Geology: scientific study of Earth’s materials and processes

- Materials: what are these, list as many as you can
- External & Internal Processes: list several of each

### Major External Processes
“change the Earth’s surface”
annual transfer rate in thousands of cubic kilometers

- The Hydrologic Cycle
- Weathering and Erosion
- Deposition and Soil Formation
- Glaciers, Rivers and Streams, Flooding
- Mass Movement (landslides, rock falls)
- Land-Sea Interactions/Coastal Erosion

### Major Internal Processes
Driven by energy (heat) in the Earth’s interior

1) Convection and Plate Tectonics
2) Rock Deformation
3) Crystallization
4) Metamorphism

### Plate Tectonics
- Outer layers of Earth made up of ~ 12 major individual rigid plates (lithospheric/tectonic plates)
- Plates move in response to convection in the mantle
- Most geologic activity occurs near plate boundaries (3 types of boundaries)

Geologic Processes create?

**Think about Plate Tectonics:**
Definition

“Boundaries = Geologic Activity”

Hazards and Resources: Associations
Transform Boundary
example: San Andreas Fault

San Andreas Fault

Divergent Boundaries
Sea Floor Spreading on Oceanic Ridges
Typically shallow focus and small earthquakes

Convergent Boundaries
Subduction at deep sea trenches, shallow to deep focus earthquakes

WEB LINK:
http://pubs.usgs.gov/gip/dynamic/understanding.html

Geologic Hazards
Result from a combination of internal and external processes. Examples include?

1. Earthquakes
2. Tsunamis
3. Volcanoes
4. Mass Movement
5. Coastal Erosion / Flooding / Rising Sea Level
6. Fluvial Systems / Flooding (Later in the Course)
Earthquakes
Over a million fatalities from earthquakes in the last 10 years.
What are the hazards / outcomes?

**Ground Shaking:** landslides, liquefaction, land subsidence, buildings, roads, bridges collapse

**Fire:** broken gas and power lines

**Flooding:** tsunamis and/or “co-seismic subsidence”

**Ground Displacement:** structures lying across fault

Major dangers are from human-made structures rather than the earthquake itself.


---

**Types of Earthquake Waves: Surface and Body**

**Love Wave**
A.E.H. Love, an British Mathematician in 1911

**Rayleigh Wave**
Sir John William Strut, aka Lord Rayleigh, a British Physicist in 1885

---

**Body Waves**

<table>
<thead>
<tr>
<th>Arrival of Pr-wave</th>
<th>Arrival of S-wave</th>
<th>Arrival of L-wave</th>
</tr>
</thead>
</table>

Background noise

---

**Amount of damage controlled by what?**

1) Strength
2) Relative Proximity
3) Foundation
4) Building Type / Codes

---

**Fig. 9-15, p.260**

---

Mud and brick buildings in Bam, Iran did not comply with earthquake standards.

Earthquake: Central CA, SLO County
Southeastern Iran, Bam

- **Date:** 12/22/03 12/26/03
- **Magnitude:** 6.5 6.6
- **Depth:** 7.6 km 10 km
- **Tectonic Setting:** Transform Convergent
- **Population:** 239,000 100,000
- **Casualties:** 2 >43,000
- **Injuries:** 40 ~30,000
- **Damages:** 40 buildings collapsed; small fires; power outages
  60% of all buildings destroyed

Napa Earthquake, 6.1 on 8/24/14

- **Reducing Earthquake Hazards?**
  - Locate active faults
  - Map high risk areas
  - Better land-use planning
  - Better building codes
  - Better prediction both on land and in the world's oceans.
  - Improved global seismic sea wave warning system

**Tsunamis**

- Seismic Sea Waves
  - Triggers
  - Speed, height, period, wavelength
  - Trough often arrives first
**Historical Tsunami Events and Resulting Fatalities**

<table>
<thead>
<tr>
<th>Event Description</th>
<th>Year</th>
<th>Approximate Fatalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indian Ocean earthquake with tsunami</td>
<td>12/26/2004</td>
<td>230,000+</td>
</tr>
<tr>
<td>1755 Havana earthquake and tsunami, Cuba, 1755</td>
<td>1755</td>
<td>100,000</td>
</tr>
<tr>
<td>1755 Lisbon earthquake and tsunami, Portugal and Morocco</td>
<td>1755</td>
<td>100,000</td>
</tr>
<tr>
<td>India tsunami, 1876</td>
<td>1876</td>
<td>36,000</td>
</tr>
<tr>
<td>Krakatoa volcano explosion, 1883</td>
<td>1883</td>
<td>5,000</td>
</tr>
<tr>
<td>Tokyo earthquake and tsunami, Japan, 1707</td>
<td>1707</td>
<td>27,000</td>
</tr>
<tr>
<td>Japan earthquake and tsunami, Japan, 1960</td>
<td>1960</td>
<td>22,070</td>
</tr>
<tr>
<td>Japan earthquake and tsunami, Japan, 15/11/11 (3/11/11)</td>
<td>2011</td>
<td>15,850 (~3,287 missing)</td>
</tr>
<tr>
<td>Southwest Kyushu, Japan, 1792</td>
<td>1792</td>
<td>15,030</td>
</tr>
<tr>
<td>Tokachi-Oki earthquake and tsunami, Japan, 1703</td>
<td>1703</td>
<td>5,000</td>
</tr>
<tr>
<td>Kii Peninsula, Japan, 1855</td>
<td>1855</td>
<td>5,000</td>
</tr>
<tr>
<td>Manila Gulf, Philippines, 1976</td>
<td>1976</td>
<td>3,000</td>
</tr>
<tr>
<td>Papua New Guinea, 1998</td>
<td>1998</td>
<td>2,000</td>
</tr>
<tr>
<td>Japan earthquake and tsunami, Japan, 1933</td>
<td>1933</td>
<td>1,000</td>
</tr>
<tr>
<td>Chile tsunami, 1960</td>
<td>1960</td>
<td>165</td>
</tr>
<tr>
<td>Aleutian Island earthquake, deaths in Hawaii, Philippines, Japan, and Japan, 1960</td>
<td>1960</td>
<td>122</td>
</tr>
</tbody>
</table>

