Earth's Contents and Seafloors

GEOL100 – Physical Geology

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

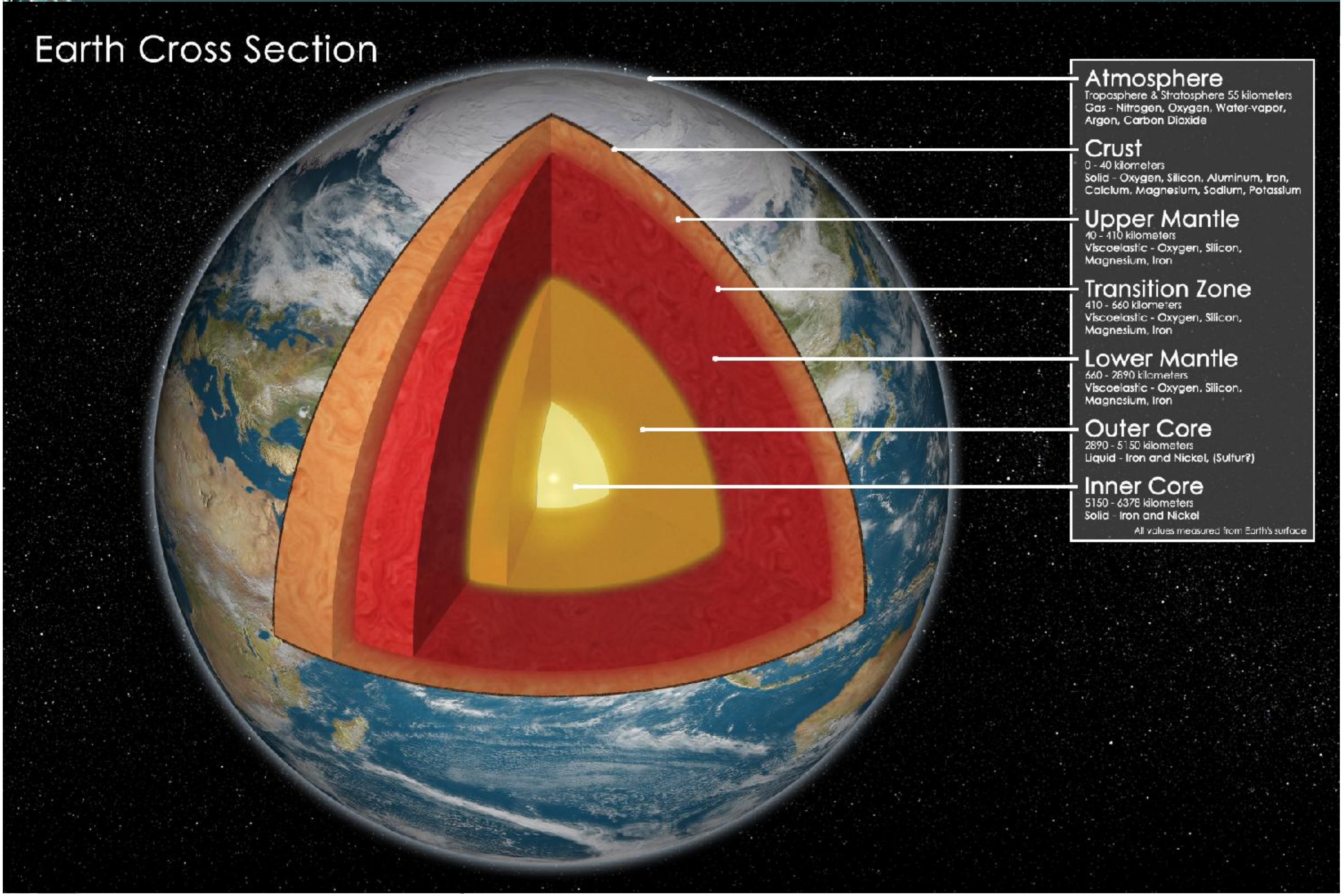
III. Continental margins and Deep Ocean basins are fundamentally different

- 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

Earth's Layers



Earth's Internal Structure

What you would see if you took the long way down: travelling between Kent, Ohio (41°N, 81°W) and its antipode in the Indian Ocean via the centre of the Earth. Most rocky planets composed of silicate minerals probably look a bit like this inside.

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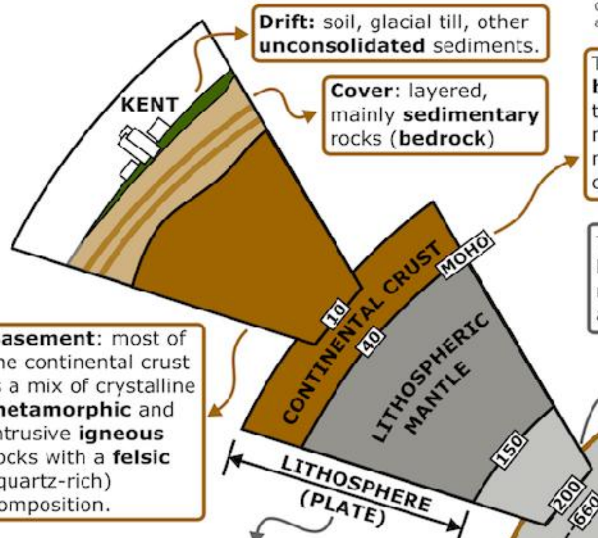


Drift: soil, glacial till, other **unconsolidated** sediments.

Cover: layered, mainly **sedimentary** rocks (**bedrock**)

Basement: most of the continental crust is a mix of crystalline **metamorphic** and intrusive **igneous** rocks with a **felsic** (quartz-rich) composition.

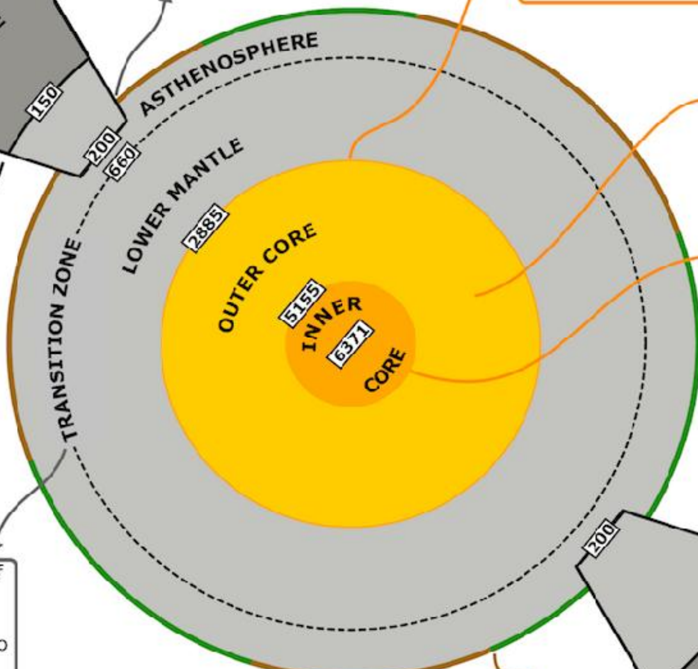
The **Moho** is a **compositional boundary** between the crust and the denser, more iron and magnesium rich peridotite of the mantle. Beneath the continents, it can range from 10-70 km depth.

The **asthenosphere** can flow, but it **is not molten** - it is still mechanically strong enough to allow the passage of S-waves.

The crust and uppermost mantle are **cold** and **brittle**. This rigid outer shell of the Earth is called the **lithosphere**.

The **base of the Earth's tectonic plates** is the **mechanical boundary** between the **lithosphere** and **asthenosphere**. Above and below this boundary, the rocks are the same, but below it the mantle gets **warm** enough (~1280°C) to become **plastic** and able to **flow**. Underneath the oldest continents the lithosphere may extend as deep as 250 km.

Deeper in the Earth, the weight of 100s of km of overlying rock causes the pressure to increase rapidly. In the **transition zone**, at around **660 km depth**, the pressure forces mantle rocks into a **more compact** atomic structure.



The **core mantle boundary** is a **compositional** boundary between silicate rock above and metal (**iron-nickel**) below. It is located just under **half way** between surface and the centre of the Earth.

The **outer core** is **liquid**, and is where the Earth's **magnetic field** is generated by the rapid convection of molten metal.

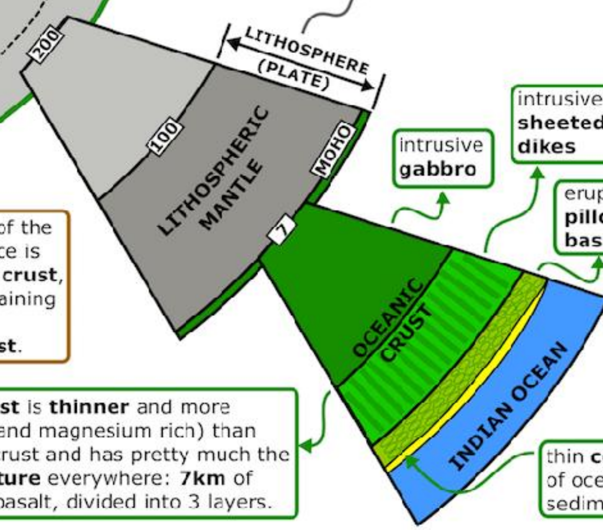
The **inner core** is **solid**, and is growing slowly as the Earth cools internally.

