Earthquakes and Tsunamis

BI 201 Natural History of Guam

Class Presentation 21

Earthquakes

- What causes an earthquake?
  - An **earthquake** is a trembling or shaking of the ground caused by the sudden release of energy stored in rock beneath Earth's surface
    - Great forces acting deep in Earth may put a *stress* on the rock, which may bend or change in volume (*strain*)
      - This stress may build up over decades

- Rock can deform only so far before it breaks
  - When rock breaks, waves of energy are sent out through Earth
  - These waves are **seismic waves**, i.e., the waves of energy produced by an earthquake
  - The crack between the two rock masses is called a **fault**

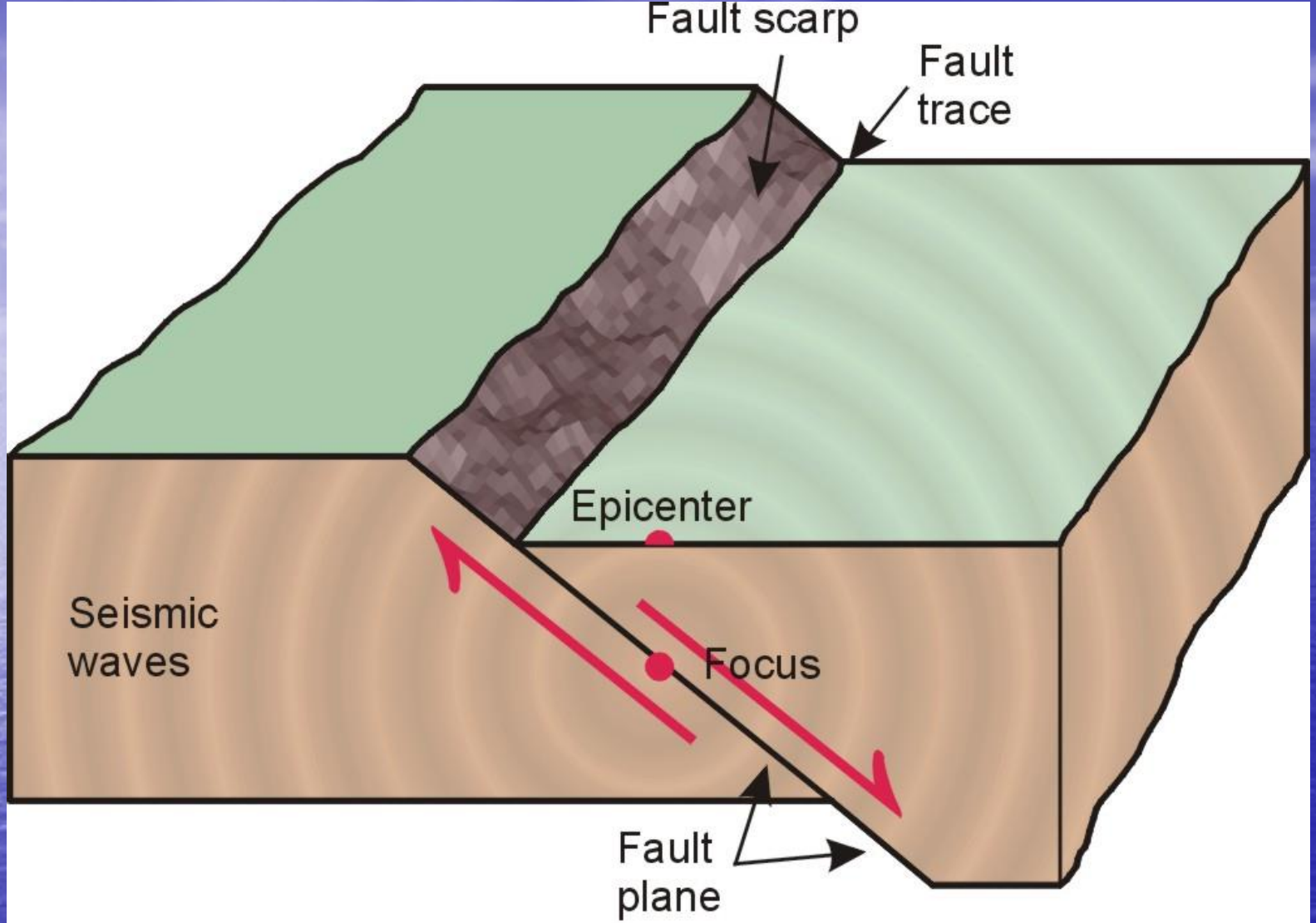
- The sudden release of energy when rock breaks may cause one huge mass of rock to slide past another mass of rock into a different relative position
  - Movement may be vertical, horizontal, or both

– Earthquakes may also occur during explosive volcanic eruptions and during movement of magma in volcanic magma chambers

- An earthquake releases strain on the rock
  - Energy is expended by moving the rock and by creating seismic waves
    - At 5:30 p.m. on March 27, 1964, southern Alaska was rocked by an earthquake that lasted for 3 minutes
    - The tremor was felt over >350,000 mi^2
    - A section of rock 30 mi wide by 125 mi long was raised as much as 40 ft, and a similar block of land sank 3 – 6 ft.
    - Parts of Anchorage, 90 mi from the center of the earthquake, were buried in landslides

- Fifteen people died as a direct result of the shaking, and 100 people were drowned by tsunami waves in Alaska and as far away as Oregon & California
- The force of this earthquake was twice as strong as the better-known 1906 San Francisco earthquake
  - Alaska's low population density resulted in relatively lower loss of life and property

- Seismic waves
  - The point within Earth where seismic waves originate is called the **focus** of the earthquake
  - The point on Earth's surface directly above the focus is called the **epicenter** of the earthquake



The focus of an earthquake is the point where the rocks first break along a fault; seismic waves radiate from the focus. The epicenter is the point on the Earth's surface directly above the focus. [Modified from Plummer & McGeary, 1991].

