

Earthquake Hazards

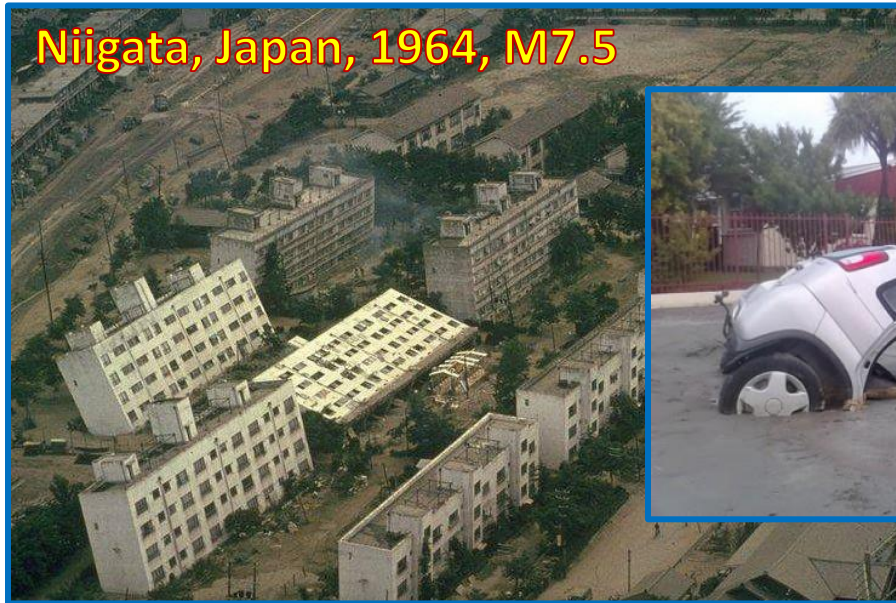
Earthquake Hazards: Shaking

Amount of structural damage due to earthquake **vibrations** strongly depends on intensity and duration of the vibrations. Buildings respond differently to shaking based on construction styles and materials (wood - more flexible, holds up well; earthen materials - very vulnerable to shaking).

- High frequency body waves shake low buildings more.
- Low frequency surface waves shake high buildings more.
- Intensity of shaking also depends on type of subsurface material.
- Unconsolidated materials (sand, mud) amplify shaking more than rocks do.
- Fine-grained, sensitive materials can lose strength and collapse when shaken.



Earthquake Hazards: Soil



Liquefaction of the ground:

- **Unconsolidated materials** (such as sand and silt) saturated with water **turn into a mobile fluid**.
- **Damage to foundation as well as sinking and tilting of structures can occur.**

Landslides:

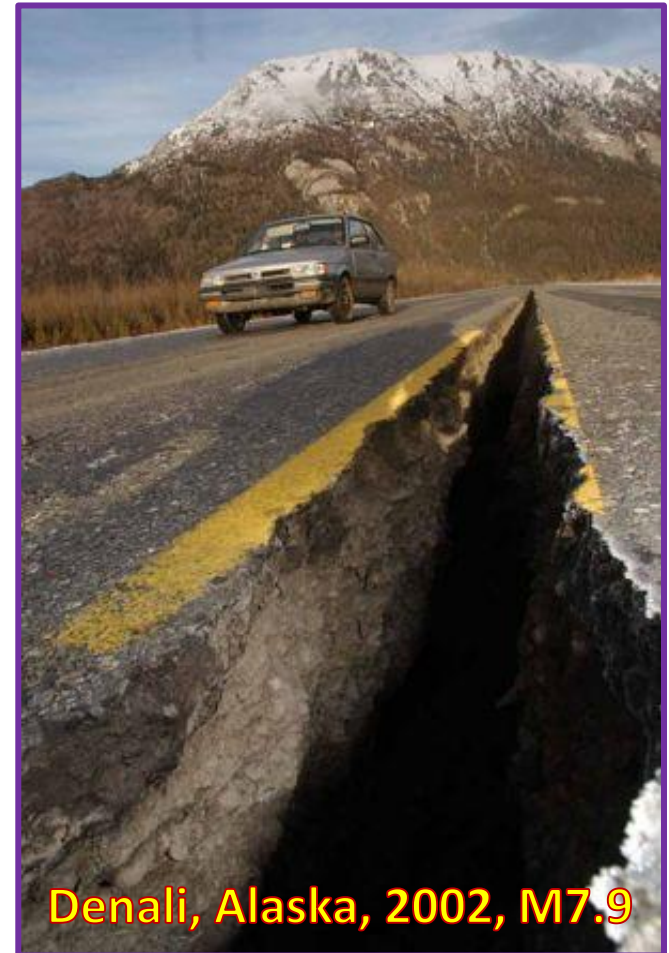
- Earthquakes can produce **slope instability** leading to landslides.

