The Killer Tsunami

Tsunami is a Japanese word meaning port (tsu) - wave (nami), thereby implying those waves which are hardly discernible at high seas but extremely potent in the port or shore. It is precisely due to such deception that they are very destructive.

All Tsunamis are caused by submarine eruptions, landslides, comet strikes, earthquakes, etc. The last of these is the most common source of Tsunamis. The rapid vertical displacement of a significant volume of ocean water by some external physical process acting either from below, at the ocean floor or from above, impacting the water surface, generates a tsunami. In the process of smoothening of such displacement of ocean surface a wave propagating away from the source is generated.

However, not all earthquakes generate Tsunamis. It is only the high magnitude events involving considerable vertical movement of sea-bottom that result in these waves. So a strike slip fault on ocean floor will not normally generate a Tsunami even if a large earthquake is generated. Sometimes, however, a strike-slip movement related earthquake can send a rapid landslide into the sea which in turn generates a killer Tsunami as was the case in 1946 Alaskan peninsula that caused a Pacific wide Tsunami.

Volcanic eruptions on sea floor as well as onshore eruptions sending large amounts of lava and pyroclasts into the sea may also generate a Tsunami. Famous Krakatau eruption of Indonesia in 1883 is one such example.

Probably one of the most extreme tsunamis in the geological history of the earth, some 65 million years ago, was caused by the impact of a meteorite near what is now known as the Chicxulub structure, on the Yucatan Peninsula in Mexico. This is believed to have caused, atleast partly, the extinction of many species including Dinosaurs. This tsunami was over 300 meter high.

In fact the term Tsunami has also been used to describe spectacular waves in water bodies like lakes, reservoirs and fjords caused by sudden displacement of their waters by rockslides or mudslides. The declared record in historic time is held by a rockslide in Lituya Bay in southeast Alaska, triggered by the 1958 Fairweather Fault strike-slip earthquake that caused a 520 m high water wall that stripped forests and soil from rocky cliffs.

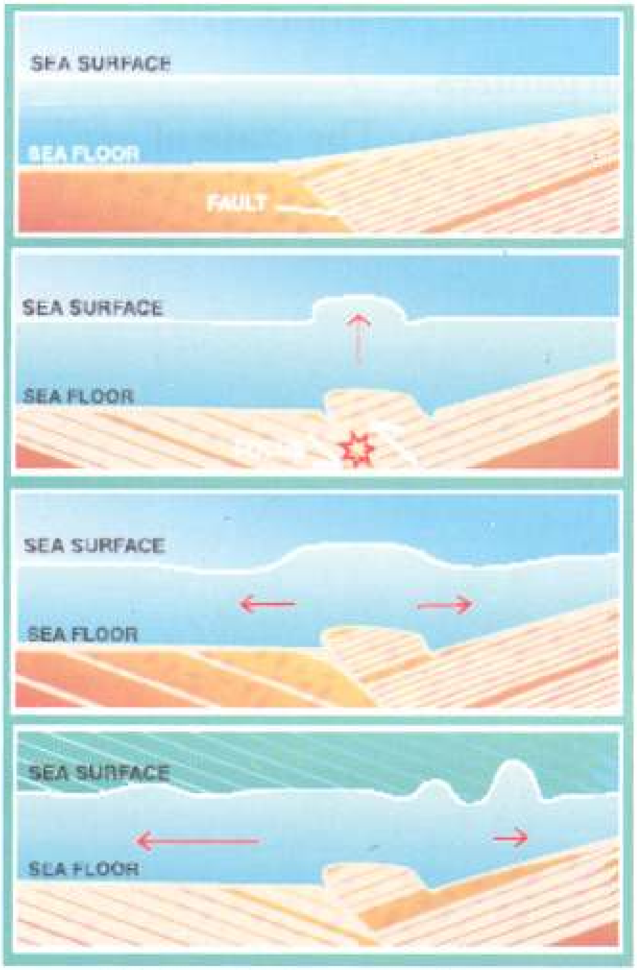
The most notorious tsunamigenic areas are near subduction zones where, one plate (an oceanic plate) can slip as much as 20 meters beneath the leading edge of the overriding plate (often a continent or volcanic island chain). Recent tsunami that wreaked havoc on coasts of Indonesia, Malaysia, India and Srilanka on December 26, 2004 was caused by subduction of India plate past the Burma plate by as much as 20 meters at one patch of the fault. The vertical component of this total inclined slip on the fault dipping 10° or 15° to Northeast was probably of the order of two meters.

A powerful tsunami also has a very long reach: it can transport destructive energy from its source to coastlines thousands of kilometers away. Hawaii, because of its mid-ocean location, is especially vulnerable to such Pacific-wide tsunamis. Twelve damaging tsunamis have struck Hawaii since 1895. In one of the most destructive episodes in 1964, 159 people died from killer waves generated almost 3,700 kilometers away in Alaska's Aleutian Islands.

