Earth's Continents and Seafloors

Physical Geology – GEOL100

Ray Rector - Instructor

OCEAN BASINS and CONTINENTAL PLATFORMS

Key Concepts

I. Earth's rocky surface covered by of two types of crust

- Dense, thin, low-standing oceanic crust
- Light, thick, high-standing continental crust

II. Seafloor is divided into two topographic regions

- Shallow continental margins
- Deep-sea oceanic basins

III. Continental margins and Deep Ocean basins are fundamentally different

- Composition
- Structure
- Age
- Tectonic origin

IV. Ocean basins are rugged and have a wide variety of topographic features

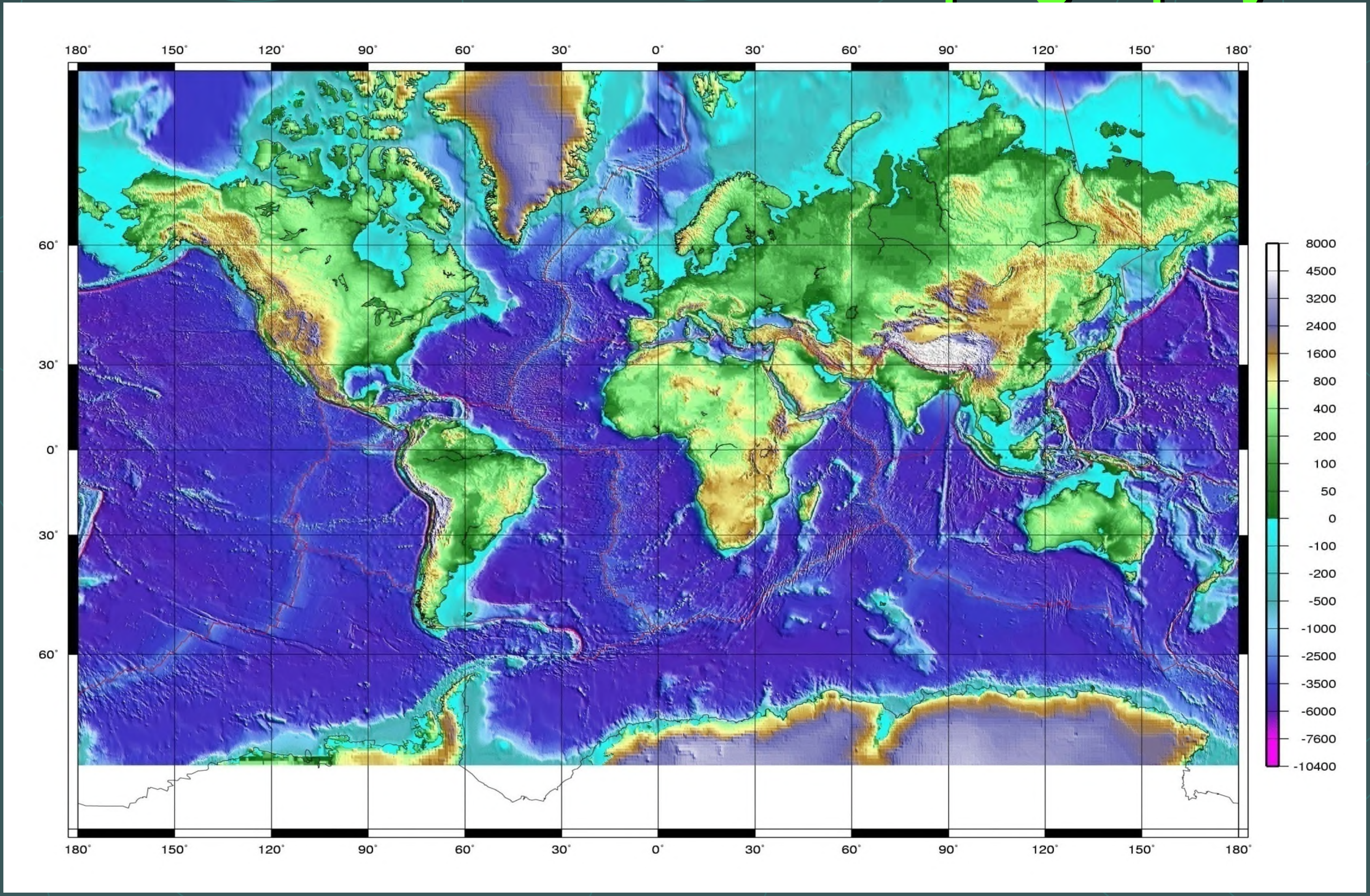
- Mid-oceanic ridges and Transform fracture systems
- Abyssal Hills and Plains
- Oceanic islands, Seamounts, and Guyots
- Trenches and Island Arcs

Two Distinctive Types of Earth Crust

Orange and dark blue regions underlain by thick, high-standing granitic continental crust

Light blue regions underlain by thin, low-standing basaltic oceanic crust

Earth's Solid-Surface Topography



The Earth has two very distinctive topographic provinces:

High-standing continental masses and low-standing ocean basins

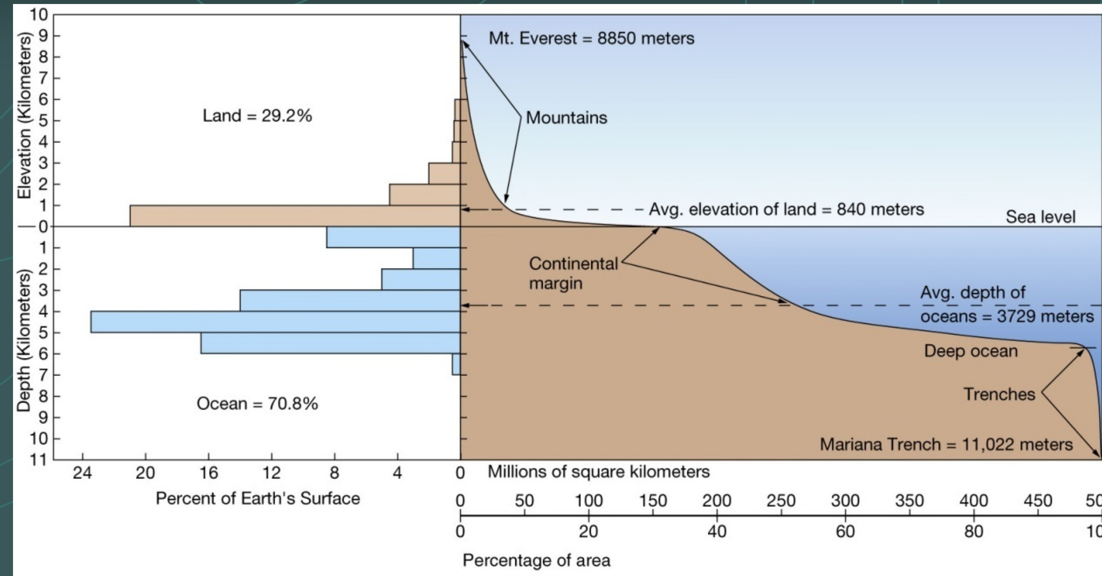
Elevation Relief Profile of Earth Surface

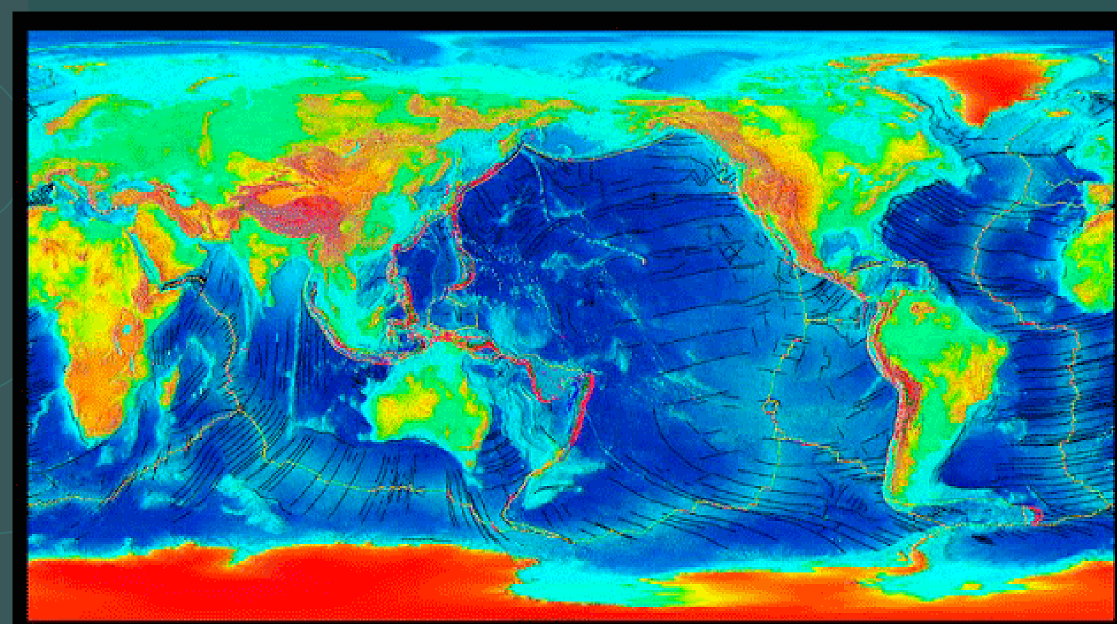
1. Sea level
2. Continental shelf
3. Continental slope
4. The deep ocean floor
5. Mean depth of ocean

   = 4 km below sea level
6. Mean altitude of land

   = 1 km above sea level
7. Mt. Everest = 8848m
8. Marianas Trench

   = 11022m

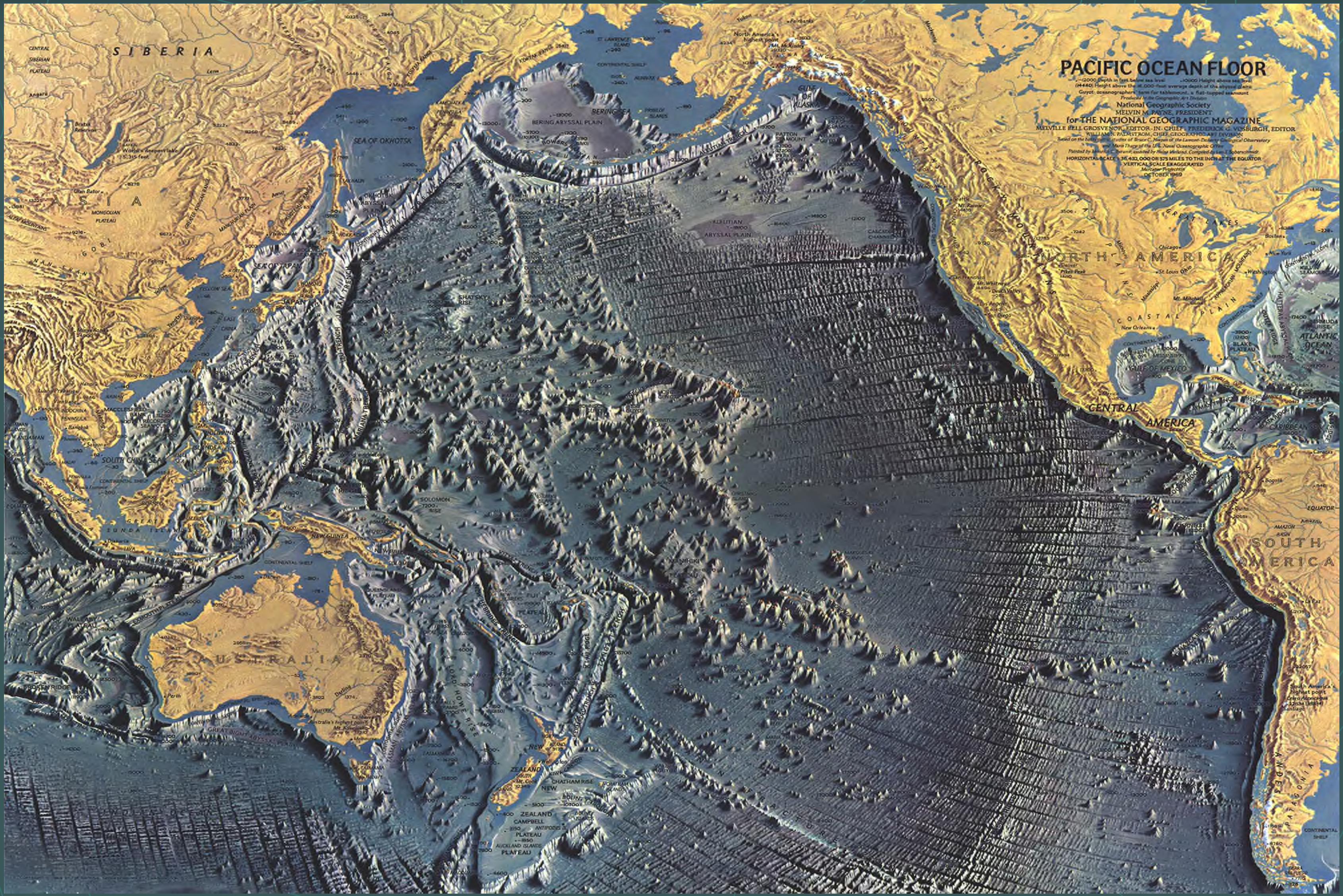




Topography of Earth's Solid Surface

If Earth's ocean were removed the most distinctive feature from space would be its sinuous, scar-like mountain belt that wraps through the low-standing ocean basins – the 70,000 km-long mid-ocean ridge system

Topography of an Ocean Basin



The largest ocean basin on Earth is the Pacific Ocean basin where most of the planet’s deep-sea trenches and active volcanic arcs are found

Topography of Continental Landmasses

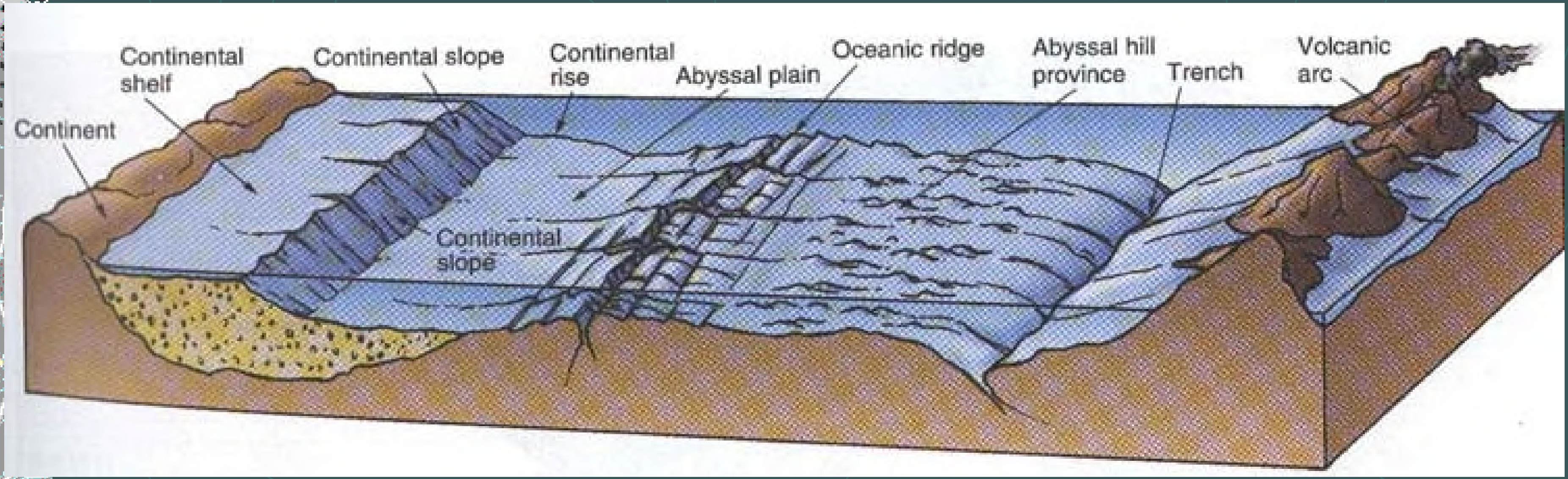
The largest continental terrain province on Earth is Eurasia where most of the planet's tallest mountains are found

Earth's Ocean Basin Features

The Earth's ocean basins have a wide variety of seafloor features that form by different geologic processes.

Globally, the earth's seafloor can be divided into several marine provinces, based on crust type, water depth, topographic slope, landforms, and tectonic and sedimentary processes

- Mid-oceanic ridge and Transform fracture
- Abyssal Hills and Plains
- Oceanic islands, Seamounts, and Guyots
- Trenches and Island Arcs
- Continental Shelf, Slope, Canyons, and Rise



Earth's Continental Features

The Earth's continents have a wide variety of landmass features that form by different geologic processes.

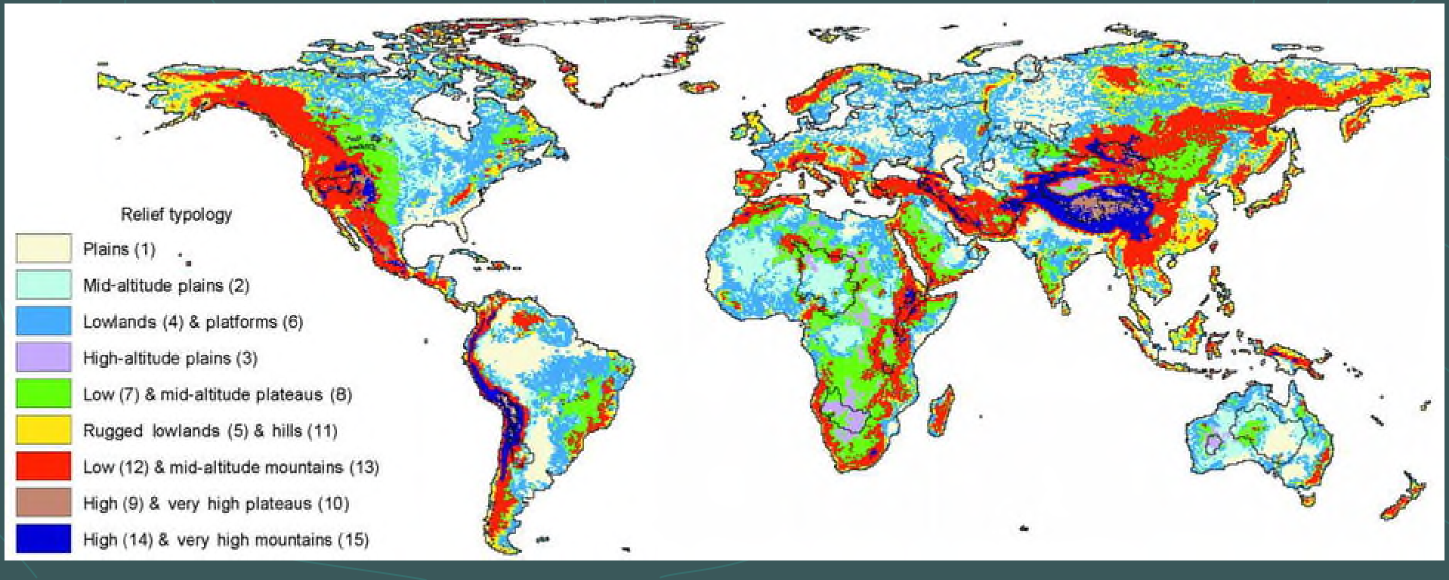
Globally, the Earth's continents can be divided into several terrestrial provinces, based on crust type, age, elevation, topographic slope, landforms, and tectonic and sedimentary processes

