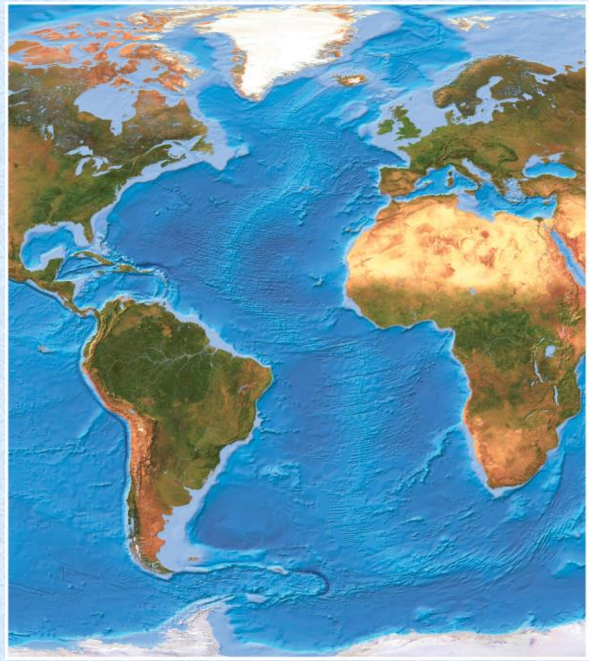
Map shows
3 main features
of ocean floor



Chapter 3 – Marine Provinces

Chapter 3 – Overview

- The study of bathymetry determines ocean depths and ocean floor topography.
- Echo sounding and satellites are efficient bathymetric tools.
- Most ocean floor features are generated by plate tectonic processes.
- Different sea floor features exist in different oceanographic locations.

Bathymetry

- Measures the vertical distance from the ocean surface to mountains, valleys, plains, and other sea floor features

Measuring Bathymetry

- **Soundings**
  - **Poseidonus** made first sounding in 85 B.C.
  - Line with heavy weight
  - Sounding lines used for 2000 years
- **Fathom**
  - Unit of measure
  - 1.8 meters (6 feet)

Measuring Bathymetry

- ***HMS Challenger***
  - Made first systematic measurements in 1872
- Deep ocean floor has **relief**
  - Variations in sea floor depth

Measuring Bathymetry

- **Echo Soundings**
  - Echo sounder or fathometer
  - Reflection of sound signals (**pings**)
  - German ship *Meteor* identified mid-Atlantic ridge in 1925
- Lacks detail
- May provide inaccurate view of sea floor

Measuring Bathymetry

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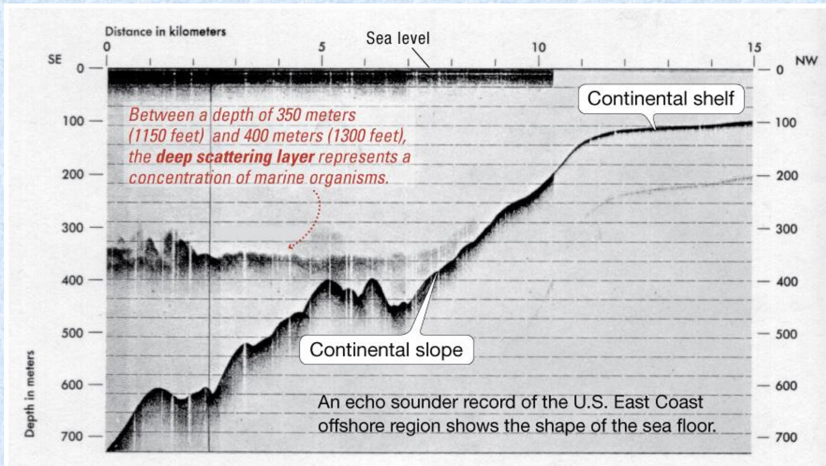
  see layer of marine organisms in figure

Echo Sounding Record

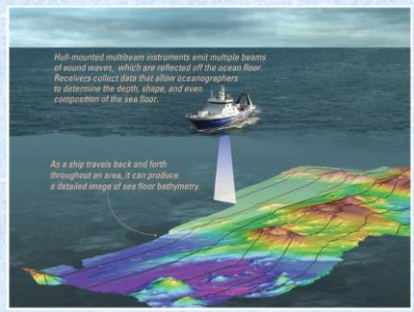


Measuring Bathymetry

- **Precision Depth Recorder (PDR)**
  - 1950s
  - Focused high-frequency sound beam
  - First reliable sea floor maps produced
  - Helped confirm sea floor spreading

