



Hawaii Hazards Awareness & Resilience Program

Produced by
Hawaii State Civil Defense



HAWAII HAZARDS AWARENESS & RESILIENCE PROGRAM:

GOAL: To enhance community resilience to multiple hazards through a facilitated education and outreach program that promotes hazard understanding and awareness, and offers tools and information resources to guide mitigation, preparedness, response and recovery.

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EARTHQUAKE BASICS

Module 1: Hazard Awareness

Contents

- What is an Earthquake?
- Effects of Earthquakes
- Advanced Topics
- Historical Earthquakes in Hawaii
- Where to Get More Information?

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Module 1: Hazard Awareness

WHAT IS AN EARTHQUAKE?

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What is an Earthquake?

- **Earthquake:** *A trembling or shaking of the ground caused by the sudden release of energy stored in the rocks beneath the earth's surface.* (McGraw-Hill)
 - Earthquakes occur on a daily basis
 - Some may not be felt, while others are highly destructive.
- **Seismology** is the study of earthquakes; seismologists seek to understand the generation, characteristics, effects, and prediction of earthquakes.

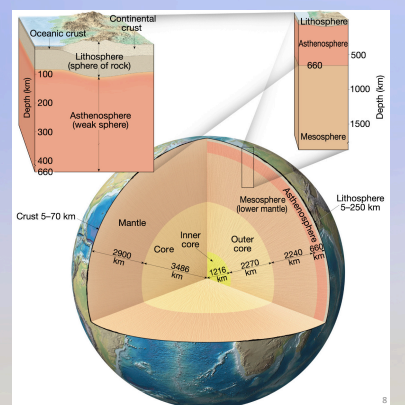
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What is an Earthquake?

- Most earthquakes originate in the earth's ***lithosphere***:
 - The solid, rocky, outer part of the earth, approximately 50 miles thick, comprised of the crust and the solid portion of the mantle.

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Earth's Layered Structure



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Causes of Earthquakes

- Through the action of geologic forces, strain builds up in the lithosphere and causes fracturing of rock formations. These fractures are referred to as ***faults***.
- Movement along faults occurs suddenly, as the friction between rock faces is overcome.
- Some faults are more active than others.

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Causes of Earthquakes

- Fault movement is especially active along ***plate boundaries*** (narrow zones between plates) where subduction (the movement of one plate under another), or formation of rifts (where plates move apart), occur.
- Volcanic activity (movement of magma) also causes earthquakes.

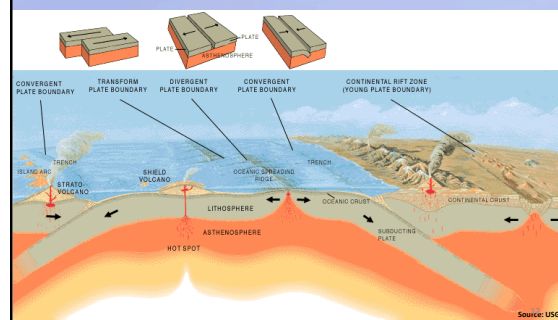
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Types of Plate Boundaries

- ***Divergent*** – new crust is generated as plates pull away from each other.
- ***Convergent*** – crust is destroyed as one plate dives under another.
- ***Transform*** boundaries – crust is neither produced nor destroyed as plates slide horizontally past each other.
- ***Plate boundary zones*** – broad belts in which boundaries are not well defined and the effects of plate interaction are unclear.

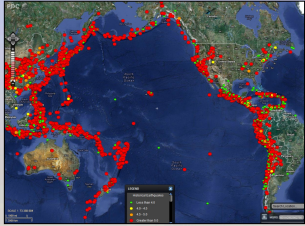
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Illustration of Plate Boundaries



Pacific Ring of Fire

- Also known as the **Circum-Pacific Ring**, one of the world's most active earthquake zones.
 - Over 70 percent of the world's earthquakes occur here.
 - Renowned for significant volcanic activity.