Central cratonal shields / platforms

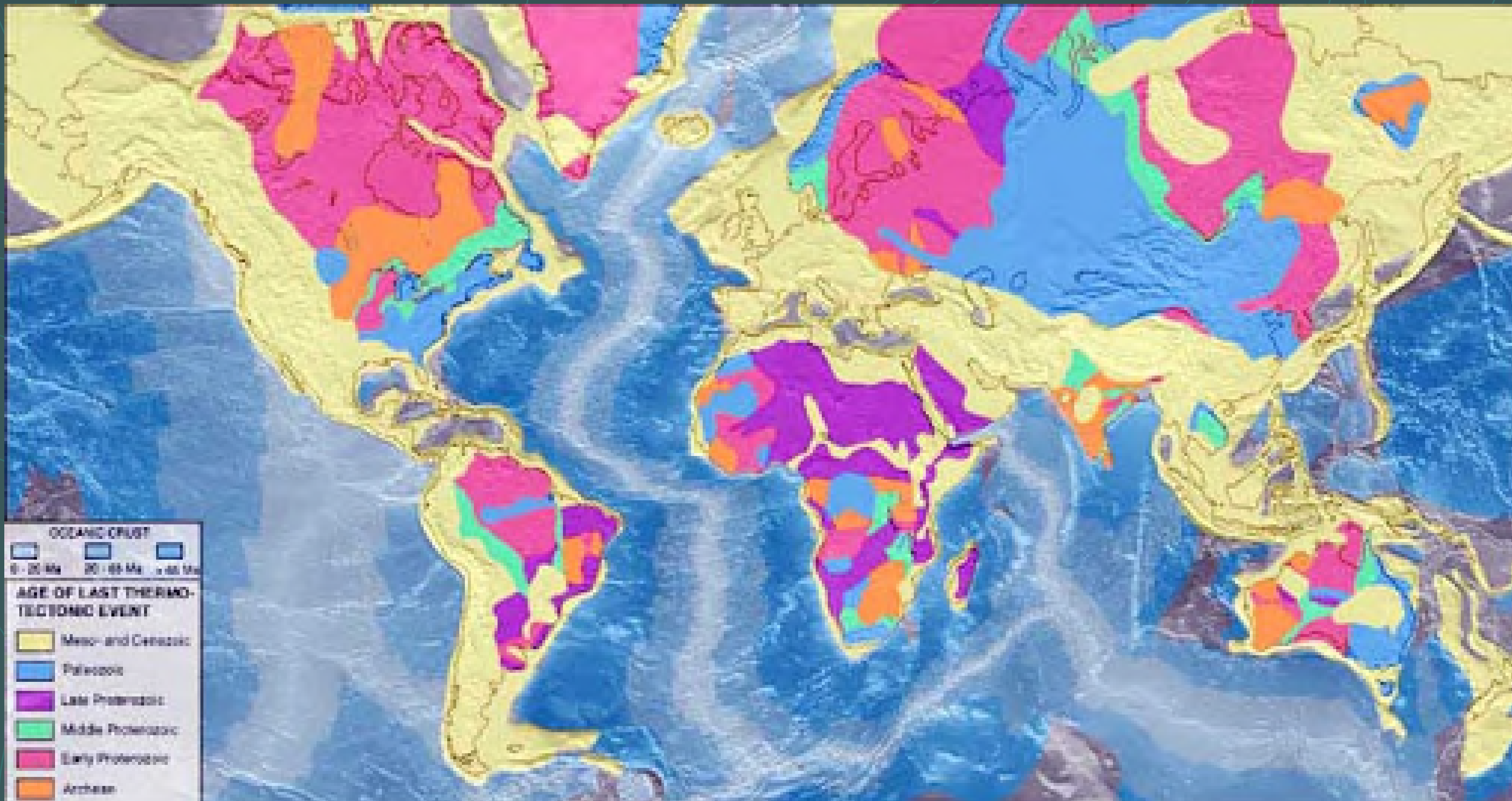
Interior mountains, plateaus, plains, and lowlands

Coastal mountains, plains, and lowlands

Continental submarine margins: Shelf, Slope, Canyons, and Rise



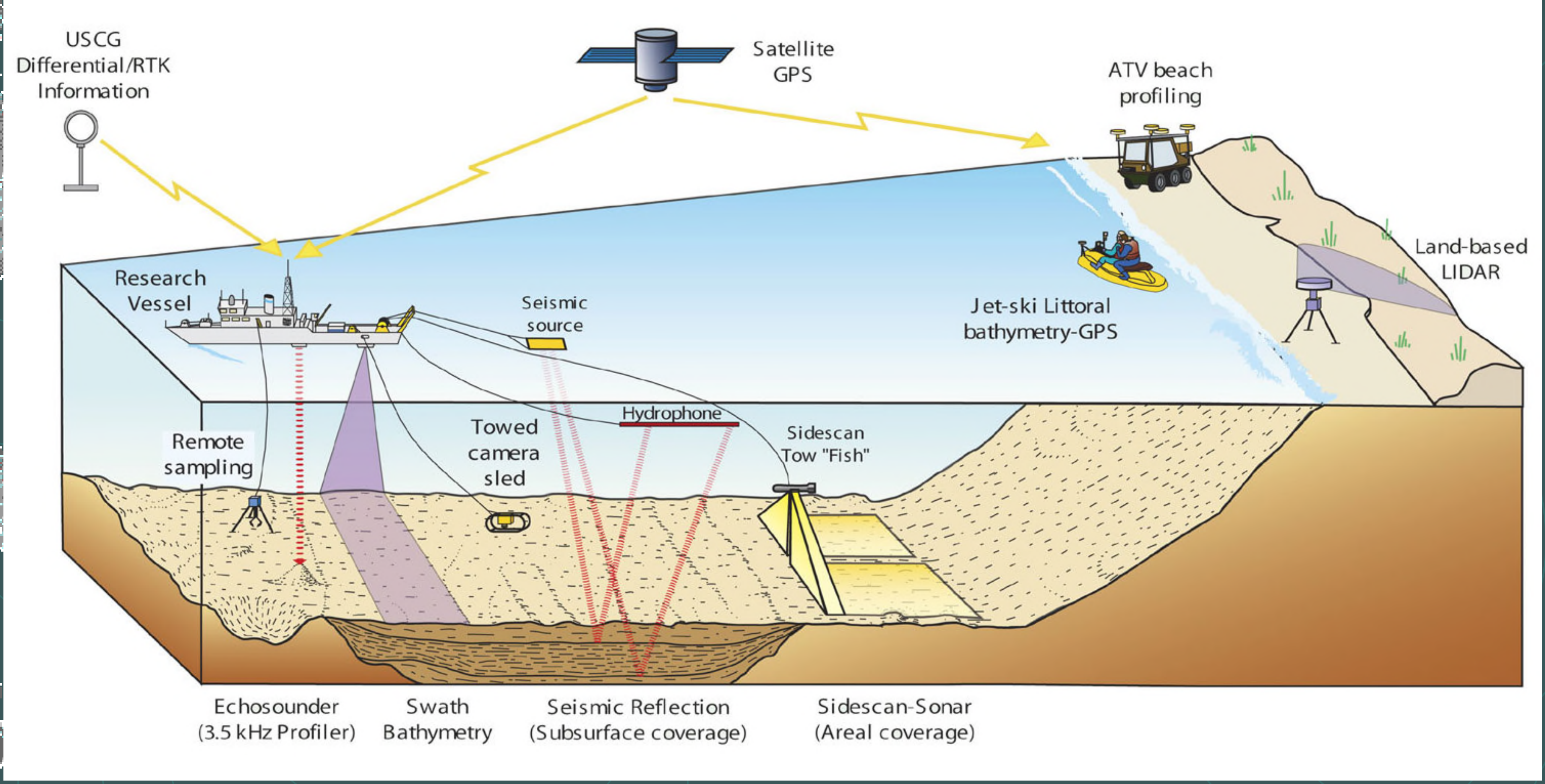
Age Variation of Earth's Crust



Earth's crust varies greatly in from one region to another with continents being much older than ocean seafloor.

- ✓ Continental crust age ranges from Archean to Cenozoic
- ✓ Oceanic crust age ranges from Mesozoic to Cenozoic

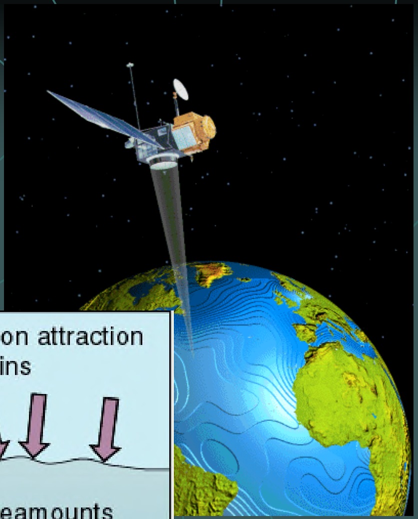
Seafloor Mapping Methods

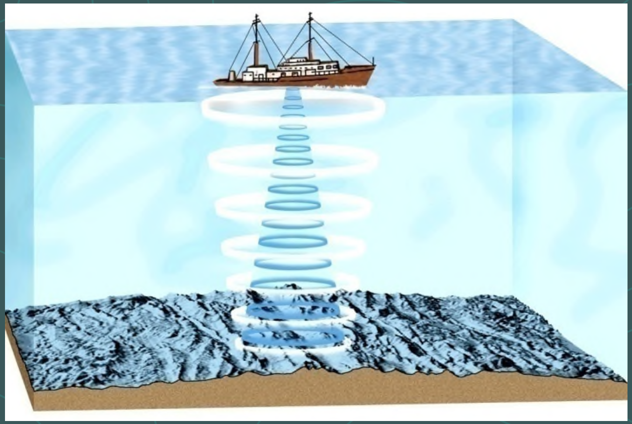


Multiple methods to map the sea bottom and shorelines:

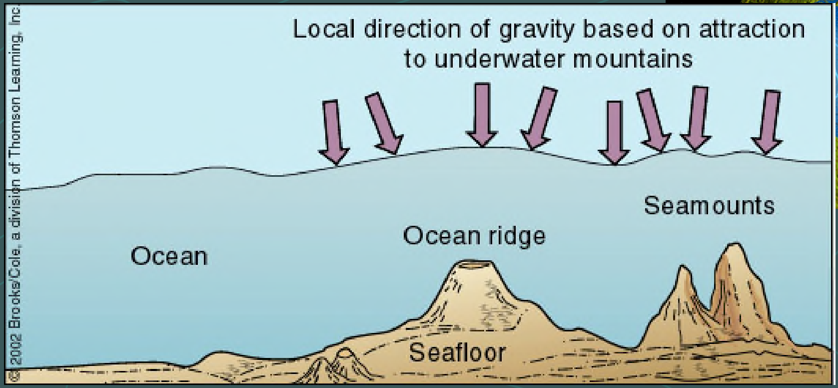
- Sea bottoms are mapped by echo-sounding, radar, camara and seismic reflection
- Shorelines are mapped by beach profiling and LIDAR

Four Principal Methods of Mapping the Ocean Bottom

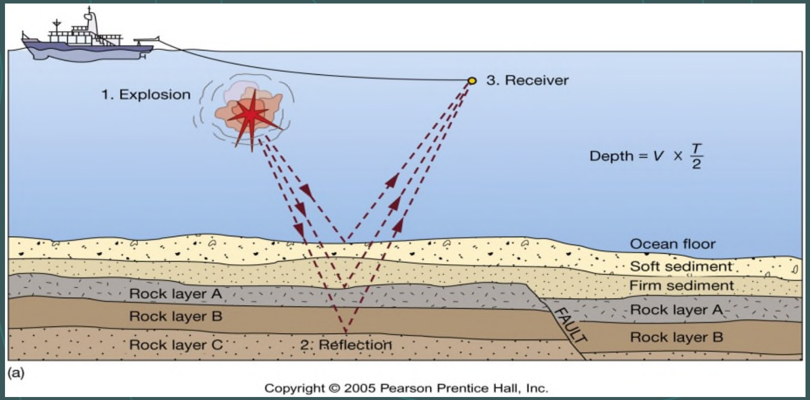




1. Ship-based Sonar



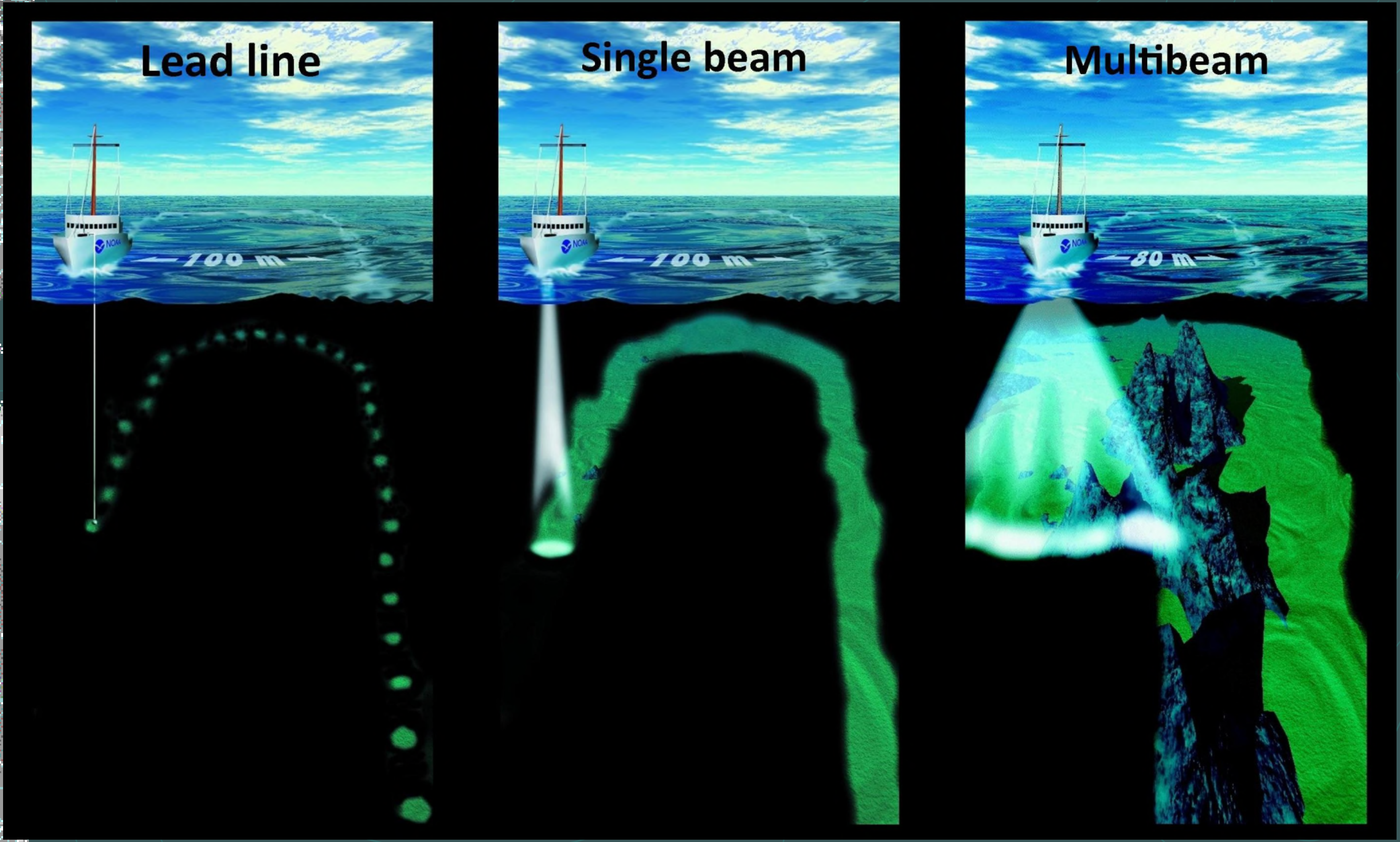
2. Satellite-based Radar



3. Ship-based Seismic Reflection

4. Submersible Survey

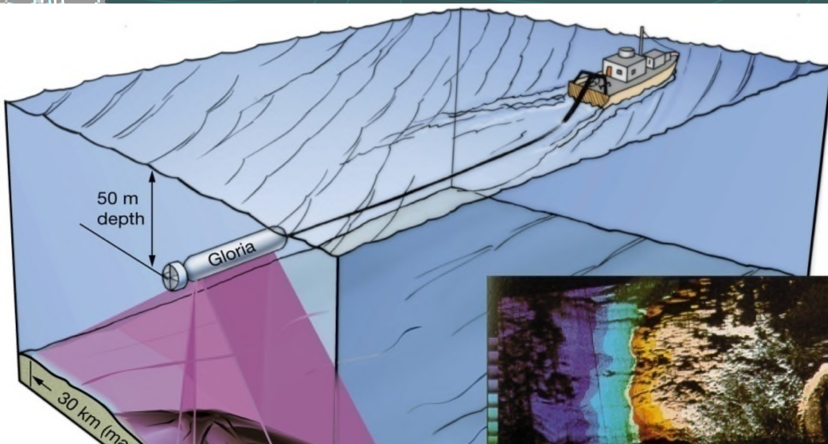
Various Methods for Sounding the Sea Bottom

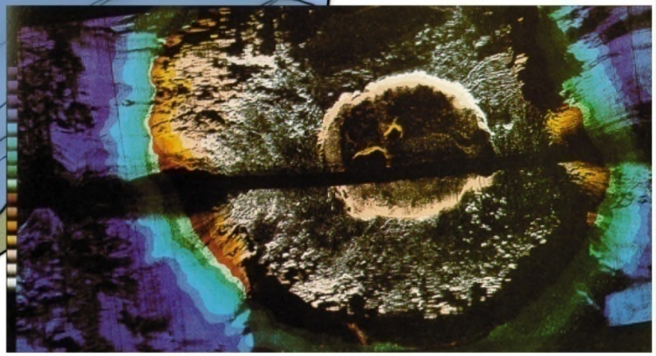


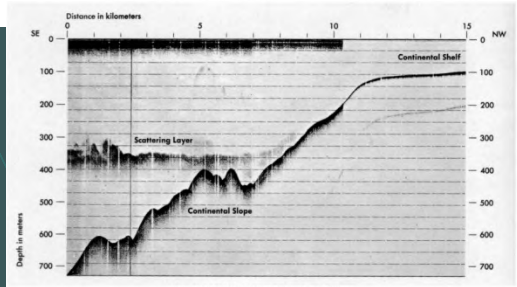
These methods determine the water depth to the sea bottom, which then can be used to determine sea bottom topography.

Means of Mapping of the Sea Floor

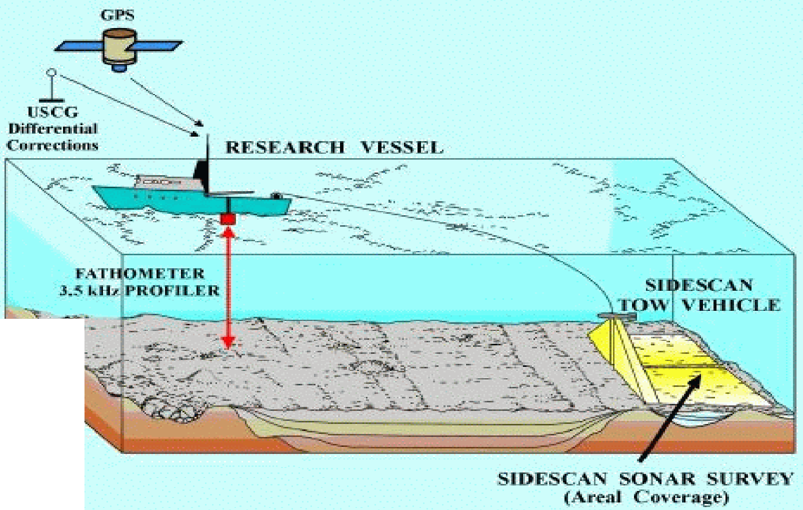
Sonar or Echo-Sounding



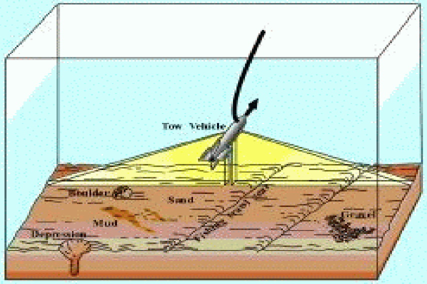


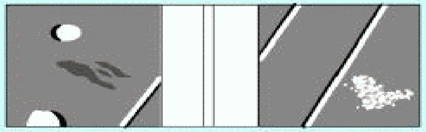


Schematic Illustrating Sidescan Sonar Data Collection



The sea floor is remotely mapped by means of sidescan sonar.