How do we know?

This picture is based on evidence from:

- **Earth's gravity** (surface rocks not dense enough)
- **Mantle xenoliths** (mantle is not dense enough either)
- **Meteorites** (missing mass is iron)
- **Seismology** (depth of Moho and core-mantle boundary, outer core is liquid)

oceanic plates are **thinner** than continental ones: because oceanic crust is **young**, there is less time for the mantle below to cool and become part of the rigid lithosphere.



intrusive **gabbro**

intrusive **sheeted dikes**

erupted **pillow basalts**

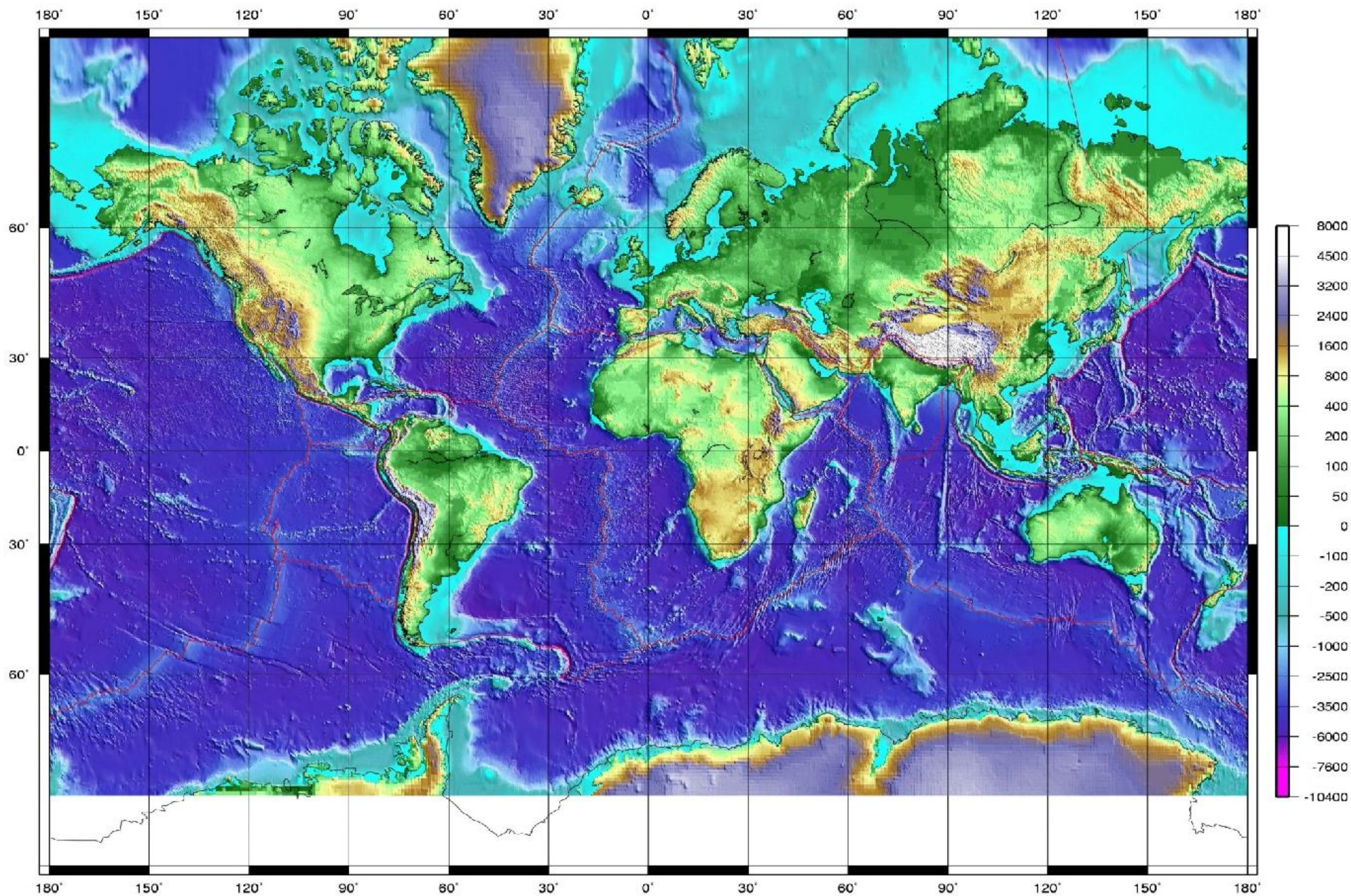
thin **cover** of ocean sediments

About **40%** of the Earth's surface is **continental crust**, with the remaining **60%** being **oceanic crust**.

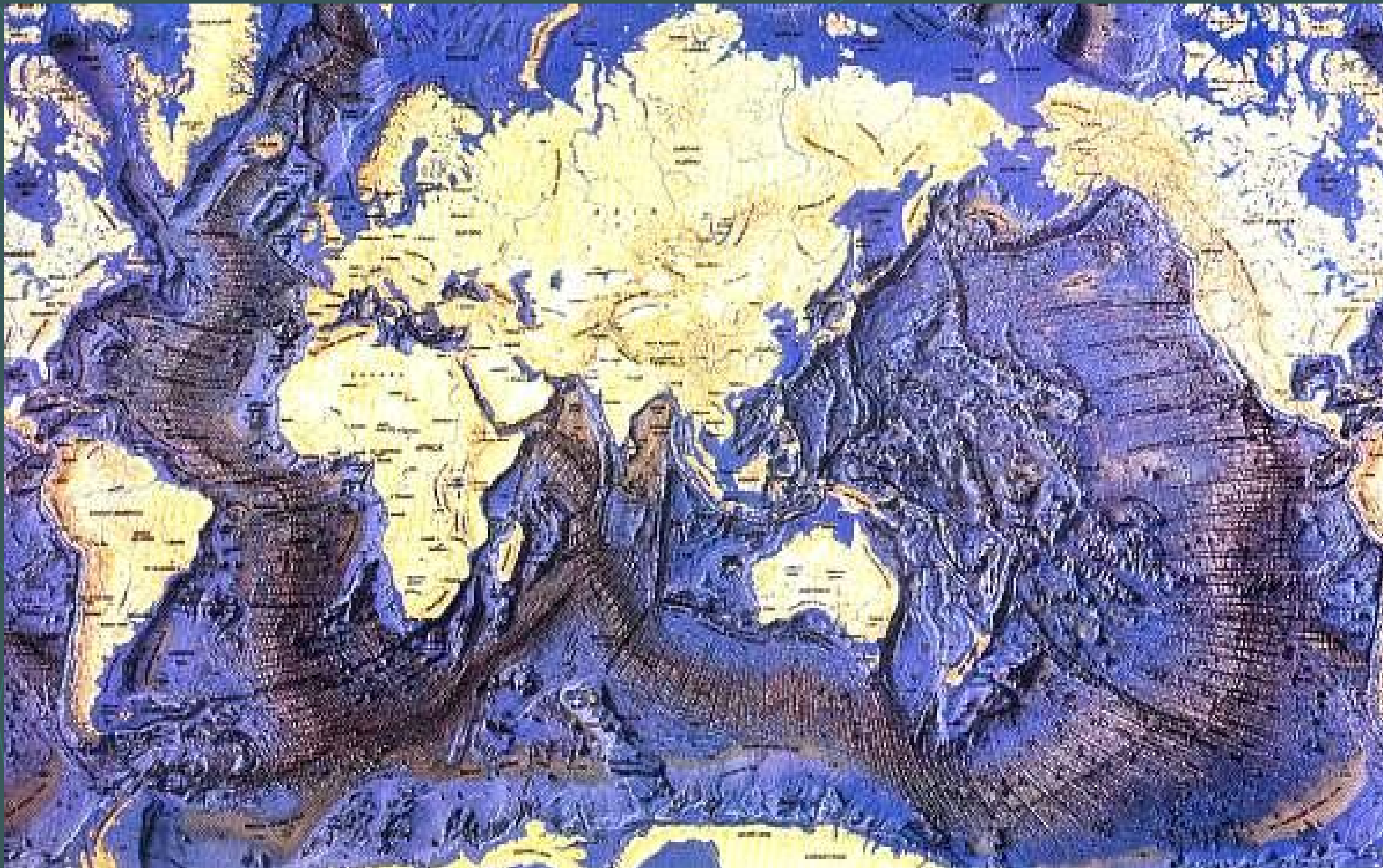
oceanic crust is **thinner** and more **mafic** (iron and magnesium rich) than continental crust and has pretty much the **same structure** everywhere: **7km** of gabbro and basalt, divided into 3 layers.

