

Natural Disasters

Lecture 23 Ch 8 – Tsunami

Text Source Today:
Chapter 8

Part III (this Ch. 8 material is not on Exam #2)

8.1: Ch. 8 – Tsunami

♦ **Tsunami:** Japanese word meaning “harbor wave”. Tsunami are mistakenly called “**tidal waves**”, but they have **nothing to do** with the tides. (Note that the plural form is still “tsunami.”)

♦ When a water mass is hit with a massive **jolt of energy**, the result is a powerful tsunami with huge water seismic waves of:

♦ **extremely large** wavelengths, $L \sim 100$ to 840 km (>500 mi)

♦ **very long** periods, $T \sim 10$ to 60 minutes

♦ **low** wave height, $H < 1$ meter

♦ **low** steepness ($S = H/L$); **never** a breaking (**1:7**) wave

♦ **very high** speeds, $C \sim 200$ m/sec (~ 450 mph)

$$C = (gD)^{1/2} = 3.13 (D)^{1/2}, \text{ where } D = \text{avg. ocean depth}$$

● **shallow** water wave ($D/L < 1/20$); affects entire water column

♦ can **pass unnoticed beneath** ships at sea

● enormous **energy** is distributed over its depth and wavelength

♦ When a tsunami enters shallow water, it **slows down** and the **wavelength shortens** (but the back of the wave is traveling faster), thus a strong buildup of its **height** must occur; most notable on steep-sloped beaches and into inlets and bays

♦ If the leading edge of the tsunami wave is a **trough**, the sea recedes from the coast **half the wave's period** before its arrival

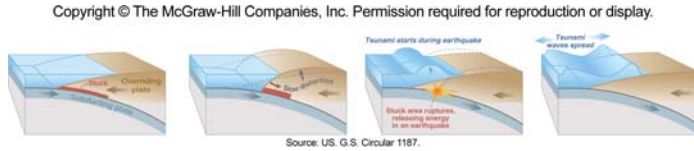
● If the leading edge of the tsunami wave is its **first crest**, successive waves can lead to further **flooding**

● A tremendous **surge of flood water** (moving slower, but still moving at **40-60 mph**) races up over the land, flooding the coast, destroying coastal structures

♦ If **drowning** does not kill people in its way, the huge amount of **floating debris** (trees, pieces of buildings, autos, etc.) will!

♦ Causes of Tsunami:

(Fig. 8.14)

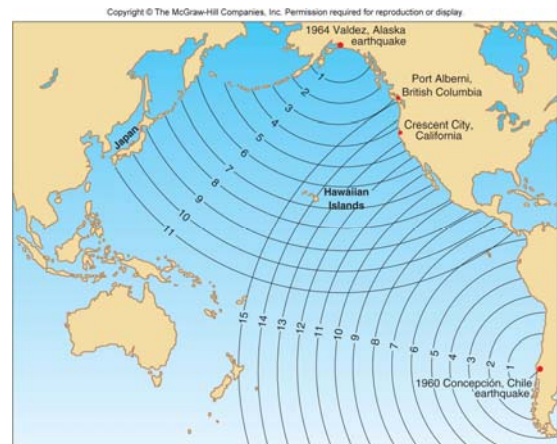


♦ **1 Earthquake-caused Tsunami:** when fault movements are **vertical** and result in uplifting or down-dropping the seabed in an **EQ** of at least 7.5 M_w .

♦ There is **no way** to tell which of the incoming tsunami waves will be the largest. Many times, the trigger-**EQ** is **not even felt**.

● **Alaska, 1 April 1946, “The April Fools Tsunami:”** two large subduction movements occurred and 20 minutes after the second **EQ**, a tsunami wave took out a steel-reinforced lighthouse, killing 5 men. **The first wave was the biggest.** This tsunami crossed the Pacific, killing 159 people in Hilo, HI. (Fig. 8.19)

● **Chile, 22 May 1960:** The largest EQ on record (**9.5 M_w**) generated a powerful tsunami that killed people throughout the Pacific basin. This time, **the third wave was the biggest.** Over 1,000 Chileans died. This tsunami wave crossed the Pacific, killing 61 people in Hilo, HI about 14 hours later and then went on to kill another **282 in Japan** about 22½ hours later.



● **Alaska, 27 March 1964:** The second largest EQ on record (**9.2 M_w**) generated a tsunami that ravaged the sparsely populated Alaska coastline, killing 125 people. Even though the

residents of **Crescent City, CA** were aware of the tsunami, they waited out **four** successive tsunami waves and then went back down into town to check on their properties. This time, **the fifth wave was the largest** and another 12 people were killed.