**Reducing Tsunami Hazards?**

- Warning system in all major oceans
- Better Land Use Planning
- Local gov’t evacuation routes and procedures
- Education about warning signs
  - Ground-shaking in coastal areas
  - Unusual disturbance of ocean, drop in SL
  - Move to high ground (several hours-days)
  - First wave generally not largest

**Volcanoes**

- **Volcanoes**: landforms created when magma escapes from Earth’s interior through vents or fissures at Earth’s surface and becomes lava. Lava cools and solidifies around vents forming volcanic rock.

- Globally, ~50 volcanoes erupt each year.

- Located at both convergent and divergent plate boundaries (not transform) and interior plate hot spots.
### Volcanism

**Hazards**
- Volcanic materials bury and destroy habitats and property; toxic gases (acid rain)
- Ash clouds can block sun and lower global temperature
- Lahars (volcanic mudflows formed from sudden ice melting)
- Tsunamis

**Benefits**
- Release of gases and water vapor forming atmosphere and hydrosphere
- Addition of fertile soils
- Addition of “real estate” (Hawaii, Pacific Islands, Iceland)
- Geothermal energy
- Info about Earth’s interior

http://www.infoplease.com/ipa/A0197833.html

### Reducing Volcanic Hazards?

- Map high risk areas
- Volcanic zoning (no development in volcanically prone areas)
- Better prediction (monitor volcano’s surface, temperature, gas release, seismic activity)
- Effective evacuation plans
- Successful case histories: Mount Pinatubo Philipinnes, Mount St Helens, Oregon


### Mass Movement

**Main Causes:** Water, Seismic Activity, Volcanoes, Humans

- Slumps / Slides
- Mudflows, Earthflows
- Rock Falls
- Lahars (volcanic)
- Debris Flows
- Avalanche

http://daveslandslideblog.blogspot.com/2008/08/la-conchita-landslide-verdict.html
Southern Italy Landslide 2/16/10

**La Conchita 1995**

125 m wide, 70 m long, and >30 m deep, with an estimated volume of 1.3 million cubic meters.

Main Causes: Water, Seismic Activity, Volcanoes, Humans:
La Conchita 1/10/05

**La Conchita 1/10/05**

2004/07/31: 10,000 cubic meters. Rock scalp of ancient landslide

**La Conchita 1/10/05**
Mass Movement
Triggered by human activities

- Irrigation
- Water leakage: septic tanks other utilities
- Surface water diversion
- Road construction
- Mining operations
- Logging
- Fires
- Excavation of slope

SOLUTIONS?

Mass Movement
Santa Cruz Mountains especially susceptible

- Topography
  - Geology (Dip Slopes)
- Rocks:
  - soft
  - fractured, folded, faulted
- Rainfall, El Niño winters
- Earthquakes
- Wildfires

The Hawaiian Islands: a combination of volcanism, slope failure and megatsunamis

Cape Verdean island of Fogo
73,000 yrs BP volcano collapse
Creates waves 240 m or 800 ft
Coastal Erosion / Flooding / Rising Sea Level

- Storms
- Waves
- Coastal slides
- Human activities

Human impacts on coastal erosion: Santa Cruz Harbor example
californiacostline.org

Coastal Armoring; seawalls, rip-rap, and more
californiacostline.org

Coastal Armoring; seawalls, rip rap and more
californiacostline.org

Reducing Coastal Erosion Hazards

- How will sea level rise impact coastal erosion?
- Establish better land-use planning
- Monitor erosion rates
- Map high risk areas
- Limit coastal armoring and damming of rivers
- Evaluate and monitor coastal engineering projects

Better land use planning
Rio Del Mar, Aptos Ca
californiacostline.org
<table>
<thead>
<tr>
<th>Geologic Processes and Hazards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition of Geology</td>
</tr>
<tr>
<td><strong>External and Internal Processes:</strong> examples of each</td>
</tr>
<tr>
<td><strong>Fundamentals of Plate Tectonics:</strong> definition, types of boundaries, general geography, hazards &amp; resources</td>
</tr>
<tr>
<td><strong>Earthquakes:</strong> focus, epicenter, types of waves, measuring strength &amp; location, outcomes, damage a function of, prediction</td>
</tr>
<tr>
<td><strong>Tsunamis:</strong> shallow water waves, Japan Earthquake</td>
</tr>
<tr>
<td><strong>Volcanoes:</strong> definition, location, hazards, benefits, prediction</td>
</tr>
<tr>
<td><strong>Mass Wasting:</strong> causes, different types, susceptibility, human influence</td>
</tr>
</tbody>
</table>

Coastal Erosion / Flooding: sea level rise, storms, land use planning