Earthquake Hazards: Shift

Ground displacement/rupture:

- Ground surface may shift and split apart, especially if the focus of the earthquake is shallow.
- Vertical displacements of surface produce fault scarps.

Thrust fault scarp: Chi Chi earthquake, Taiwan, 1999, M7.6



Denali, Alaska, 2002, M7.9

Fires: As a result of ground displacement, fires can occur from **shifting of subsurface utilities** (electric and gas lines).

Earthquake Hazards: Water Bodies

Seiches: rhythmic back-and-forth sloshing of water in lakes, reservoirs, and enclosed basins.



Such waves **can weaken reservoir walls and cause destruction.**

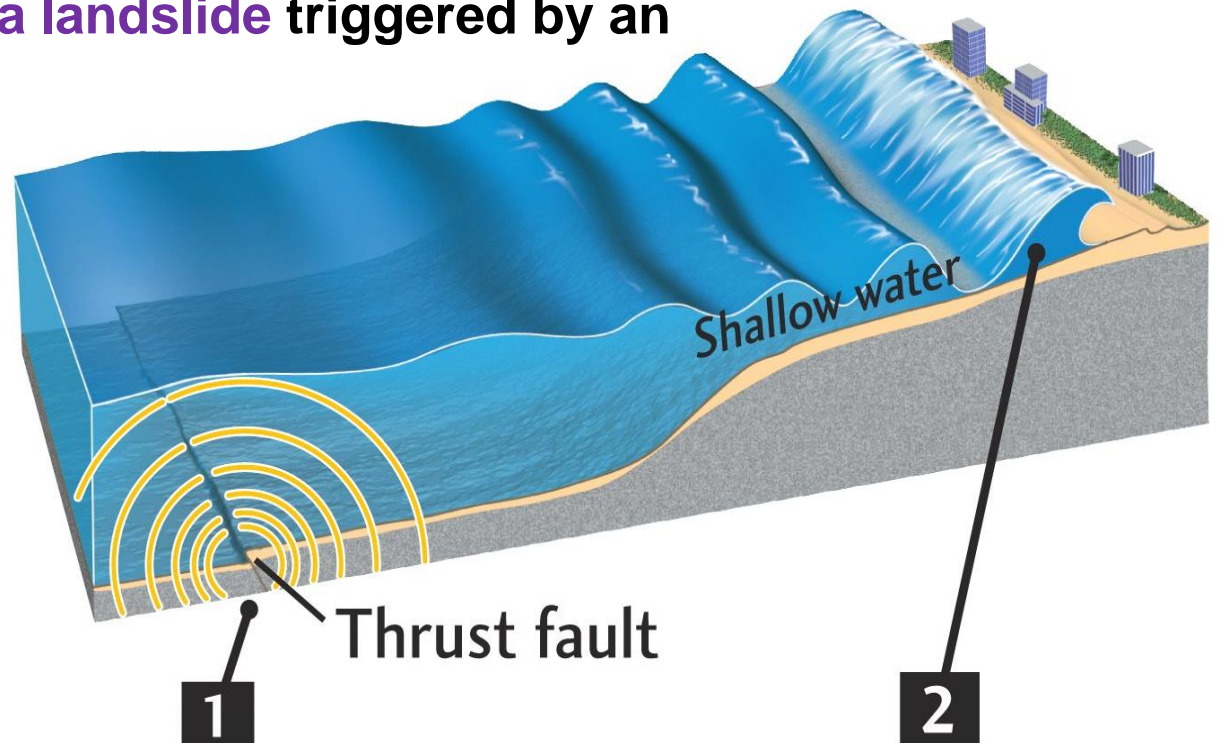


Earthquake Hazards: Water Bodies

Tsunami: Japanese for “harbor wave” – harmless until it enters the harbor...

1. Destructive **seismic sea waves** that result from **vertical displacement of the ocean floor** or a **large undersea landslide** triggered by an earthquake.

