# ISCI 2001
# Chapter 27
# Environmental Geology



## What Is an Earthquake?

- An Earthquake is a shaking or vibration of the Earth.
- Earthquakes typically occur at plate boundaries.
- Earthquakes occur where stressed and deformed blocks of rock are held together by friction.
- When stress in rock exceeds the friction holding sections of rock together, the rock slips or breaks. This slippage or breakage of rock is an earthquake.



## What Is an Earthquake?

- Elastic energy stored in deformed rock is released in the form of seismic waves, mechanical waves similar to shock waves or sound waves.
- Some seismic waves travel through the Earth, while other seismic waves travel at its surface.

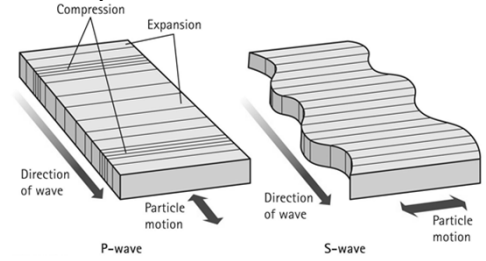


## Earthquake Vocabulary

- Seismology: the study of earthquake waves
- Seismic waves: mechanical waves that distribute the energy released in an earthquake.
- There are two types: body waves and surface waves.
- Body waves are further classified as S-waves and P-waves.
- Surface Waves are classified as Rayleigh waves and Love waves.

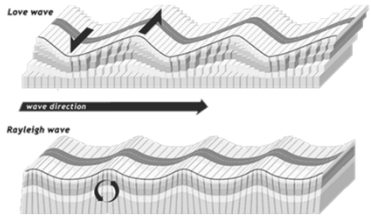


## Earthquake Waves






## Earthquake Waves

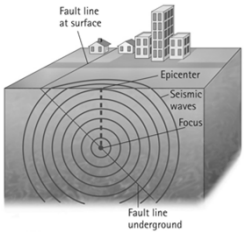


## Earthquake Vocabulary

- Focus: the site of the original displacement of rock in an earthquake
- Epicenter: the point at Earth's surface directly above an earthquake focus
- Fault: a fracture where rocks on either side have moved relative to one another.
- Intraplate quake: an earthquake that occurs away from plate boundaries



## Earthquake Vocabulary






## New Madrid Earthquake

- The earthquake occurred in 1811–1812 in New Madrid, Missouri.
- There were three major quakes with aftershocks.
- The topography was altered and over 150,000 acres of forest were destroyed.



## New Madrid Earthquake

- The New Madrid Earthquake is an example of a natural event that didn't become disastrous to humans. Why? People were not in the path of destruction.



## Earthquake Prediction

- Methods:
  - Measure strain in rocks
  - Map seismic gaps (not so good)
  - Probabilities of Occurrence (Hazard Maps)
- Currently, prediction allows risk to be identified within a broad timeframe (30–100 years)



## Earthquake Prediction

**TABLE 27.1 EARTHQUAKE SEVERITY AND DEPTH RELATED TO TECTONIC SETTING (GENERAL TRENDS)**

| Plate Setting | Focus Depth and Earthquake Intensity |
|---|---|
| Diverging boundary | Shallow; mild |
| Subduction zone | Shallow to deep; high intensity |
| Continental–continental convergent boundary | Shallow to medium depth; moderate to high intensity |
| Transform boundary | Shallow; moderate to high intensity |

## Earthquake Measurement

- Moment magnitude scale
  - Measures energy released in an earthquake
  - Favored by seismologists; uses seismometer measurements
- Richter scale – just one of several log-based scales
  - Measures ground shaking
  - Favored by media; also uses seismometer measurements



## Earthquake Measurement

TABLE 27.2 THE RICHTER SCALE

| Intensity | Description | Effects |
|---|---|---|
| Less than 2.0 | Microquake | Can be recorded by a seismometer |
| 2.0–2.9 | Minor | Potentially detectable by average person |
| 3.0–3.9 | Minor | May be felt near the epicenter; rarely causes damage |
| 4.0–4.9 | Light | Strong shaking and rattling |
| 5.0–5.9 | Moderate | Possible structural damage |
| 6.0–6.9 | Strong | Widespread damage |
| 7.0–7.9 | Major | Can cause serious damage over a large area; approximately 20 per year worldwide |
| 8.0–8.9 | Great | Can cause severe damage hundreds of miles from the epicenter; approximately 1 per year worldwide |
| 9.0–9.9 | Catastrophic | Devastating across areas thousands of miles in diameter; recorded once every 20 years on average |



## Tsunami

- A tsunami is
- a huge seismic sea wave
- a large, fast-moving mass able to travel as far as a mile or more inland
- destructive because it strikes objects on shore with enormous mechanical force
- can cause secondary effects (Ex. the Fukushima Daiichi nuclear power plant)