- Two types of seismic waves radiate outward from the earthquake focus
  1) **Body waves** are seismic waves that travel through Earth's interior, spreading outward from the focus in all directions, much like sounds waves in air
  2) **Surface waves** are seismic waves that travel on Earth's surface away from the epicenter, much like ripples spreading out from a pebble thrown into a pool of water

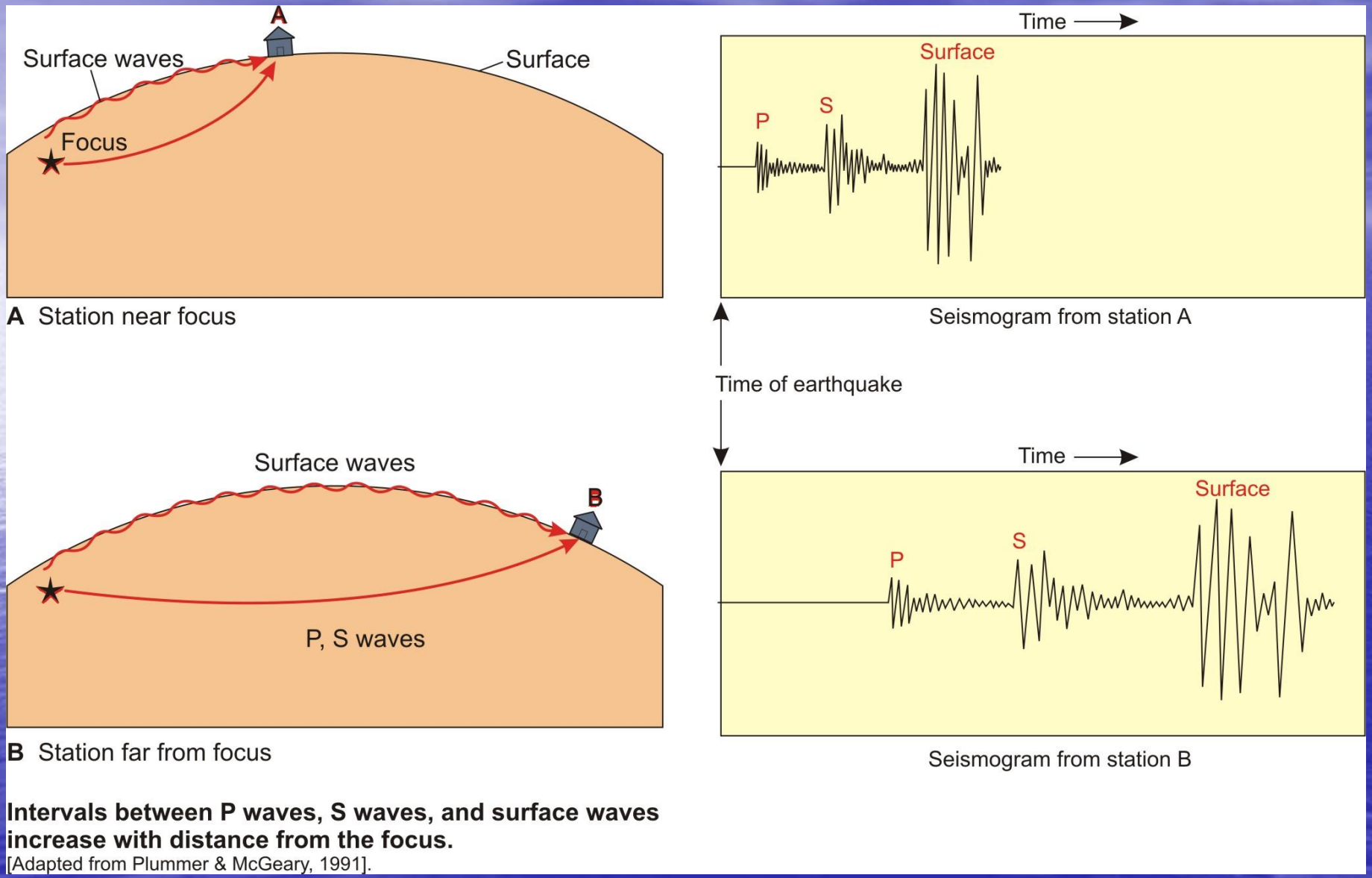
- There are two main types of body waves
  a) A **P wave** is a compressional (or longitudinal) wave in which rock vibrates parallel to the direction of wave propagation (i.e., in the same direction as the waves are moving)
     - P waves are very fast waves, traveling through rock at speeds of 4–7 km/sec (~9,000–15,000 mph)
     - Therefore, P waves are the first (or *primary*) waves to arrive from the earthquake focus or epicenter

b) An **S wave** is a slower, transverse wave that travels at 2–5 km/sec
   - An S (*secondary*) wave is propagated by a shearing motion, with rock vibrating perpendicular to the direction of the waves are moving
   - Both P waves and S waves can pass easily through solid rock
   - A P wave can also pass through fluid (i.e., liquid or gas), but an S wave cannot

- Surface waves are the slowest waves produced by an earthquake
  - However, surface waves cause more property damage than body waves, because
    1) surface waves produce more ground movement
    2) they travel more slowly, so they take longer to pass

- Locating and Measuring Earthquakes
  - A **seismometer** is an instrument used to detect seismic waves
    - It can measure the amount of ground motion and can be used to find the location of an earthquake
  - P, S, and surface waves all start out from an earthquake at essentially the same time
    - As they travel away from the quake, the three types of waves gradually separate, because they are traveling at different speeds

- The farther the seismic waves travel, the longer the time intervals between the arrivals of P and S waves, and the more they are separated on the seismograms