2. In shallow coastal waters tsunami waves can occasionally **exceed 30 meters (100 feet)**.



Hazards and Risks of Tsunami

Tsunamis are **most devastating near the earthquake**. They are **larger** and **strike** the region **soon** after the earthquake.

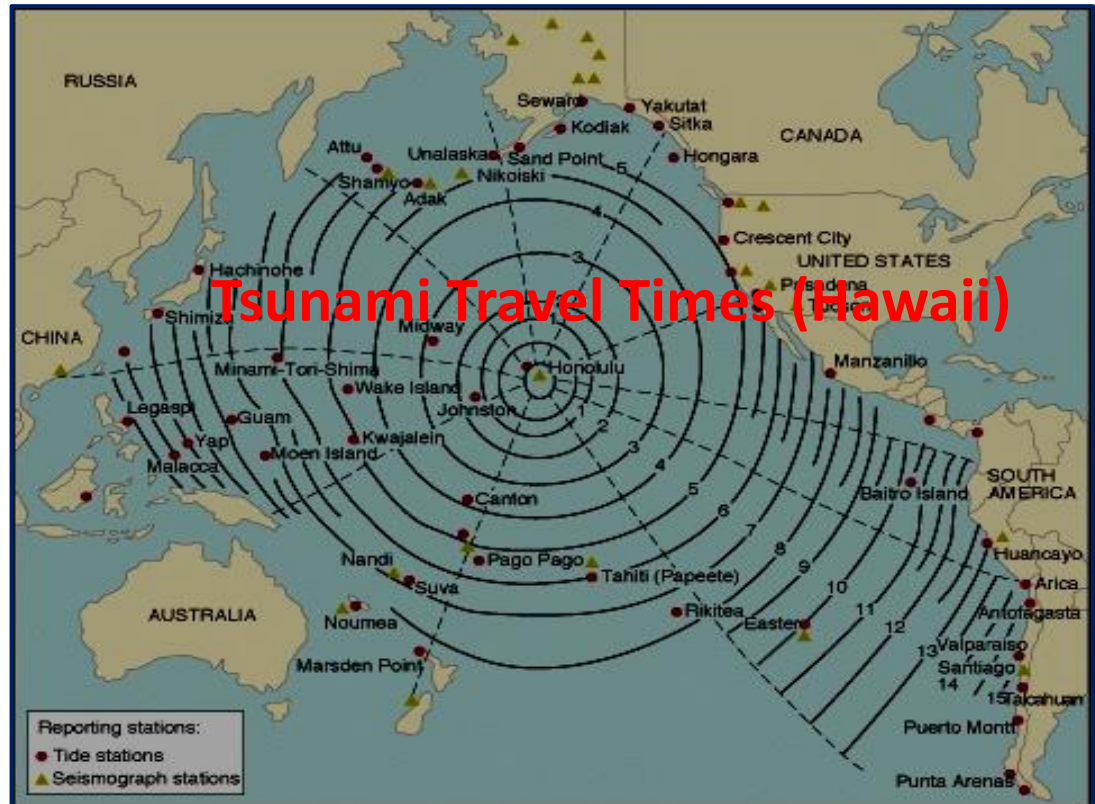
- Tsunamis also travel across entire oceans and cause damage and death thousands of miles from the earthquake.
- Tsunamis travel very quickly relative to normal ocean waves, especially in open water, where velocities increase with water depth and can reach 1,000 km/hr (normal ocean wave: ~90 km/hr)
- The most tsunami prone areas are those associated with volcanoes and earthquakes, mainly subduction zones. **Large subduction zones** produce the most tsunamis: Pacific ~80%, Atlantic ~10%, elsewhere ~10%.



