1 ***Earthquakes***

***Earth*, 9th edition, Chapter 11**

2 ***Key Concepts***

- Earthquake basics.
- "Seismology" and locating earthquakes.
- Measuring the size of earthquakes.
- Destruction resulting from earthquakes.
- Predicting earthquakes.
- Earthquakes and the Plate Tectonics Model.

3 ***What is an earthquake?***

- An earthquake is the vibration of Earth produced by the rapid release of energy
  - Energy released radiates in all directions from its source, the focus
  - Energy is in the form of waves
  - Sensitive instruments around the world record the event

4 ***Earthquake focus and epicenter***

5 ***What is an earthquake?***

- Earthquakes and faults
  - Movements that produce earthquakes are usually associated with large fractures in Earth's crust called faults
  - Most of the motion along faults can be explained by the plate tectonics theory

6 ***What is an earthquake?***

- Elastic rebound
  - Mechanism for earthquakes was first explained by H.F. Reid
    - Rocks on both sides of an existing fault are deformed by tectonic forces
    - Rocks bend and store elastic energy
    - Frictional resistance holding the rocks together is overcome

7 ***What is an earthquake?***

- Elastic rebound
  - Earthquake mechanism
    - Slippage at the weakest point (the *focus*) occurs
    - Vibrations (earthquakes) occur as the deformed rock "springs back" to its original shape (*elastic rebound*)
  - Earthquakes most often occur along existing faults whenever the frictional forces on the fault surfaces are overcome

8 ***What is an earthquake?***

- Foreshocks and aftershocks
  - Adjustments that follow a major earth-quake often generate smaller earthquakes called *aftershocks*
  - Small earthquakes, called *foreshocks*, often precede a major earthquake by days or, in some cases, by as much as several years

9 ***San Andreas: An active earthquake zone***

- San Andreas is the most studied fault system in the world
- Displacement occurs along discrete segments 100 to 200 kilometers long
  - Some portions exhibit slow, gradual displacement known as *fault creep*
  - Other segments regularly slip producing small earthquakes

10 ***San Andreas: An active earthquake zone***

- Displacements along the San Andreas fault
  - Still other segments store elastic energy for hundreds of years before rupturing in great earthquakes
    - Process described as *stick-slip motion*
    - Great earthquakes should occur about every 50 to 200 years along these sections

11 ***Displacement produced by the 1906 San Francisco earthquake***

12 ***Seismology***

- The study of earthquake waves, *seismology*, dates back almost 2000 years to the Chinese
- *Seismographs*, instruments that record seismic waves
  - Records the movement of Earth in relation to a stationary mass on a rotating drum or magnetic tape

13 ***Seismograph designed to record vertical ground motion***

14 ***Seismology***

- *Seismographs*
  - More than one type of seismograph is needed to record both vertical and horizontal ground motion
  - Records obtained are called *seismograms*
- Types of seismic waves
  - *Surface waves*
    - Travel along outer part of Earth

15 ***Seismographs***

16 ***A seismogram records wave amplitude vs. time***

17 ***Seismology***

- Types of seismic waves
  - *Body waves*
    - Travel through Earth's interior
    - Two types based on mode of travel
    - *Primary* (*P*) waves
      - Push-pull (compress and expand) motion, changing the volume of the intervening material
      - Travel through solids, liquids, and gases
      - Generally, in any solid material, P waves travel about 1.7 times faster than S waves

18 ***Primary (P) waves***

19 ***Seismology***

- Types of seismic waves
  - Body waves
    - *Secondary* (*S*) waves
      - "Shake" motion at right angles to their direction of travel
      - Travel only through solids
      - Slower velocity than P waves
      - Slightly greater amplitude than P waves

20 ***Secondary (S) waves***

21 ***Earthquake Waves***

22 ***Locating the source of earthquakes***

- Terms:
  - *Focus*
    - the place within Earth where earthquake waves originate
  - *Epicenter*
    - location on the surface directly above the focus
- Epicenter is located using the difference in velocities of P and S waves

23 ***Locating the source of earthquakes***

- Locating the epicenter of an earthquake
  - Three station recordings are needed to locate an epicenter
  - Each station determines the time interval between the arrival of the first P wave and the first S wave at their location
  - A travel-time graph is used to determine each station's distance to the epicenter

24 ***A travel-time graph is used to find the distance to the epicenter***

25 ***Locating the source of earthquakes***

- Locating the epicenter of an earthquake
  - A circle with a radius equal to the distance to the epicenter is drawn around each station
  - The point where all three circles intersect is the earthquake epicenter

26 ***Epicenter is located using three or more seismographs***

27 ***Locating the source of earthquakes***

- Earthquake belts
  - About 95 percent of the energy released by earthquakes originates in a few relatively narrow zones that wind around the globe
  - Major earthquake zones include:
    - the Circum-Pacific belt
    - Mediterranean Sea region to the Himalayan complex
    - the oceanic ridge system

28 ***Distribution of magnitude 5 or greater earthquakes, 1980 - 1990***

29 ***Locating the source of earthquakes***

- Earthquake depths
  - Earthquakes originate at depths ranging from 5 to nearly 700 kilometers
  - Earthquake foci arbitrarily classified as:
    - *shallow* (surface to 70 kilometers)
    - *intermediate* (between 70 and 300 kilometers)
    - *deep* (over 300 kilometers)

30 ***Locating the source of earthquakes***

- Earthquake depths
  - Definite patterns exist
    - Shallow focus occur along the oceanic ridge system
    - Almost all deep-focus earthquakes occur in the circum-Pacific belt, particularly in regions situated landward of deep-ocean trenches