Layer	Composition	Physical State	Fraction of Earth radius	Fraction of Earth volume
Crust	silicates	Rigid	< 0.3%	1-2%
Lithospheric Mantle	Peridotite (silicate)	Rigid	45%	83%
Asthenosphere & Lower Mantle		Plastic		
Outer Core	Iron-Nickel	Liquid	55%	16%
Inner Core		Solid		

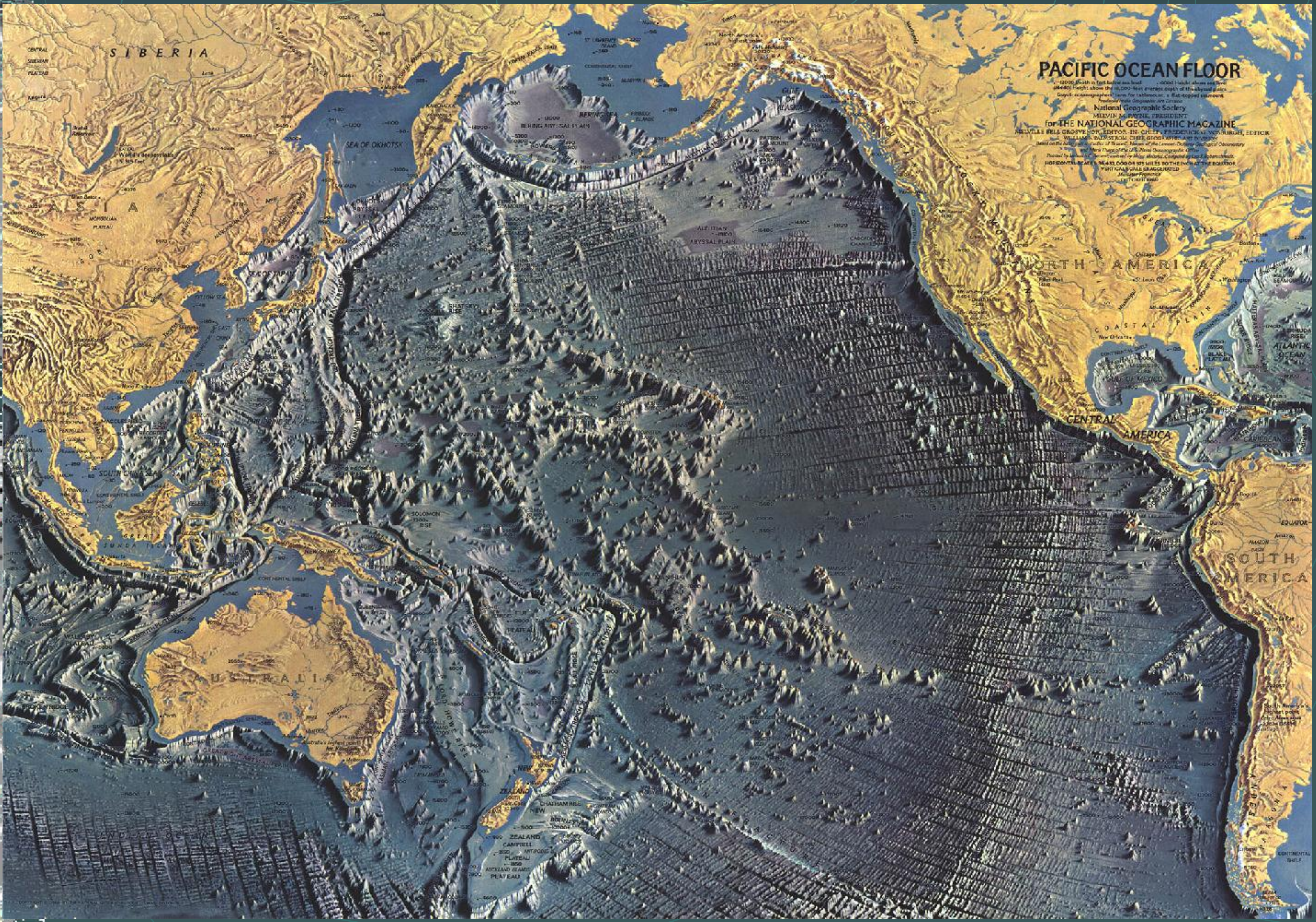
Earth's Solid-Surface Topography



Topography of Earth’s Ocean Basins

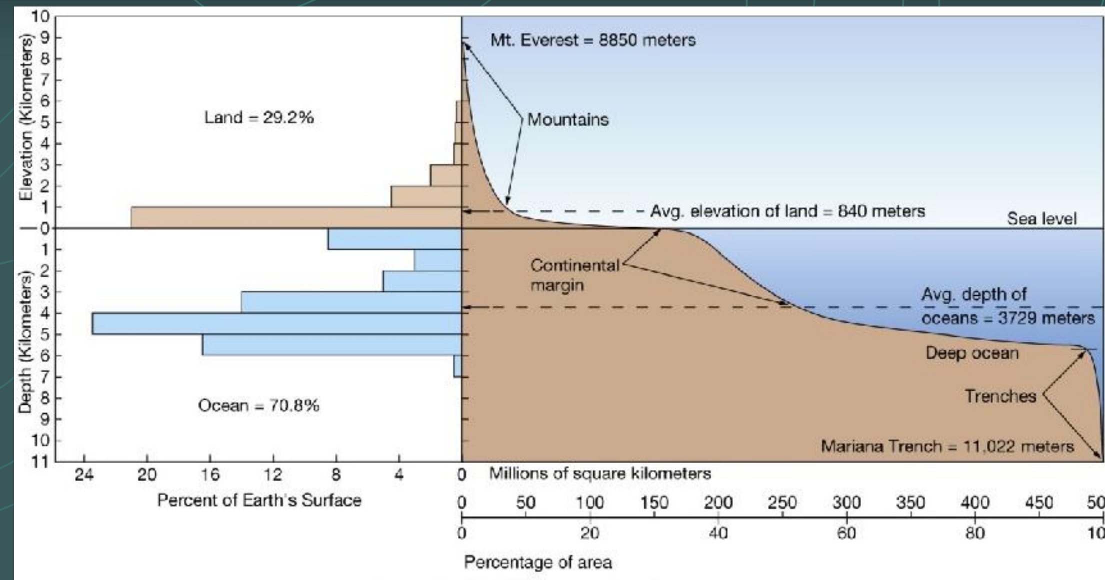


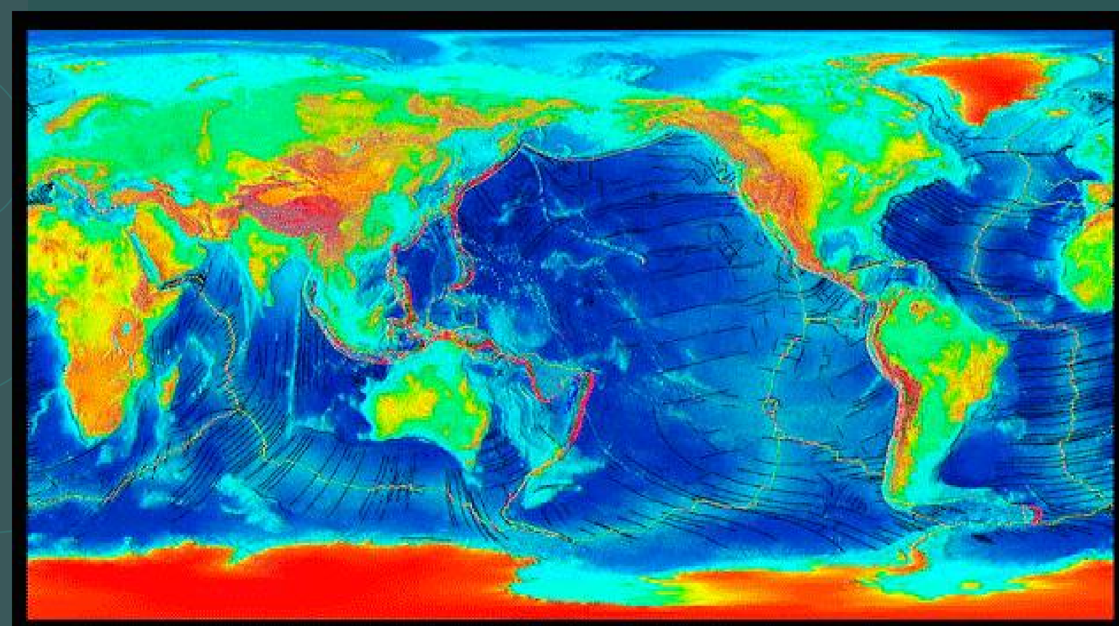
Topography of Pacific Ocean Basin



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





Earth's Continents and Ocean Basins

1) Two Different Types of Crust

- ✓ Continental - Granitic
- ✓ Oceanic - Gabbroic

2) Continental Crust

- ✓ Lighter (2.7 g/ml)
- ✓ Thicker (30 km)
- ✓ High Standing (1 km elev.)