## Tsunami Mechanics

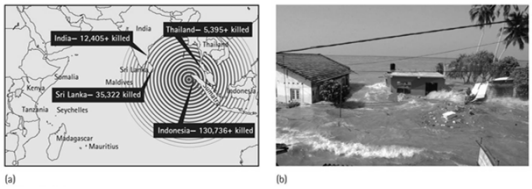
- Tsunami are triggered by a large disturbance, such as a subduction-related earthquake.
- As a descending plate slips, the overlying plate is deformed.
- When friction can no longer hold the deformed overlying plate in place, it springs upward.
- This motion of the overlying plate produces a tsunami that propagates across the ocean.
- When a tsunami reaches shore, it is compressed so that its amplitude greatly increases and its wavelength decreases.



## 2004 Tsunami

- A strong tsunami occurred on December 26, 2004.
- A historic magnitude 9.1 subduction earthquake off the coast of Sumatra in Indonesia triggered the tsunami.
- Tsunami are heavy and fast, so they have enormous momentum and energy.
- *The 2004 tsunami released more energy than all the bomb blasts of World War II.*
- The 2004 tsunami was *one of deadliest natural disasters in history*. Over 220,000 people were killed in 14 countries.



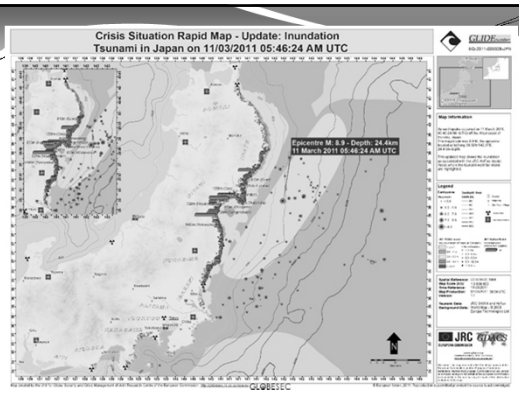



(a) The December 26, 2004, tsunami began with a strong subduction earthquake off the coast of Sumatra. (b) The tsunami strikes a coastline in Sri Lanka.

## 2011 Tsunami

- On March 11, 2011, a 9.0-magnitude earthquake struck off the coast of Japan.
- The earthquake moved Honshu (the main island of Japan) 2.4 m (8 ft) east.
- It triggered a powerful tsunami that reached heights of over 40 m (130 ft).
- The tsunami caused meltdowns at three nuclear reactors in the Fukushima Daiichi nuclear power plant complex.
- The radiation leak required evacuation within a 20 mile radius.







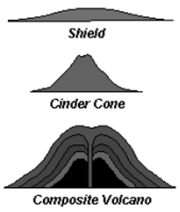

## Volcanoes

- Volcanoes are essentially vents that allow heat to escape from Earth's interior.
- Erupted magma is called *lava*.
- There are three types of magma: basaltic, andesitic, and rhyolitic.
- Andesitic and rhyolitic lavas are thicker than basaltic lavas. They can clog a volcano's vent and produce an explosive eruption.



## Three Kinds of Volcanoes

- Shield
- Composite (also called stratovolcano)
- Cinder cone




## Comparison of Volcano Types

| | Shield | Composite | Cinder Cone |
|---|---|---|---|
| Appearance | Broad and low elevation | Steep-sided and tall | Steep-sided but small |
| Plate setting | Hot spot in ocean floor | Subduction zone or hot spot | Independent or inside another volcano |
| Type of lava | Basalt | Basalt and andesite | Basalt and andesite, rarely rhyolite |
| Main hazards | Toxic gases and lava | Toxic gases, lava, pyroclastics, ash | Pyroclastics |



## The Ring of Fire

- The Ring of Fire
- is a ring-shaped region surrounding the Pacific Plate.
- contains active subduction zones throughout the region.
- is home to over 75% of the world's volcanoes and 90% of the world's earthquakes.

## Important Volcanic Eruptions Throughout History

- **Eruption at end of Permian period (250 million years ago)** lasted for millions of years; triggered climate change; caused a mass extinction that wiped out 90% of life on Earth.
- **Island of Krakatoa** in Indonesia was site of explosive eruption in 1883; heard thousands of miles away; triggered tsunami; over 30,000 people killed; Krakatoa completely destroyed.
- **Mt. Thera, Island of Santorini, Greece**; 1610 BC; energy release equal to several hundred atomic bombs over a period of less than a second; probably the strongest explosion ever witnessed by people; altered climate; disrupted human culture; ash deposits 100 feet thick found within a 19-mile radius from the caldera.