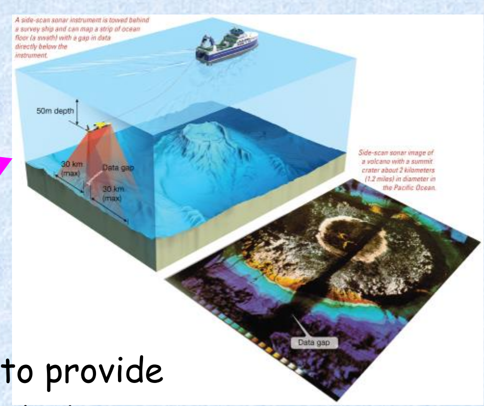
Modern Bathymetry Measuring

- **Multibeam Echo Sounders**
  - Multiple simultaneous sound frequencies
- **Seabeam**
  - First multibeam echo sounder
  - Map sea floor strips up to 60 km (37 mi) wide



Modern Bathymetry Measuring

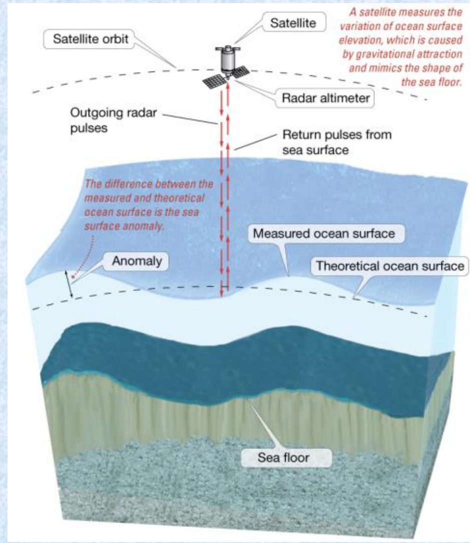
- **Sonar**
  - Sound navigation and ranging (acronym)



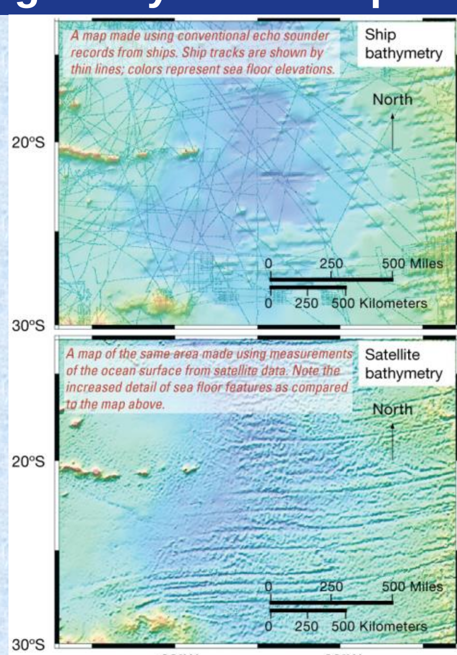
- **Side scan sonar**
- Can be towed behind ship to provide detailed bathymetric strip map

Sea Floor Mapping from Space

- Uses satellite measurements
- Measures sea floor features based on gravitational bulges in sea surface
- Indirectly reveals bathymetry, e.g., **seamounts**