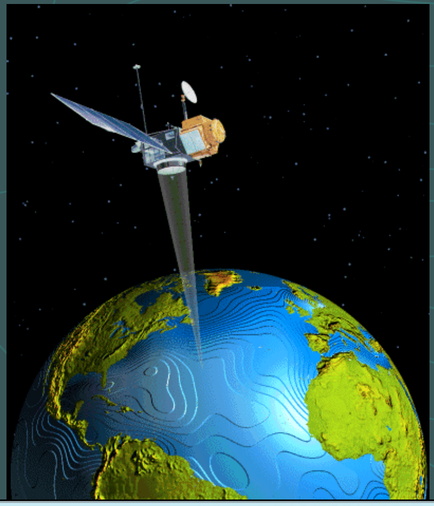


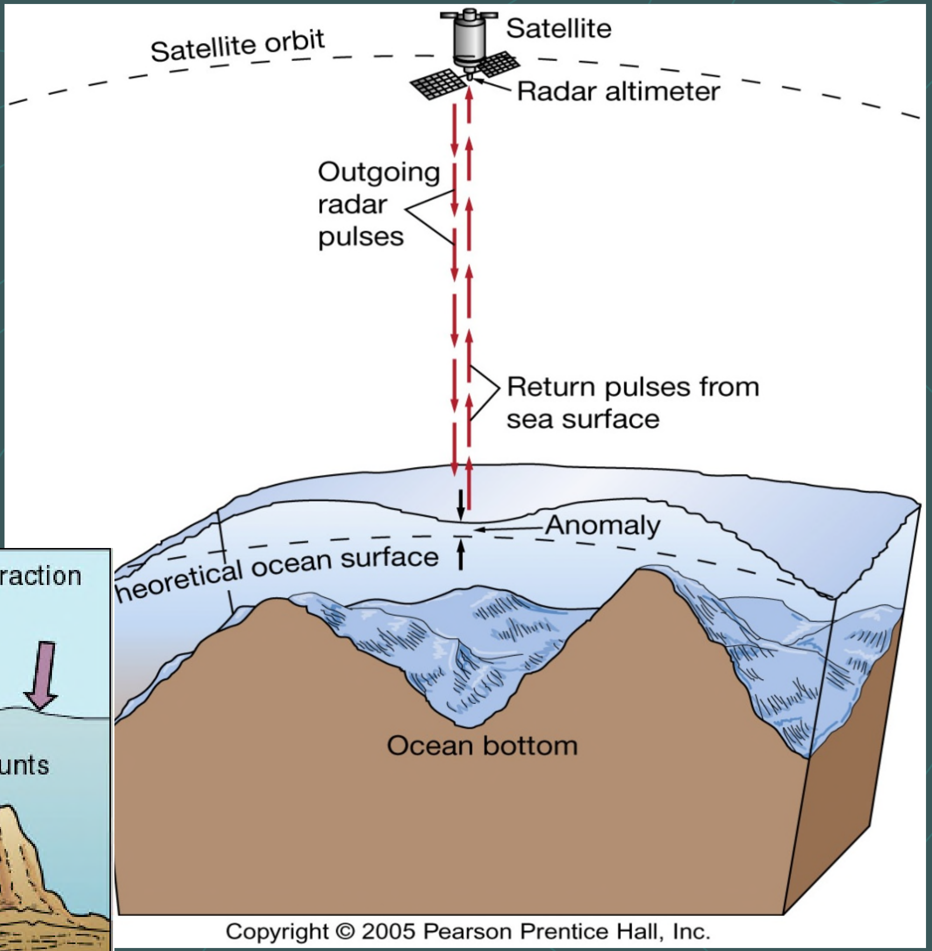


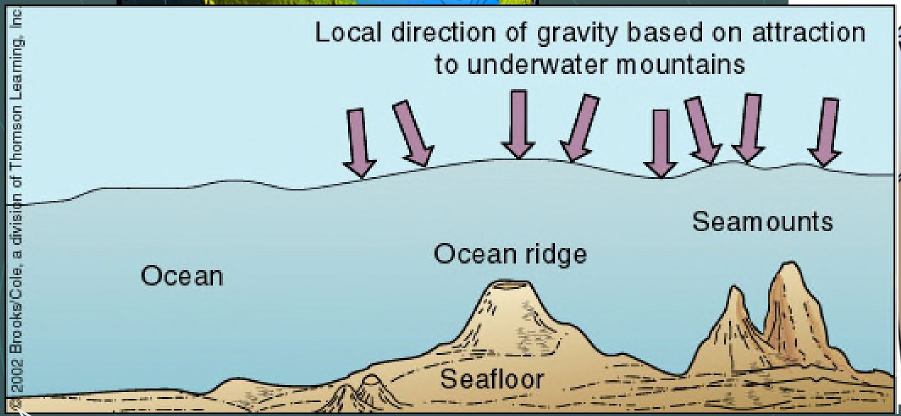
The intensity of sound received by the sidescan sonar tow vehicle from the sea floor provides information as to the general distribution and characteristics of the surficial sediment. In this schematic, strong reflections from boulders, gravel and vertical features facing the sonar transducers are white; weak reflections from finer sediments or shadows behind positive topographic features are black. The sea floor is typically surveyed in swaths 100-500 meters wide; the swaths are mosaicked together to form a composite image of the survey area.

Means of Mapping the Ocean Bottom

Satellite Radar



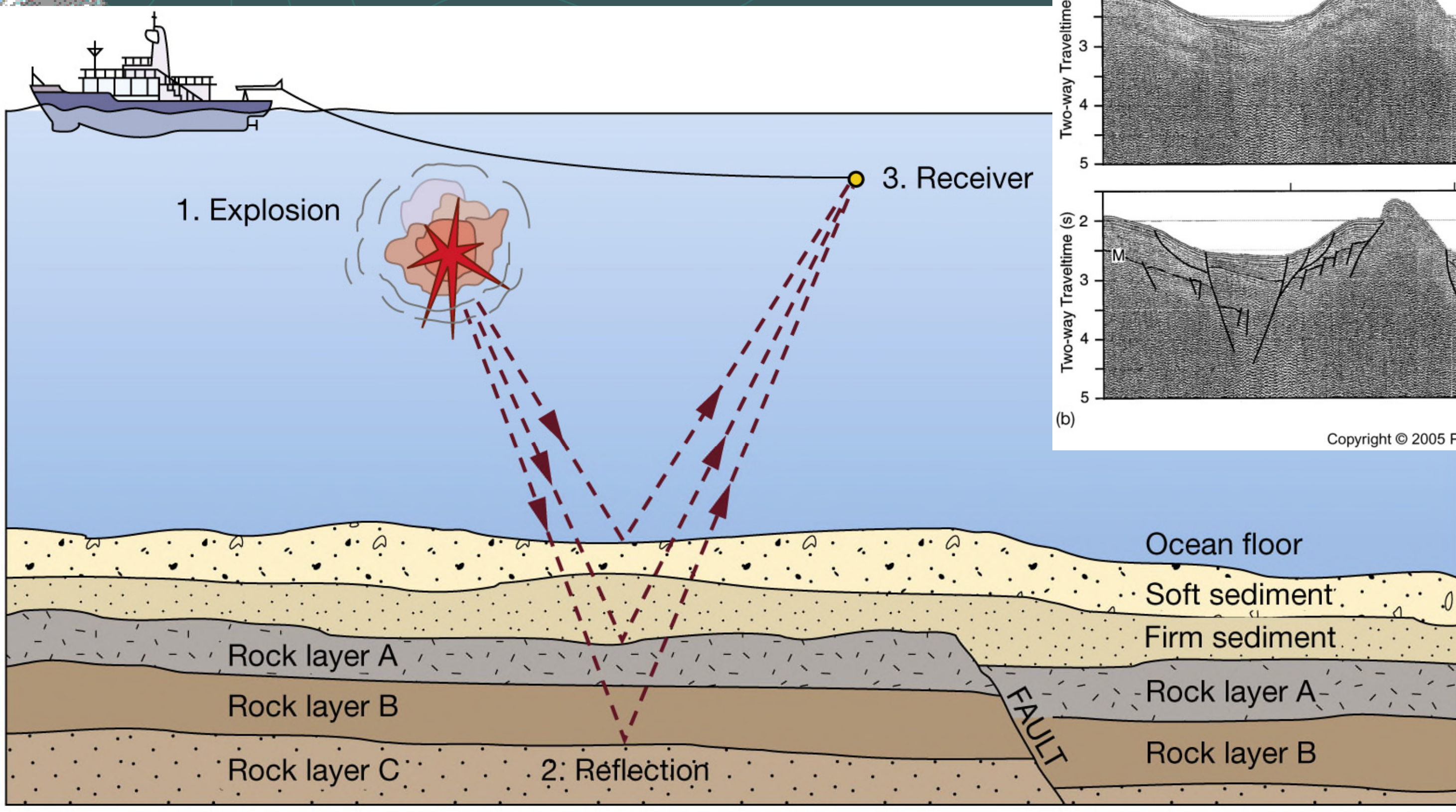


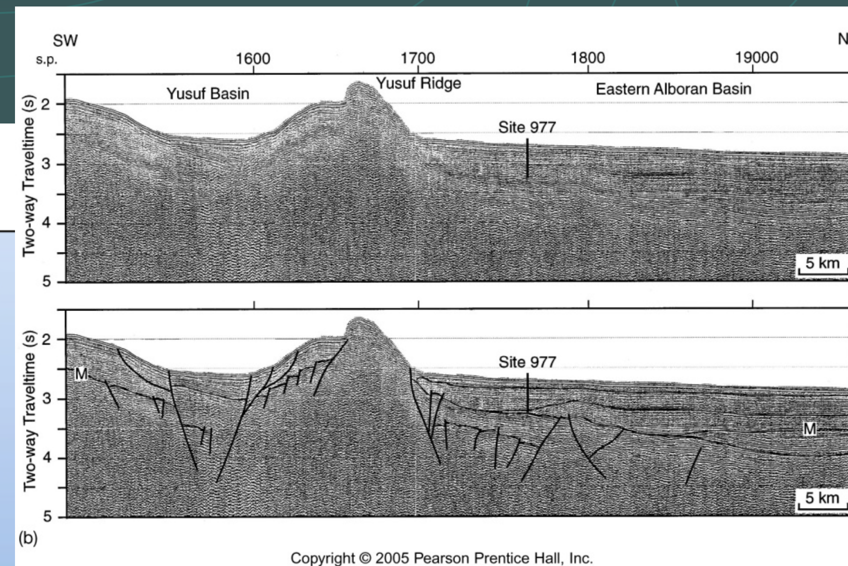


➢ Use of space-based radar to reflect off ocean surface, giving a very precise sea surface profile; sea surface profile anomalies closely mimic the underlying seafloor profile

Means of Mapping the Ocean Bottom

Seismic Reflection

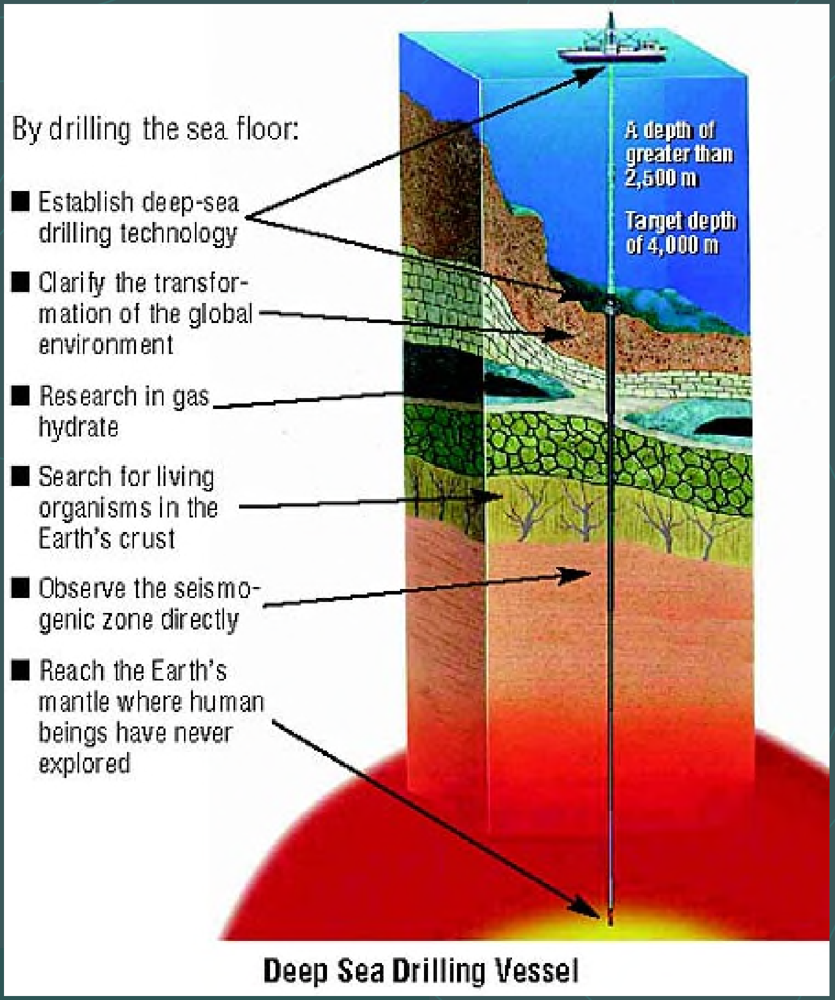




- Use of underwater explosions to penetrate seafloor with seismic waves that reflect off seafloor and subsurface strata and faults, providing a subsurface image

Means of Sampling the Seafloor

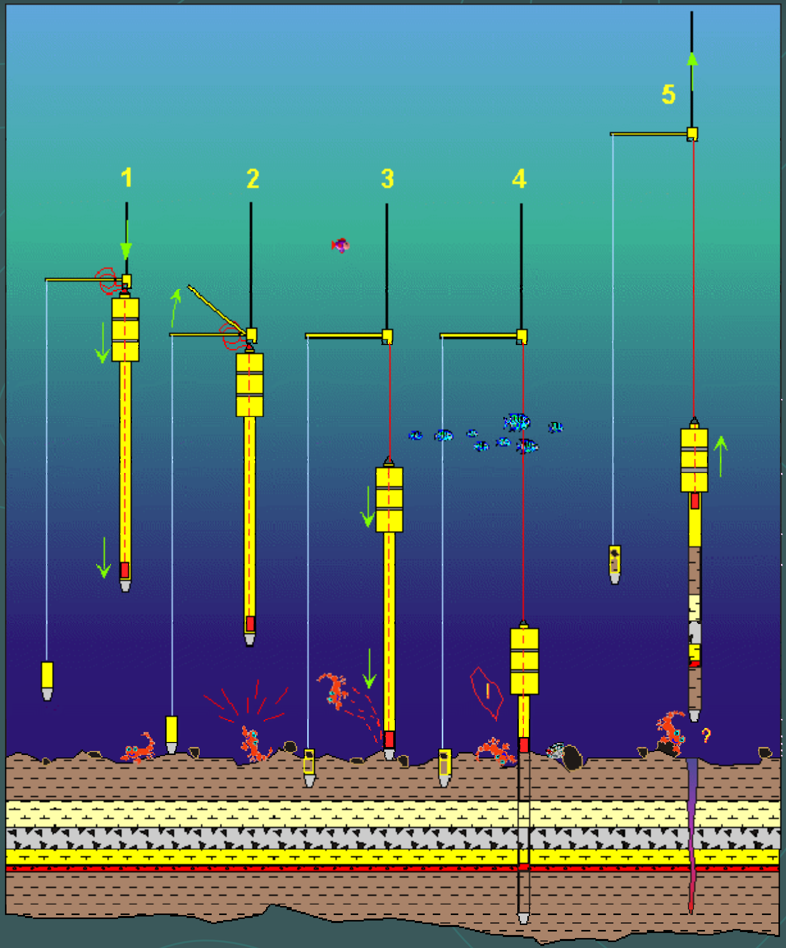
Deep Sea Drilling



- Use of underwater drilling to penetrate seafloor and recover core samples of seafloor down to depths of over 3000 meters

Means of Sampling the Seafloor

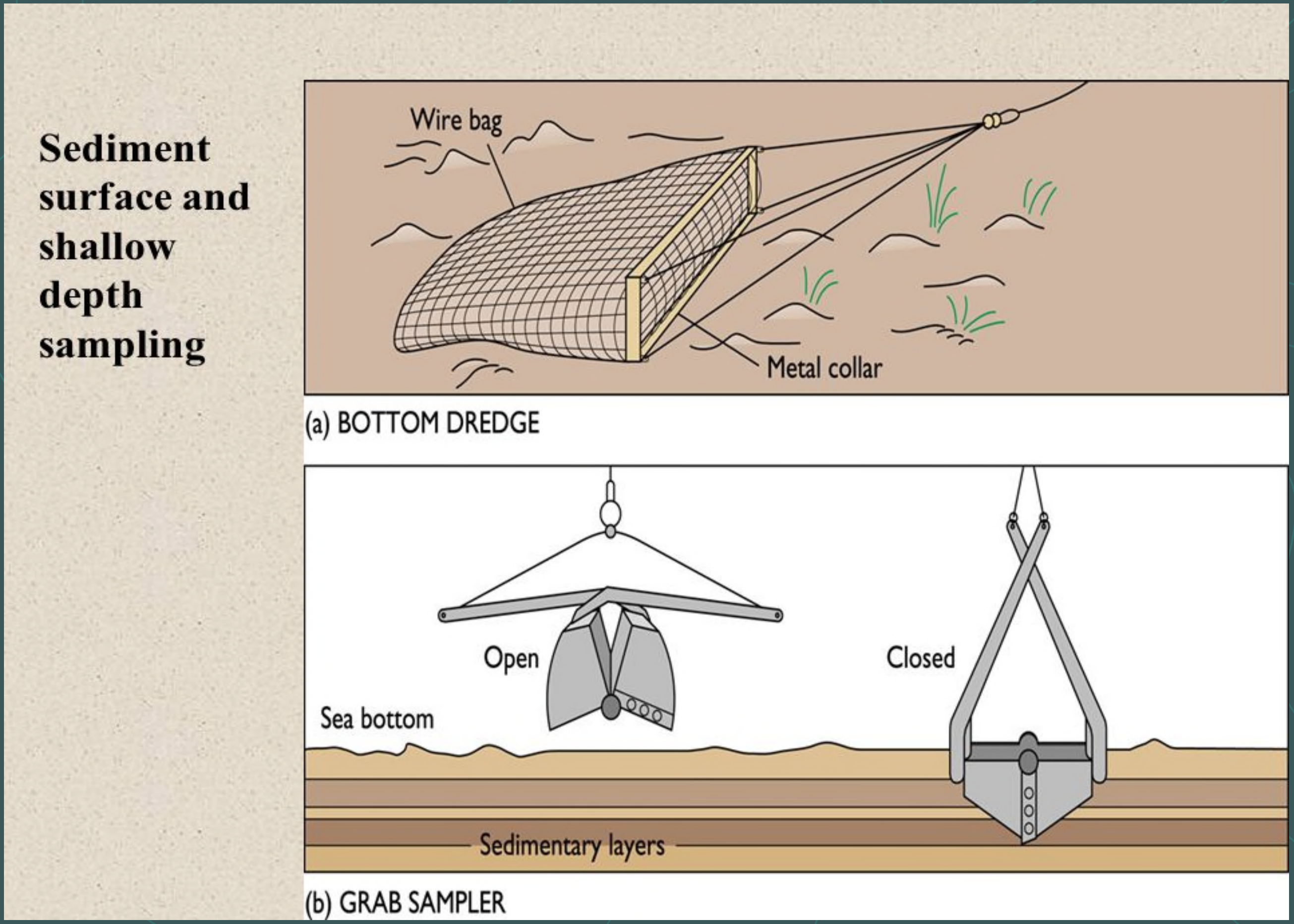
Deep Sea Coring



- Use of piston coring devices to penetrate seafloor and recover sea bottom core samples of seafloor

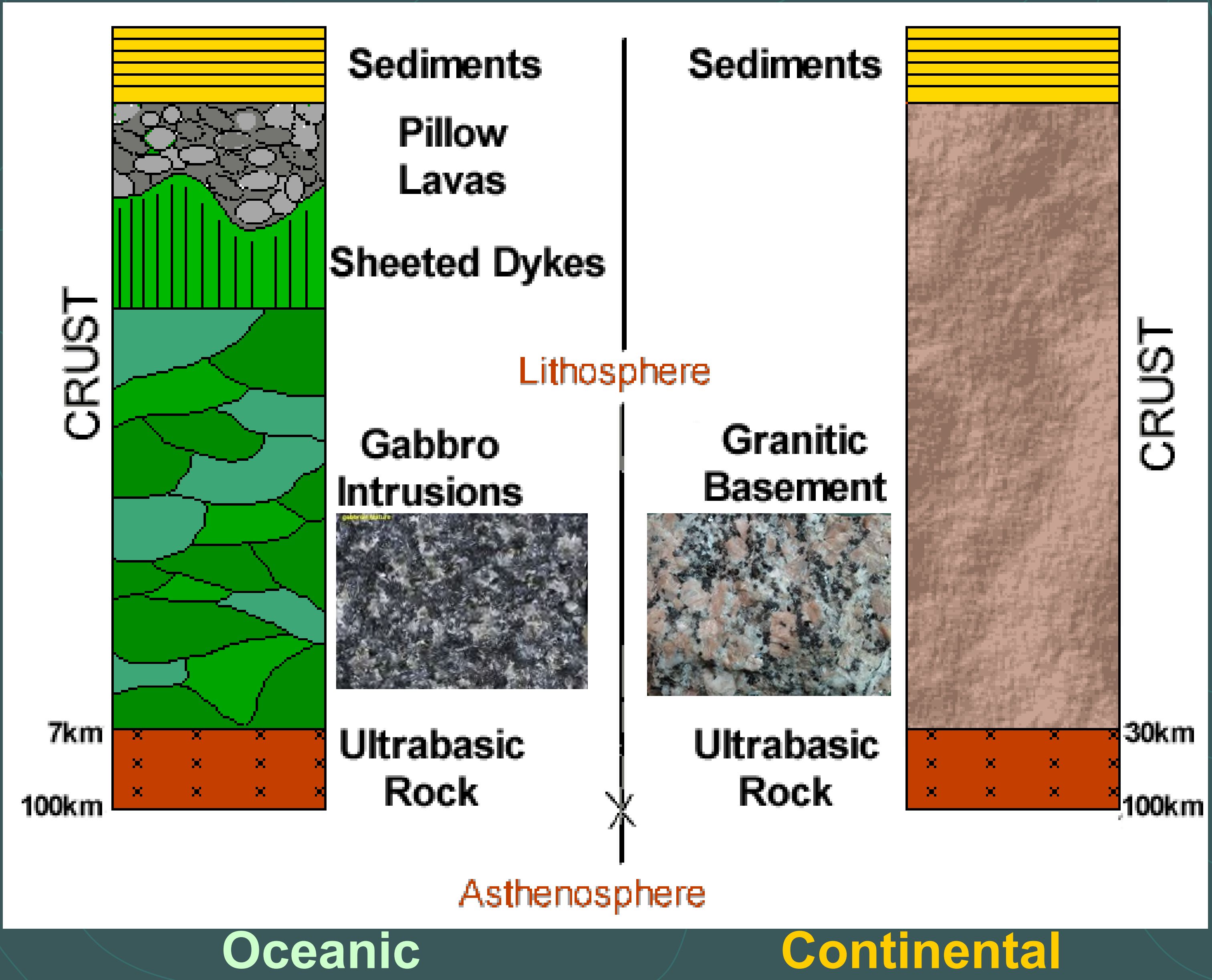
Means of Sampling the Seafloor

Bottom Dredge and Clam Grab



- Use of box/net-dragging and clam-shell-like scooping devices to recover samples of off surface of seafloor