- **Pacific NW, 20??:** Subduction zone EQs generate more killer tsunami than any other source. **No ocean is safe from tsunami**, though the **Pacific** is hit most often. A **9 M_w** EQ in the Pacific NW back in **1700** sent a killer tsunami all the way to Japan. The Pacific NW is “overdue” for an EQ/tsunami event! (Fig. 8.15)

- ◆ **Indian Ocean Tsunami, 26 Dec. 2004:** the seafloor west of northern Sumatra in Indonesia split and ruptured northward for **1200 km** for nearly **7 minutes!** This created the **2nd largest EQ (9.1 M_w)** in the last 100 years. The rupture began 30 km (19 miles) below the seafloor and caused movements up to 20 m (65 feet) that shifted the positions of some **Indonesian islands** and tilted others. Any significant **EQ** damage in northern Sumatra was erased by the powerful tsunami about **15 minutes later**.



- ◆ The tsunami raced across the Indian Ocean, causing death and destruction in **13 countries**. The estimated death toll is **245,000**. Many native people had **never** experienced a tsunami, as the last one to occur in the Indian Ocean was caused by the collapse of Indonesia's **Krakatau volcano in 1883**.

- ◆ **Education** and a **warning system** would have saved lives.

- ◆ **Japan Tsunami, 11 March 2011:** a **9.0 M_w** EQ sent a tsunami 20 to 133 feet high into Japan, killing over 19,000.

♦2 **Volcano-caused Tsunami:** volcanoes can explode, collapse, and can even send avalanches of debris into the water.

(Fig. 8.21)

♦ **Krakatau, Indonesia, 26-27 August**

1883: This stratovolcano sits between the islands of **Sumatra and Java**. This famous eruption sequence set off many killer tsunami, with the biggest one coming with the overwhelming final explosion (heard for thousands of miles), that led to the **collapse of the mountain**. Over a period of 20 hours, several tsunami destroyed 165 villages and killed more than 36,000 people. This tsunami death toll was not exceeded until **Dec. 26, 2004**.



♦3 **Landslide-caused Tsunami:** energy is transferred to the water, when gravity pulls rock and sediment into and beneath the seas. Can cause locally higher and larger run-ups of water than EQ-generated tsunami.

● **Volcano Collapses:** The largest submarine mass movements were recognized first on the seafloor along the **Hawaiian Island** volcanic chain. There have been at least 70 flank collapses in the last 20 million years. **Kilauea** may be next! (Fig. 8.25)

♦ **Canary Islands:** A computer simulation showing a 500 km^3 (120 mi^3) flank collapse of the **Cumbre Vieja** volcano on the island of **La Palma** would generate a 10-20 m (30-65 ft) high tsunami that could travel across the Atlantic and strike the east coasts of the Americas!



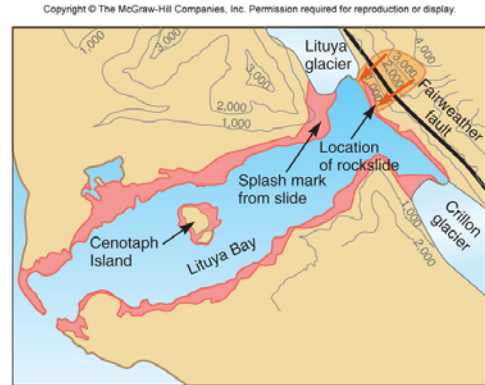
- **EQ-Triggered Mass Movement:** EQs can trigger tsunami indirectly by triggering a mass movement, usually undersea. When this happens in bays and lakes, it can be extra dramatic.

(Fig. 8.28)

◆ **Lituya Bay, Alaska, 9 July 1958:**

The largest historic **tsunami wave run-up** on record occurred when a massive **rockfall** dropped into **Lituya Bay** in Glacier National Park, Alaska.

An **8 M_w EQ** caused 90 million tons of rock and ice to drop more than 900 m (3000 ft) into the water! The wave swept over Cenotaph Island and **stripped away trees** along both walls of the bay, 35 m (110 ft) above sea level, all the way to the open ocean!



- ◆4 **Impact-caused Tsunami:** the **largest** tsunami of all are created by the impact of high-velocity asteroids and comets, but they are the **rarest** of all.

- **Tsunami Mitigation:** **Seafloor sensors**, activated in 2003 in the Pacific and Atlantic, can detect the passage of a tsunami and give ample warning for distant shores. The Indian Ocean had **no such system** in 2004.

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TABLE 8.5

Surviving a Tsunami

Abandon your belongings.

Many lives are lost while trying to save possessions.

Head for high ground—and stay there.

If there is no high ground nearby, then

Climb to an upper floor or roof of a strong building.

If there is no sturdy building, then

Climb a tree.

If there are no climbable trees, then

Grab onto something that floats.

Look for something to use as a raft.

- ◆ **Tsunami Safety:** If you are near a shoreline and feel an **EQ**, see the sea level pull away from shore, or hear the wave coming, **run to higher ground**, go upstairs in a well-built building, or climb a tree. **Seek “vertical evacuation!”**