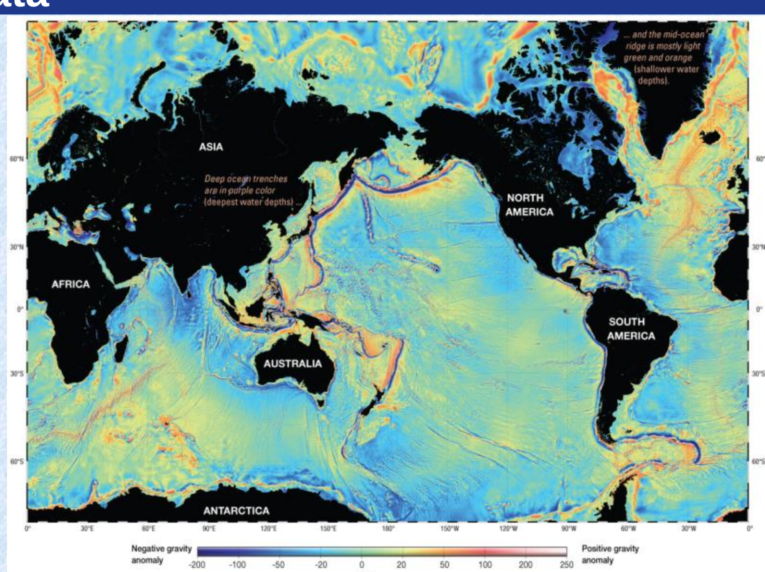
Comparing Bathymetric Maps



Sea Floor Mapping from Space

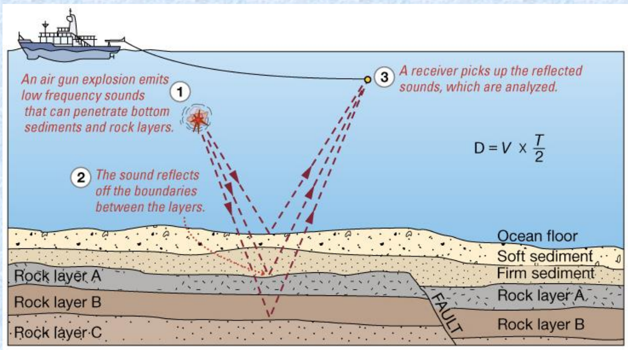
- Satellite-derived ocean surface gravity
- Reveals bathymetry where ships have not conducted research
- Uses depth soundings to calibrate sea surface height measurements

Global Sea Surface Elevation from Satellite Data



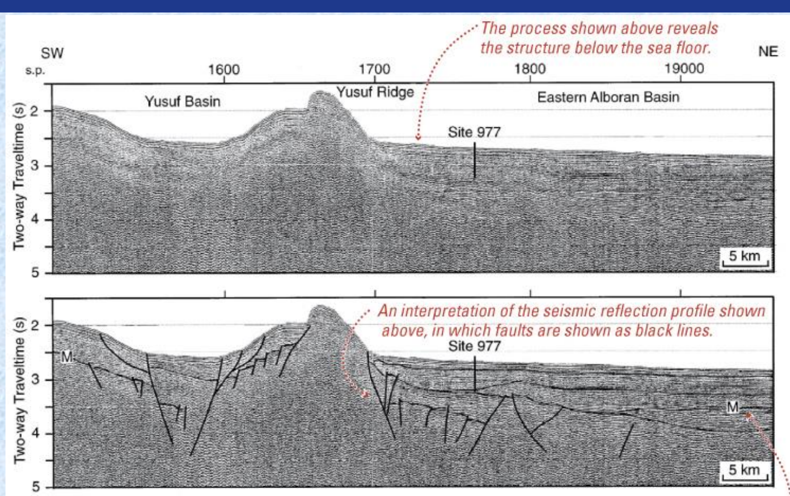
Measuring Bathymetry

- **Seismic Reflection Profiles**
  - Strong, low-frequency sounds
  - Detail ocean structure beneath sea floor



(a) A ship conducting seismic profiling. Note that depth D can be determined by knowing the velocity V (speed of sound in seawater) and the travel time T of the sound.

Seismic Reflection Profile

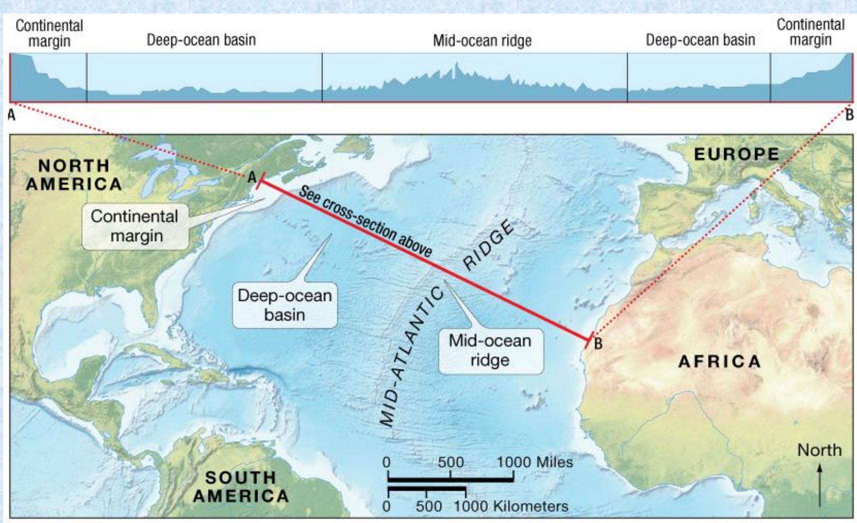


(b) Paired seismic reflection profiles (raw above, interpreted below) of the western Mediterranean, showing the location of *JOIDES Resolution* Drill Site 977.