3) Oceanic Crust

- ✓ Denser (2.9 g/ml)
- ✓ Thinner (7 km)
- ✓ Low Standing (- 4 km elev.)

Two Primary Types of Earth Crust

1) Two Different Types of Crust

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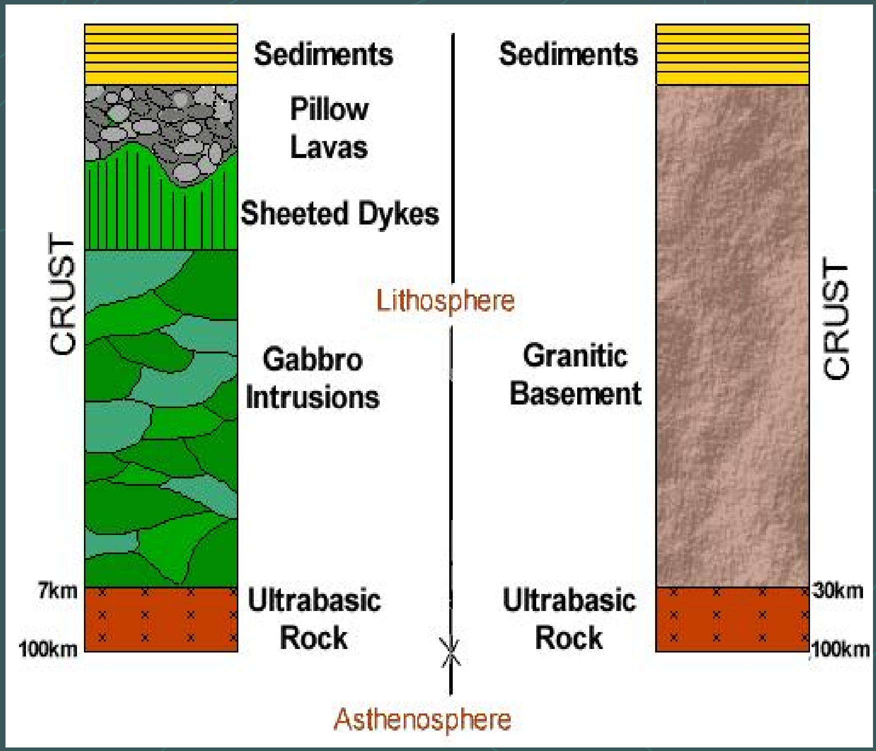
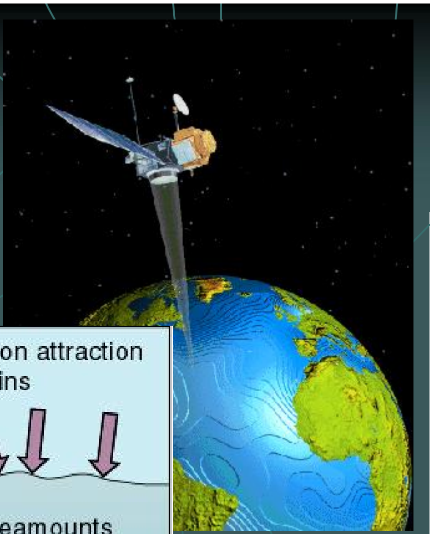
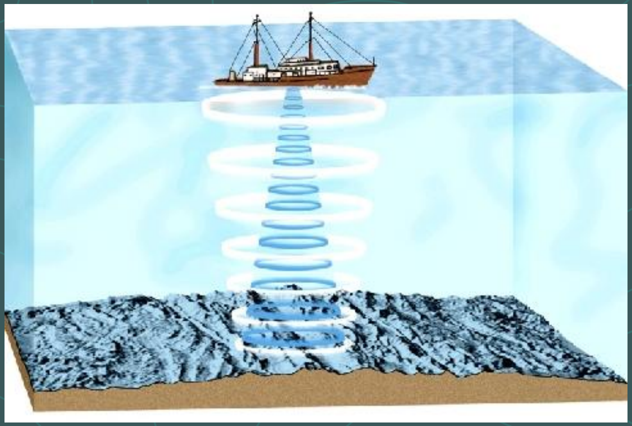
Oceanic Crust | **Continental Crust**