31 ***Relationship of earthquake depth to subduction zones***

32 ***Measuring the size of earthquakes***

- Two measurements that describe the size of an earthquake are:
  - *Intensity*
    - a measure of the degree of earthquake shaking at a given locale based on the amount of damage
  - *Magnitude*
    - estimates the amount of energy released at the source of the earthquake

33 ***Santa Clara County Richter Scale***

34 ***Measuring the size of earthquakes***

- Intensity scales:
  - *Modified Mercalli Intensity Scale*
    - was developed using California buildings as its standard
  - The drawback of intensity scales is that destruction may not be a true measure of the earthquakes actual severity

35

36 ***Measuring the size of earthquakes***

- Magnitude scales
  - *Richter magnitude*
    - concept introduced by Charles Richter in 1935
  - *Richter scale*
    - Based on the amplitude of the largest seismic wave recorded
    - Accounts for the decrease in wave amplitude with increased distance

37 ***Measuring the size of earthquakes***

- Magnitude scales
  - *Richter scale*
    - Largest magnitude recorded on a Wood-Anderson seismograph was 8.9
    - Magnitudes less than 2.0 are not felt by humans
    - Each unit of Richter magnitude increase corresponds to a tenfold increase in wave amplitude and a 32-fold energy increase

38 ***Richter Scale of Earthquake Magnitude***

39 ***Measuring the size of earthquakes***

- Magnitude scales
  - *Other magnitude scales*
    - *Several "Richter-like" magnitude scales have been developed*
    - Moment magnitude *was developed because none of the "Richter-like" magnitude scales adequately estimates the size of very large earthquakes*
    - *Derived from the amount of displacement that occurs along a fault*

40 ***Earthquake destruction***

- Amount of structural damage attributable to earthquake vibrations depends on:
  - Intensity and duration of the vibrations
  - Nature of the material upon which the structure rests
  - Design of the structure

41 ***Earthquake destruction***

- Destruction from seismic vibrations
  - Ground shaking
    - Regions within 20 to 50 kilometers of the epicenter will experience about the same intensity of ground shaking
    - However, destruction varies considerably mainly due to the nature of the ground on which the structures are built

42 ***Damage caused by the 1964 Anchorage, Alaska earthquake***

43 ***Earthquake destruction***

- Destruction from seismic vibrations
  - Liquefaction of the ground
    - Unconsolidated materials saturated with water turn into a mobile fluid
  - Seiches
    - The rhythmic sloshing of water in lakes, reservoirs, and enclosed basins
    - Waves can weaken reservoir walls and cause destruction

44 ***Earthquake destruction***

- Destruction from seismic vibrations
  - Landslides
    - Hebgen Lake quake, 1959, M 7.5
    - Landslide buried Forest Service Campground, killing 26 campers
    - Quake Lake created by landslide
    -

45 ***Damage caused by the 1959 Hebgen Lake, Montana earthquake***

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50 ***Mid-continent Earthquakes:***
Life NOT on the Edge

51 ***Earthquake Hazards in the U.S.***

52 ***Now, for the exception...***

Reelfoot Rift Zone

53 ***Seismicity:***

locations of earthquakes since 1974

source: USGS

54 ***Way back in 1811 and 1812…***

55

56 ***New Madrid in 1774***

57 ***New Madrid in 1810***

58

59 ***Waves on the Mississippi***

60 ***Destruction on Land***

61 ***Mercalli***
vs.
Richter

62 ***Fault Structure***

63 ***1811 – 1812 estimated magnitudes***

64 ***1811 – 1812 estimated magnitudes***

65 ***Intensity Map for 1811 - 1812***

66 ***Relative Earthquake***
Energy Transfer:

67 ***Oh no! A quiz!***

What's round on the ends and "high" in the middle?

68 ***Answer:***

69 ***t***

70 ***t***

71 ***1811 – 1812 estimated magnitudes***

72 ***Reelfoot Lake: cypress trees***

73 ***Reelfoot Lake***

74 ***Reelfoot Lake***

75 ***Memphis in the Crosshairs***

The King:
Jan. 8, 1935 – Aug. 16, 1977

76 ***Memphis***

77 ***AutoZone HQ, Memphis***

78 ***The Sterick Building, Memphis***

Completed in 1930, repainted in 1960's, vacant since 1980's

79 ***The St. Louis Arch***
Completed in 1965, brought down in 20??

80 ***Earthquake Survival Kit***
do you know where yours is?

81 ***It could happen tomorrow…***

82 ***Earthquake destruction***

- *Tsunamis*, or *seismic sea waves*
  - Destructive waves that are often inappropriately called “tidal waves”
  - Result from vertical displacement along a fault located on the ocean floor or a large undersea landslide triggered by an earthquake

83 ***Earthquake destruction***

- Tsunamis, or seismic sea waves
  - In the open ocean height is usually less than 1 meter
  - In shallower coastal waters the water piles up to heights that occasionally exceed 30 meters
  - Can be very destructive
- Landslides and ground subsidence

84 ***Formation of a tsunami***

85 ***Can earthquakes be predicted?***

- Short-range predictions
  - Goal is to provide a warning of the location and magnitude of a large earthquake within a narrow time frame
  - Research has concentrated on monitoring possible precursors
    - phenomena that precede a forthcoming earthquake such as measuring uplift, subsidence, and strain in the rocks

86 ***Can earthquakes be predicted?***

- Short-range predictions
  - Currently, no reliable method exists for making short-range earthquake predictions
- Long-range forecasts
  - Give the probability of a certain magnitude earthquake occurring on a time scale of 30 to 100 years, or more

87 ***Can earthquakes be predicted?***

- Long-range forecasts
  - Based on the premise that earthquakes are repetitive or cyclical
    - Using historical records or paleoseismology
  - Are important because they provide information used to
    - Develop the Uniform Building Code
    - Assist in land-use planning

88 **End of Chapter**