Ocean Provinces

- Three Major Provinces
- **Continental margins**
  - Shallow-water areas close to shore
- **Deep-ocean basins**
  - Deep-water areas farther from land
- **Mid-ocean ridge**
  - Submarine mountain range

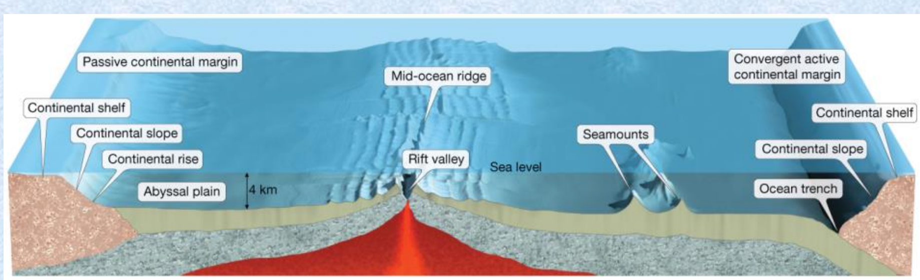
Major Regions of the North Atlantic



Continental Margins

- **Passive**
  - Not close to any plate boundary
  - No major tectonic activity
  - East coast of United States
- ***Active***
  - *Associated with convergent or transform plate boundaries*
  - *Much tectonic activity*

Passive and Active Continental Margins



Active Continental Margins

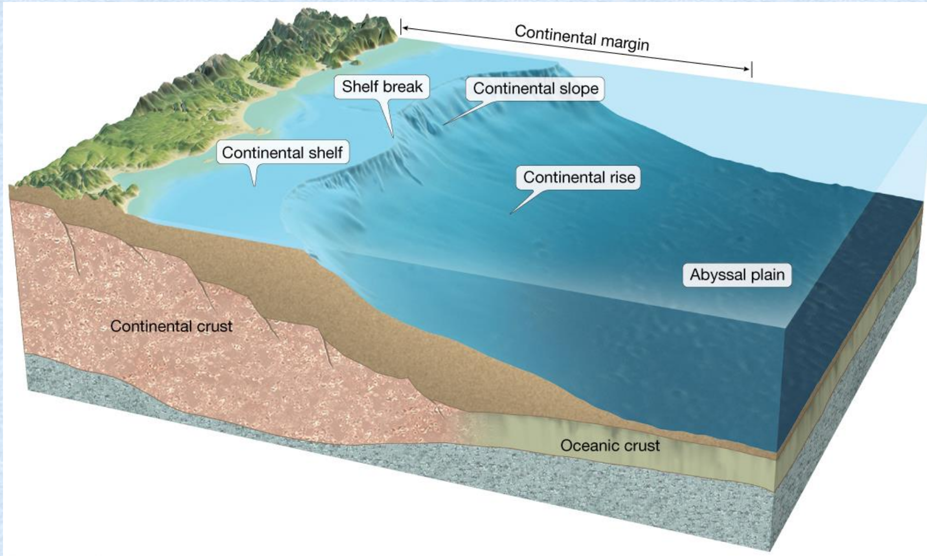
- **Convergent Active Margin**
  - Oceanic-continent convergent plate boundaries
  - Active continental volcanoes
  - Narrow shelf
  - Offshore trench
  - Western South America

- **Transform Continental Margin**
  - Less common
  - Transform plate boundaries
  - Linear islands, banks, and deep basins close to shore
  - Coastal California along San Andreas Fault

Continental Margin Features

- **Continental shelf**
- **Shelf break**
- **Continental slope**
- **Continental rise**

Passive Continental Margin Features



Continental Shelf

- Flat zone from shore to **shelf break**
  - Shelf break is where marked increase in slope angle occurs.
- Geologically part of continent
- Average width is 70 km (43 miles) but can extend to 1500 km (930 miles)
- Average depth of shelf break is 135 meters (443 feet)

Continental Shelf

- Type of continental margin determines shelf features.
- Passive margins have wider shelves.
- California's transform active margin has a **continental borderland.**

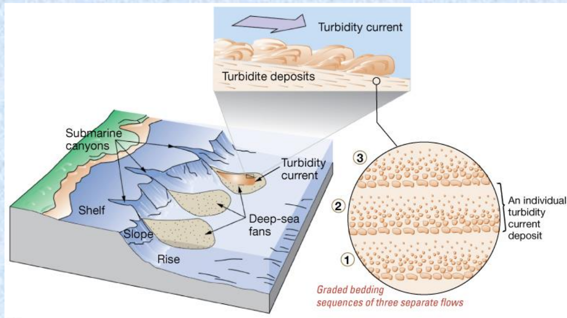
Continental Slope

- Where deep ocean basins begin
- Topography similar to land mountain ranges
- Greater slope than continental shelf
  - Averages 4° but varies from 1–25° gradient
- Marked by **submarine canyons**