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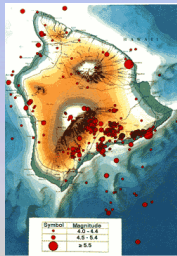
Earthquakes in Hawaii

- Most of Hawaii's earthquakes are directly related to volcanic activity and are caused by magma moving beneath the earth's surface.
- Earthquakes may occur before or during an eruption, or they may result from the underground movement of magma that comes close to the surface but does not erupt.

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Earthquakes in Hawaii (Continued)

- A few of the island's earthquakes are less directly related to volcanism; these earthquakes originate in zones of structural weakness at the base of the volcanoes or deep within the earth beneath the island.



Source: USGS
Earthquakes on and near the Island of Hawaii, 1962-1985.

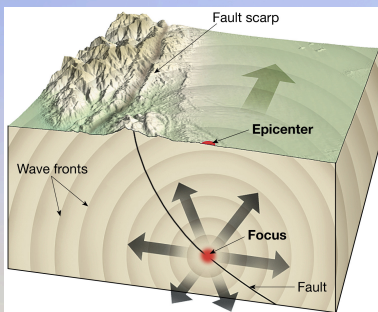
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Earthquake Characteristics

- The earthquake **focus** is the point within the earth where seismic waves originate. Earthquake foci can range in depth from several miles beneath the earth's surface, to 430 miles (690 km).
- The earthquake **epicenter** is the point at the earth's surface directly above the focus.

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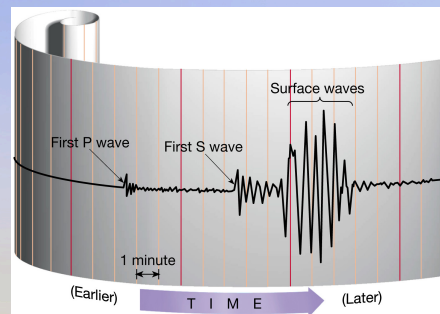
Earthquake Focus and Epicenter



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Detecting Earthquakes

Illustration of a Seismogram



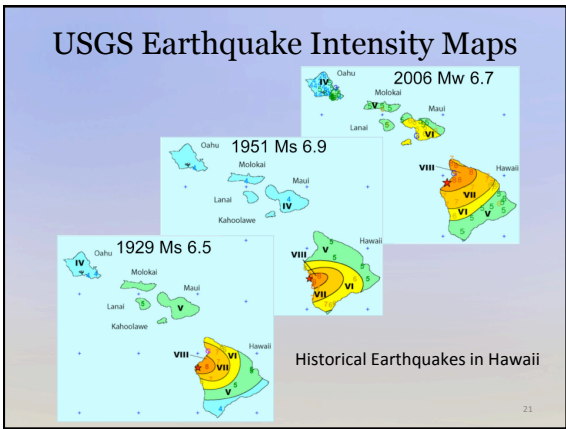
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Earthquake Characteristics

- The “strength” of an earthquake is measured in terms of:
 - **Intensity** – measures the strength of shaking produced by the earthquake at a certain location. Intensity is determined from effects on people, human structures, and the natural environment.
 - Expressed using the Modified Mercalli Intensity (MMI) Scale.
 - **Magnitude** – measures the amount of energy released at the source of the earthquake.
 - Richter Scale – developed in 1935; most familiar.
 - Moment Magnitude – now used by scientists to measure earthquake magnitude.


Earthquake Characteristics

- Intensity scale:
 - Modified Mercalli Intensity (MMI) Scale
 - Tends to be more descriptive to the non-scientist than magnitude because it describes observed effects on people and buildings.
 - Uses Roman numerals ranging from I to XII, representing effects ranging from “not felt” to “total damage.”




Earthquake Characteristics

- Magnitude Scale:
 - Moment Magnitude (M, MMS, or M_w)
 - Based on the “seismic moment” of the earthquake, which is “a measure of the size of an earthquake based on the area of fault rupture, the average amount of slip, and the force that was required to overcome the friction sticking the rocks together that were offset by faulting.” (USGS)
 - Developed in the 1970’s.
 - Succeeds the Richter magnitude scale due to its enhanced precision in measuring large or “great” earthquakes of 8.0 and higher.



