# EARTHQUAKE

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# What are Earthquakes?

- The shaking or trembling caused by the sudden rele ase of energy
- Usually associated with faulting or breaking of rock
  <u>s</u>
- <u>Continuing adjustment of position results in aftersh</u> <u>ocks</u>

#### What is the **Elastic Rebound Theory**?

- Explains how energy is Sault tored in rocks
  - Rocks bend until the strength of the rock i s exceeded
  - Rupture occurs and t he rocks quickly rebo und to an undeforme d shape
  - Energy is released in waves that radiate ou tward from the fault



**Original position** 











#### The Focus and Epicenter of an Earthquake

- The point within Earth w here faulting begins is t he focus,
- The point directly above the focus on the surface is the epicenter



# Seismographs record earthqu ake events





At convergent boundaries, focal d epth increases along a dipping seismic zone called a Benioff z one

#### Where Do Earthquakes Occur and How Often?

- ~80% of all earthquakes occur in the circum-Pacific belt
  - most of these result from convergent margin activity
  - ~15% occur in the Mediterranean-Asiatic belt
  - remaining 5% occur in the interiors of plates and on spreadin g ridge centers
  - more than 150,000 quakes strong enough to be felt are recor ded each year



# What are Seismic Waves ?

- Response of material to the arrival of energy fronts released by rupture
- Two types:
  - Body waves
    - P and S
  - Surface waves
    - R and L

#### **Body Waves: P and S waves**



Body waves

#### P or primary waves

- fastest waves
- travel through solids, liquids, or gases
- compressional wave, material movement is in the same direction as wave movement

#### S or secondary waves

- slower than P waves
- travel through solids only
- shear waves move material perpendicul ar to wave movemen t

# Surface Waves: R and L wa ves



- Surface Waves
  - Travel just below or along the ground's surface
  - Slower than body waves; rolling and side-to-side mov ement
  - Especially damaging to buildings

#### How is an Earthquake's Epicenter Located?

#### Seismic wave behavior

- P waves arrive first, then S waves, then L and R
- Average speeds for all these waves is known
- After an earthquake, the difference in arrival times at a seis mograph station can be used to calculate the distance from the seismograph to the epicenter.



## **Shadow Zones**

- The shadow zone is the area of the earth from angular distances of <u>104</u> to <u>140</u>
- The shadow zone results from S waves being stopped entirely by the liquid core and P waves being bent (refracted) by the liquid core.
- From the lack of S waves and a great slowing of the P wave velocity (by about 40%) it was deduced that the outer core is made of



#### How is an Earthquake's Epicenter Located?

Time-distance graph showin g the average travel times for P- and S-waves. The f arther away a seismograp h is from the focus of an earthquake, the longer th e interval between the arri vals of the P- and S- wave S



# How is an Earthquake's Epicente r Located?

- Three seismograph stations are needed to locate the epi center of an earthquake
- A circle where the radius eq uals the distance to the epi center is drawn
- The intersection of the circl es locates the epicenter



#### How are the Size and Strength of an Earthquake Measured?



- Intensity
  - subjective measure of the kind of dama ge done and people 's reactions to it
  - isoseismal lines ide ntify areas of equal intensity

- Modified Mercalli Intensity Map
  - 1994 Northridge, CA earthquake, magnitude 6.7

#### How are the Size and Strength of an Earthquake Measured?

- Magnitude
  - Richter scale measure s total amount of ener gy released by an eart hquake; independent o f intensity
  - Amplitude of the large st wave produced by a n event is corrected fo r distance and assigne d a value on an open-e nded logarithmic scale



## **Richter vs Mercalli**

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#### Modified Mercalli Scale

- Not felt. Ī.
- II. Felt by persons at rest, on upper floors, or favorably placed.
- III. Felt indoors. Vibration like passing of light trucks.
- IV. Vibration like passing of heavy trucks.
- V. Felt outdoors. Small unstable objects displaced or upset.
- Felt by all. Furniture moved. Weak plaster/masonry cracks. VI.
- VII. Difficult to stand. Damage to masonry and chimneys.
- VIII. Partial collapse of masonry. Frame houses moved.
  - IX. Masonry seriously damaged or destroyed.
  - Х. Many buildings and bridges destroyed.
  - XI. Rails bent greatly. Pipelines severely damaged.
- XII. Damage nearly total.

#### **Seismic Event Frequency & Impact**

#### 9.0 **Global Frequency** Magnitude Impact 2011 Japan 9-9.9 Catastrophic: can cause irreparable damage 1 a decade Earthquake and immense loss of life 8-8.9 Great: can cause severe damage and loss of life 1 per year 7-7.9 Major: can cause serious damage over large areas 1 per month 6-6.9 Strong: can be destructive in populated areas 2 a week 5-5.9 Moderate: can cause damage to poorly 4 per day constructed buildings over small regions 4-4.9 Light: noticable shaking but significant damage 1 per hour is unlikely 3-3.9 Small: often felt but rarely causes damage 15 per hour 2-2.9 Minor: easily recorded at surface but not felt 2 per minute GREAT С ш 63,000,000,000,000,000 <2 Micro: not felt at surface, causes no damage 8.0 and can only be measured deep underground continual MAJOR 7.0 2,000,000,000,000,000 6.0 63.000.000.000.000 Vibrations felt by a passing truck 5.0 MODERATE -1 0 1.0 2.0 3.0 4.0 2.000.000.000.000 LIGHT 63.000.000.000 SMAL MINOR 2 000 000 000 63,000,000 **NOT FELT/MICRO** 2,000,000 -1 Q **Typical microseismic** MAGNITUDE\* events during hydraulic ON RICHTER SCALE fracturing are -2 Source: USGS

\*Each whole number increase on the Richter scale represents 32 times more energy release and 10 times more ground motion.

#### The Economics and Societal Impacts of EQs

- Building collapse
- Fire
- Tsunami
- Ground failure





#### What are the Destructive Effects of Earthquakes?

- Ground Shaking
  - amplitude, duration, and damage increases in poorly con solidated rocks



#### **Can Earthquakes be Predicted?**

**Earthquake Precursors** 

- changes in elevation or tilting of land surfa ce, fluctuations in gro undwater levels, mag netic field, electrical r esistance of the grou nd
- seismic dilatancy mod el
- seismic gaps



### Can Earthquakes be Predicte d?

**Earthquake Prediction Programs** 

- include laboratory and field studies of rocks before, during, a nd after earthquakes
- monitor activity along major faults
- produce risk assessments



#### **Can Earthquakes be Controlled?**

- Graph showing the relati onship between the amo unt of waste injected into wells per month and the average number of Denv er earthquakes per mont h
- Some have suggested th at pumping fluids into se ismic gaps will cause sm all earthquakes while pre venting large ones