Gabbroic Rock | **Granitic Rock**

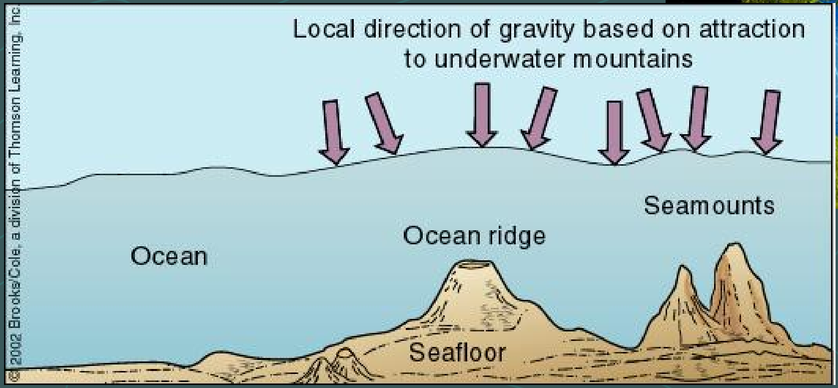


Four Principle Methods of Mapping the Ocean Bottom

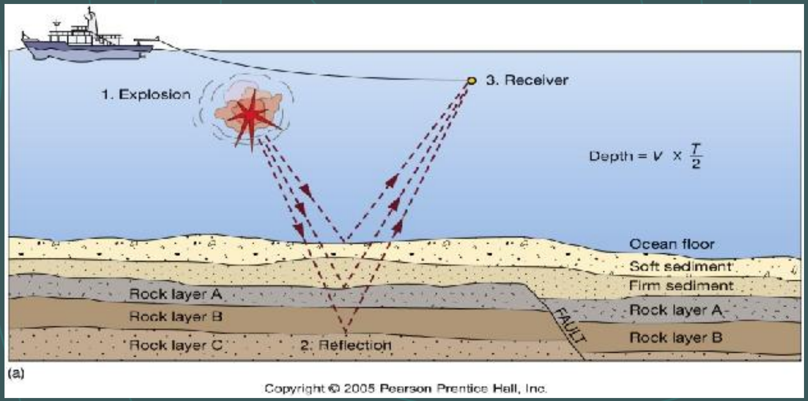




1. Ship-based Sonar



2. Satellite-based Radar

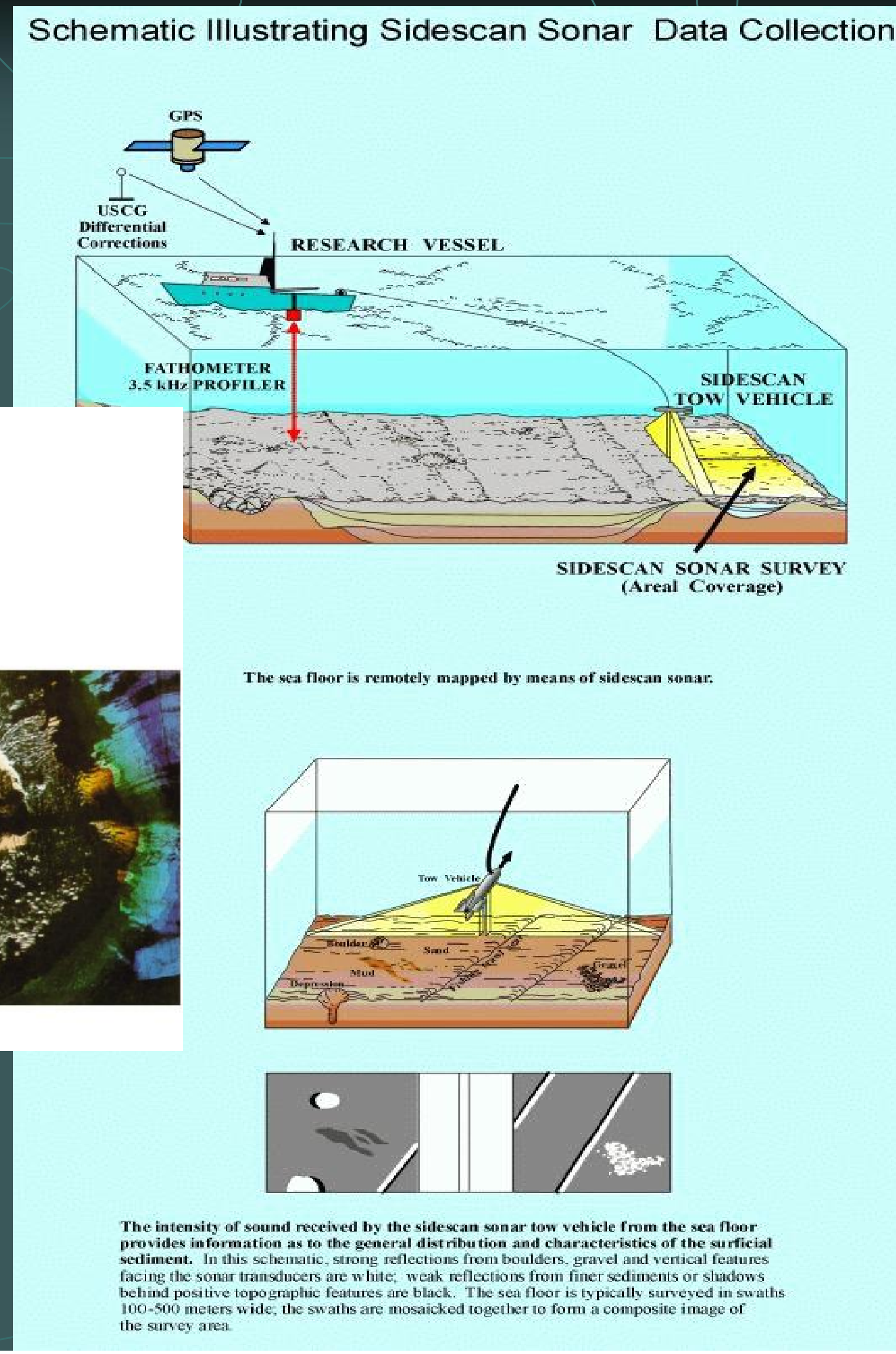


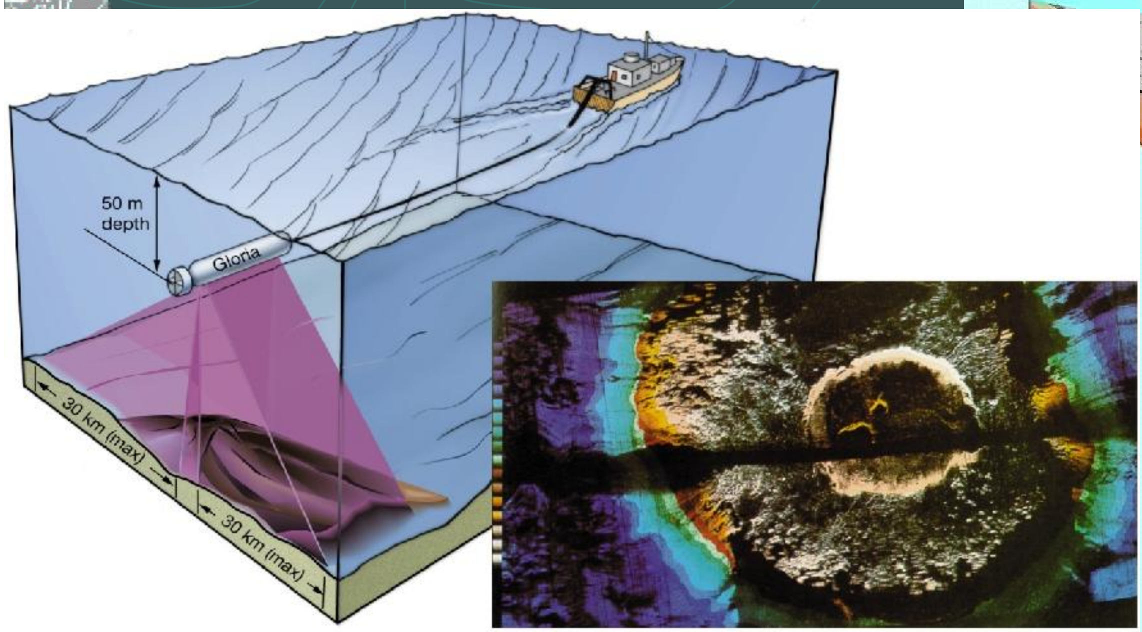
3. Ship-based Seismic Reflection

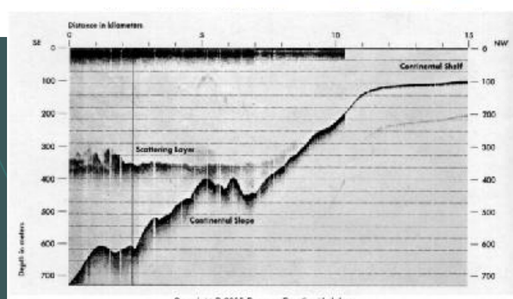
4. Submersible Survey

Means of Mapping the Ocean Bottom

Sonar

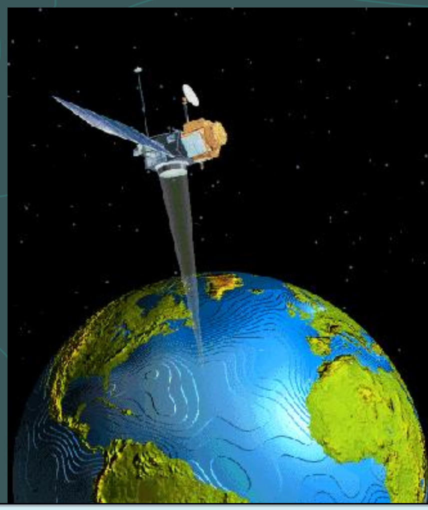


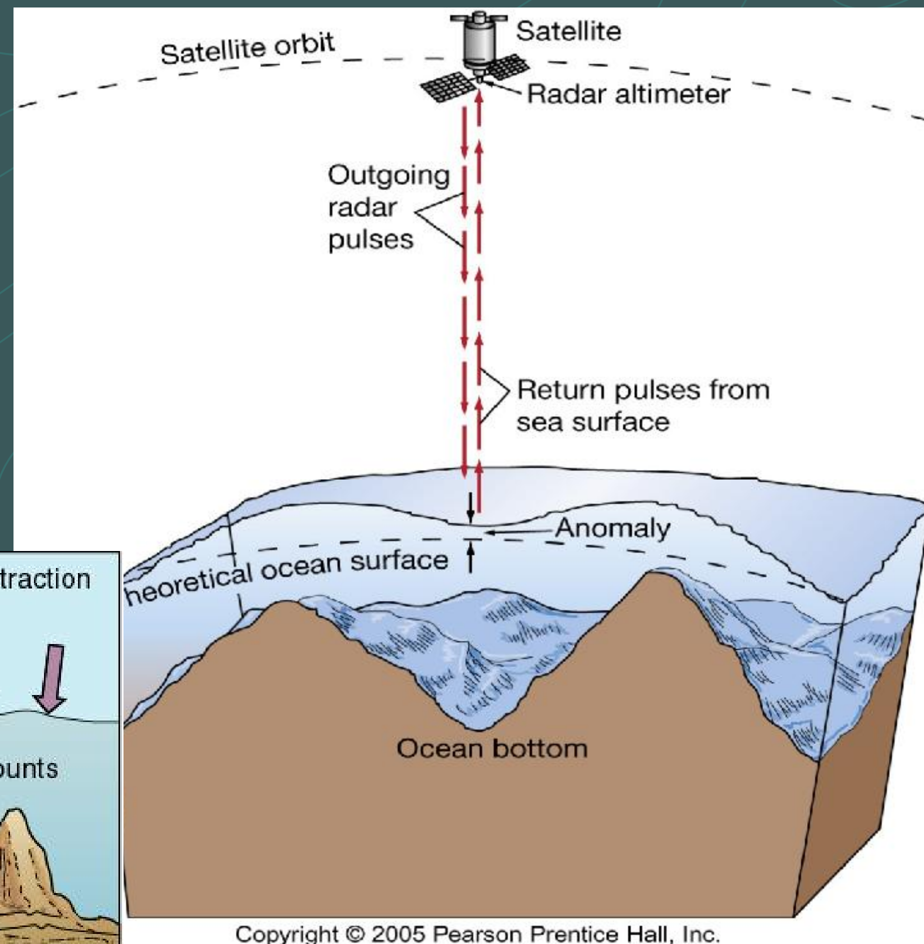


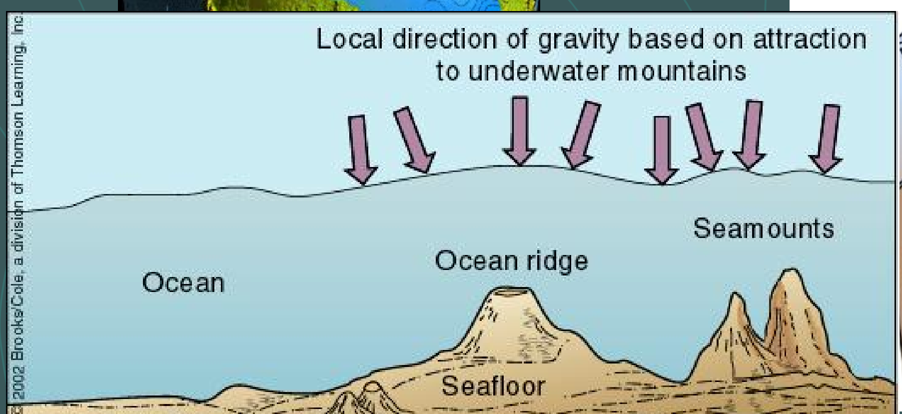