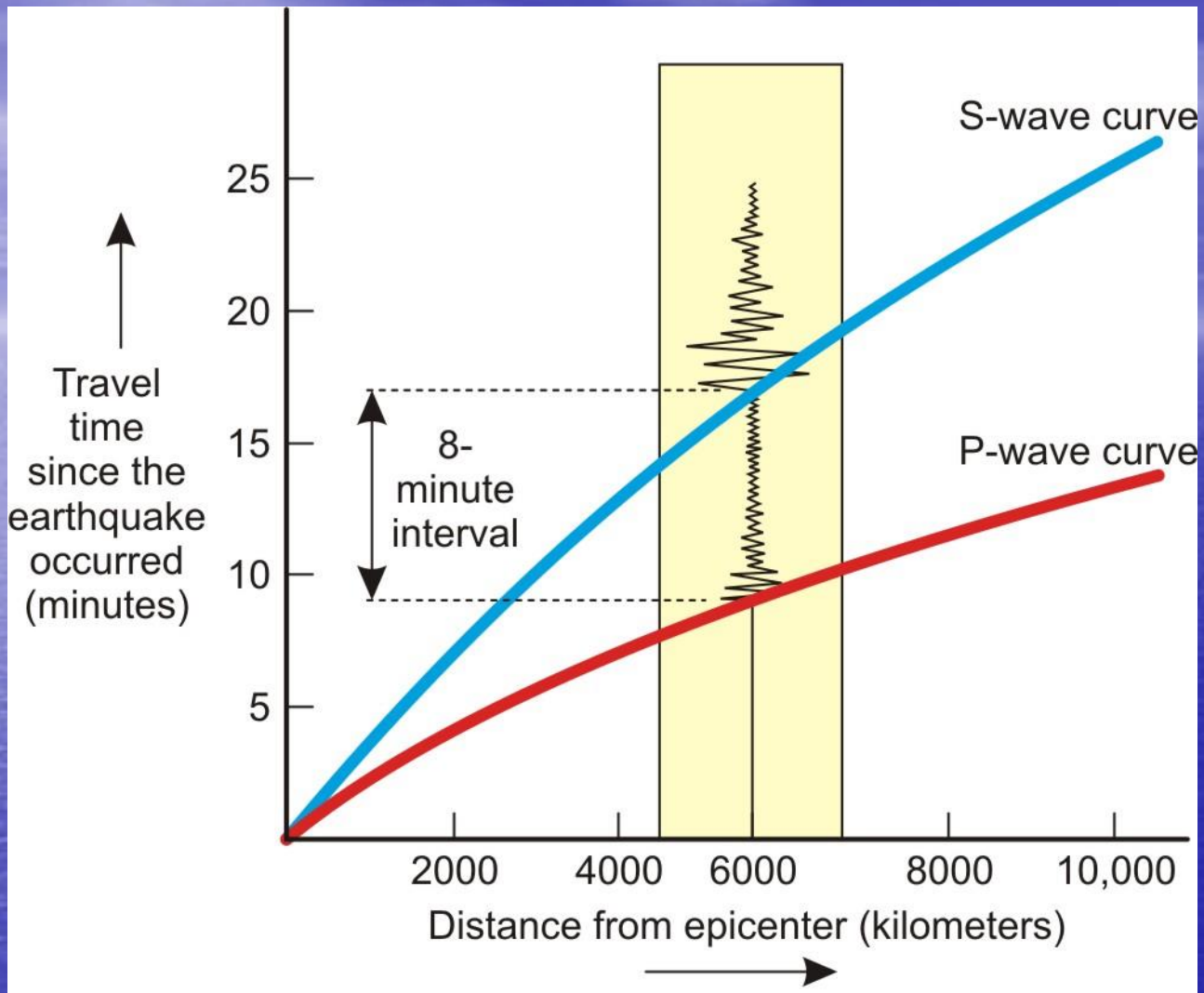


A Station near focus

B Station far from focus

Intervals between P waves, S waves, and surface waves increase with distance from the focus.
[Adapted from Plummer & McGeary, 1991].

- The P-S interval increases with increasing distance from the earthquake
- This relationship can be plotted in a travel-time curve, which plots seismic-wave arrival time vs distance



A travel-time curve is used to determine the distance to an earthquake. Notes that the time interval between the first arrival of P and S waves increases with distance from the epicenter. This seismogram has an interval of 8 minutes, so the earthquake occurred 5,500 kilometers away. [Adapted from Plummer & McGeary, 1991].

- However, a single seismic station can determine only the distance to a quake, not the location where it occurred
- Therefore, a global network of seismic stations has been established, any any three stations can be used to pinpoint the location of an earthquake by triangulation

- Analysis of seismograms can also indicate the depth at which a quake occurs
  - The maximum **depth of focus** is about 670 km down into the lithosphere
  - Deeper in the lithosphere, the rocks become semi-molten, and stresses and strains cannot build up

– Earthquakes are classified by depth

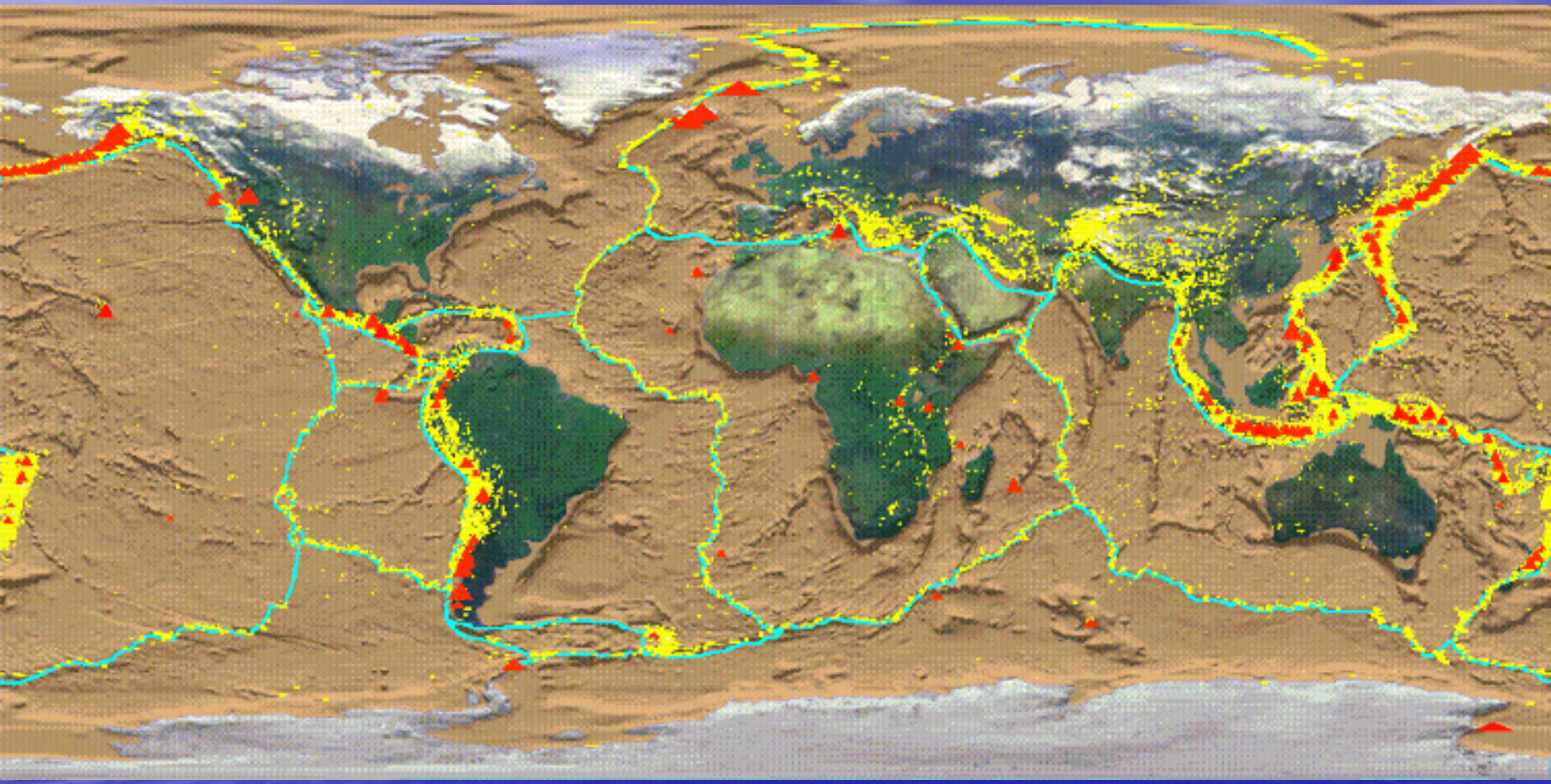
	Depth	Frequency
shallow focus	0–70 km	85%
intermediate focus	70–350 km	12%
deep focus	350–700 km	3%