Learning Check

1. What is an earthquake?
2. Where do earthquakes occur?
3. How are earthquakes measured?



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EFFECTS OF EARTHQUAKES

Effects of Earthquakes

- Ground motion can collapse buildings and elevated roadways, break pipes, and knock down power lines.
- The degree of damage is dependent upon the amount of energy released and the earth materials through which the seismic waves pass.
 - Greater damage potential for buildings constructed on sedimentary soil;
 - Less for those constructed of reinforced concrete, or built on solid bedrock.

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Effects of Earthquakes

- Soil composition and water content are contributing factors to **liquefaction** that can occur during severe shaking.
- **Liquefaction** is a phenomenon in which the strength and stiffness of a soil is reduced by earthquake shaking, where the space between particles of soil becomes filled with water, allowing the particles to move readily with respect to one another.

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Effects of Earthquakes

- Aftershocks
 - Common after a large earthquake, and can topple damaged structures and hamper rescue efforts.
- Fires
 - Frequently break out after an earthquake.
 - 1906 San Francisco and 1923 Tokyo fires caused more damage and loss of life than the earthquakes that triggered them.

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Effects of Earthquakes

- Permanent displacement of the land surface:
 - *Land subsidence* - a gradual or sudden lowering of the land surface.
 - Landslides, mud flows, and avalanches.

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Effects of Earthquakes

- **Tsunamis** or seismic sea waves:
 - Result from vertical displacement along a fault located on the ocean floor or a large undersea landslide triggered by an earthquake.
 - In the open ocean height is usually < 3 feet.
 - In shallower coastal waters the water piles up to heights over 90 feet.

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Learning Check

1. List the potential effects of earthquakes.
2. How is a tsunami generated?

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ADVANCED TOPICS

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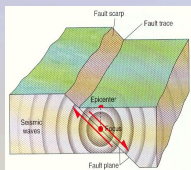
Seismic Waves

- When an earthquake occurs, stored *potential energy* is released as *kinetic energy* (energy of motion).
- This energy disperses from the earthquake's *focus* in all directions, but at different velocities and in different types of waves.
- Two basic types of waves:
 - Body waves
 - Surface waves

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Body Waves


- Seismic waves that travel through the earth's interior, spreading outward from the focus in all directions.
- Two major forms of **body waves** are:
 - Primary (P) Waves
 - Secondary (S) Waves



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Body Wave – Primary

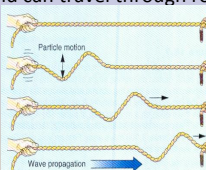
- P (primary) Body Wave
 - A compressional (or longitudinal) wave in which rock vibrates back and forth parallel to the direction of wave propagation. P-waves can travel through rock, gas, or liquid, and travel about 1.7 times faster than secondary waves.



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Body Wave – Secondary

- S (secondary) Body Wave
 - A slower, transverse wave that travels through near surface rocks at 1 to 3 miles per second. The rock vibrates perpendicular to the direction of wave propagation, and can travel through rock but not gas or liquid.



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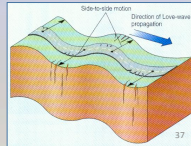
Surface Waves

- Seismic waves that travel on the earth's surface away from the epicenter.
- Two major forms of **surface waves** are:
 - Love Waves
 - Rayleigh Waves

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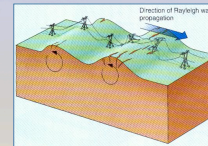
Surface Wave - Love

- Love Surface Wave
 - Waves having no vertical displacement.
 - Move side to side in a horizontal plane perpendicular to the direction the wave is traveling or propagating;
 - Tend to knock buildings off their foundations.