Means of Mapping the Ocean Bottom

Satellite Radar



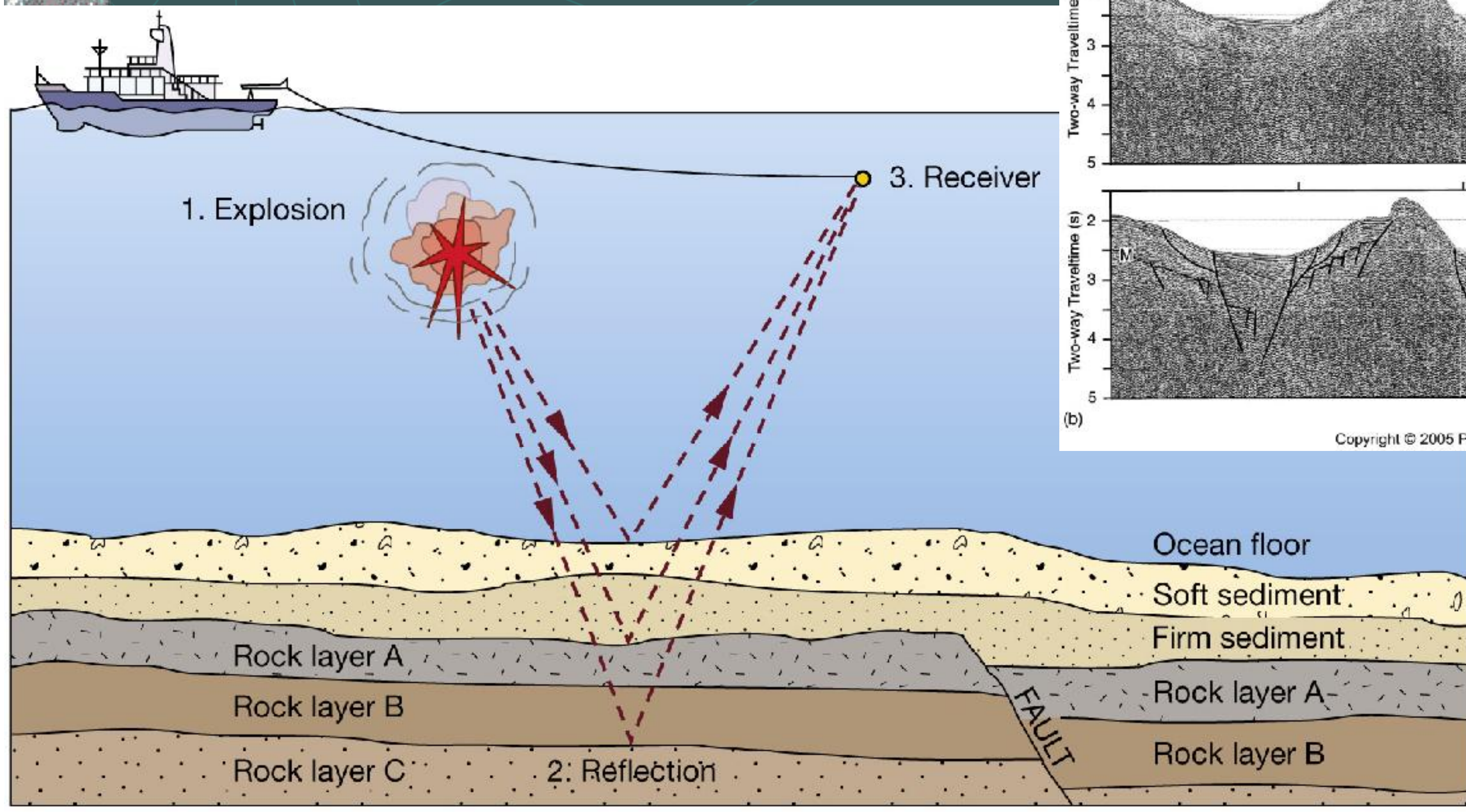


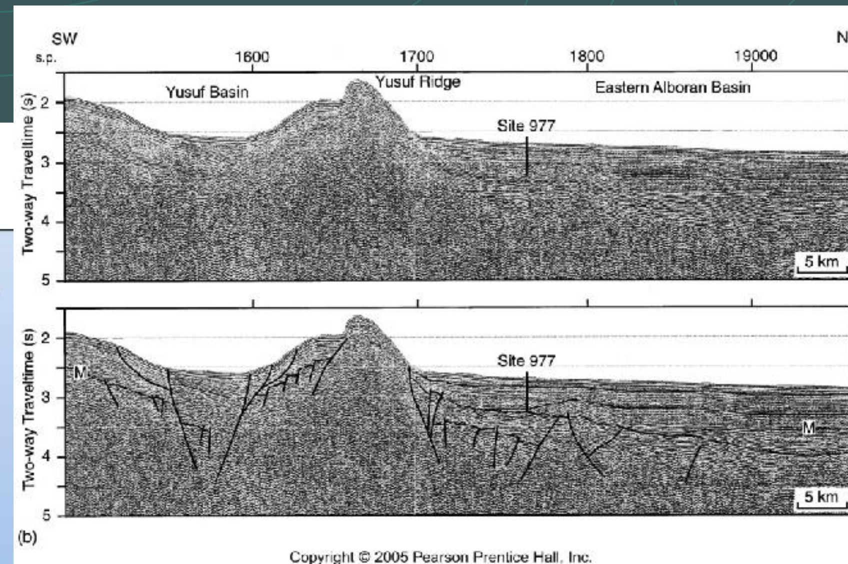


- Use of space-based radar to reflect off ocean surface, giving a very precise sea surface profile; sea surface profile anomalies closely mimic the underlying seafloor profile

Means of Mapping the Ocean Bottom

Seismic Reflection

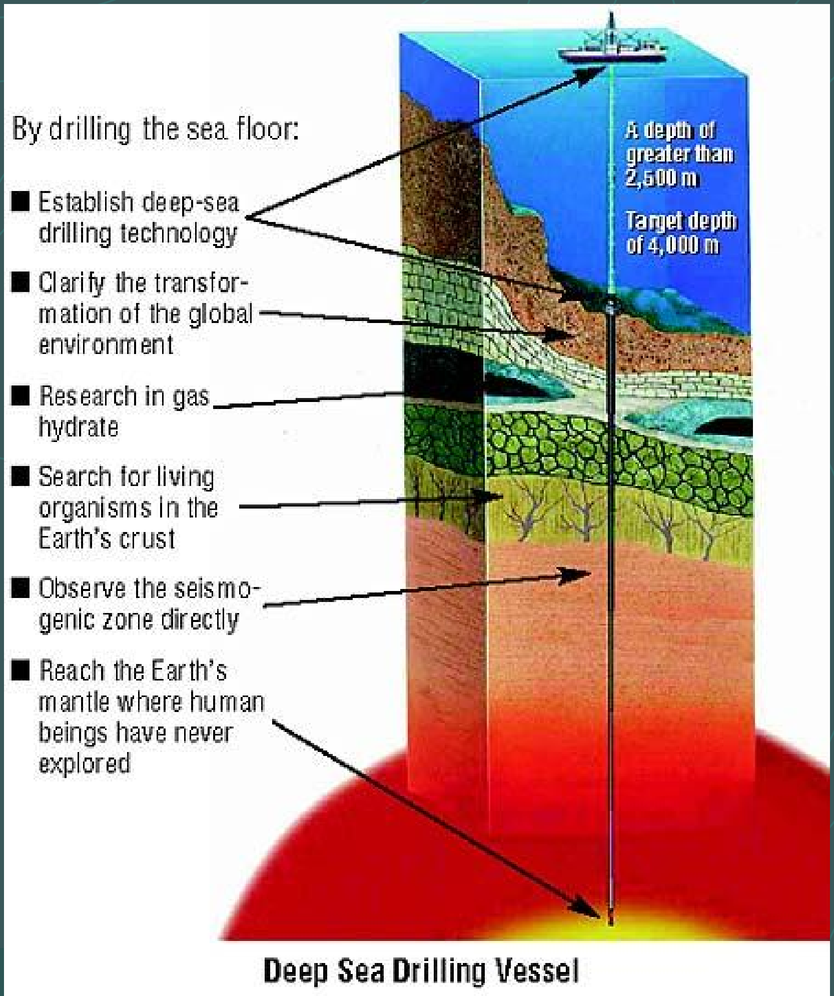




- Use of underwater explosions to penetrate seafloor with seismic waves that reflect back, providing a subsurface image