- The strength of an earthquake can be measure in two ways: intensity and magnitude
  1) **Intensity** is a measure of an earthquake's effects on people and buildings
     - Intensity is expressed as Roman numerals (I–XVII) on the **modified Mercalli scale**
     - No instruments are required, so this method may be too subjective

2) **Magnitude** is the measure of the energy released during the earthquake
   - This measurement based on amplitude of lines on a seismogram
   - Magnitude is expressed numerically by the **Richter scale**, which assigns a number of 0 up to about 10.0
     - The Richter scale is logarithmic, meaning each whole number increase in magnitude represents a tenfold increase in measured amplitude The largest earthquake ever recorded, the Great Chilean quake of 1960, had a Richter magnitude of 9.5

- Because the Richter scale is logarithmic and open-ended, quakes >9.5 could be recorded in the future
- However, values near 9.0 represent a limit of the elastic strength beyond which all types of rock will break
- Therefore, earthquakes larger than 9.0 are considered rare and unlikely

- Distribution of Earthquakes
  - Most earthquakes are concentrated in narrow geographic belts, e.g., circum-Pacific belt, or Mediterranean-Himalayan belt



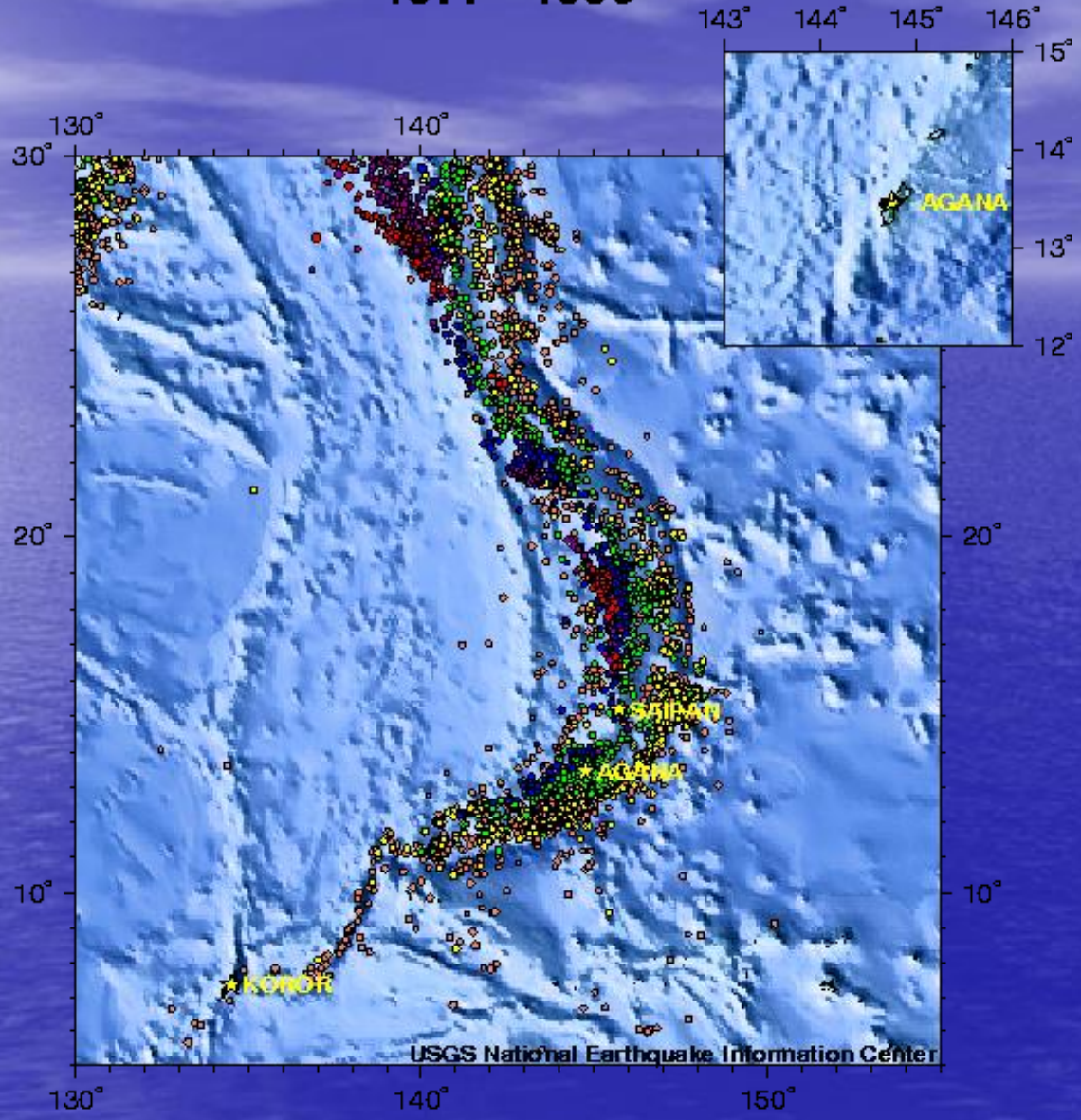
N.B.: highest frequencies of earthquakes occur at tectonic plate boundaries