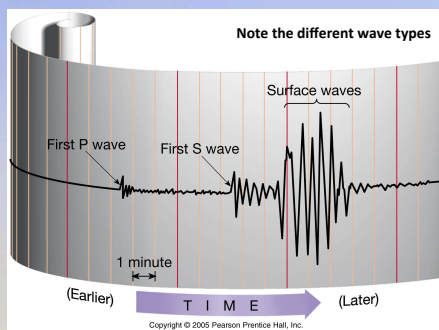
Surface Wave - Rayleigh

- Rayleigh Surface Wave
 - Behave like rolling ocean waves, and cause the ground to move in an elliptical path as the wave passes.
 - Tend to be incredibly destructive because they produce significant ground movement and take longer to pass.



Detecting Earthquakes

Illustration of a Seismogram



Learning Check

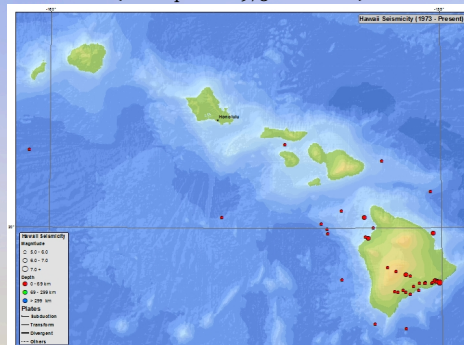
1. What are the two major types of earthquake waves?
2. What are the two types of body waves?
3. What are the two types of surface waves?



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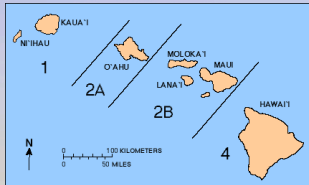
HISTORICAL EARTHQUAKES IN HAWAII

USGS Seismicity Map (Earthquakes 1973 to Present)



Hawaii Seismic Zone Assignments

- The Uniform Building Code (UBC) has established six seismic zones, ranging from 0 (no chance of severe ground shaking) to 4 (10% chance of severe shaking in a 50-year interval).
- Classification takes into account the expected strength of ground shaking (peak ground acceleration) and the probability of the shaking actually occurring within a specified time (50 years).



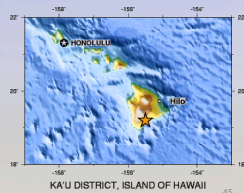
Destructive Earthquakes in Hawai`i County since 1868

Date	Epicenter Location	Maximum Intensity	Magnitude	Number of Deaths	Damage
Mar 28, 1868	South Hawai`i	IX	7.0	0	Extensive (S. Hawai`i)
Apr 02, 1868	South Hawai`i	XII	7.9	81	>100 homes destroyed, tsunami
Oct 05, 1929	Hualalai	VIII	6.5	0	Extensive (Kona)
Aug 21, 1951	Kona	VIII	6.9	0	Extensive (Kona)
Apr 26, 1973	North of Hilo	VIII	6.2	0	Extensive (Hilo), \$5.6M
Nov 29, 1975	Kalapana	VIII	7.2	2	Extensive (Hilo), \$4.1M
Nov 16, 1983	Ka`oiki	IX	6.7	0	Extensive (S. Hawai`i), > \$6M
Jun 25, 1989	Kalapana	VII	6.2	0	SE Hawai`i, near \$1M
Oct 15, 2006	Kiholo Bay	VIII	6.7, 6.0	0	NW Hawai`i, >\$100M

Source: USGS HVO, <http://hvo.wr.usgs.gov/earthquakes/destruct/>

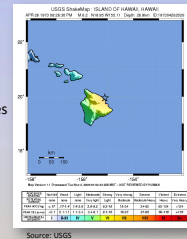
April 2, 1868 – M7.9

- Ka`u, Big Island
- Largest recorded earthquake in Hawaii
 - Possibly caused by movement of the south flank of Kilauea
 - Preceded by March 28th M7.0 and aftershocks
- Felt on all islands
 - Damage greatest on Big Island
 - Local tsunami generated 39-49 feet (12-15m) in some areas
- Damages
 - Extensive damages to infrastructure
 - Severe shaking:
 - People unable to stand
 - Ground fissures
 - Landslides
 - Ground subsidence at Kalapana coast
- Fatalities:
 - 77 deaths
 - 46 – tsunami
 - 31 – landslide