With speeds that can exceed 700 kilometers per hour in the deep ocean, a tsunami wave could easily keep pace with a Boeing 747. Despite its high speed, a tsunami is not dangerous in deep water. A single wave is less than a few meters high, and its length can extend more than 750 kilometers in the open ocean. This creates a sea-surface slope so gentle that the wave usually passes unnoticed in deep water. A tsunami can therefore move silently and undetected across the ocean, and then unexpectedly rise as very high waves in shallow coastal waters.

Regardless of their origin, tsunamis evolve through three overlapping but quite distinct physical processes: generation by any force that disturbs the water column, propagation from deeper water near the source to shallow coastal areas and, finally, inundation of dry land. Of these, the propagation phase is best understood, whereas generation and inundation are more difficult to model and simulate.

For generation, modelers assume that sea-surface displacement is identical to that of the ocean bottom. Though direct measurements of seafloor motion have never been available researchers use an idealized model of the quake assuming that crustal plates slip past one another along a simple, rectangular plane inside the earth. Even then, predicting the tsunami's initial height requires at least ten descriptive parameters, including the amount of slip on each side of the imaginary plane and its length and width. As a consequence, this first simulation frequently underestimates the effect of Tsunami, sometimes by factors of 5 to 10. Analyses of seismic data cannot resolve energy distribution patterns any shorter than the seismic waves themselves, which extend for several hundred kilometers. Satisfactory simulations are achieved only after months of labor-intensive work, but every simulation that matches the real disaster improves scientists' ability to make better predictions in future.



A simple model of generation of Tsunami

Propagation of the tsunami transports seismic energy away from the earthquake site through undulations of the water, just as shaking moves the energy through the earth. At this point, the wave height is so small compared with both the wavelength and the water depth that researchers apply linear wave theory, which assumes that the height itself does not affect the wave's behaviour. The theory predicts that the deeper the water and the longer the wave, the faster the tsunami. This dependence of wave speed on water depth means that refraction by bumps and grooves on the seafloor can shift the wave's direction, especially as it travels into shallow water. In particular, wave fronts tend to align parallel to the shoreline so that they wrap around a protruding headland before smashing into it with greatly focused incident energy. At the same time, each individual wave must also slow down because of the decreasing water depth, so they begin to overtake one another, decreasing the distance between them in a process called shoaling. Refraction and shoaling squeeze the same amount of energy into a smaller volume of water and create higher waves and faster currents.

Inundation and run-up, the last stage of evolution, in which a tsunami may run ashore as a breaking wave, a wall of water or a tidelike flood, is the most difficult to model. The wave height being large, linear theory fails to describe the complicated interaction between the water and the shoreline. Vertical run-up can reach tens of meters. Horizontal inundation, if unimpeded by coastal cliffs or other steep topography, can penetrate hundreds of meters inland. Both kinds of flooding are aided and abetted by the typical crustal displacement of a subduction zone earthquake, which lifts the offshore ocean bottom and lowers the land along the coast. This type of displacement propagates the waves seaward with a leading crest and landward with a leading trough (so a receding sea sometimes precedes a tsunami). Near-shore subsidence also facilitates tsunami penetration inland.

Tsunami prediction requires placement of ocean bottom recorder that detects the increased pressure from the additional volume of overlying water. Even 6,000 meters deep, these sensors can detect a tsunami no higher than a single centimeter. Ship and storm waves are however not detected, because their length is short and, as with currents, changes in pressure are not transmitted all the way to the ocean bottom. Ideally, when these bottom recorders detect a tsunami, acoustic chirps will transmit the measurements to a car-size buoy at the ocean surface, which will then relay the information to a ground station via satellite. Geophysicists can then analyse the data and help issue warnings. Even the most reliable warning is, however, ineffective if people do not respond appropriately. Community education is perhaps the most important aspect of the mitigation program.

Predicting where a tsunami may strike helps to save lives and property only if coastal inhabitants recognize the threat and respond appropriately. More than a quarter of all reliably reported Pacific tsunamis since 1895 originated near Japan as it lies precariously near the colliding margins of four tectonic plates. Japanese have invested heavily over the years in tsunami hazard mitigation, including comprehensive educational and public outreach programs, an effective warning system, shoreline barrier forests, seawalls and other coastal fortifications

Over the past century, in Japan, approximately 15 percent of 150 tsunamis were damaging or fatal. That track record is much better than the tally in countries with few or no community education programs in place. For example, more than half of the 34 tsunamis that struck Indonesia in the past 100 years were damaging or fatal.

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