. Similar research offshore found evidence of 13 local tsunamis since the eruption of Mt. Mazama (Crater Lake) ~7,600 years ago. Thus, local tsunamis have a recurrence interval of about 500-600 years.

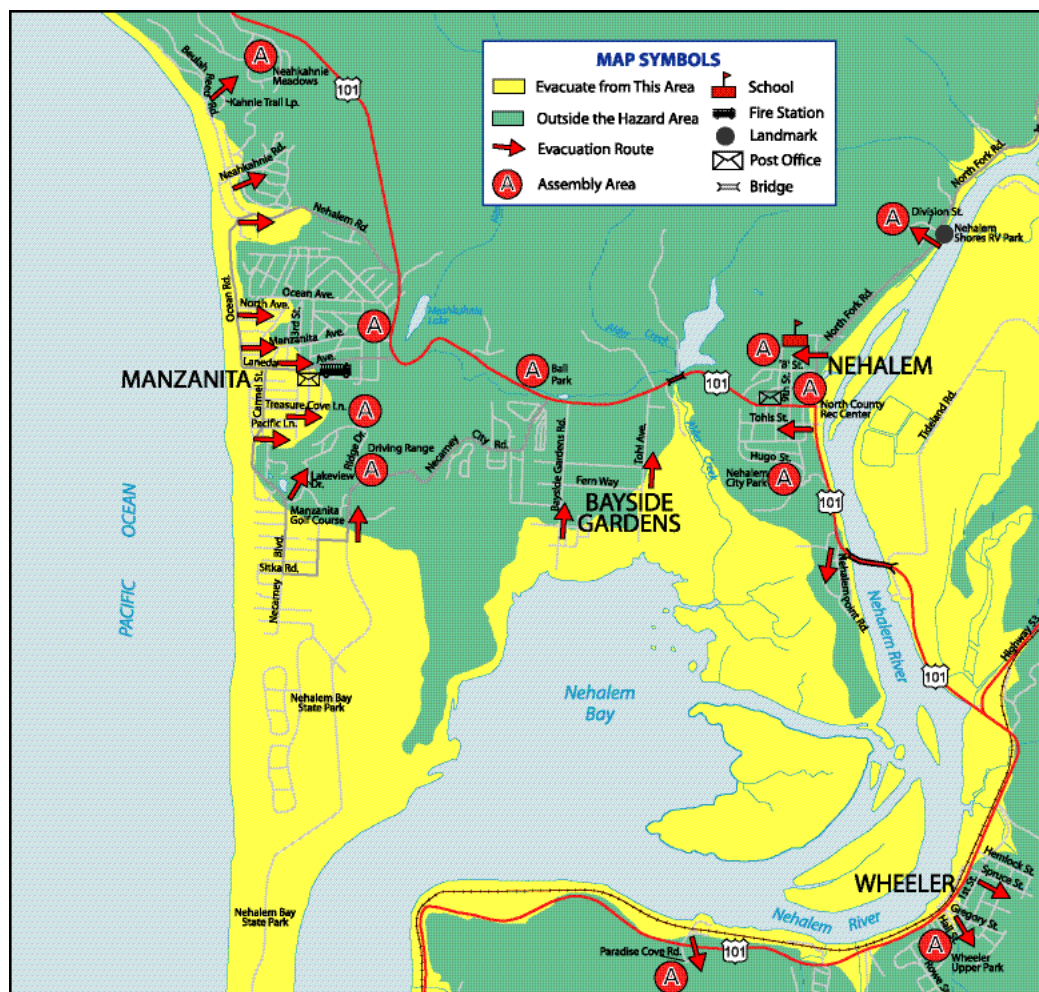
However, this doesn't necessarily mean that the next Cascadia earthquake is 200 to 300 years in the future. Geological evidence, like that illustrated in the photo below, suggests that some Cascadia earthquakes are separated by relatively short (200 years) intervals, while others were separated by as much as 1,000 years between quakes. So, we could experience a large magnitude Cascadia earthquake at any time. Scientists estimate the chance in the next 50 years of a Cascadia Subduction Zone earthquake is on the order of 10 and 20 percent.



## How big are the tsunami waves when they hit the shoreline?

Tsunamis are actually a series of large waves, instead of a single wave. In fact, the succeeding waves are often higher than the first waves to hit the shoreline. When tsunamis resulting from the 1964 Anchorage, Alaska earthquake hit the Crescent City, California area, the first wave was nine feet above the tide level, but the fourth wave was more than 16 feet above the usual tide level. Local tsunamis can generate wave heights of over 100 feet in bays where the waves are funneled into V-shaped valleys, or when large landslides are triggered close to the shoreline. However, waves of only 10 to 20 feet have been very destructive and caused many deaths.

Tsunami inundation zones, as mapped by the Oregon Department of Geology and Mineral Industries (see the example below), are based on computer simulations of the way the tsunami waves interact with the seafloor and the coastline. Undersea and coastal valleys can amplify the waves, while coastal jetties and sand spits can block them. All of these factors substantially affect the wave's height and power.