- Earthquakes and Guam
  - Most earthquakes in Guam originate in or near the Mariana Trench
    - As the Pacific Plate subducts beneath the Mariana Microplate, large compressive forces build up until the tensile strength of the rock is exceeded and slippage occurs along the plate interface
    - These quakes tend to be intermediate to deep focus earthquakes

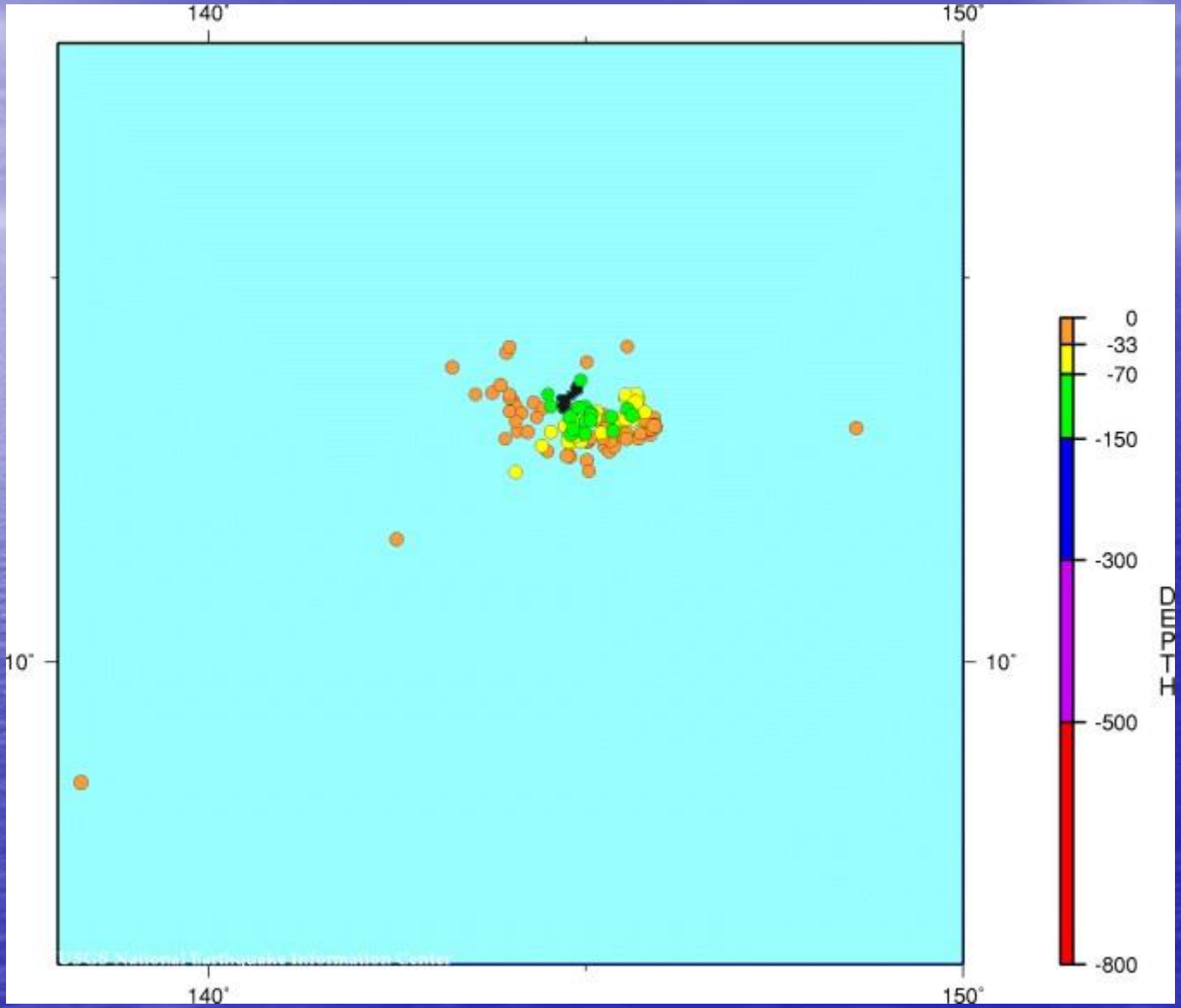
- However, some Guam earthquakes originate near Tracey Seamount and the Mariana Trough
  - These quakes are usually caused by movements of magma, and they tend to be shallow focus earthquakes
- The total number of earthquakes in the southern Mariana Arc since 1973 is 3318