- Narrow, deep, V-shaped in profile
- Steep to overhanging walls
- Extend to base of continental slope, 3500 meters (11,500 feet) below sea level
- Carved by **turbidity currents**

Turbidity Currents

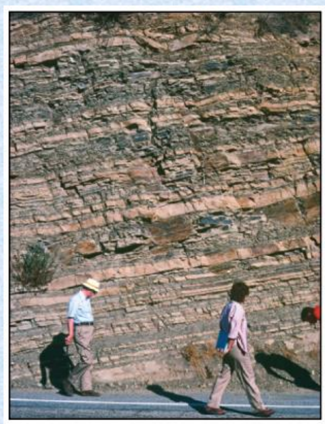
- Underwater avalanches mixed with rocks and other debris
- Sediment from continental shelf
- Moves under influence of gravity
- Sediments deposited at slope base



(a) Turbidity currents move downslope, eroding the continental margin to enlarge submarine canyons. Deep-sea fans are composed of turbidite deposits, which consist of sequences of graded bedding (*inset*).

Continental Rise - 1

- Transition between continental crust and oceanic crust
- Marked by **turbidite deposits** from turbidity currents
- **Graded bedding** in turbidite deposits

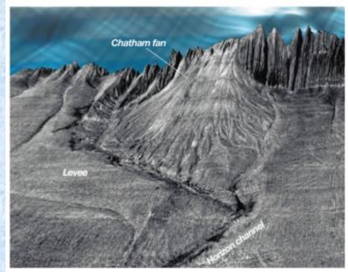


(c) Outcrop of layered turbidite deposits that have been tilted and uplifted onto land in California. Each light-colored layer is sandstone that marks the coarser bottom of a graded bedding sequence.

Continental Rise - 2

- Deposits generate **deep-sea fans**, or **submarine fans**
- Distal ends of submarine fans become flat **abyssal plains**

(a) Map of the Indus Fan, a large but otherwise typical example of a passive margin fan.

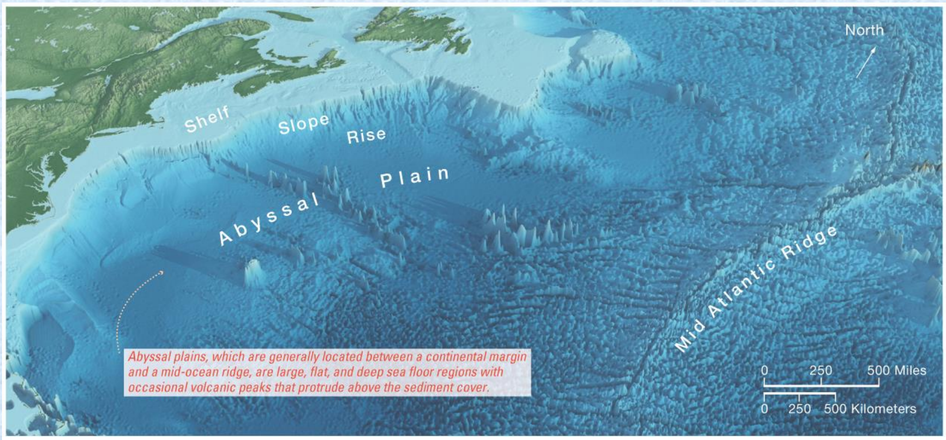


(b) Sonar perspective view of southeast Alaska's Chatham Fan, which rises 450 meters (1500 feet) above the surrounding sea floor. Vertical exaggeration is 20 times; view looking northeast.