## What kinds of damage are caused by tsunamis?

The greatest damage is generally caused at the shoreline when the surge of water hits coastal natural features and man-made structures. However, inland areas away from the shoreline are also at risk for serious damage. The debris picked up by the waves act as battering rams on inland structures, and wide areas in harbors and up river valleys are usually flooded. Fires may follow the initial devastation, as gas and electrical services are interrupted and gas coming from broken pipes is ignited by sparks from downed electrical lines. Boats anchored in harbors have been sucked out to sea or swept ashore as far as a quarter of a mile.

On the evening of July 17, 1998, a magnitude 7.1 earthquake occurred near the northwest coast Papua New Guinea 510 miles northwest of Port Moresby, the capital of Papua New Guinea (PNG). The earthquake was followed by a series of three catastrophic tsunami waves that devastated the villages of Sissano, Warupu, Arop and Malol, killing at least 2,182, injuring 1,000, and displacing more than 10,000. The top frame is the 76-year-old church at Sissano Mission, photographed in 1990. The bottom frame shows all that remained after the event—a concrete slab. The wave swept inland from right to left. A collapsed two-story classroom building can be seen on the far right of the photo. A classroom building, almost 1,200 feet from the shoreline, was only slightly damaged (on the left of the photograph in the background). (Photo credits: Father Eugene McKinnon, OFM; Hugh Davies, University of PNG.)



## How are people usually killed by tsunamis?

As with other major natural calamities, like hurricanes and volcanic eruptions, people often are drawn to an area that is expected to experience a tsunami. They want to see the massive waves for themselves. Other people think that they will be able to surf the tsunami waves. In both cases these ideas have caused numerous deaths because the waves hit the shoreline at speeds of 15 to 50 mph. Chances are that, if a person can see the tsunami wave coming, they will not be able to out-run it. The sudden drop in the water level at the shore that sometimes precedes a tsunami has also been a lure for people to walk out on areas that are usually underwater. Then, when the tsunami actually comes onshore they are caught and drowned.

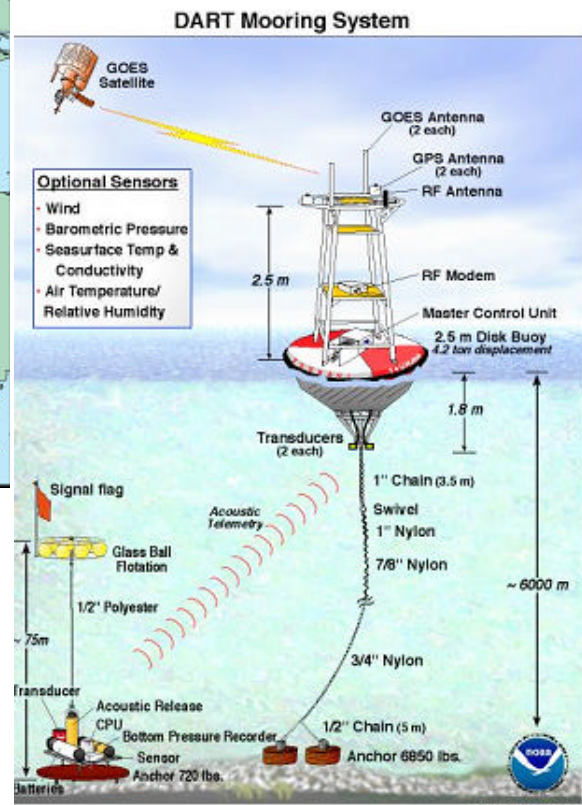
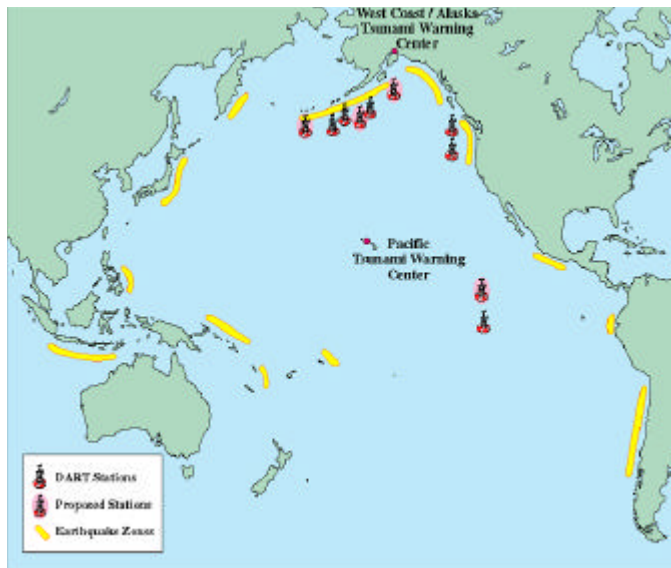
In the photo below a tsunami wave is breaking over Pier No. 1 in Hilo Harbor, Hawaii. It was generated by an earthquake on April 1, 1946 in the Aleutian Islands, Alaska. The man in the foreground became one of the 159 fatalities in the Hawaiian Islands from that tsunami. The photo was taken from a ship, the Brigham Victory, which was in the harbor at the time of the event. It was caught by the waves and tossed about but was able to use its own power to avoid the reefs in the harbor and get past the breakwater to the open sea. (Photo credit: NOAA. Photo has been retouched.)