Seismicity of Guam

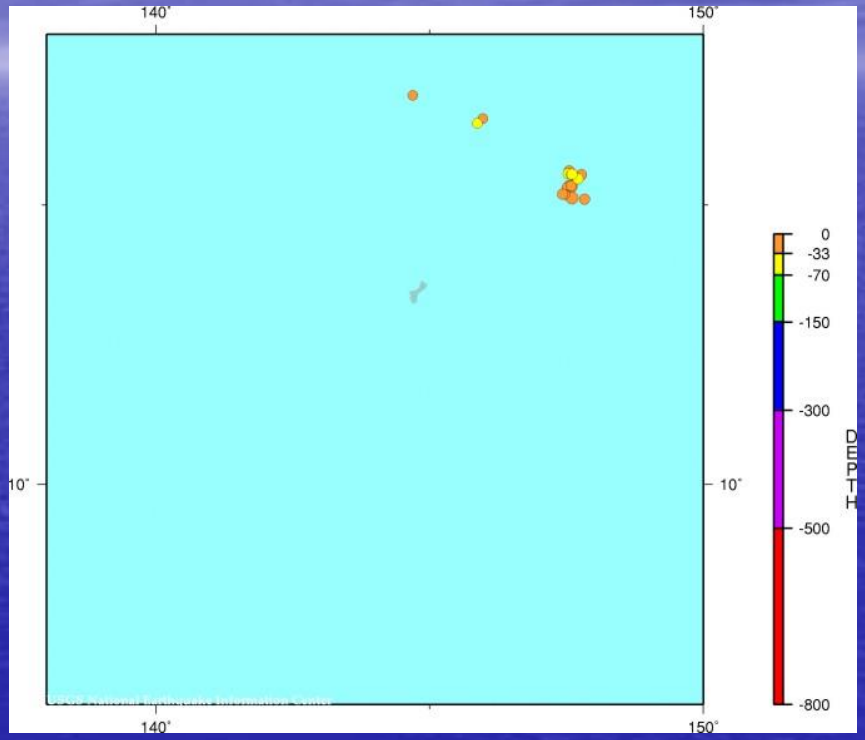
1977 - 1996



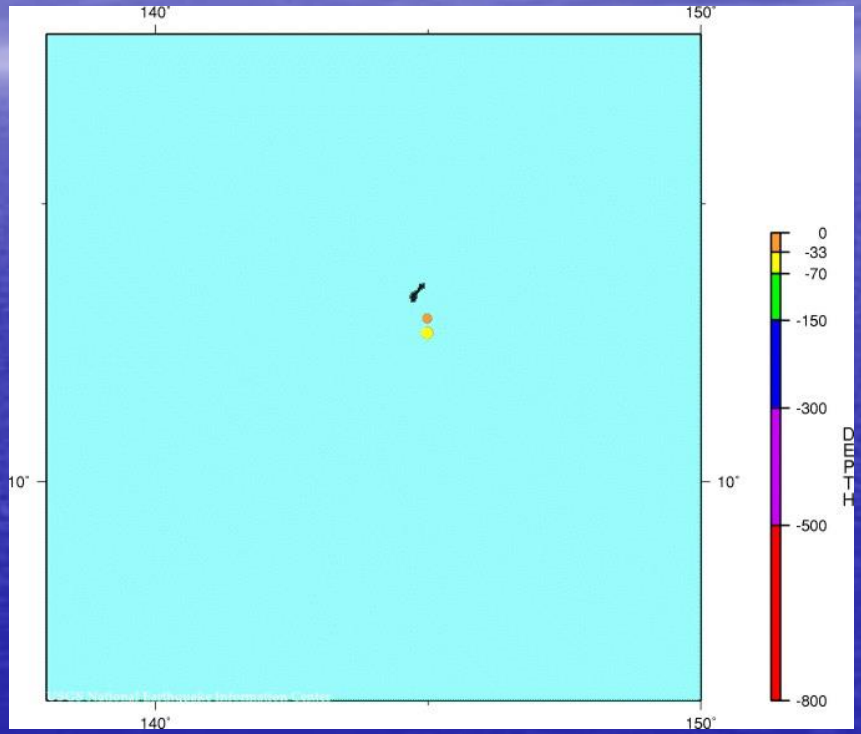
- Large earthquakes of Guam
  - August 8, 1993
    - Origin time: 18:34 GST
    - Epicenter: 12.982°N, 144.801°E
    - Depth: 59 km
    - Magnitude: 8.0 = largest ever recorded in the Mariana Arc region
    - Total of 108 aftershocks recorded by August 31, 1993


140°
150°
10°
10°
140°
150°
0
-33
-70
-150
-300
-500
-800
DEPTH

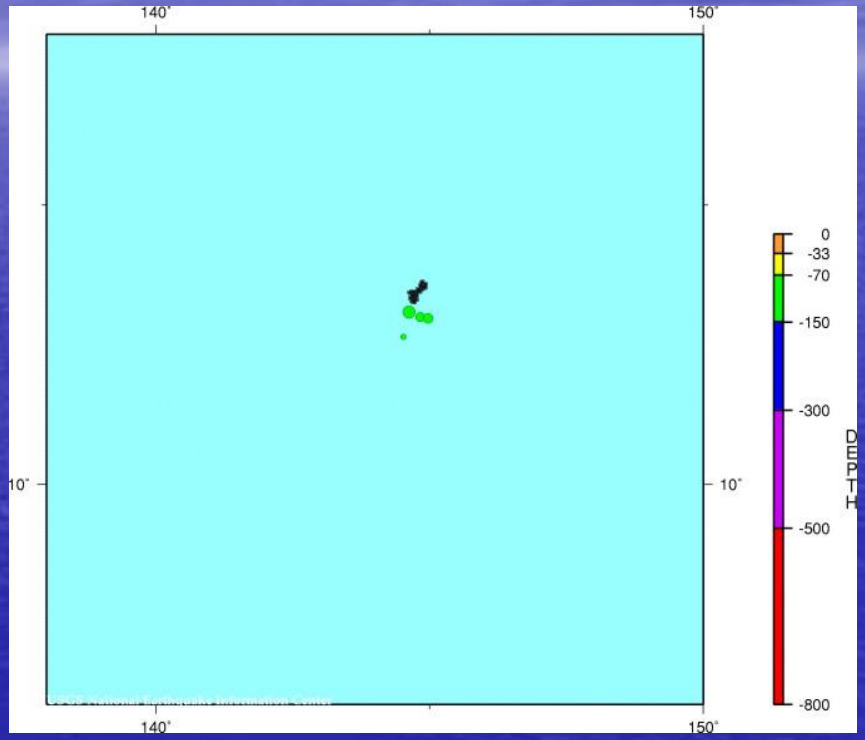
- April 6, 1990
  - Origin time: 07:12 GST
  - Epicenter: 15.12°N, 147.60°E
  - Depth: 11 km
  - Magnitude: 7.5



- October 13, 2001
  - Origin time: 01:02 GST
  - Epicenter: 12.662°N, 144.914°E
  - Depth: 37 km
  - Magnitude: 7.0



- April 27, 2002
  - Origin time: 02:06 GST
  - Epicenter: 13.088°N, 144.619°E
  - Depth: 86 km
  - Magnitude: 7.1
  - At least 5 people slightly injured and some minor damage to buildings on Guam. Water and sewer lines broke, and power outages occurred throughout the island. Felt strongly on Guam. Also felt on Saipan.