Two Primary Types of Earth Crust



Earth's Continents and Seafloors

Gabbro Granite

Oceanic Continental

Two Different Types of Crust

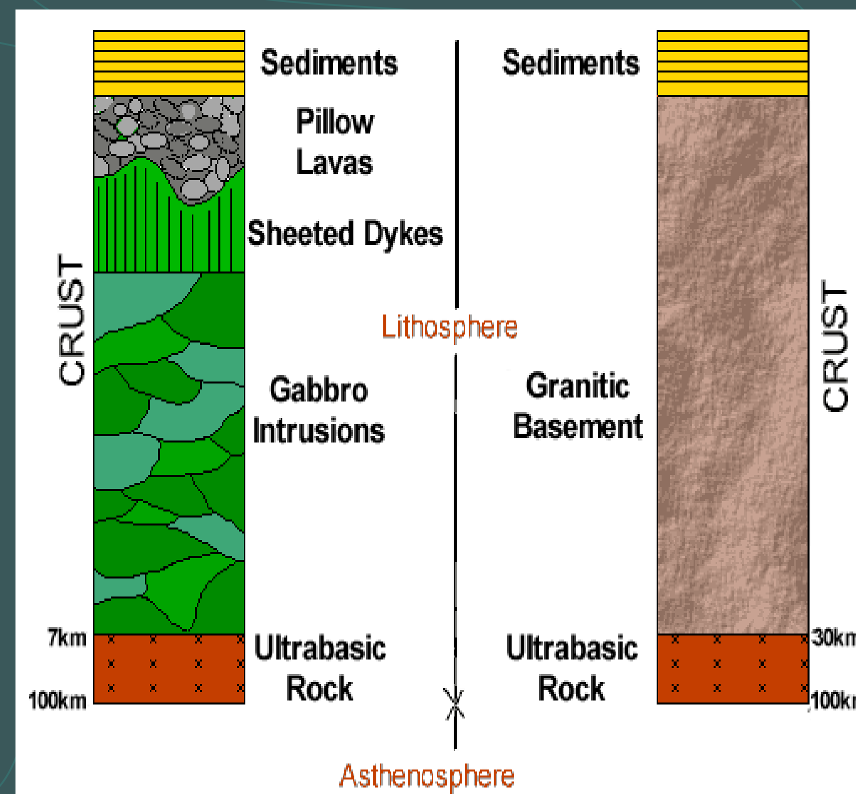
- ✓ Continental – Granitic rock
- ✓ Oceanic – Basaltic rock

Continental Crust

- ✓ Lighter (2.7 g/ml)
- ✓ Thicker (30 km)
- ✓ High Standing (1 km elev.)
- ✓ New crust by subduction-generated magmas

Oceanic Crust

- ✓ Denser (2.9 g/ml)
- ✓ Thinner (7 km)
- ✓ Low Standing (- 4 km elev.)
- ✓ New crust by seafloor spreading-generated magmas



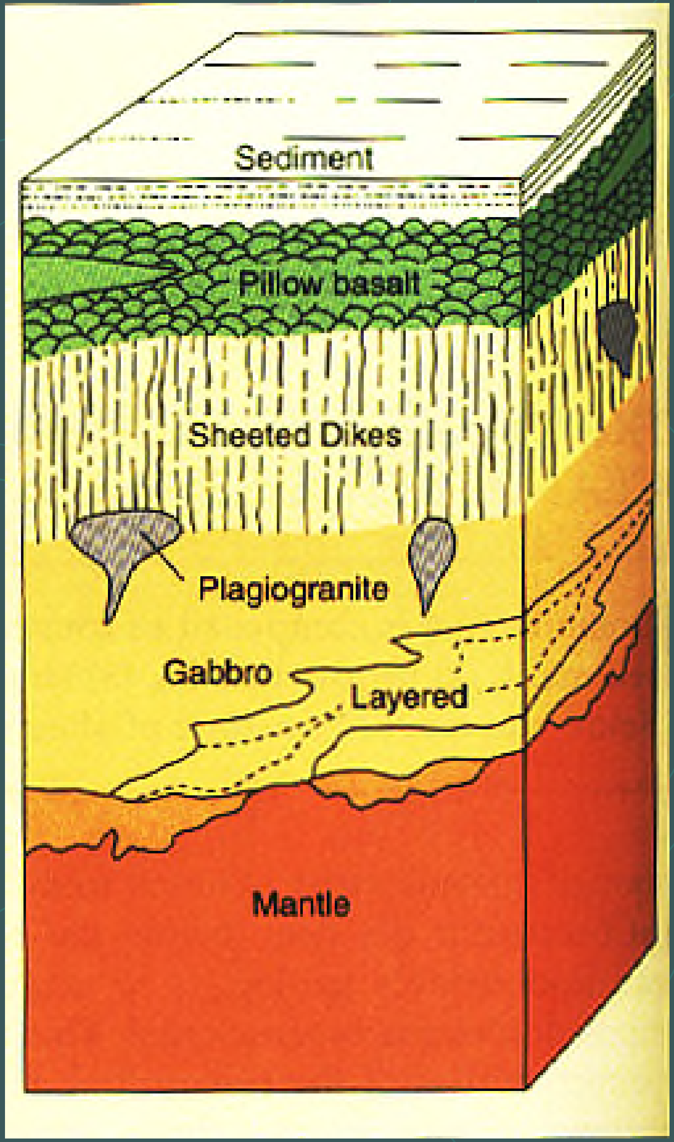
Cross Section: Oceanic Crust

1) Oceanic crust is made up of mafic-rich layers of rock having minerals of olivine, pyroxene, amphibole, calcium plagioclase and magnetite.

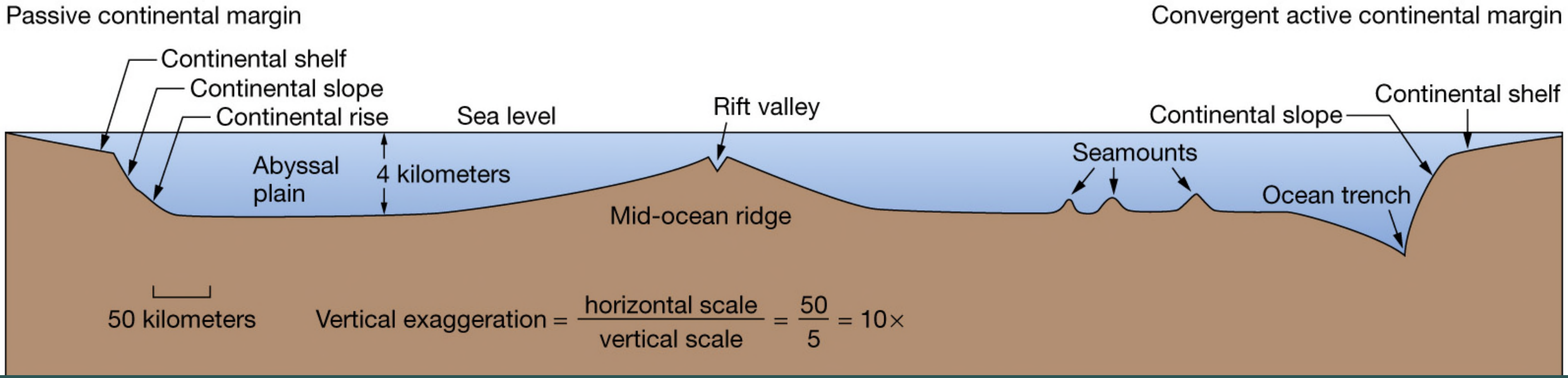
2) New oceanic crust forms at mid-ocean ridges by seafloor spreading

3) Ocean crust obducted onto continental edges called "Ophiolite" complexes

4) Worldwide, vertical sampling of the oceanic crust has revealed a rather simple layer cake-like structure and composition



Cross-Section Profile of an Ocean Basin

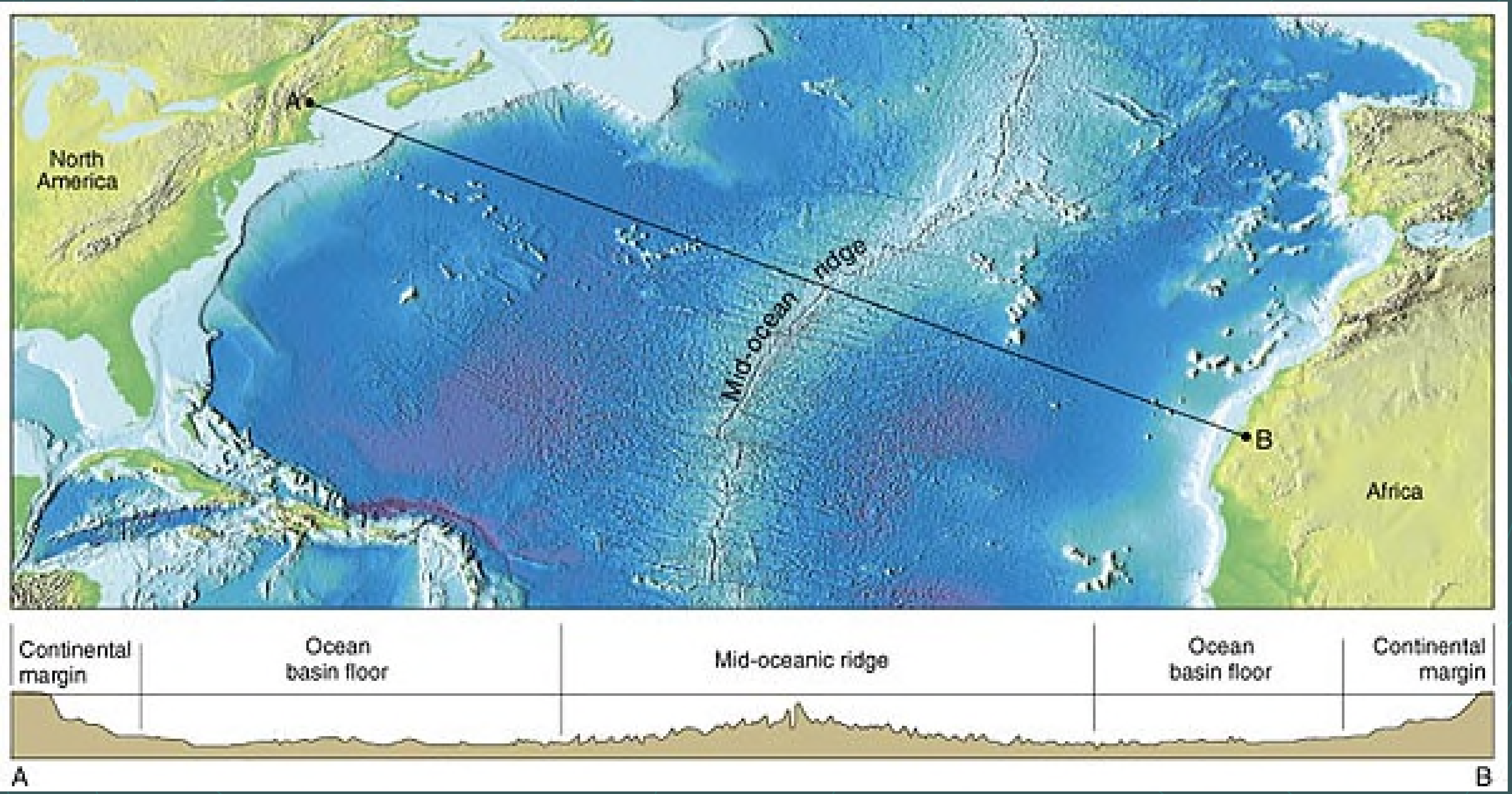


Large-Scale Ocean Bottom Features

- ✓ Continental shelf, slope, and rise
- ✓ Abyssal plains and hills
- ✓ Mid-ocean ridge and rift valley
- ✓ Oceanic islands, seamounts, and guyots
- ✓ Ocean trench

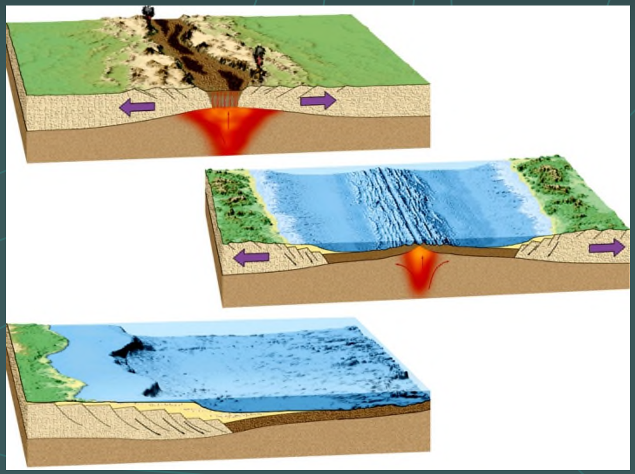
Most of these features are the result of tectonic processes that create and eventually destroy oceanic crust

Cross-Section of the North Atlantic Ocean Basin



The North Atlantic Ocean basin is very symmetrical in terms of its central mid-ocean ridge and fracture system, which is flanked on both sides by abyssal basin floors and rimmed by passive continental margins.

Earth Processes That Create Seafloor Features

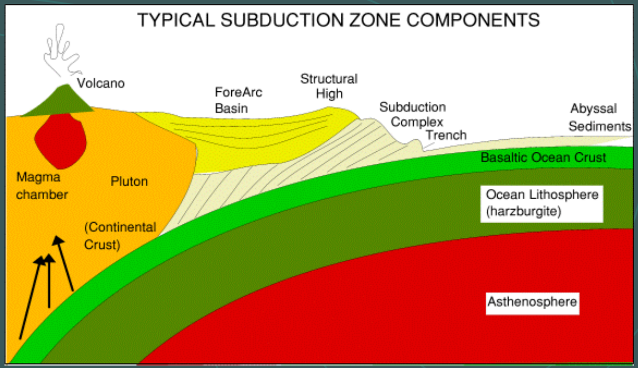


Continental Margins

1) Features resulting from Continental Rifting

- Continental Shelf and Slope

Deep-Sea Oceanic Basins



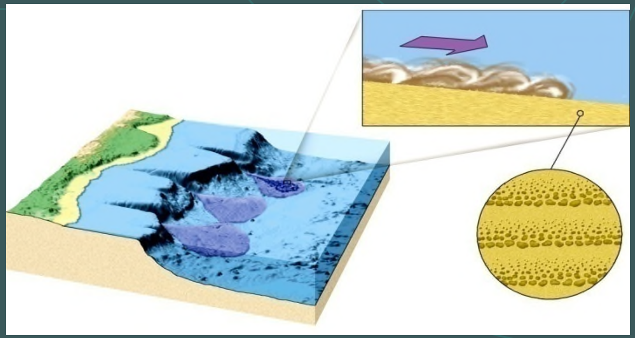
1) Features generated by Seafloor Spreading

- Mid-Ocean Ridges and Fracture Systems
- Oceanic Islands, Seamounts and Plateaus

2) Features generated by Subduction

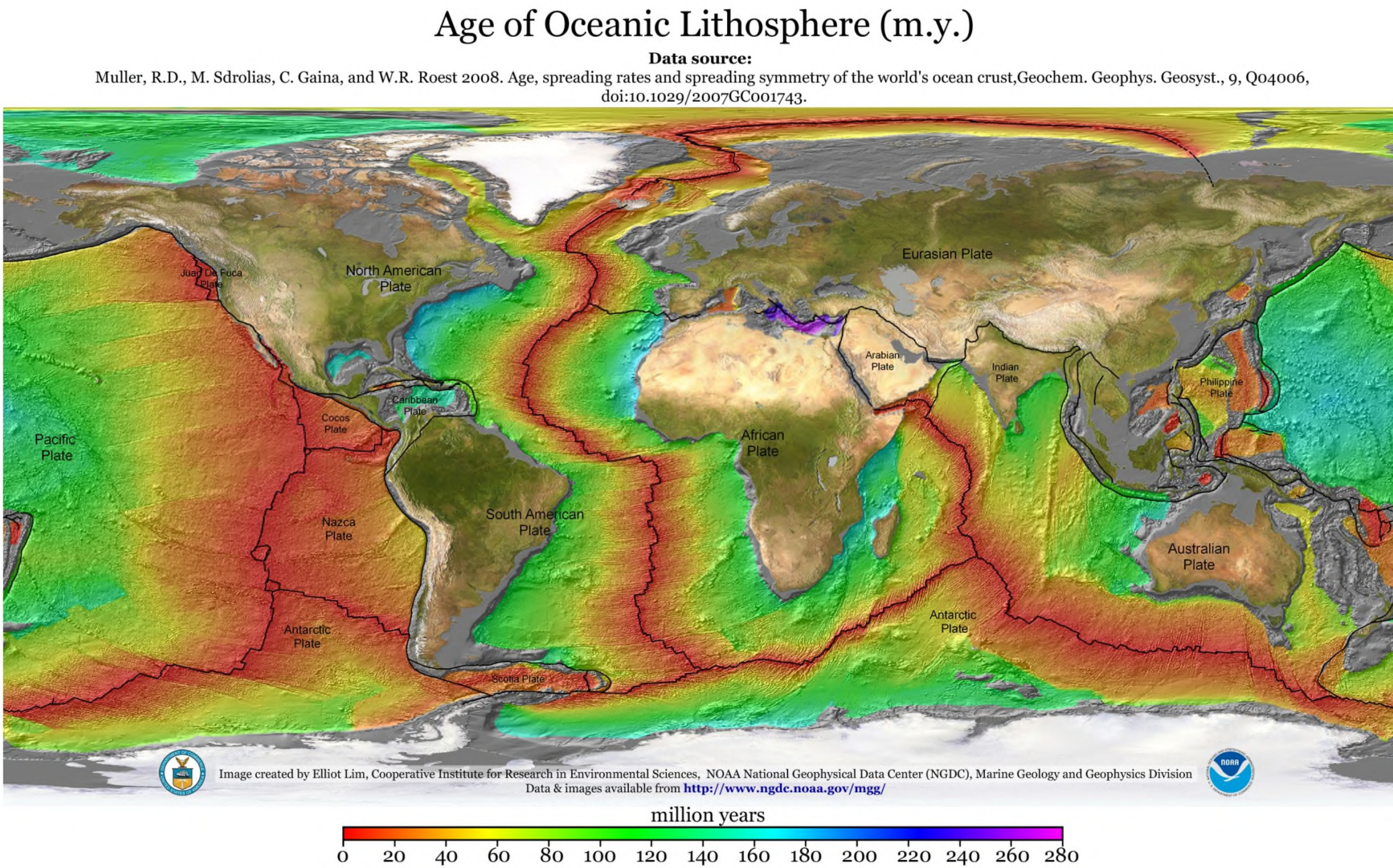
- Trenches and Island Arcs
- Forearc Islands

3) Features resulting from Sedimentary processes



- Abyssal Plains and Hills
- Continental Rises
- Submarine Canyons

AGE OF EARTH'S OCEAN BASINS

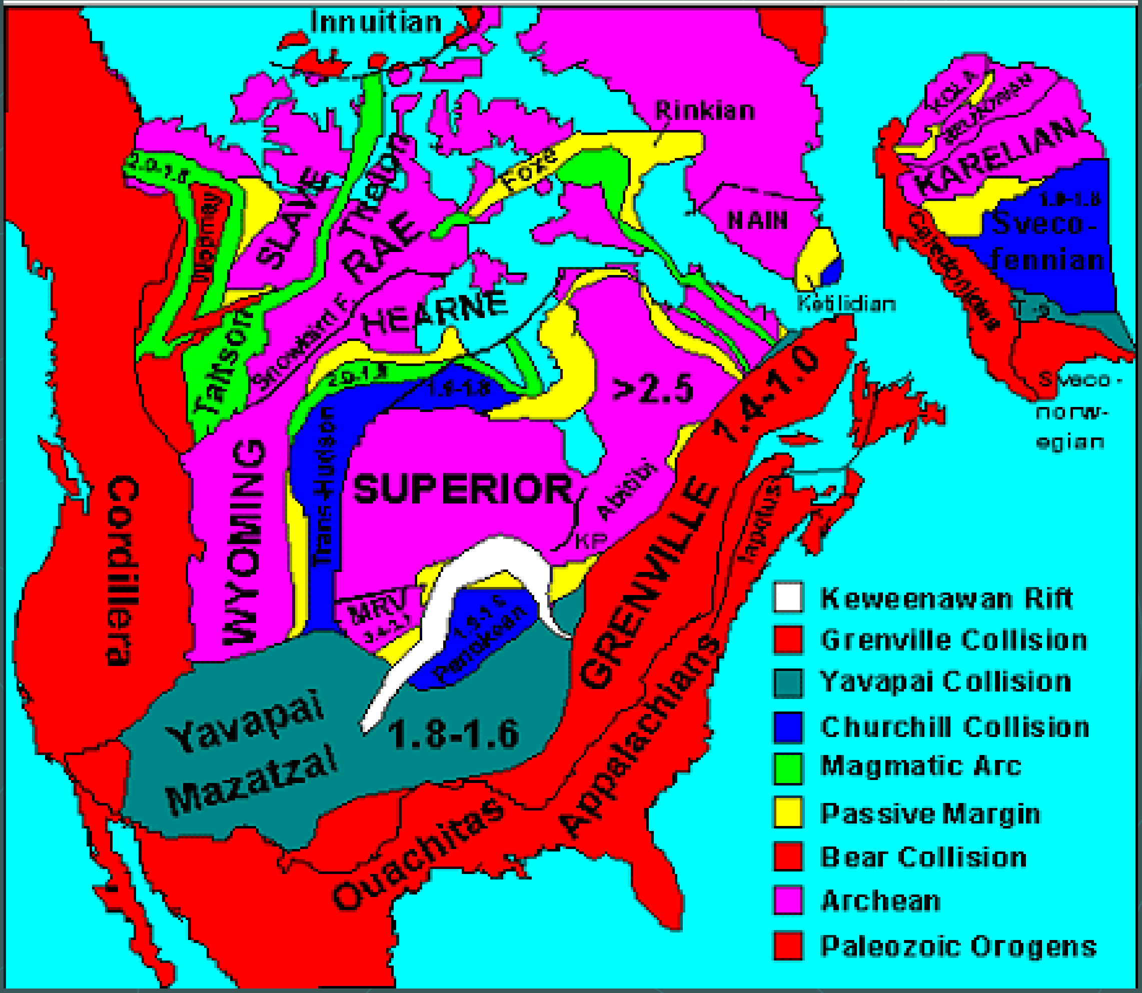


AGE PROFILE of the NORTH AMERICAN CONTINENT

The North American continent's oldest rocks form its central region termed craton or shield, with younger belts of rock wrapping the craton