Tsunami Warning

Regions with a high tsunami risk typically use tsunami warning systems to warn the population before the wave reaches land:

- The **Pacific Tsunami Warning System** is based in Honolulu, Hawaii. It monitors Pacific Ocean seismic activity.
- As soon as an earthquake of magnitude >6.5 is located in the sea, the **alarm starts**.
- Using computer simulations based on real-time data from bottom pressure sensors, attached to buoys, scientists forecast the time of tsunami arrival in different locations.



Greatest Earthquakes Ever Recorded

1. **(M 9.5)** 22 May 1960 – Great Chilean Earthquake, Valdivia, Chile:
most powerful earthquake ever recorded; lasted ~10 min; triggered tsunami which reached Hawaii and Japan; 3000-5000 dead.



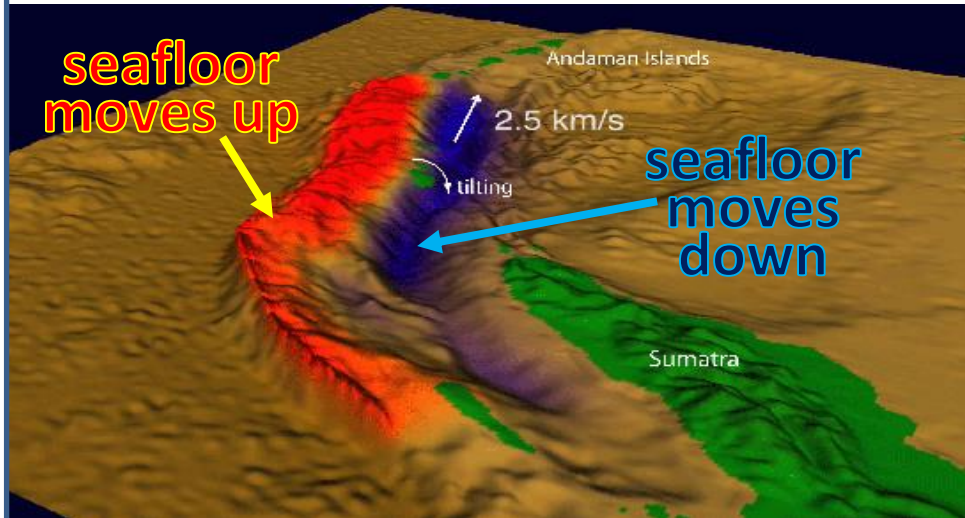
2. **(M 9.2)** 27 March 1964 – Great Alaskan Earthquake (aka Good Friday earthquake), Prince William Sound, AK:
lasted ~4.5 min; tsunami, soil liquefaction; 128 dead.



Greatest Earthquakes

3. (M 9.1-9.3) 26 December 2004 – Indian Ocean Earthquake (aka Sumatra-Andaman earthquake), off the west coast of Sumatra:

shaking lasted ~8 min; **surface wave oscillations exceeded 1 cm everywhere on Earth**; the **longest ever fault rupture of 1600 km** triggered tsunami waves (up to 30 m high reaching as far as 2 km inland in Indonesia); killed 230,000 people in 14 countries.



Ever Recorded

4. (M 9.0) 11 March 2011 – Great East Japan Earthquake (aka Tohoku earthquake), off the west coast of Japan:

lasted ~6 min; tsunami waves (up to 40 m high, travelled as far as 10 km inland); the disaster caused **partial meltdown at Fukushima Daiichi Nuclear Power Plant**; 15,800 dead.