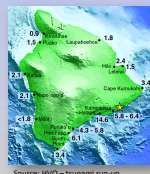
April 26, 1973 – M6.2

- Honolulu, Big Island
- Depth – 48 km (28.8 mi)
- Felt on all islands
 - Greatest damage on Big Island
- Damages - \$5.75 million
 - Major Disaster Declaration – FEMA
 - Heavy damage to infrastructure and pipe-lines
 - Landslides
 - Road damage
 - No tsunami
- Fatalities:
 - None recorded



November 29, 1975 – M7.2

- Kalapana, Island of Hawaii
- Depth – 28.8 miles (48 km)
- Felt on all islands
- Damages - \$4.1 million
 - Major Disaster Declaration – FEMA
 - Local tsunami – result of off-shore landslide
 - Damage to infrastructure and utilities
 - Roads damaged
 - Subsidence of coast at Halape was 11.5 feet (3.5m)
- Fatalities:
 - 2 due to tsunami



Nov 29, 1975 – Kalapana M7.2



Nov 29, 1975 – Kalapana M7.2



Photograph by UPI. Two children were trapped in this damaged home about 4.5 miles (7 km) north of Hilo. Source: USGS HVO

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Nov 29, 1975 – Kalapana M7.2



Photograph by Peter Lipman, USGS. Crack in Hilina Pali road, Hawaii Volcanoes National Park. Source: USGS HVO



Photograph by Larry Kadooka, Hawaii Tribune-Herald. Spilled merchandise in Hilo supermarket. Source: USGS HVO

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Nov 29, 1975 – Kalapana M7.2

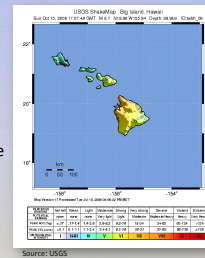


Photograph by Boone Morrison. Small landslide from spatter and cinder cone partially blocking Chain of Craters Road, Hawaii Volcanoes National Park. Source: USGS HVO

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October 15, 2006 – M6.7

- Kiholo Bay, Big Island
- Depth – 18.0 miles (29 km)
- Felt on all islands
- Damages - \$100 million
 - Major Disaster Declaration – FEMA
 - Damage to infrastructure
 - Roads and bridges damaged
 - 4 inches (10 cm) tsunami at Kawaihae Harbor
- Fatalities:
 - None reported



Source: USGS

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October 15, 2006 – M6.7



Source: HSCD – Kealahou Bay

Source: HSCD – Kawaii Bridge, Hwy 19

Source: HSCD – Kahauna Church, Kapahu


Source: HSCD – Waipoua Elementary



Learning Check

1. Which two earthquakes in Hawaiian history generated fatal local tsunamis?
2. Which of the Hawaiian Islands is most likely to experience the strongest earthquakes?

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Module 1: Hazard Awareness

FOR MORE INFORMATION


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For More Information

- Hawaii State Civil Defense
 - www.scd.hawaii.gov
- Hawaiian Volcano Observatory
 - <http://hvo.wr.usgs.gov/>
- U. S. Geological Survey
 - <http://www.usgs.gov/>
- Pacific Disaster Center
 - <http://www.pdc.org>
- USGS Real-time Earthquakes for Hawaii
 - <http://earthquake.usgs.gov/earthquakes/map/>
- City and County of Honolulu Department of Emergency Management
 - <http://www1.honolulu.gov/dem/index.htm>
- Maui County Civil Defense Agency
 - <http://www.co.maui.hi.us/index.aspx?nid=70>
- Hawaii County Civil Defense Agency
 - <http://www.hawaicounty.gov/civil-defense/>
- Kauai Civil Defense Agency
 - <http://www.kauai.gov/civildefense>

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Questions?






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The Hawaii Hazards Awareness & Resilience Program (HHARP) is the result of a collaborative partnership between Hawaii State Civil Defense and the Pacific Disaster Center.

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