## What is the Tsunami Warning System in the Pacific (TWSP)?

A Pacific Ocean-wide tsunami warning system has been developed with the cooperation of the nations and island states that have coastlines that are vulnerable to tsunamis. The system is operated by the Pacific Tsunami Warning Center located in Hawaii. It provides an international warning about one-half to one hour after the occurrence of a major earthquake. Other local and regional warning systems are operated in Palmer, Alaska for the North American Pacific Coast and in Japan, the Russian Federation, France and Chile for other areas.

At each of these centers computers receive and analyze both seismographic and water level information. The seismic information is recorded by a network of seismic recording stations located around the Pacific Rim. The water level information is received from both offshore and onshore instruments. Recently, scientists in the United States have developed devices (DART) that rest on the ocean floor and can sense changes in the sea level of less than a millimeter. They measure the weight of the water column above them, and when a tsunami wave passes over them the difference in the weight of the water between the crest and the trough signals the presence of a large wave. The sensor then transmits a signal to a buoy riding on the ocean's surface and it is rebroadcast to the warning centers.





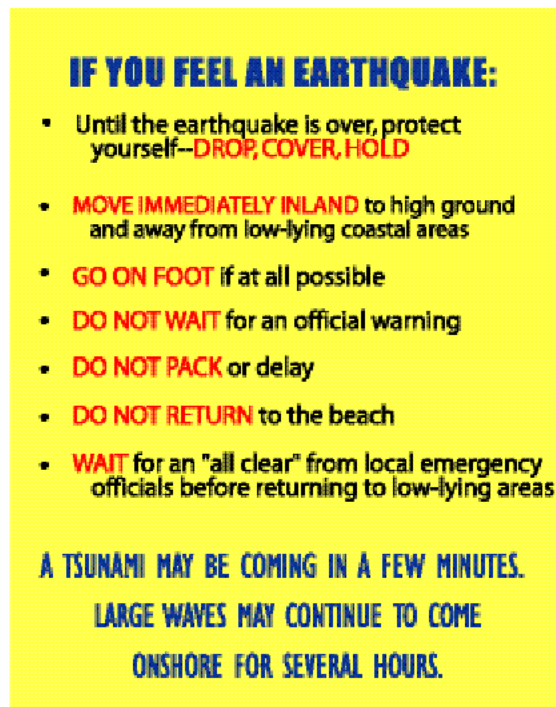
## What is the best way to react to the possible arrival of a tsunami?

Although it may seem like the obvious thing to do is to first gather some supplies together and then head for high ground in your car, the truth is that the best way to escape from a known tsunami inundation zone is to immediately start walking toward higher ground.

In the case of local tsunamis, buildings and roads damaged by the earthquake will pose obstacles for driving cars. Traffic jams are also a problem. Some evacuation route roads may actually lead down toward the shoreline before they head up to higher ground. Cutting across country on foot, therefore, is the best way to get a head start on the first of the tsunami waves, which, literally may be arriving within minutes after the earthquake's shaking.

Even for distant tsunamis, which have longer evacuation lead times, the best way for people to ensure their personal safety is to leave the possible inundation zone as quickly as possible. Again, except for people who are truly physically unable to walk, the best evacuation mode is on foot, due to the massive traffic jams resulting from any evacuation.

After the first tsunami wave arrives it is still not necessarily safe to return to the shoreline. Tsunami waves can persist for up to ten hours. In addition, secondary hazards, like fires and hazardous chemical spills, may pose a threat in some areas for long periods after the last tsunami waves have subsided. So, the best plan is to wait for an official "all clear" from local emergency management authorities before going back into the inundation zone.



**IF YOU FEEL AN EARTHQUAKE:**

- Until the earthquake is over, protect yourself--**DROP, COVER, HOLD**
- **MOVE IMMEDIATELY INLAND** to high ground and away from low-lying coastal areas
- **GO ON FOOT** if at all possible
- **DO NOT WAIT** for an official warning
- **DO NOT PACK** or delay
- **DO NOT RETURN** to the beach
- **WAIT** for an "all clear" from local emergency officials before returning to low-lying areas

**A TSUNAMI MAY BE COMING IN A FEW MINUTES.**  
**LARGE WAVES MAY CONTINUE TO COME**  
**ONSHORE FOR SEVERAL HOURS.**