Cratons are fragments of super ancient continental terranes that accreted together during Archean and Proterozoic times

The younger orogenic belt-like terranes (1 BY and younger) that wrap around the craton represent major episodes of subduction and continental collision



Tectonic Provinces of North America

(Ages are in **Billions** of Years)

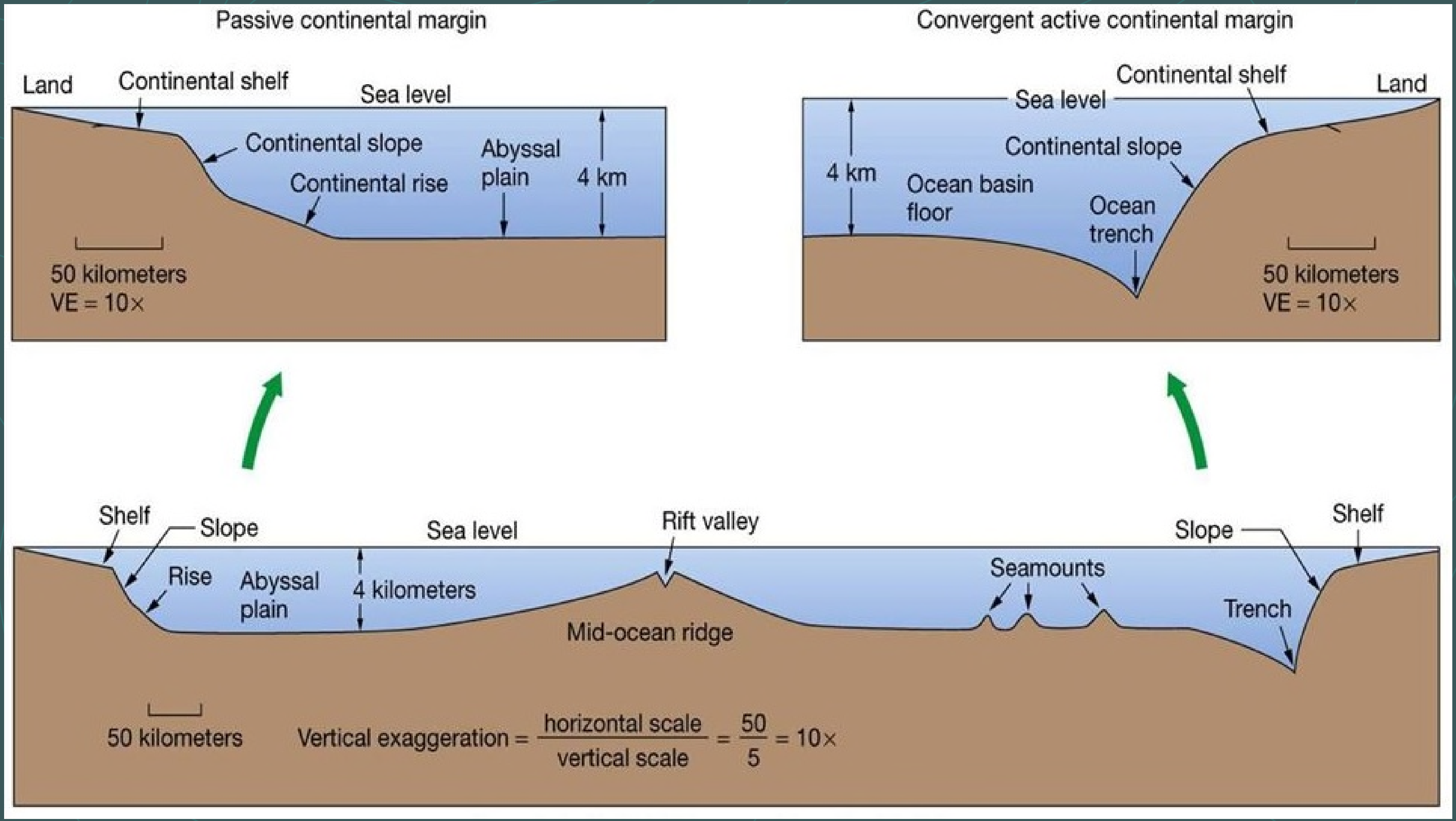
The other continents have similar age patterns and structural design

Continental Margins of the World

- Submerged continental margins shown in pale orange color
- Submerged continental margins make up nearly 20% of Earth's solid surface
- Continental margins represent the rifted, foundered edges of a past supercontinent

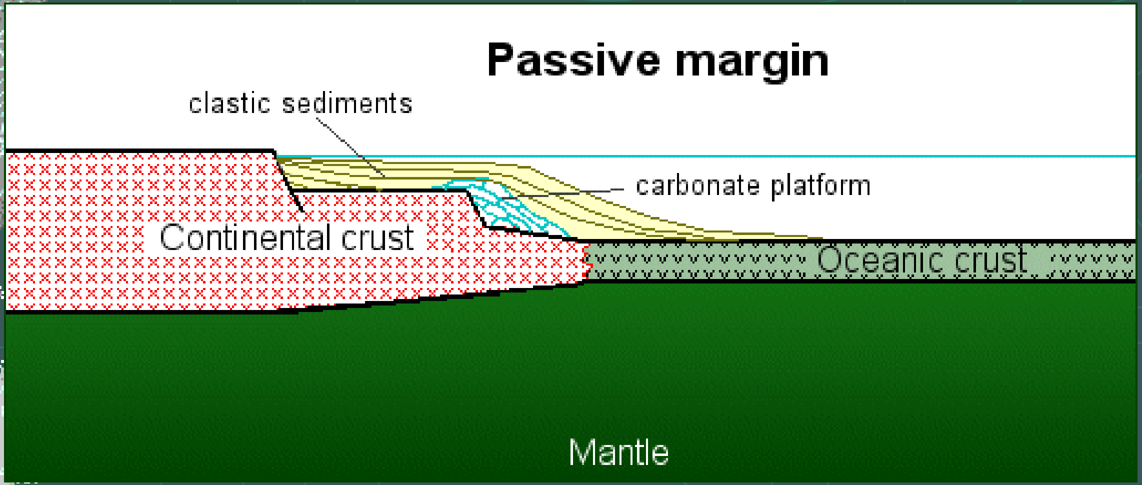
Two Types of Continental Margins

- **Passive** = Tectonically Active
- **Active** = Tectonically Inactive



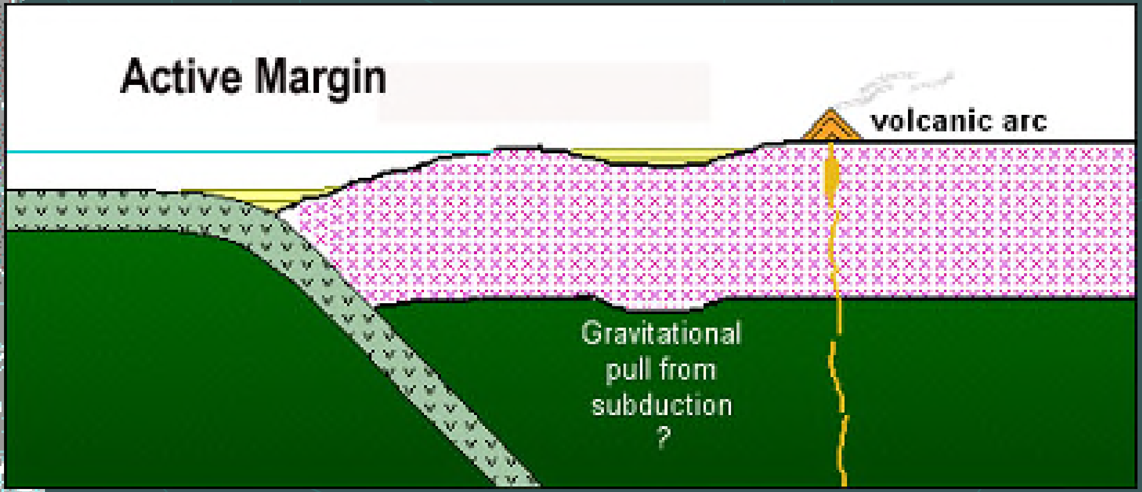
Two Types of Continental Margins

- **Passive** = Tectonically Inactive = Atlantic Type
- **Active** = Tectonically Active = Pacific Type



Passive Margins

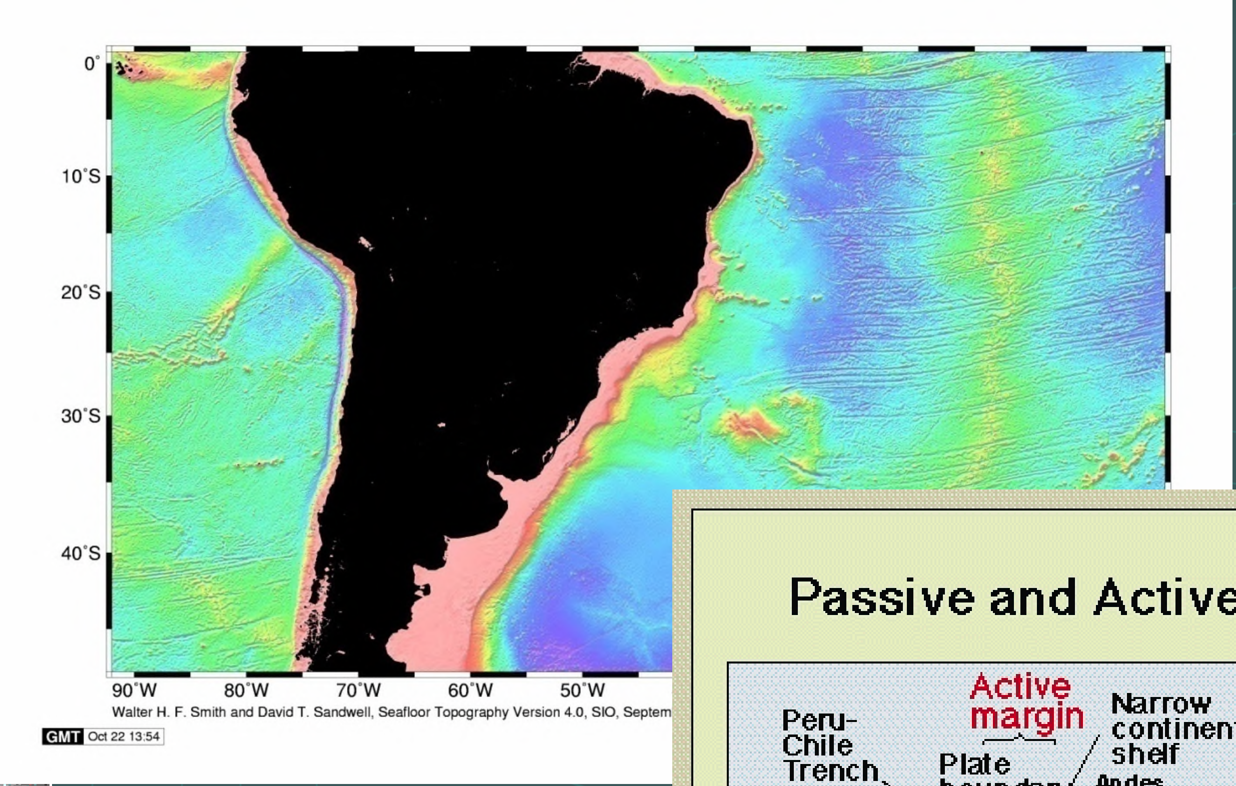
- Broad shelves
- Subdued coastline
- Little to no tectonic activity
- No Plate Boundary



Active Margins

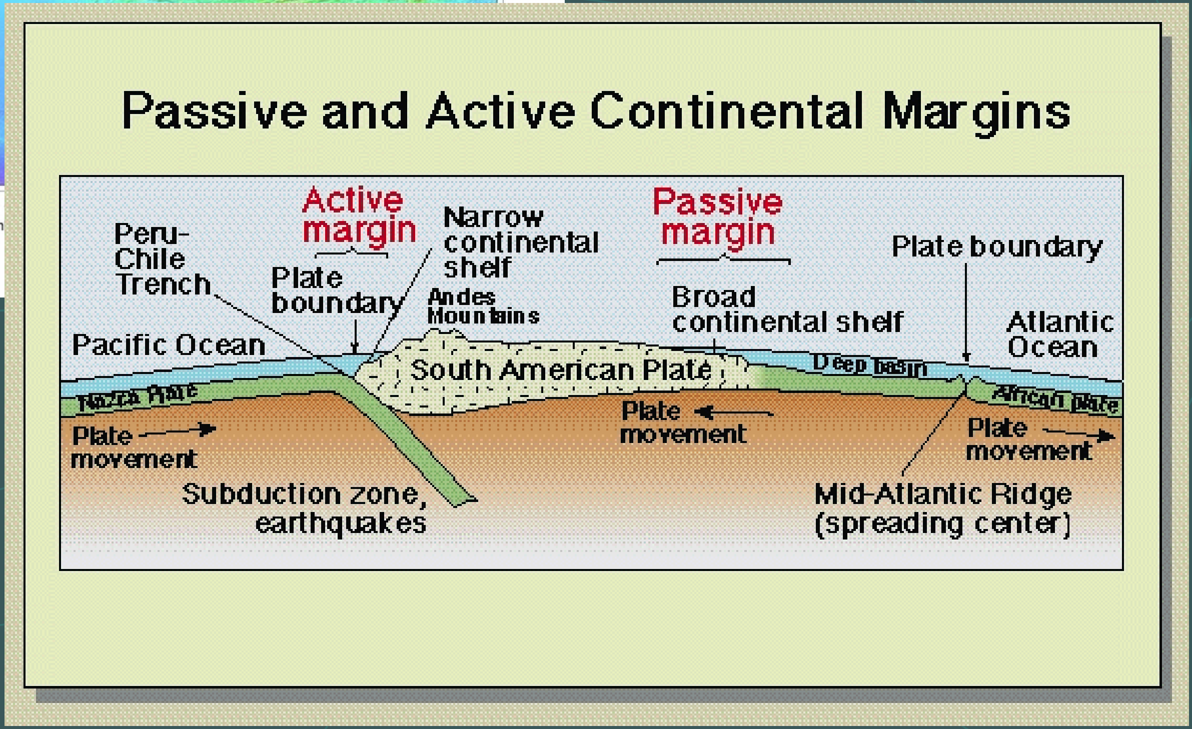
- Narrow shelves
- Rugged coastline
- Tectonically active
- Plate Boundary

Active versus Passive Margins



Excellent Example:

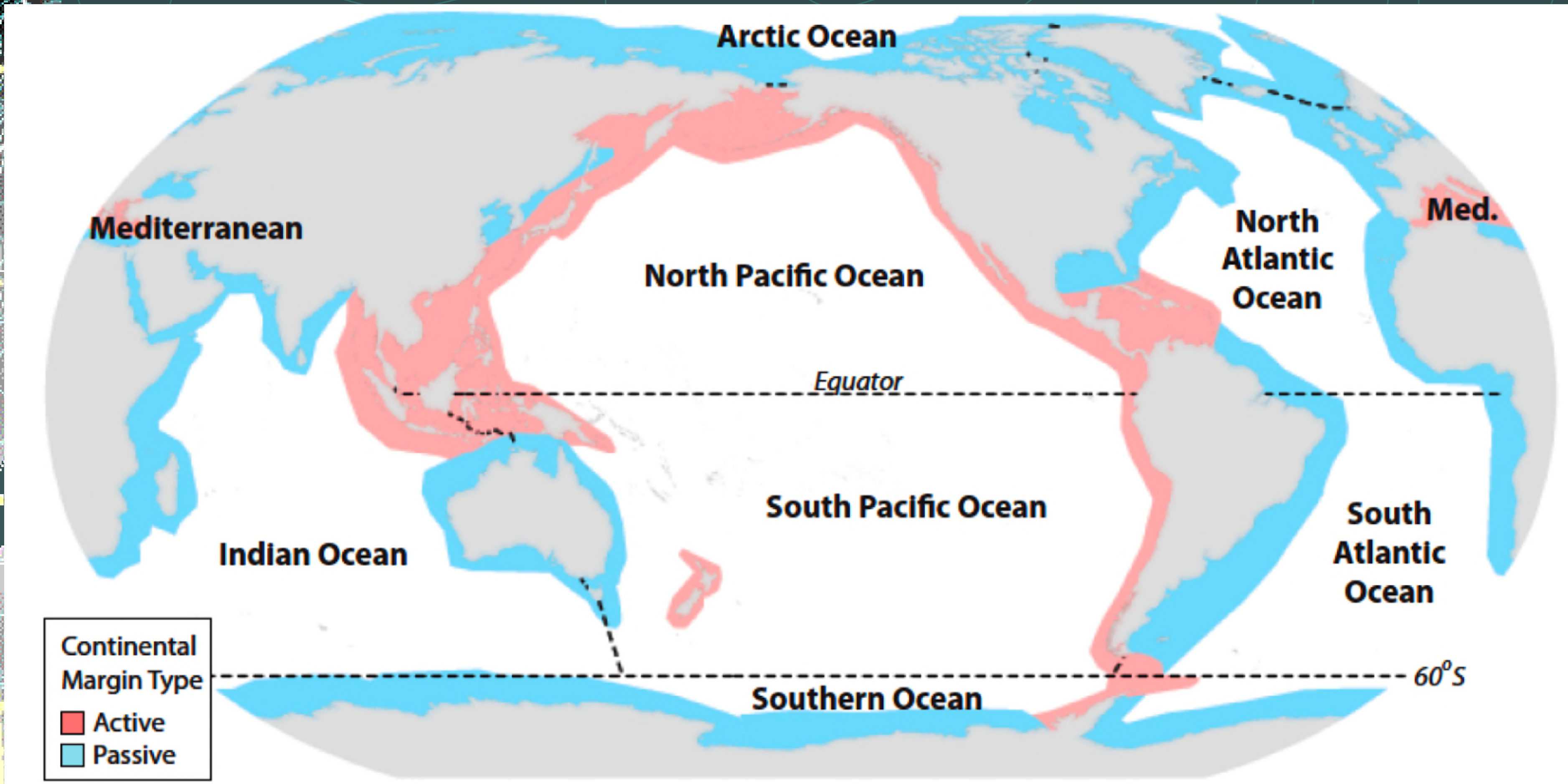
South America



Active = West Coast

Passive = East Coast

Global Distribution of Active and Passive Margins



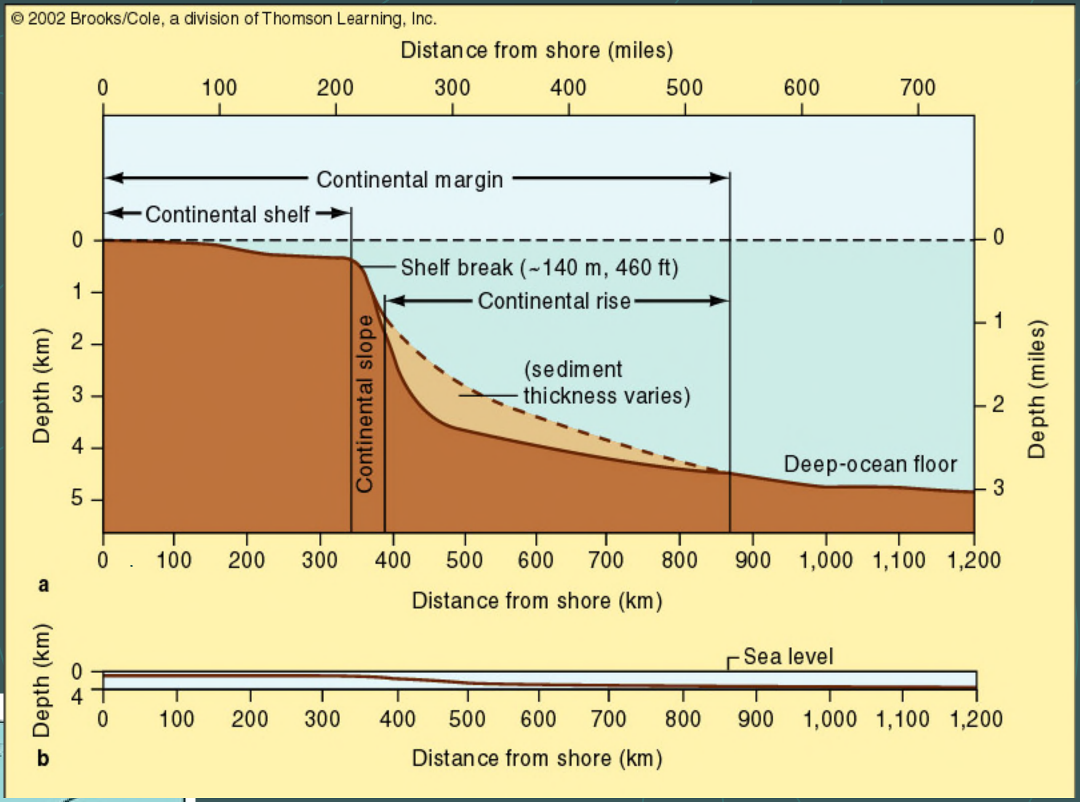
Most active margins are found around the Pacific Basin