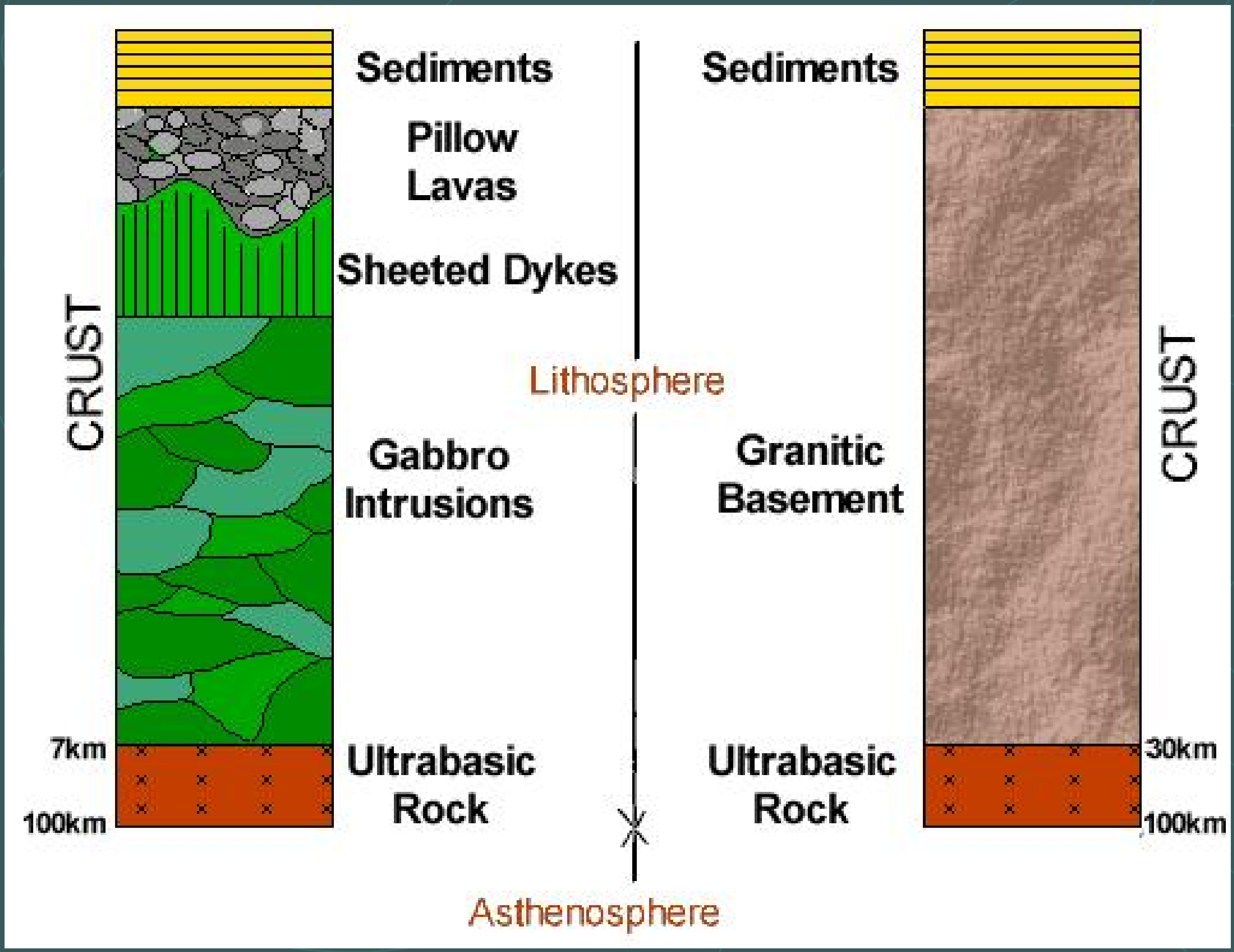
Means of Mapping the Ocean Bottom

Deep Sea Drilling



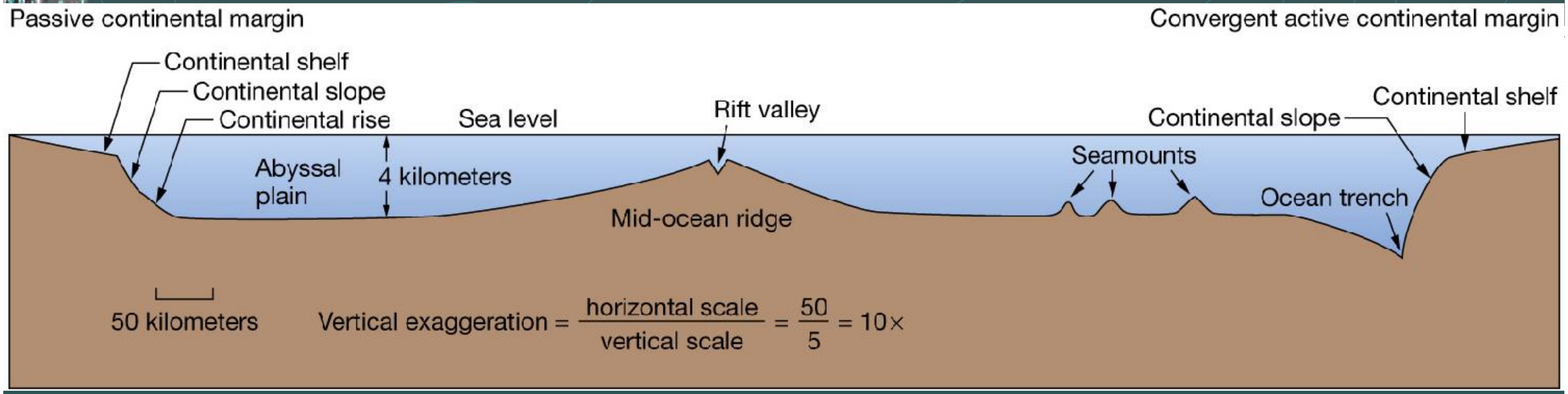
- Use of underwater drilling to penetrate seafloor and recover core samples of seafloor down to depths of over 3000 meters