- The latest information on Guam earthquakes can be found at

  http://neic.usgs.gov/neis/last_event/world_guam.html

Tsunami

- Tsunami is the name given to **seismic sea waves**
  - The word is from Japanese, for 'harbor wave'
  - Tsunamis are frequently and erroneously called tidal waves
  - Tsunamis are a series of very long waves generated by any rapid, large-scale disturbance of the sea, such as great quakes (M > 8.0) and submarine landslides

- Tsunamis may have wavelengths up to 100 mi
- Their wave heights may be only 5–6 ft on the open sea, but as the waves enter shallow water near land, the wave length is compressed, and wave height increases to 50–100 ft high
  - The maximum recorded waveheight is 278 ft in the Ryukyu Is. in 1971

- Tsunamis may cause catastrophic loss of life and property
  - The April 1, 1946 earthquake in Alaska (M = 7.8) generated a tsunami that struck Hilo, Hawaii killing 159
    - Tsunami waves also destroyed Scotch Cap Lighthouse on Unimak Is. (40 ft above sea level and 5 stories high)

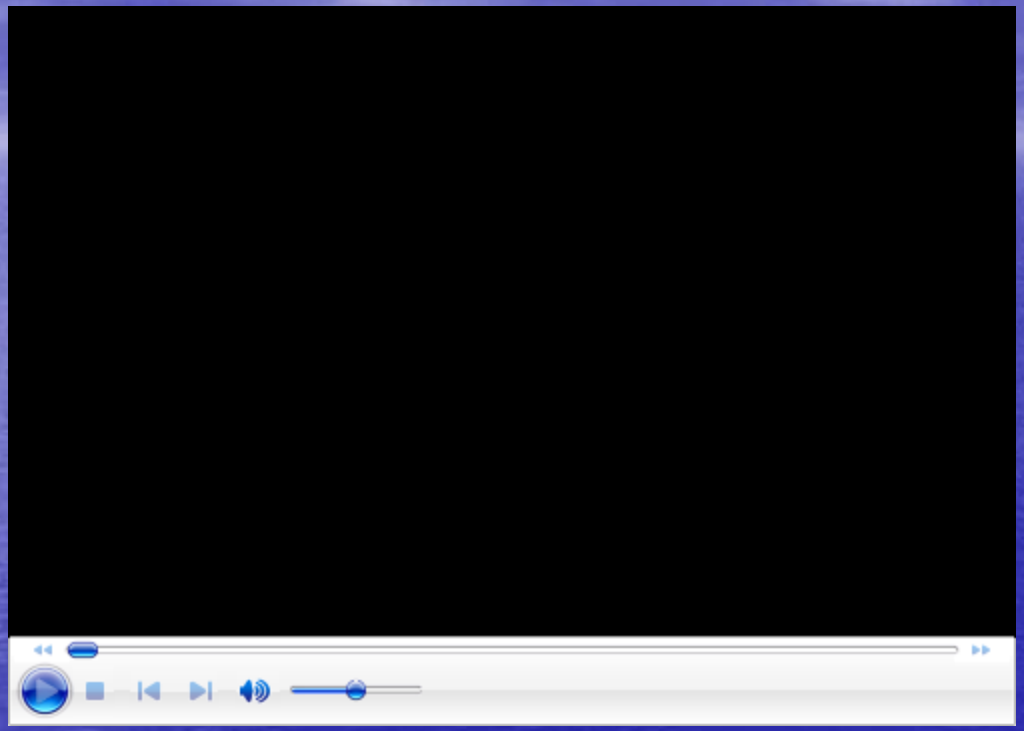
- On July 17, 1998, three tsunami waves, with a cumulative amplitude of 50 ft, inundated the area of Sissano on the northeast shore of Papua New Guinea, leaving a trail of death and destruction
  - More than 2,000 people died and three villages were obliterated and four more badly damaged

- The tsunami was believed to result of a submarine landslide immediately offshore of Sissano Lagoon
- The landslide apparently was triggered by a 5.8 magnitude earthquake that occurred in the Sissano vicinity, although the exact position is uncertain
- Tsunami waves struck 20 min after the quake and traveled inland as much as 1.5 km in some places

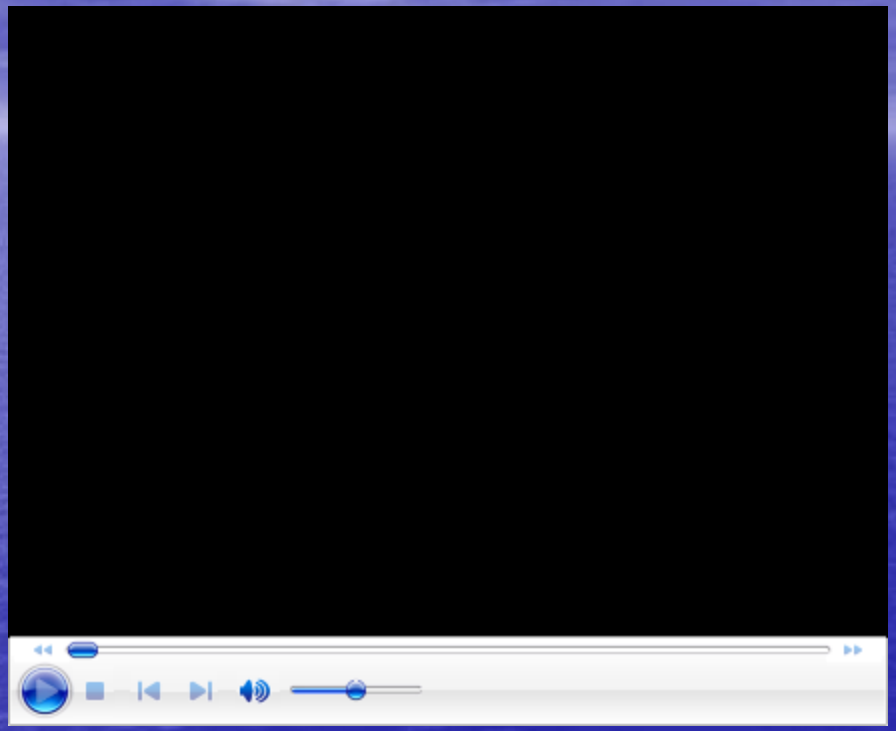

Sissano Lagoon
Arop
Malol Villages

- On December 26, 2004, a 9.0 earthquake in the Sunda Trench off Sumatra generated a large tsunami that swept throughout the Indian Ocean basin and around the world
  - Some 300,000 lives were lost to the tsunami