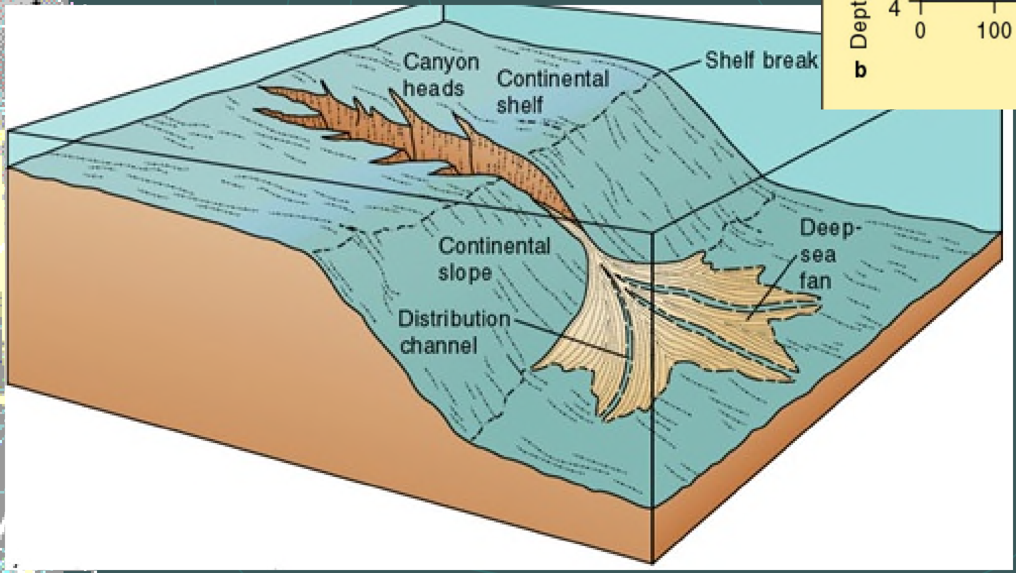
Most passive margins are found around the Arctic, Atlantic and Indian Ocean Basins

Continental Margin Features

Major Features

- Continental Shelf
- Continental Slope
- Slope Break
- Continental Rise
- Submarine Canyons
- Deep-sea Fans

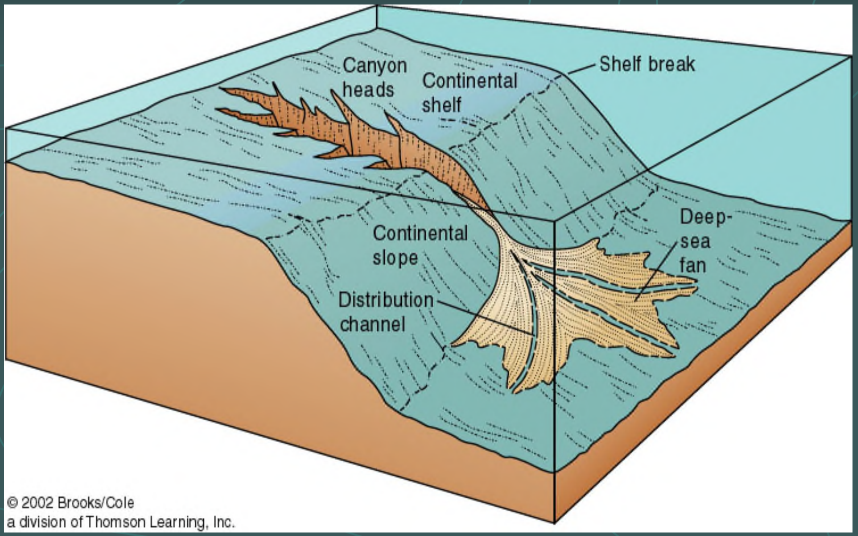


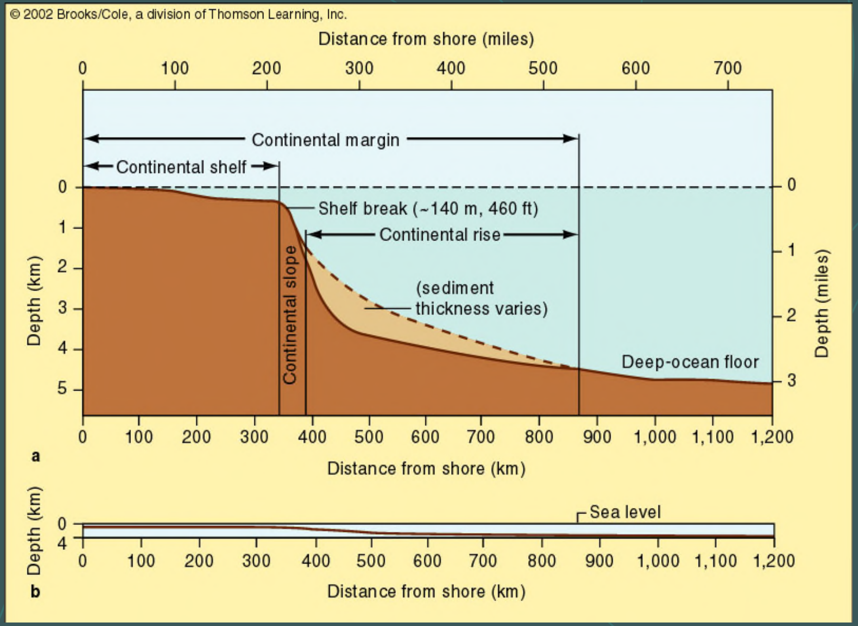


Continental Slope and Rise Sediments

Key Points

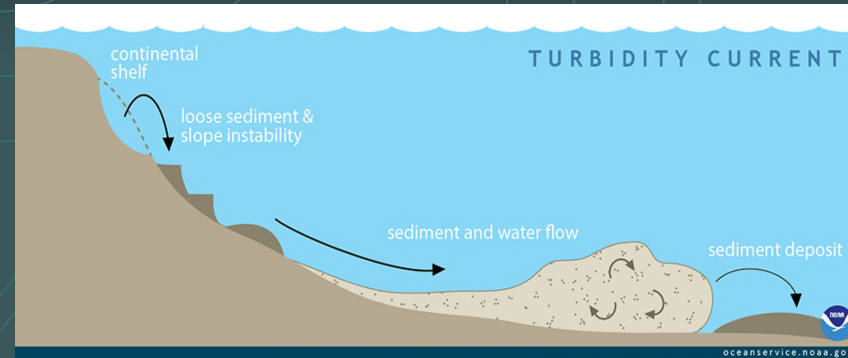
- Thickest ocean sediment piles
  - ✓ Up to 20 km thick!
- Thickest sections found at base of submarine canyons in the form of fan-shape sediment wedges
- Mainly consists of sand, silt and clay within “graded” bedding layers
- Continentally derived, but classified as transitional-deep sediment
- Primarily transported and deposited by turbidity current processes
- Turbidity currents are dense mixtures of sediment and seawater that flow down slopes of seafloor
- Associated with submarine canyons

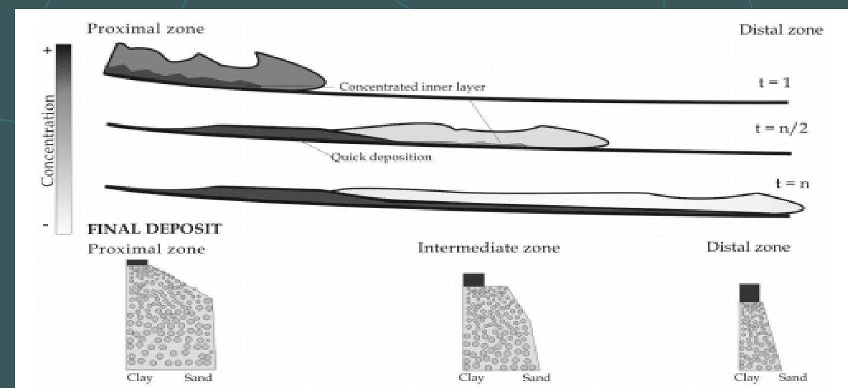




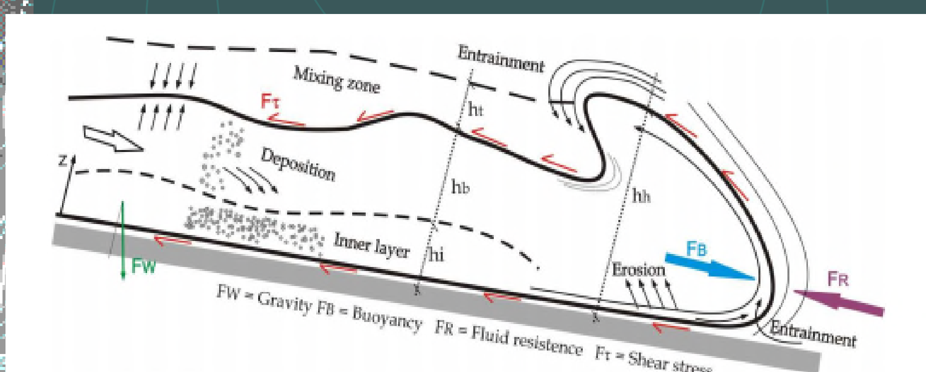
TURBIDITY CURRENT PROCESSESES

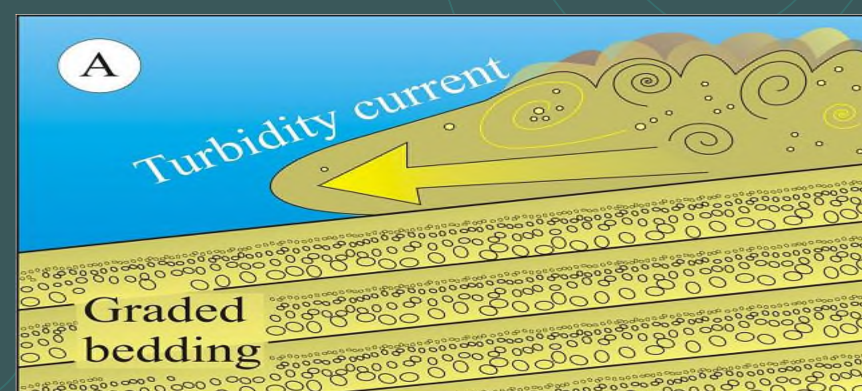
Lab Simulation of Turbidity Currents and Deposition of Graded Bedding



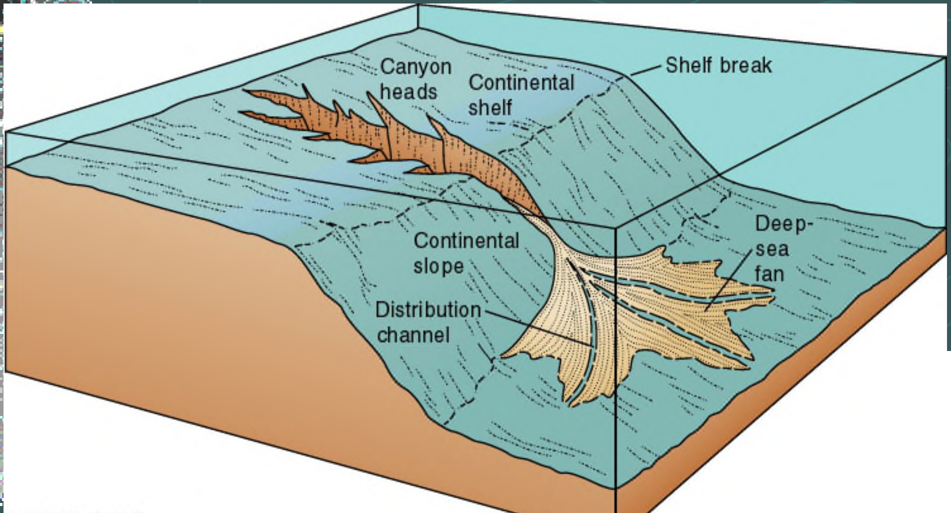


Turbidity currents erode submarine canyons and deposit sediments as deep-sea fans





Turbidity Current Processes at Continental Margins



Turbidity currents are responsible for the formation of submarine canyons on the continental shelves and slopes and the deep-sea sediment fans on the continental rises

Turbidity currents cut/erode downward in submarine canyons and deposit sediments as thick sequences of graded beds (turbidites) that form the deep-sea sediment fans on the continental rise

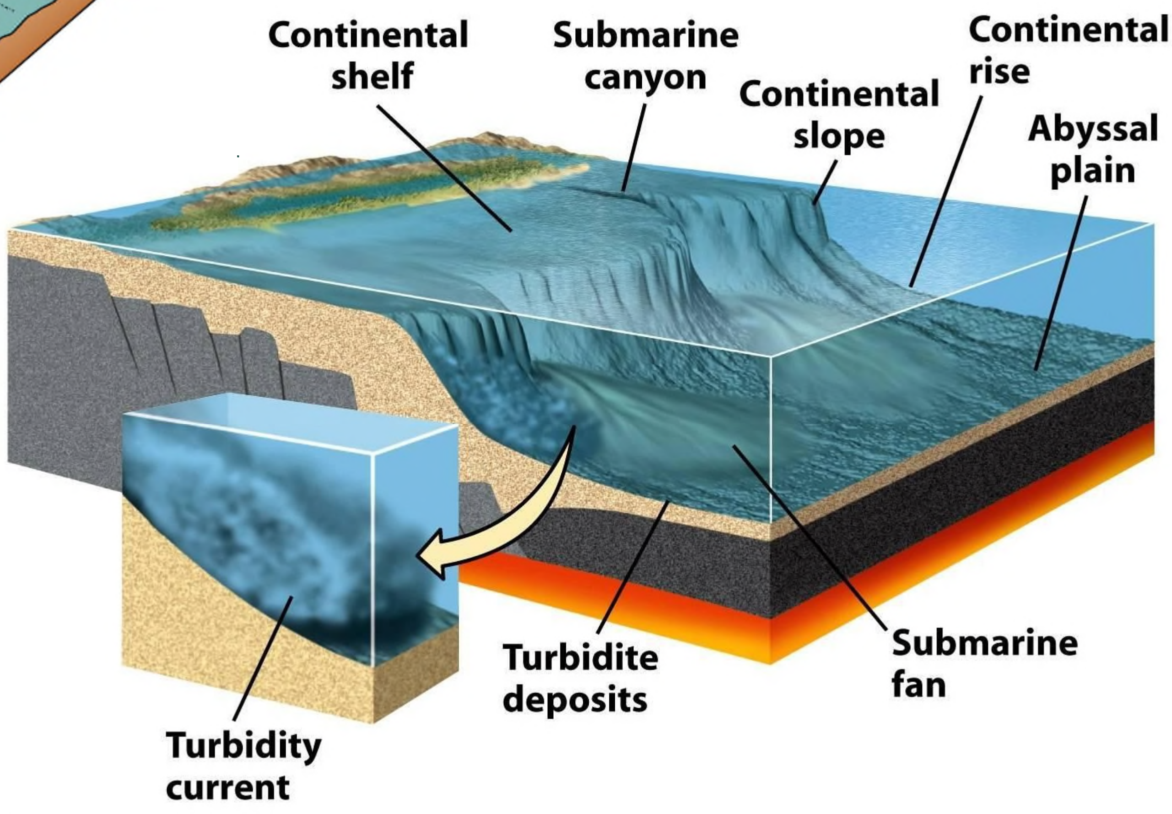
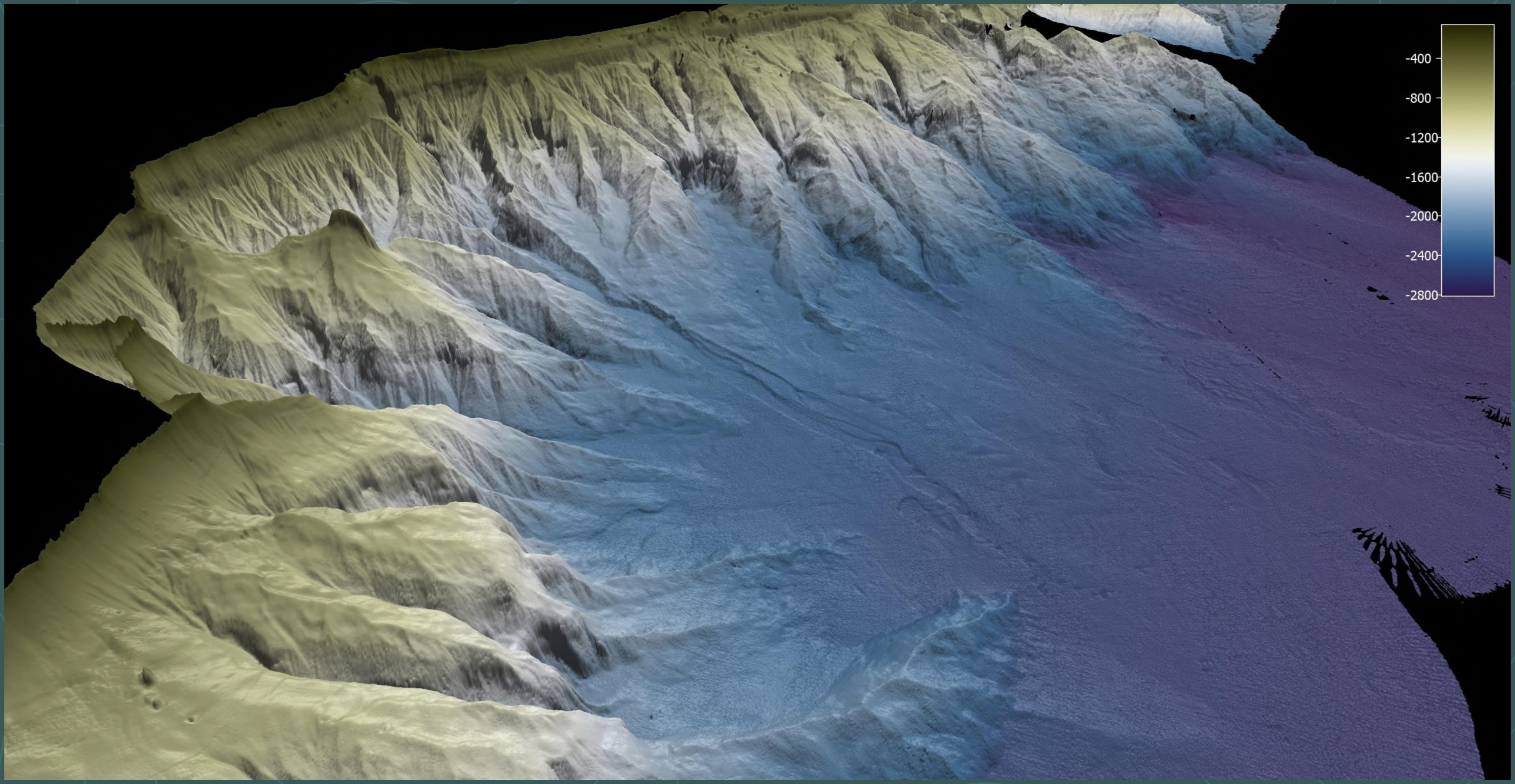


Figure 20.19a
Understanding Earth, Sixth Edition

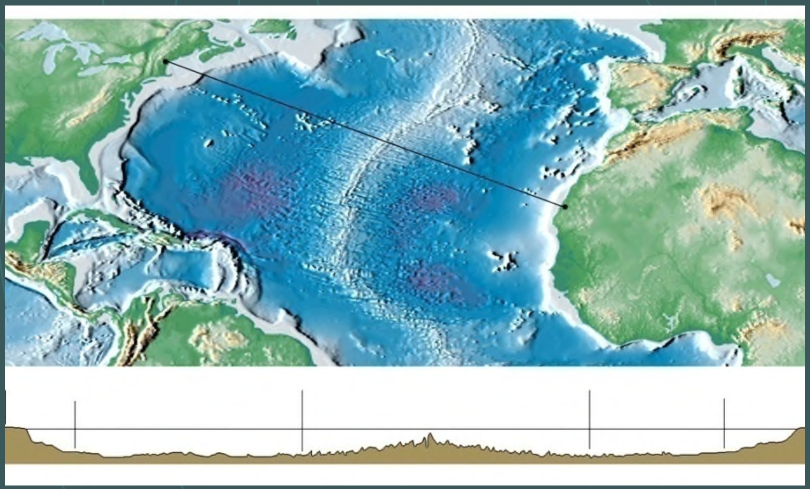
Example of Submarine Cayons on a Continental Margin