## Important Volcanic Eruptions Throughout History

- **Mt. Tambora, Indonesia**; 1815; death toll estimated at 71,000 people; summer in 1816 "canceled" in North America and Europe.
- **Yellowstone National Park** is situated over a hot spot; three huge calderas in park; oldest caldera is over 60 miles wide and 2 million years old; cooled climate; deposited ash layer covered much of the land area that is now the western and midwestern United States.
- **Mt Vesuvius** is the only active volcano in mainland Europe; erupted in 79 AD destroying the Roman cities of Pompeii and Herculaneum; victims buried alive in ash fall.



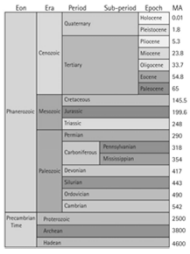
## What Is Climate Change?

- *Weather* is the state of the atmosphere at a particular time. *Climate* is the average weather over several decades or longer.
- Climate change is a lasting alteration to average weather conditions so that new patterns of temperature, precipitation, humidity, and so on, become established.
- Climate change also can involve a change in the frequency of extreme weather events over a long (decades or more) time period.



## Climate Change in Geologic History

- The geologic time scale divides Earth's 4.6-billion-year history into time units of different size.
- Most divisions of the time scale mark major turning points in geologic history or the history of life.





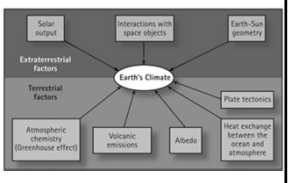

## Ice Ages

- An ice age is a period with cold enough global average temperature that there's extensive glaciation.
- An interglacial is a pulse of warmer temperatures within an ice age such that glaciers melt back to high latitudes.
- ***Humans have existed only within an ice age.*** Civilization developed in an interglacial period.



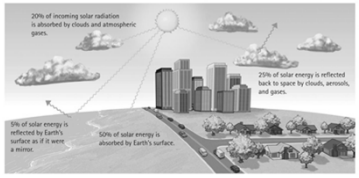
## Natural Climate Change

- Natural drivers of climate change:
  - Solar output
  - Interactions with space objects
  - Earth-Sun geometry (e.g., Milankovich cycles)
  - Atmospheric chemistry
  - Volcanic emissions
  - Albedo
  - Ocean-atmosphere interactions
  - Plate tectonics



## Albedo: A Factor in Temperature

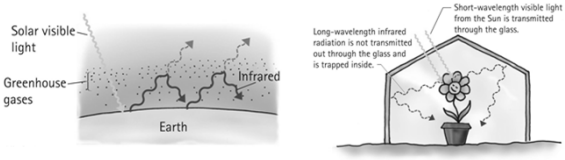
- Albedo is a measure of surface reflectivity.
- Albedo depends on the color and chemical composition of a material.






## The Greenhouse Effect

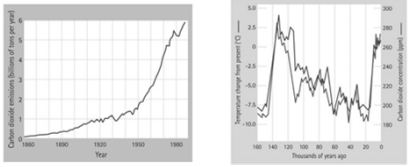
- Short-wave radiation from the Sun passes through the atmosphere and is absorbed at Earth's surface.
- Earth absorbs the short-wave radiation and in turn emits long-wave (infrared) radiation (also called "terrestrial radiation").
- The infrared radiation is absorbed and re-emitted many times by atmospheric molecules. This warms the atmosphere and is similar to what happens in a florist's greenhouse.






## Anthropogenic Climate Change

- Evidence, including chemical analysis of the isotopes in atmospheric carbon dioxide, shows that most of the carbon dioxide in the atmosphere comes from burning fossil fuels.
- Carbon dioxide emissions from combusting fossil fuels have increased exponentially since the beginning of the Industrial Revolution.
- Carbon dioxide levels and temperature correlate well.






## Effects of Climate Change

- The approximately 1°F increase in global climate has many effects on the world today, including:
  - raised sea level
  - melting sea ice
  - migration of species
  - disruption of ecosystems
  - agricultural effects
  - increased incidence of extreme weather
  - economic impacts
  - thawing permafrost



## Effects of Climate Change

The IPCC forecasts a temperature rise of 2.5°F to 10°F over the next century.

**TABLE 27.5 GLOBAL CLIMATE CHANGE: FUTURE TRENDS**

| Phenomena | Likelihood of Trend |
|---|---|
| Contraction of snow cover areas, increased thaw in permafrost regions, decrease in sea ice extent | Virtually certain |
| Increased frequency of hot extremes, heat waves, and heavy precipitation | Very likely to occur |
| Increase in hurricane intensity | Likely to occur |
| Precipitation increases in high latitudes | Very likely to occur |
| Precipitation decreases in subtropical land regions | Very likely to occur |
| Decreased water resources in many semi-arid areas, including western U.S. and Mediterranean basin | High confidence |



## What You Can Do About Climate Change

- Learn More!
- Understand your impact and reduce your Carbon Footprint.
- Stay connected to science and work with others to produce meaningful change.