Map shows 3 main features of ocean floor.

Chapter 3 – Marine Provinces
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.

Chapter 3 – Overview

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

• **Echo Soundings**
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  *see layer of marine organisms in figure*
Echo Sounding Record

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

Measuring Bathymetry
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

- A map made using conventional echo sounder records from ships. Ship tracks are shown by thin lines; colors represent sea floor elevations.
- A map of the same area made using measurements of the ocean surface from satellite data. Note the increased detail of sea floor features as compared to the map above.
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
  
  ![Diagram of Seismic Reflection Profiles](image)

  - An air gun explosion emits low frequency sounds that can penetrate bottom sediments and rock layers.
  - The sound reflects off the boundaries between the layers.
  - A receiver picks up the reflected sounds, which are analyzed.
  - Depth $D = \frac{V \times T}{2}$

**Seismic Reflection Profile**

- The process shown above reveals the structure below the sea floor.

![Seismic Reflection Profile Diagram](image)

- An interpretation of the seismic reflection profile shown above, in which faults are shown as black lines.
- An M-reflector, which is a layer of evaporite minerals (salts) that was created during the drying up of the Mediterranean Sea approximately 5.5 million years ago.
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

- 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
**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

Continental Rise - 1

- Transition between continental crust and oceanic crust
- Marked by turbidite deposits from turbidity currents
- Graded bedding in turbidite deposits
Deposits generate **deep-sea fans**, or **submarine fans**

Distal ends of submarine fans become flat **abyssal plains**

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**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, which are generally located between a continental margin and a mid-ocean ridge, are large, flat, and deep sea floor regions with occasional volcanic peaks that protrude above the sediment cover.

Abyssal Plains from Suspension Settling

Fine sediment from suspension settling covers irregularities.
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

![Diagram showing abyssal plain, seamount, abyssal hill, 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)
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

- 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

- 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

<table>
<thead>
<tr>
<th>SmartTable 3.1</th>
<th>COMPARISON BETWEEN TRANSFORM FAULTS AND FRACTURE ZONES</th>
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<tbody>
<tr>
<td></td>
<td>Transform faults</td>
</tr>
<tr>
<td>Plate boundary?</td>
<td>Yes—a transform plate boundary</td>
</tr>
<tr>
<td>Relative movement across feature</td>
<td>Movement in opposite directions</td>
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<td></td>
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<tr>
<td>Earthquakes?</td>
<td>Many</td>
</tr>
<tr>
<td>Relationship to mid-ocean ridge</td>
<td>Occur between offset mid-ocean ridge segments</td>
</tr>
<tr>
<td>Geographic examples</td>
<td>San Andreas Fault, Alpine Fault, Dead Sea Fault</td>
</tr>
</tbody>
</table>
Oceanic Islands

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

New Volcanic Island Emerges