Example: Set of Submarine Canyons on the Slope-Rise Region Outboard of the Great Barrier Reef – Eastern Australia

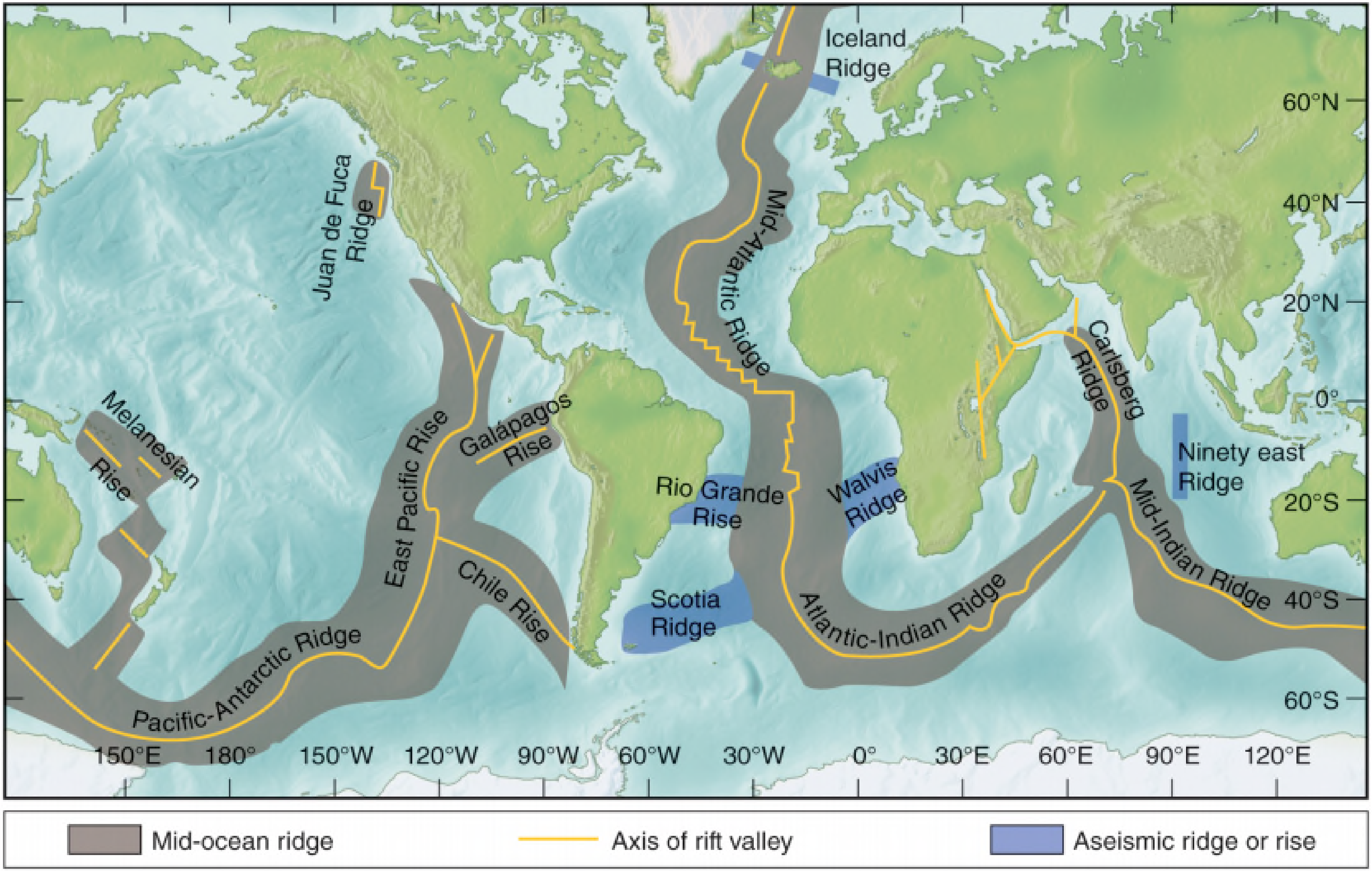
Earth's Deep-Sea Basin Features

- Mid-Oceanic Ridge, Rises and Transform Fracture Systems
- Abyssal Hills and Plains
- Seamounts and Guyots
- Oceanic Islands and Plateaus
- Trenches and Island Arcs

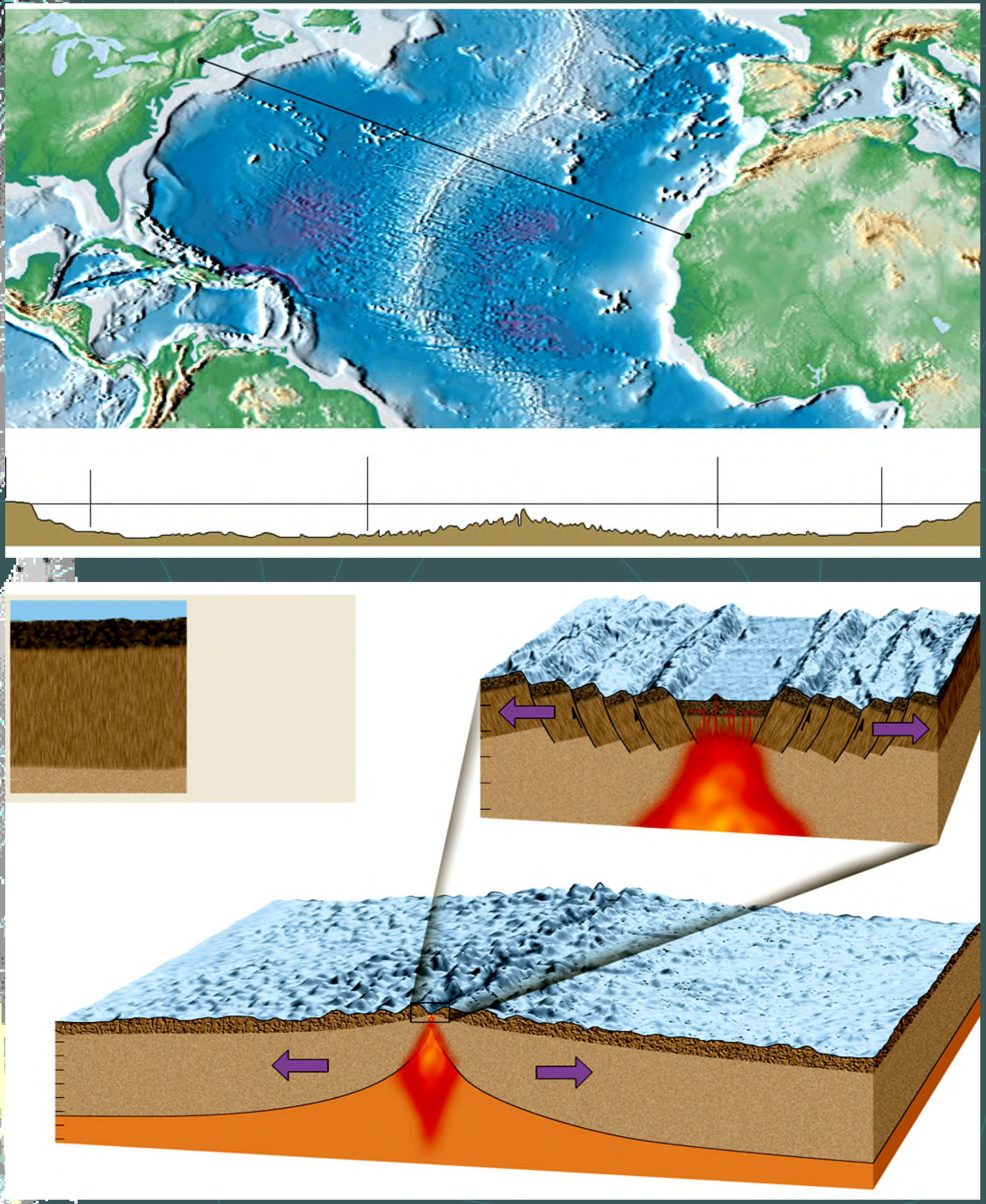


Profile: North Atlantic Ocean Basin

Ocean Ridges and Rises



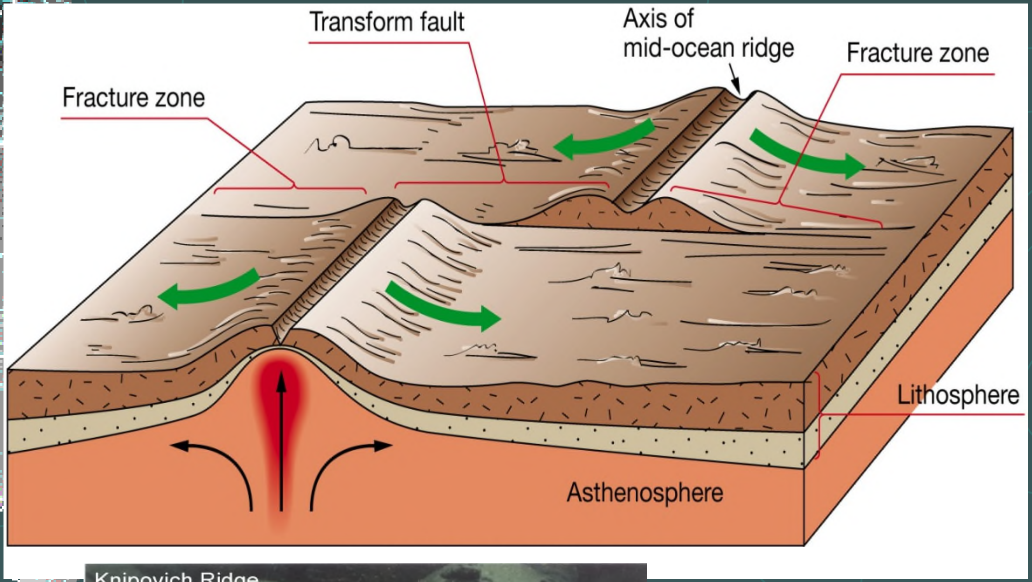
Mid-Ocean Ridge, Rises & Fracture Systems



Key Points

- Mid-ocean ridge systems represent the most extensive chain of active mountains on Earth
- Active faulting and volcanism
- Sea bottom is covered by rugged bedrock of young pillow basalt
- Little to no pelagic sediment
- Site of active hydrothermal vents

Mid-Ocean Ridge and Fracture Systems



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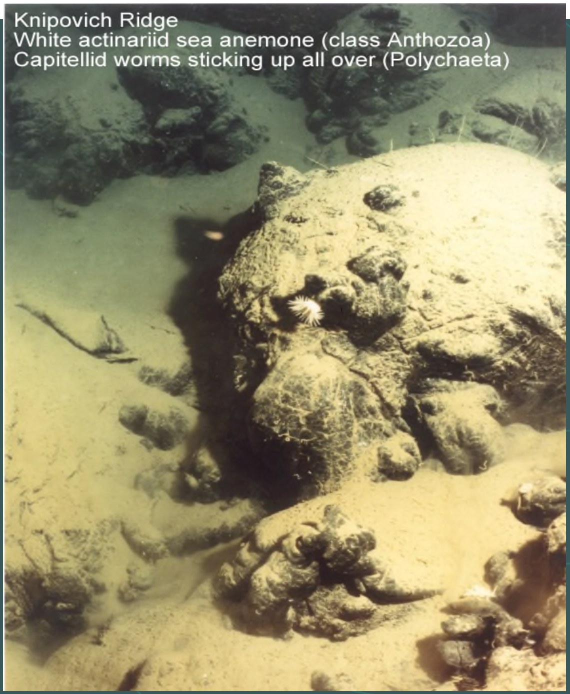
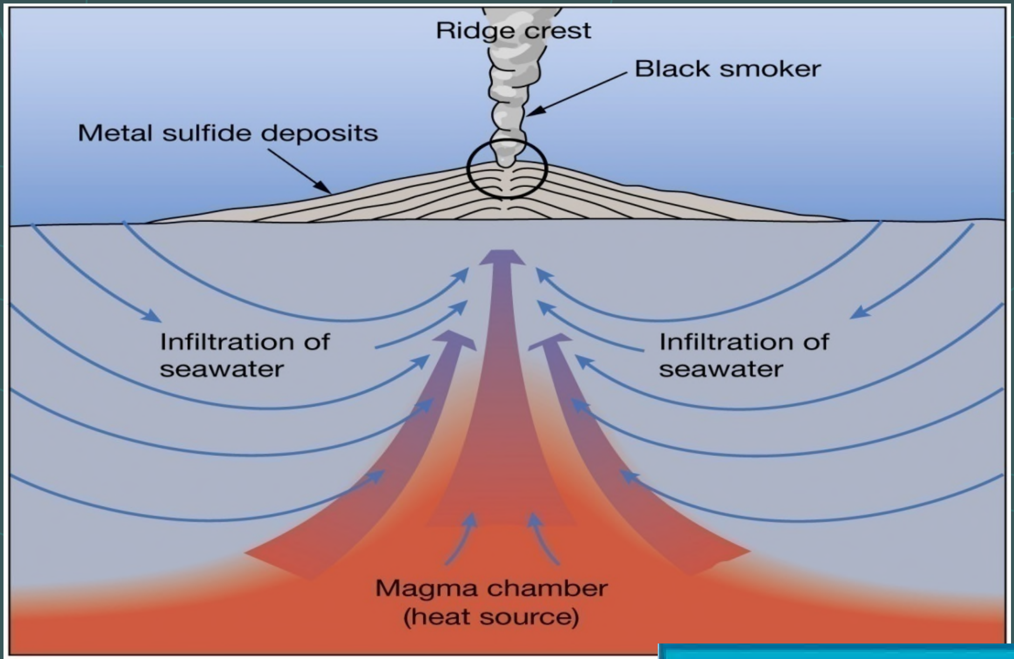
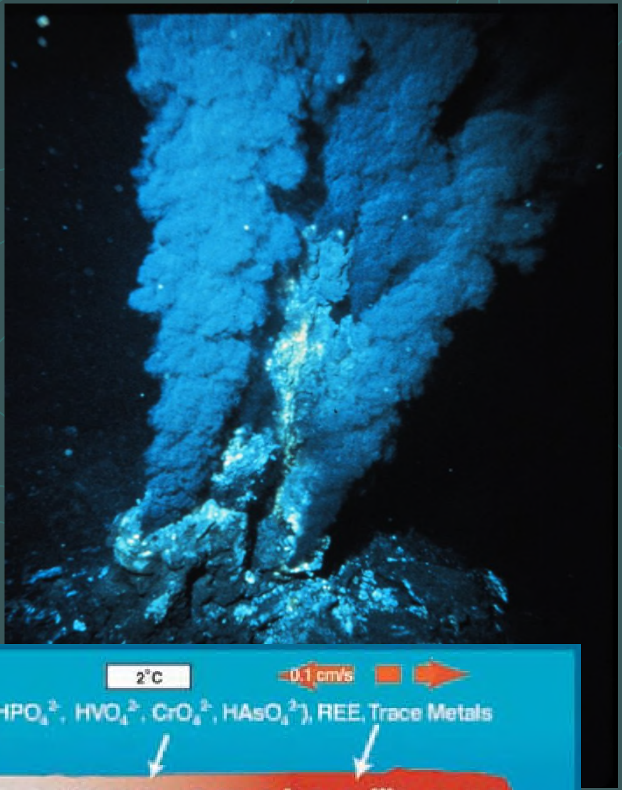
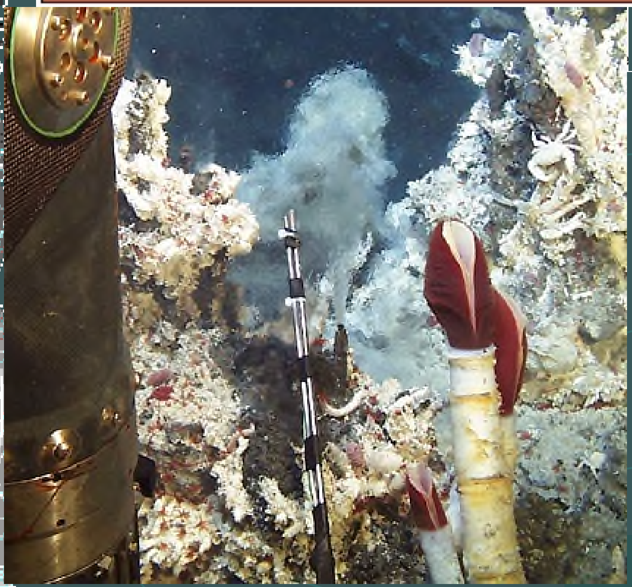
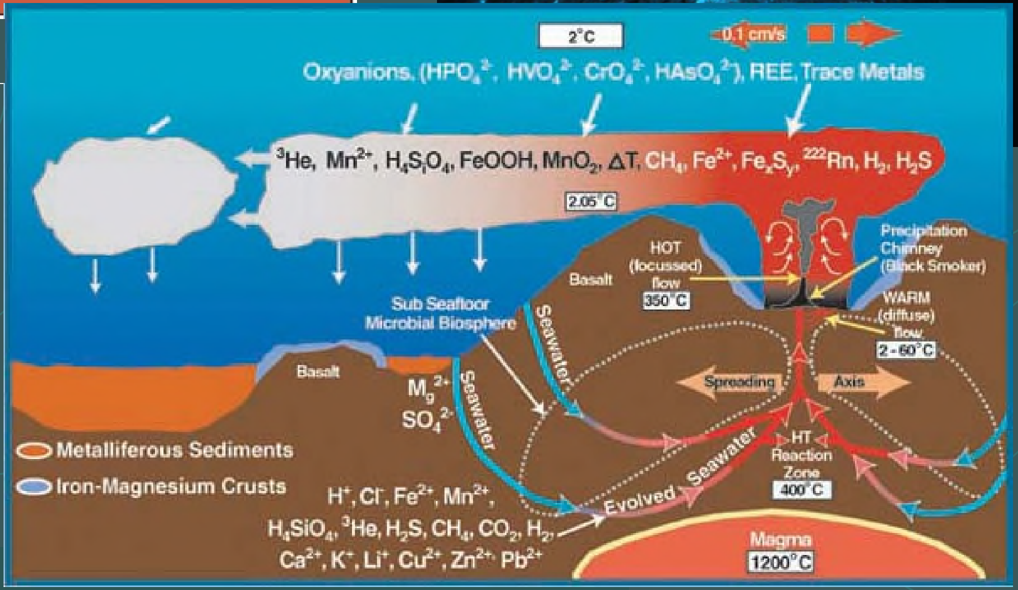