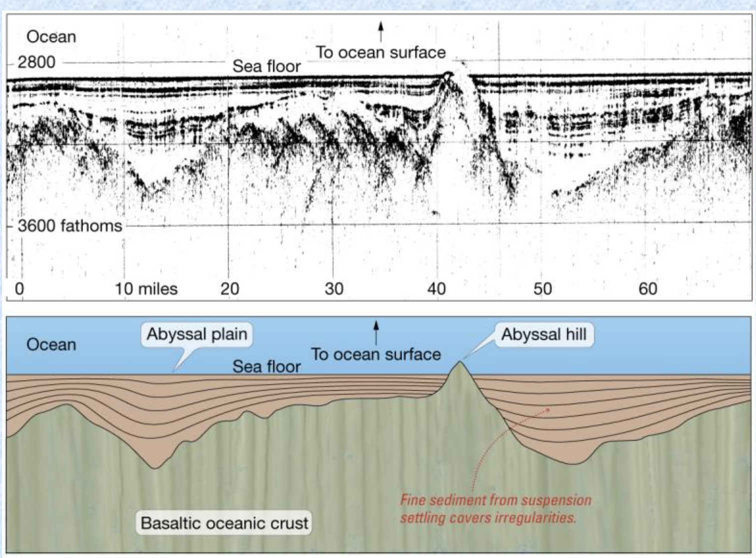
Abyssal Plains

- Extend from base of continental rise
- Some of the deepest, flattest parts of Earth
- **Suspension settling** of very fine particles
- Sediments cover ocean crust irregularities
- Well-developed in Atlantic and Indian oceans

Atlantic Ocean Abyssal Plain



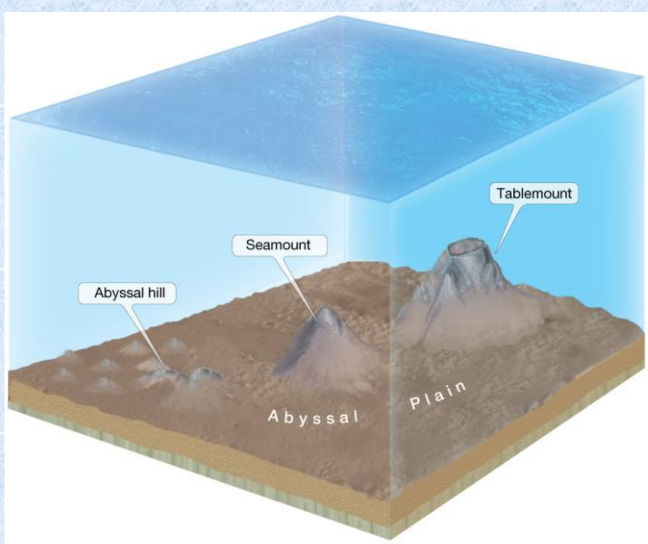
Abyssal Plains from Suspension Settling



Abyssal Plain Volcanic Peaks

- Poke through sediment cover
- Below sea level:
  - **Seamounts, tablemounts**, or **guyots** *at least* 1 km (0.6 mile) above sea floor
  - **Abyssal hills** or **seaknolls** are *less than* 1 km (0.6 mile) above sea floor
- Above sea level:
  - **Volcanic islands**

Abyssal Hill, Seamount, and Tablemount



Ocean Trenches and Volcanic Arcs

- Convergent margins generate **ocean trenches**.
  - Deepest part of oceans
  - Most in Pacific Ocean
  - Deepest trench – Mariana Trench at 11,022 meters (36,161 feet)

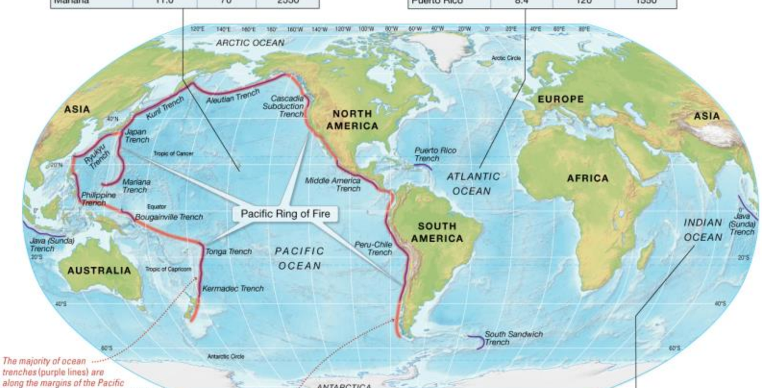
Ocean Trenches

Selected Pacific Ocean Trenches

Name	Depth (km)	Width (km)	Length (km)
Middle America	6.7	40	2800
Aleutian	7.7	50	3700
Peru–Chile	8.0	100	5900
Kermadec–Tonga	10.0	50	2900
Kuril	10.5	120	2200
Mariana	11.0	70	2550

Atlantic Ocean Trenches

Name	Depth (km)	Width (km)	Length (km)
South Sandwich	8.4	90	1450
Puerto Rico	8.4	120	1550



The majority of ocean trenches (purple lines) are along the margins of the Pacific Ocean, where plates are being subducted.