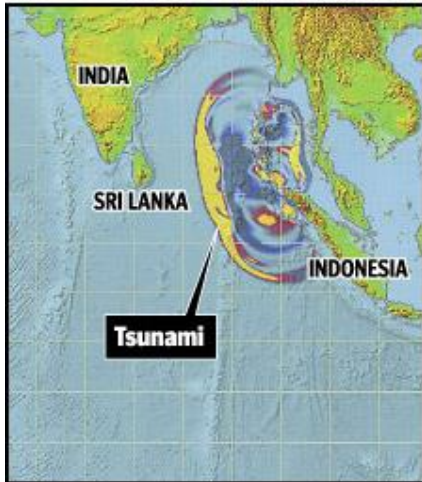


Tsunami: 2004 Indian Ocean Earthquake

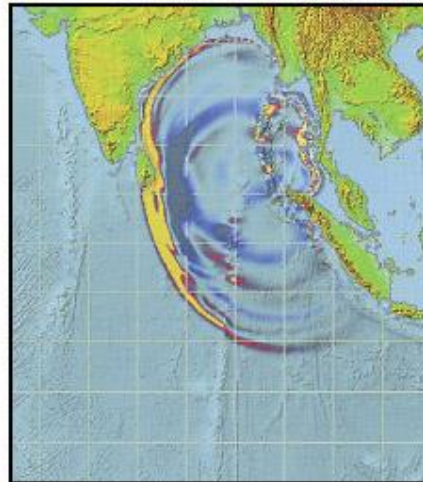
This giant 9.1 magnitude earthquake ruptured the **greatest fault length of any recorded earthquake**, spanning a distance of **990 miles** (1600 km), or *longer than the state of California*.

- Such a giant push of water generated a series of **ocean-wide tsunami waves**, the first of which hit Indonesia 25 minutes **after** the start of the quake.

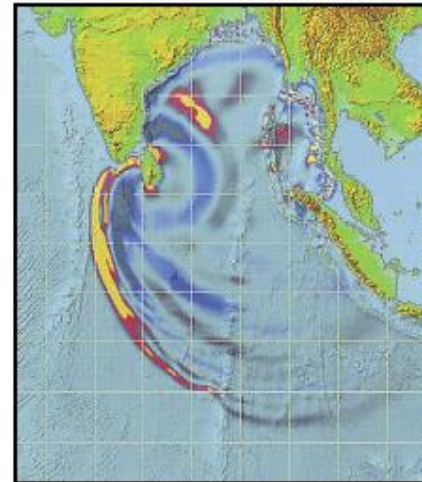
1 HOUR



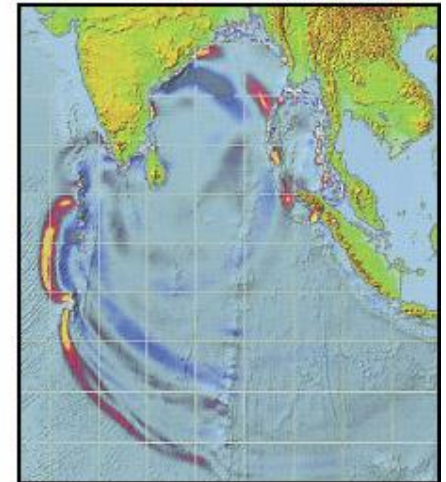
2 HOURS



3 HOURS



4 HOURS



- The waves had grown to **100 feet (30 m)** high in some places; more tsunami waves struck Thailand two hours later, and other countries across the Indian Ocean were hit a few hours later.

BANDA ACEH, INDONESIA: June 23, 2004
A satellite image of the waterfront area of Aceh province's capital city before the tsunami.



BANDA ACEH, INDONESIA: December 28, 2004
An image taken after the tsunami shows destroyed housing and the shoreline nearly wiped out.



And after the water is gone...