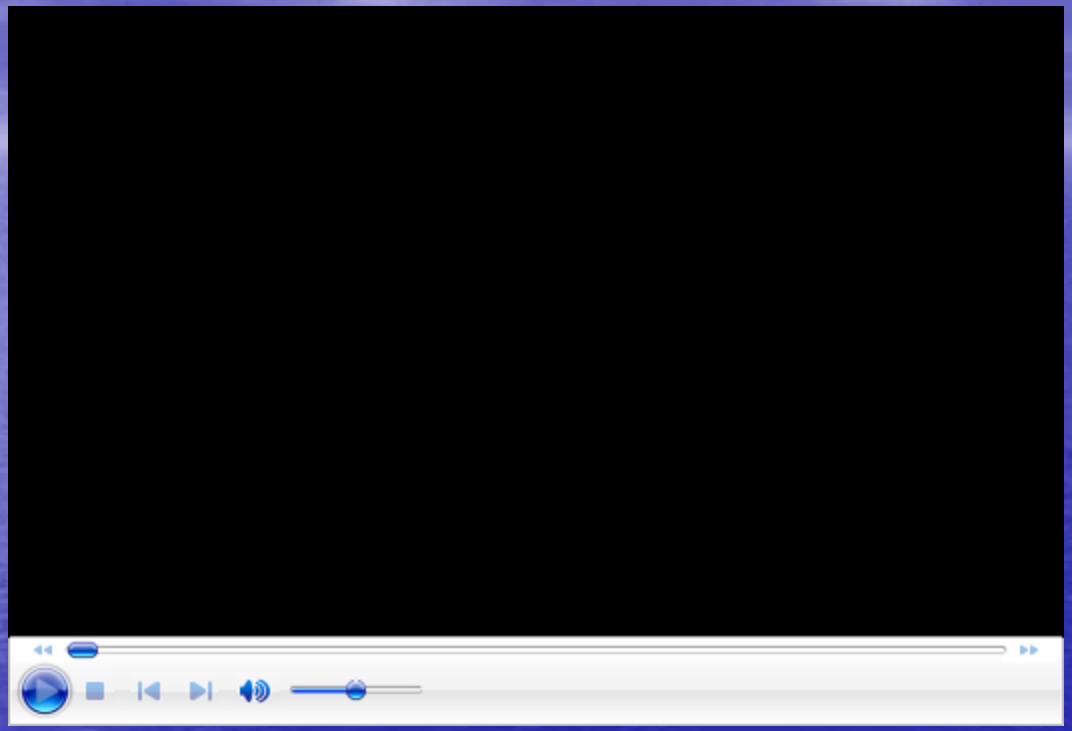
Animation of world propagation of Banda Aceh tsunami



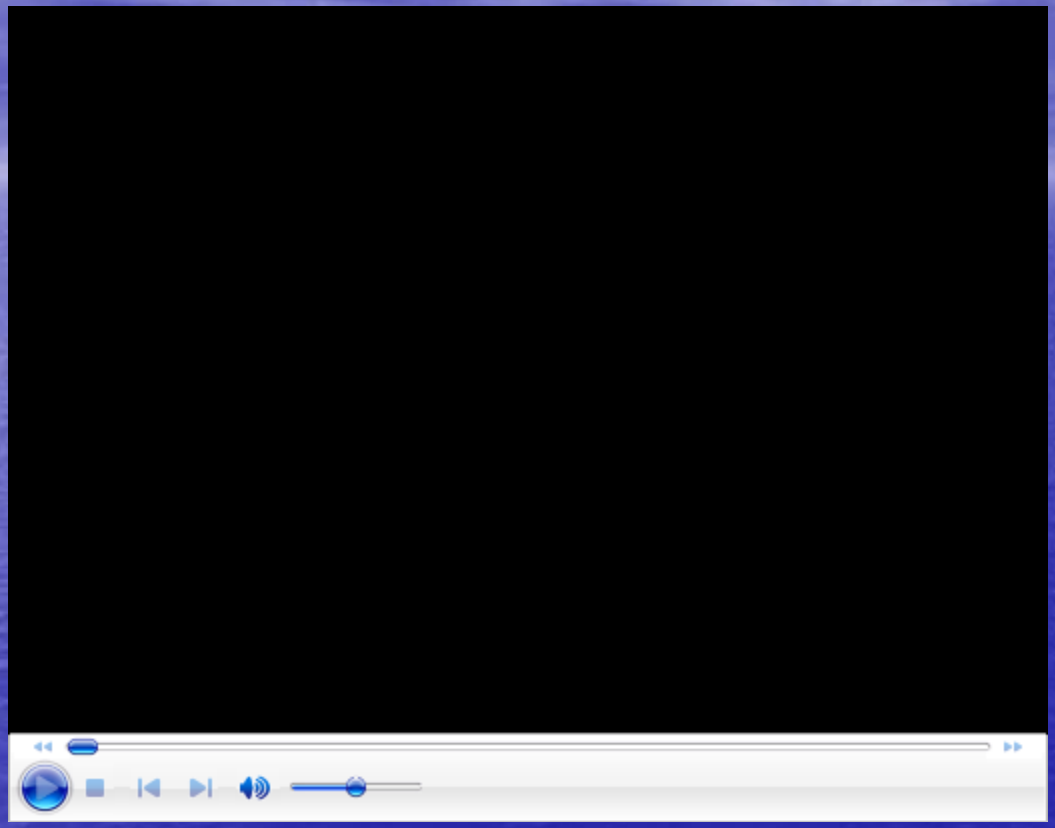
Banda Aceh tsunami_Indonesia



Banda Aceh tsunami at Khao Lak, Thailand



Banda Aceh tsunami at Koh Lanta Thailand



Banda Aceh tsunami at Penang Malaysia