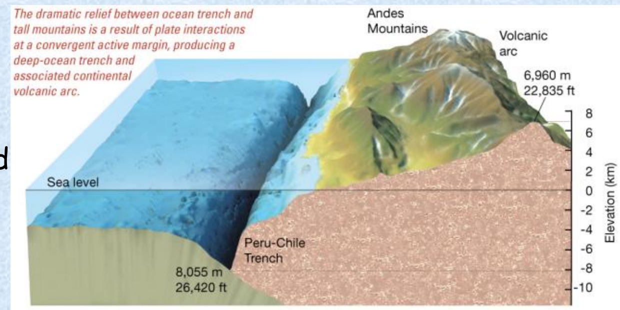
Most of the world's large earthquakes (due to subduction) and active volcanoes (as volcanic arcs) occur around the Pacific Rim, which is why the area is also called the ***Pacific Ring of Fire*** (red shading).

Indian Ocean Trenches

Name	Depth (km)	Width (km)	Length (km)
Java (Sunda)	7.5	80	4500

Island and Continental Arcs

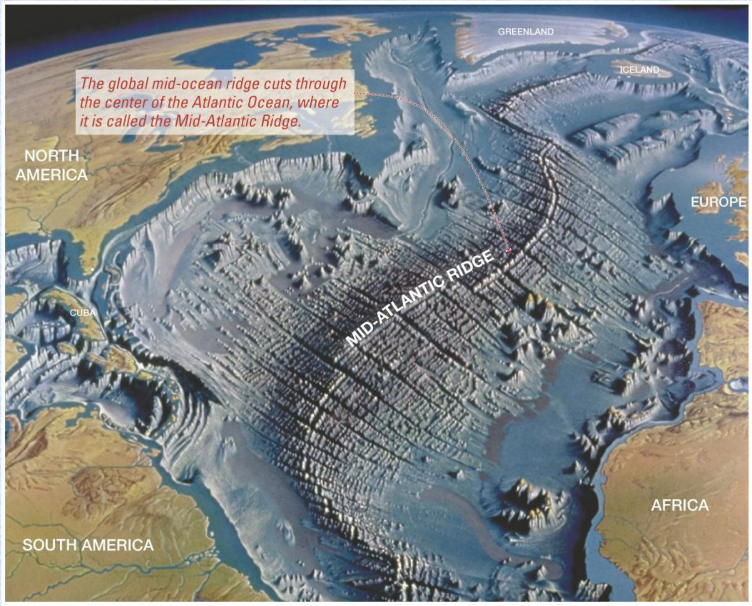
- **Volcanic arc** on nonsubducted ocean plate
- **Island arc**
  - Islands in ocean
  - Japan
- **Continental arc**
  - Mountains on land
  - Andes Mountains



Mid-Ocean Ridge – 1

- Longest mountain chain
- On average, 2.5 km (1.5 miles) above surrounding sea floor
- Volcanic
- Basaltic lava
- Divergent plate boundary

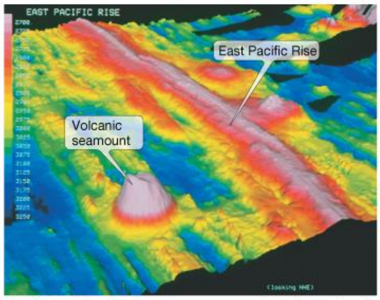
North Atlantic Mid-Ocean Ridge – 2



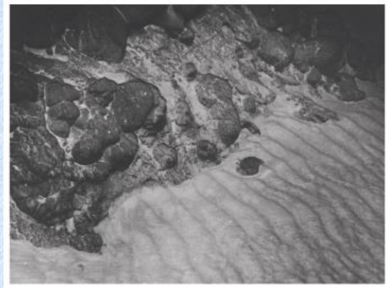
Mid-Ocean Ridge Features – 1

- **Rift Valley**
  - Downdropped area on crest of ridge
  - Marked by fissures and faults
  - Small earthquakes
- **Seamounts** – tall volcanoes (see figure below)
- **Pillow lava** or **pillow basalt** – shapes formed when hot basaltic lava quickly cools

Mid-Ocean Ridge Features – 2



(a) Perspective view based on sonar mapping of a portion of the East Pacific Rise (*center*) showing volcanic seamount (*left*). Colors represent sea floor elevation; the depth, in meters, is indicated by the color scale along the left margin. Vertical exaggeration is six times.