Mid-Ocean Ridge Hydrothermal Vents

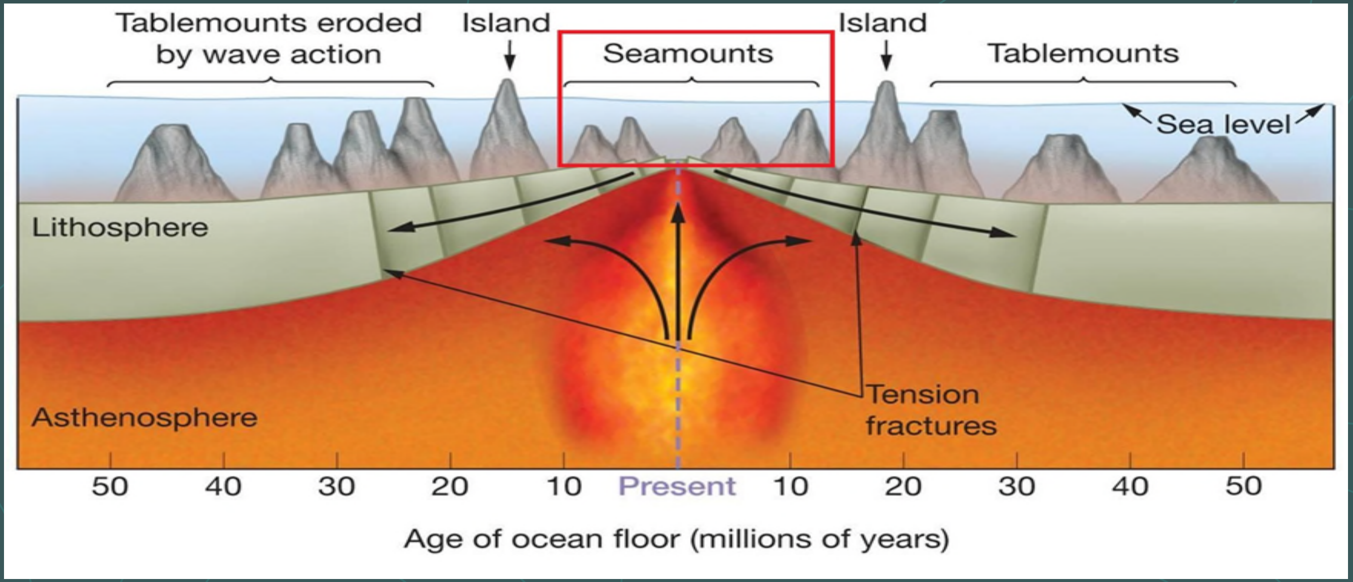






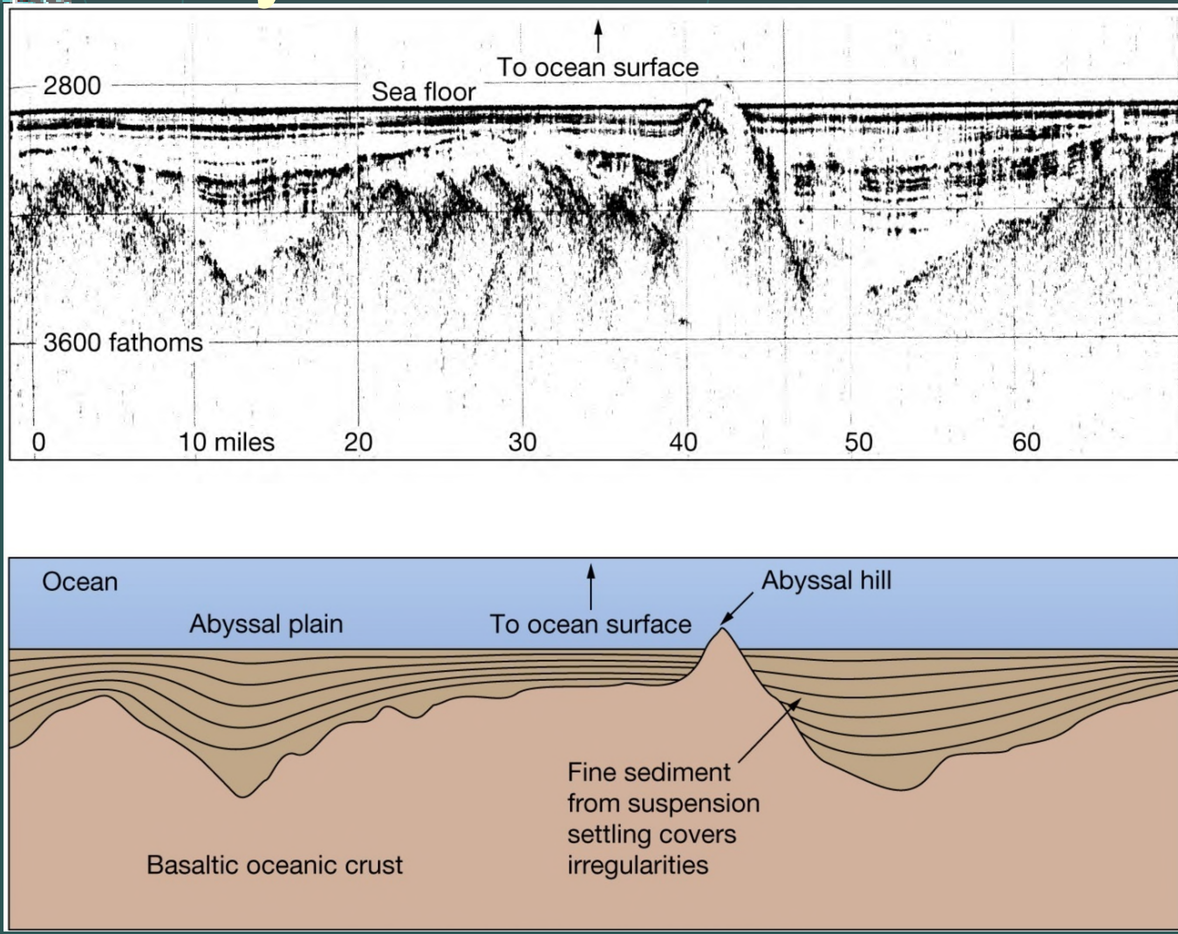


Seamounts, Islands, and Tablemounts



- Excessive basaltic volcanism at spreading centers create seamounts and islands along mid-ocean ridge.
- Over time, seamounts and islands move off the elevated ridges and into deeper and deeper water as oceanic crust becomes older, cooler, denser
- Eroded flat-topped islands eventually sink below sea level to become tablemounts or guyots. Tops of guyots deeper with distance from ridge
- Seamounts, and guyots eventually become buried beneath thickening pelagic sediment pile to become part of the abyssal plains and hills

Abyssal Plains and Hills



Key Points

- ➢ Thick pelagic sediment covers a rugged subsurface bedrock of basalt
- ➢ Abyssal plains are the flattest, most featureless provinces on Earth
- ➢ Abyssal hills are tops of seamounts sticking out
- ➢ Abyssal plains and hills cover the most extensive tracts of ocean seafloor

➢ Subsurface imaging of abyssal plains and hills from seismic reflection studies and deep sea drilling

Abyssal Plains and Hills

Key Points

- Abyssal sediments are predominately clays and oozes
- Soft pelagic sediment is loaded with benthic organisms
- Benthic organisms crawl over and and burrow through the sediment = Bioturbation

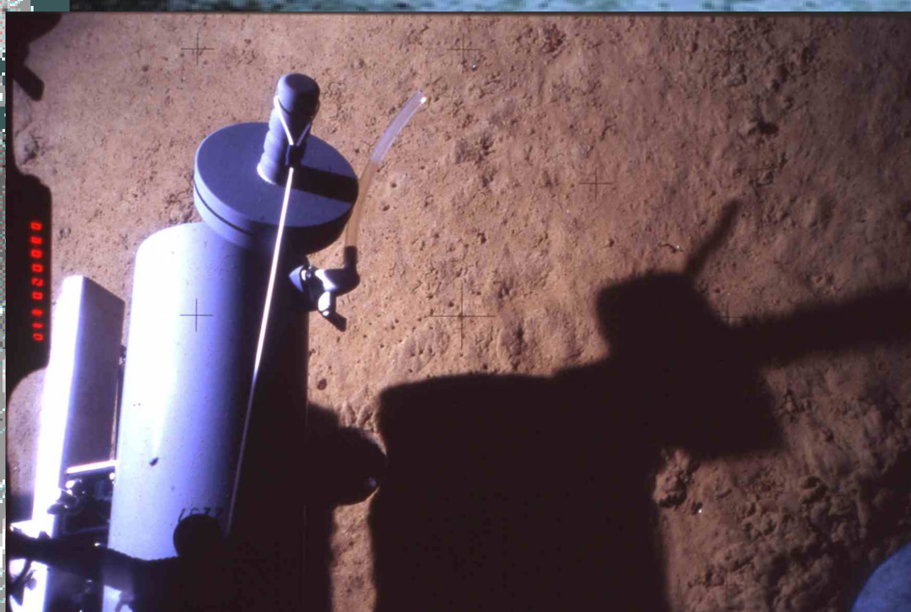
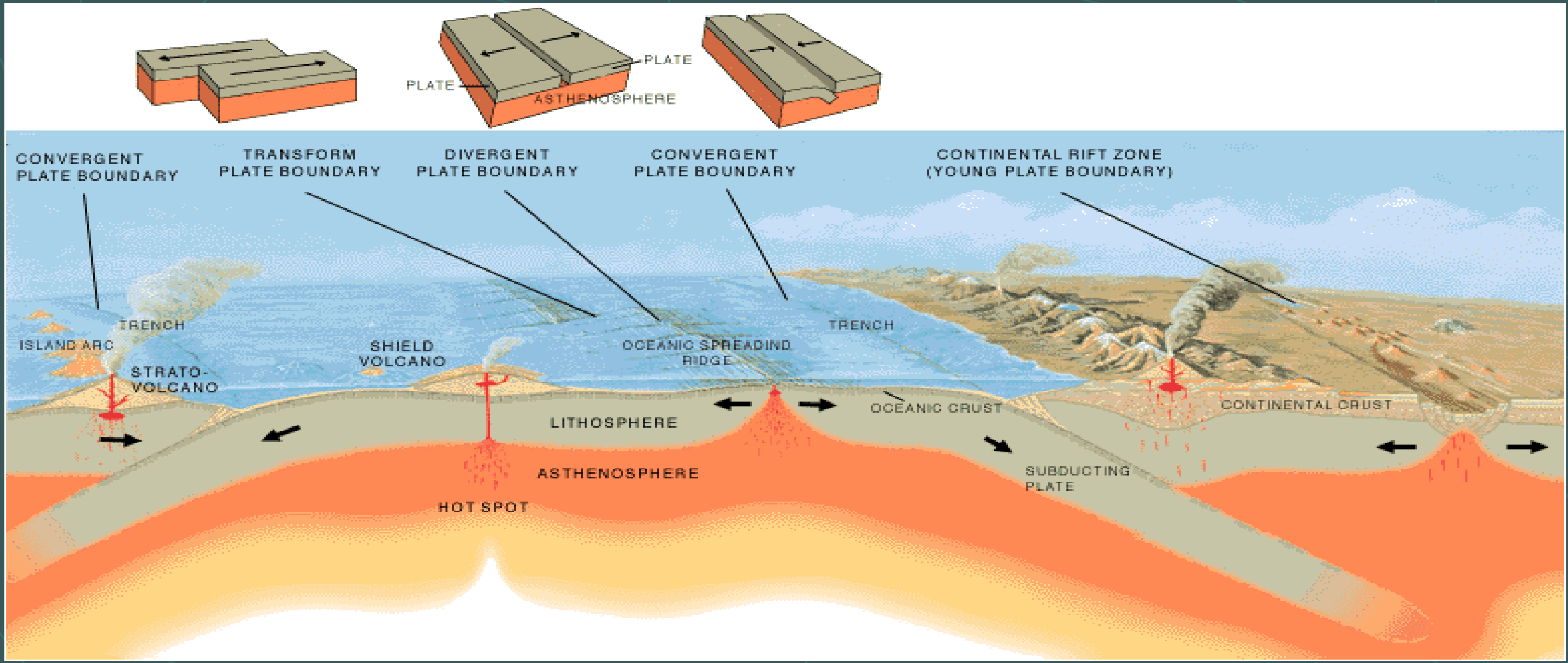
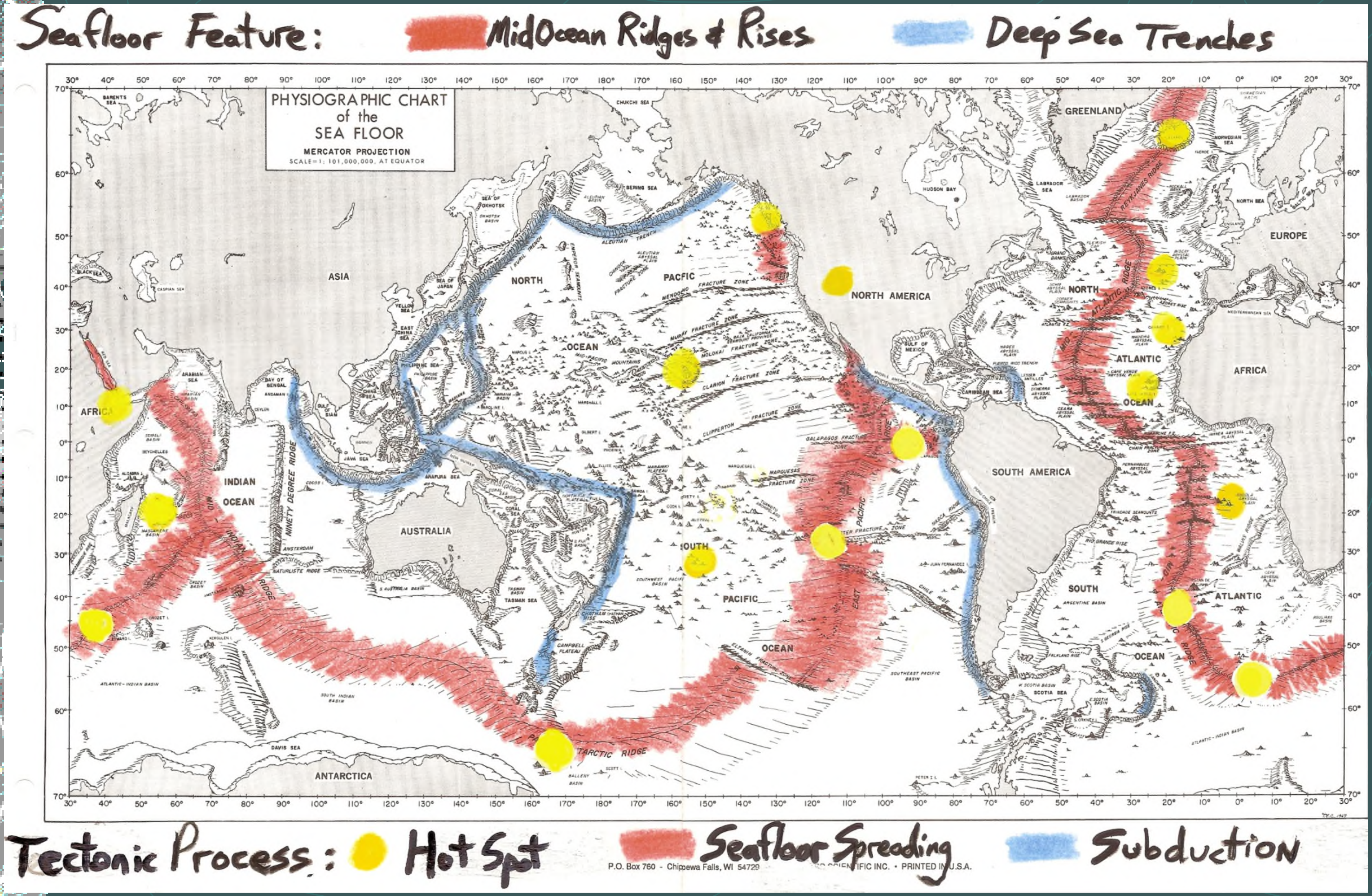


PLATE TECTONICS and the SEAFLOOR

- Seafloor Spreading
- Subduction
- Transform Faulting
- Continental Rifting and Collision
- Hot Spots



Seafloor Ridge and Trench Map

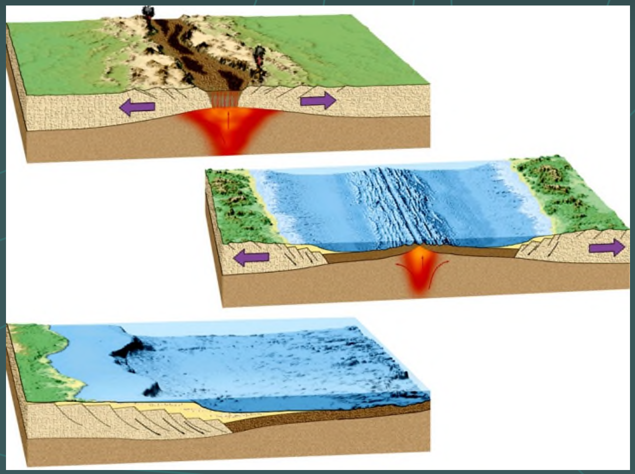


Earth Processes That Create Seafloor Features

Continental Margins

1) Features resulting from Continental Rifting

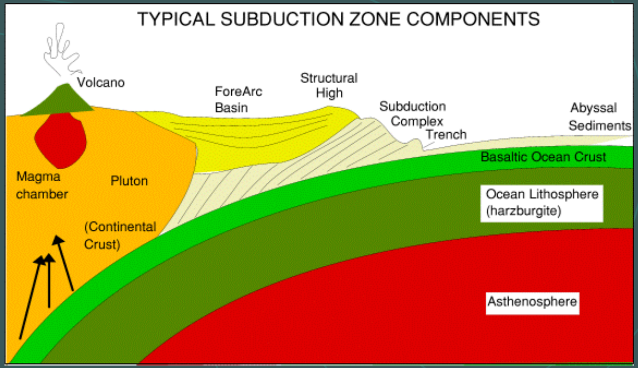
- Continental Shelf and Slope



Deep-Sea Oceanic Basins

1) Features generated by Seafloor Spreading

- Mid-Ocean Ridges and Fracture Systems
- Oceanic Islands, Seamounts and Plateaus

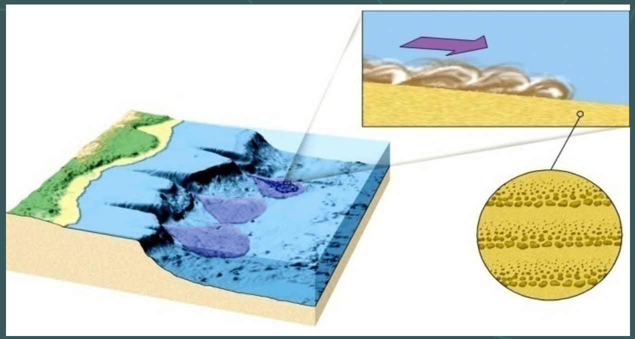


2) Features generated by Subduction

- Trenches and Island Arcs
- Forearc Islands

3) Features resulting from Sedimentary processes

- Abyssal Plains and Hills
- Continental Rises
- Submarine Canyons



OCEAN BASINS and CONTINENTAL PLATFORMS

Summary of Concepts

I. Earth's rocky surface covered by of two types of crust

- Dense, thin, low-standing oceanic crust
- Light, thick, high-standing continental crust

II. Seafloor is divided into two topographic regions

- Shallow continental margins
- Deep-sea oceanic basins

III. Continental margins and Deep Ocean basins are fundamentally different

- Composition, Structure, Age, and Tectonic origin

IV. Shallow ocean basin edges have a wide variety of topographic features

- Shelf, Slope, Rise, Submarine canyons
- Floored by continental Crust
- Formed by continental rifting

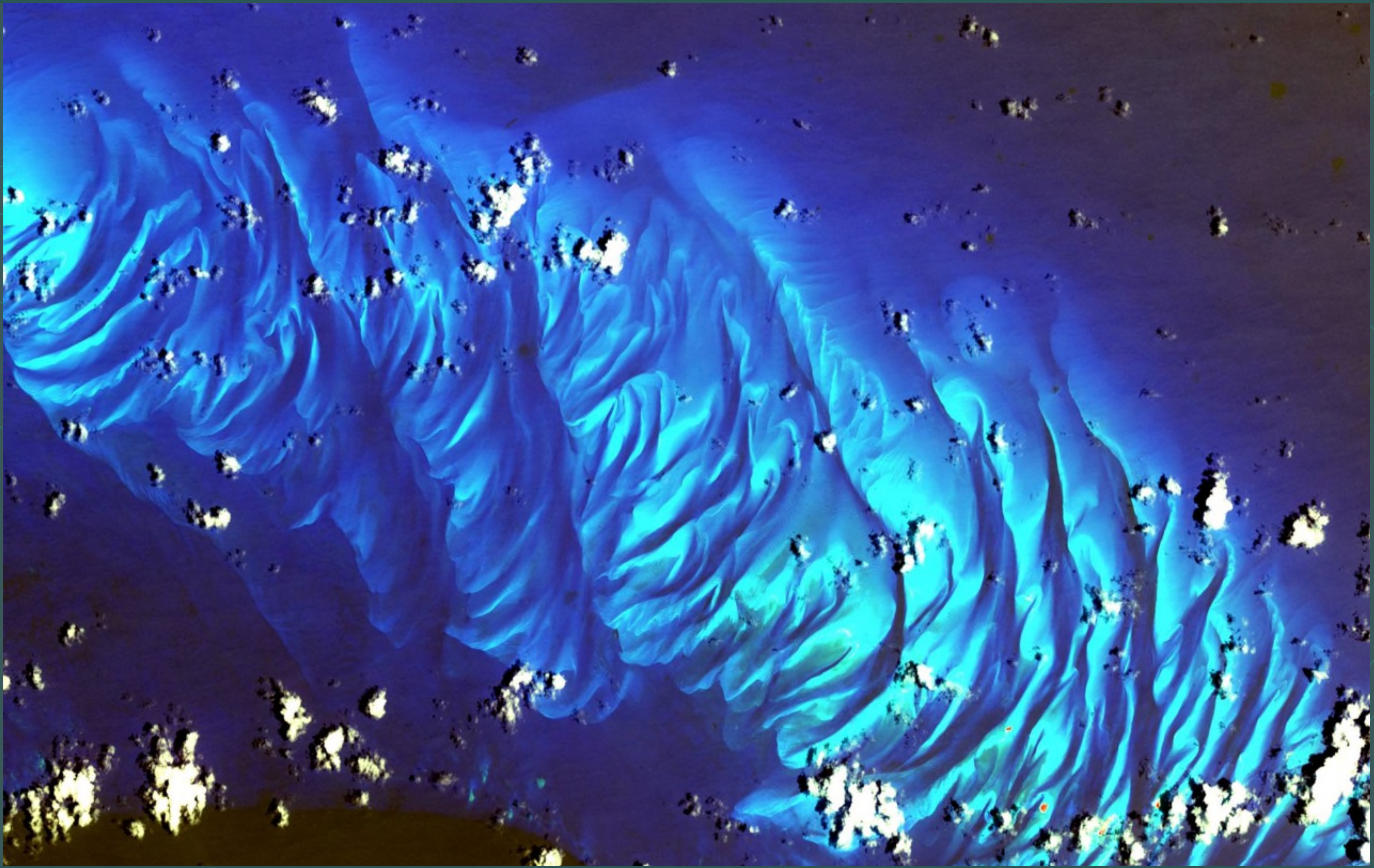
V. Deep ocean basins are rugged and have a wide variety of topographic features

- Mid-oceanic ridges and Transform fracture systems
- Abyssal Hills and Plains
- Oceanic islands, Seamounts, and Guyots
- Trenches and Island Arcs

OCEAN BASINS and SEAFLOORS
Discussion

Ocean Basins are Vast Sinks for Sediment

Next Lecture: Seafloor Sediments



Shallow Underwater Carbonate Sand Dunes - Bahamas