(b) Recently formed pillow lava along the East Pacific Rise. Photo shows an area of the sea floor about 3 meters (10 feet) across that also displays ripple marks from deep-ocean currents.

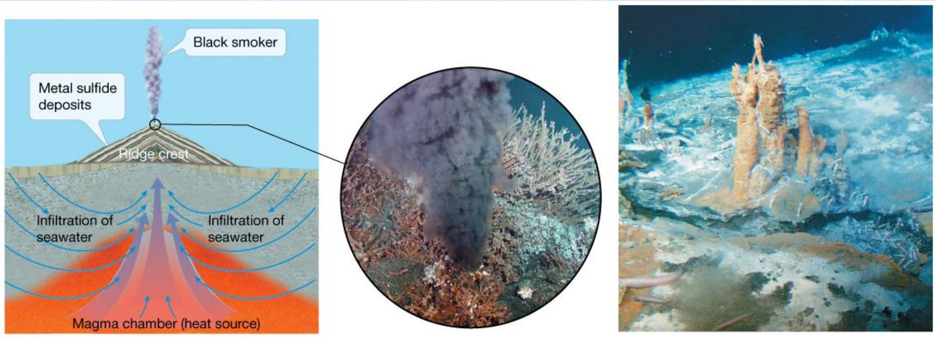
(c) Pillow lava that was once on the sea floor but has since been uplifted onto land at Port San Luis, California. Maximum width of a pillow in this photo is 1 meter (3.3 feet).

Mid-Ocean Ridge Features – 3

- **Hydrothermal Vents**
- Sea floor hot springs
- Foster unusual deep-ocean ecosystems able to survive without sunlight

- **Warm water vents** – temperatures below 30°C (86°F)
- **White smokers** – temperatures from 30–350°C (86–662°F)
- **Black smokers** – temperatures above 350°C (662°F)

Hydrothermal Vents



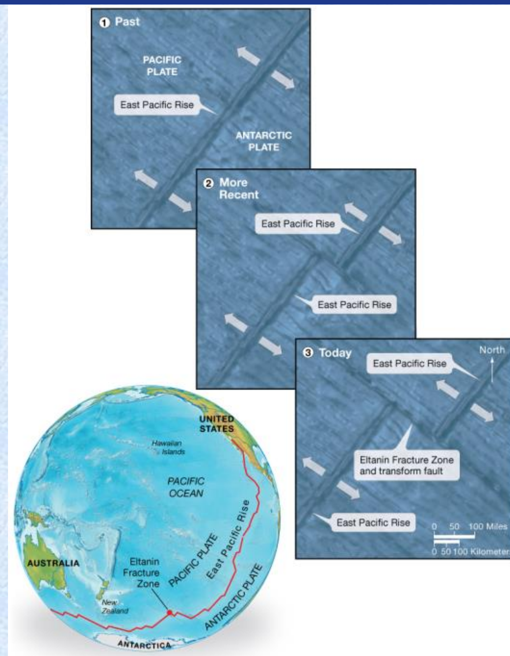
(a) Diagram showing hydrothermal circulation along the mid-ocean ridge and the creation of black smokers; photo (*inset*) showing a close-up view of a black smoker along the East Pacific Rise.

(b) Black smoker chimney and fissure at Susu north active site, Manus Basin, western Pacific Ocean. Chimney is about 3 meters (10 feet) tall.

Fracture Zones and Transform Faults

- **Transform faults** along mid-ocean ridge offset spreading zones.
  - Linear ridge on spherical Earth
  - Seismically active
- **Fracture zones** along Pacific Ocean mid-ocean rise
  - Seismically inactive
  - Occur beyond offset fragments of rise

Fracture Zones



Fracture Zones and Transform Faults

SMARTTABLE 3.1 COMPARISON BETWEEN TRANSFORM FAULTS AND FRACTURE ZONES

	Transform faults	Fracture zones
Plate boundary?	Yes—a transform plate boundary	No—an intraplate feature
Relative movement across feature	Movement in opposite directions ← →	Movement in the same direction ← ←
Earthquakes?	Many	Few
Relationship to mid-ocean ridge	Occur *between* offset mid-ocean ridge segments	Occur *beyond* offset mid-ocean ridge segments
Geographic examples	San Andreas Fault, Alpine Fault, Dead Sea Fault	Mendocino Fracture Zone, Molokai Fracture Zone

Oceanic Islands

- Volcanic activity
- Hotspots
- Island arcs
- Islands that are part of continents

New Volcanic Island Emerges