Two Primary Types of Earth Crust



Oceanic Continental

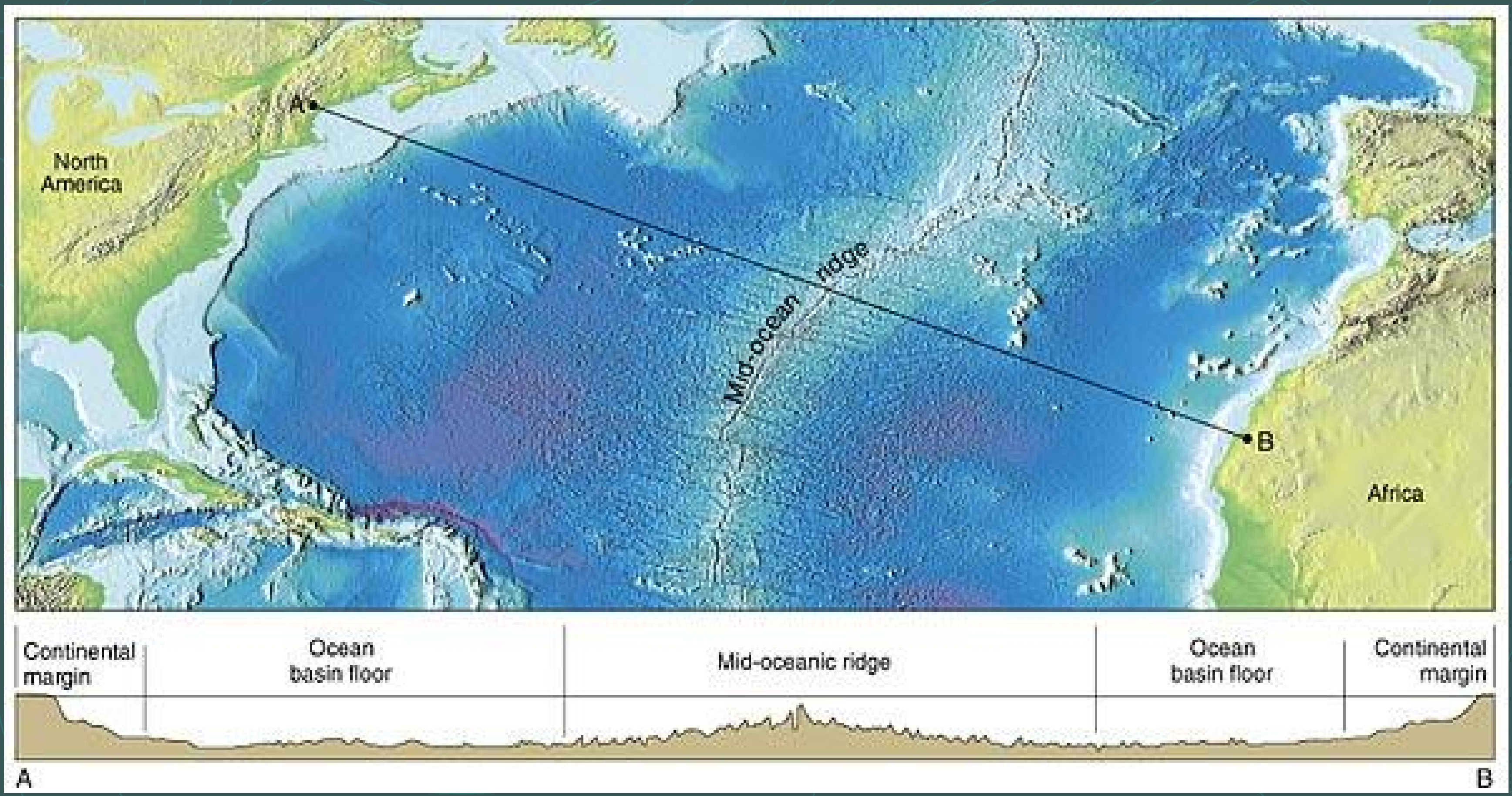
Cross-Section Profile of an Ocean Basin



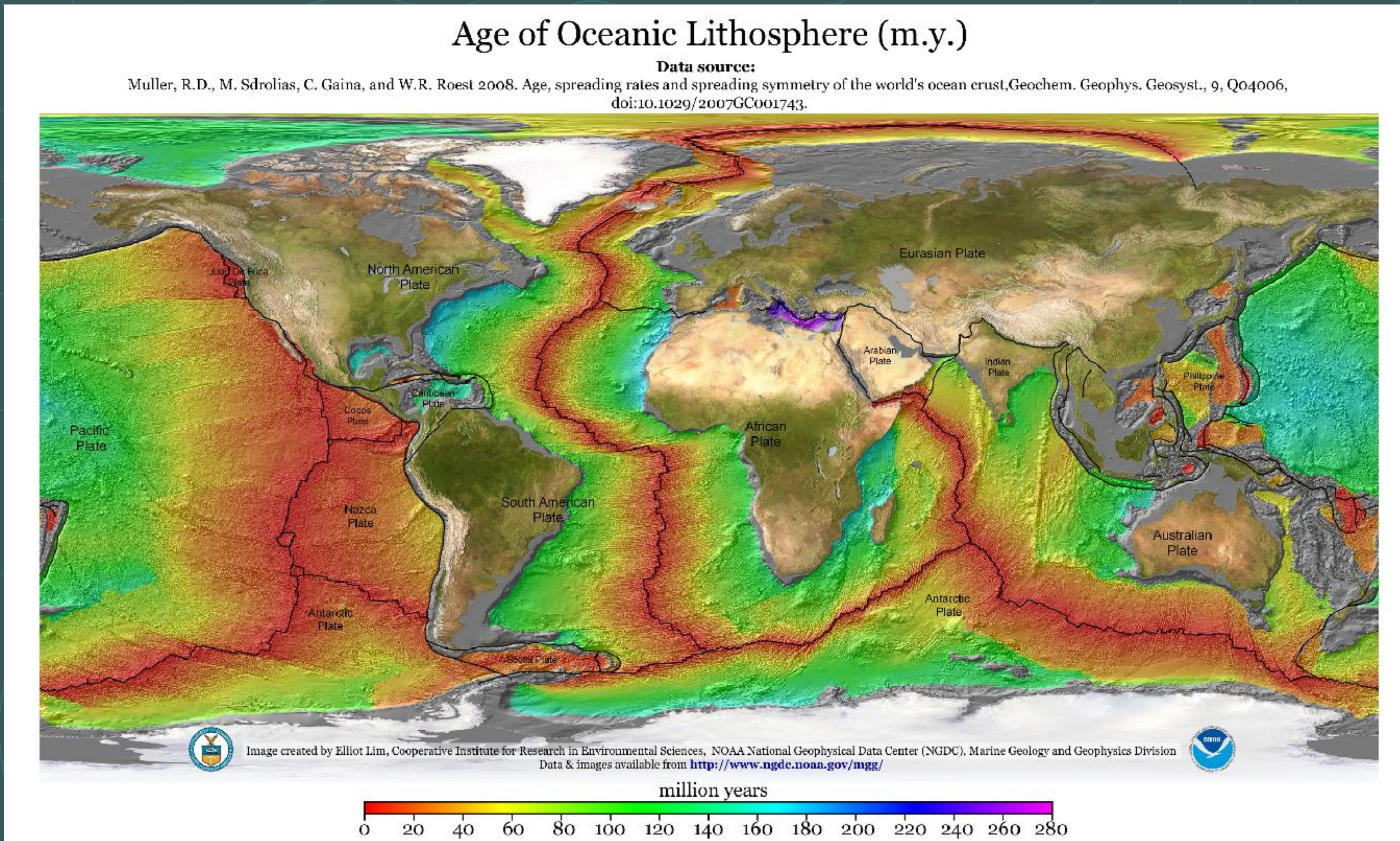
Large-Scale Ocean Bottom Features

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

Cross-Section of the North Atlantic Ocean Basin

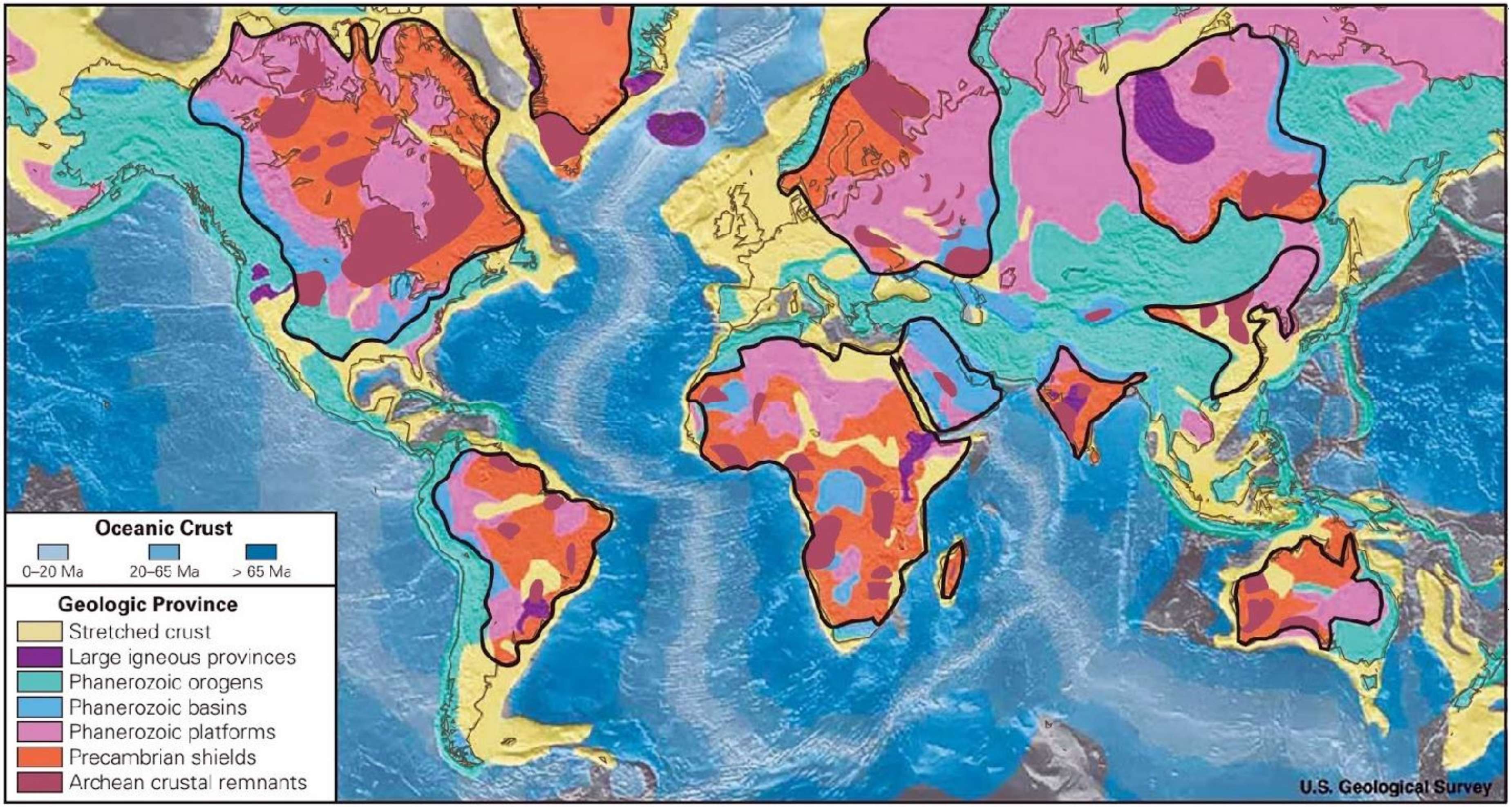


AGE OF EARTH'S OCEAN BASINS



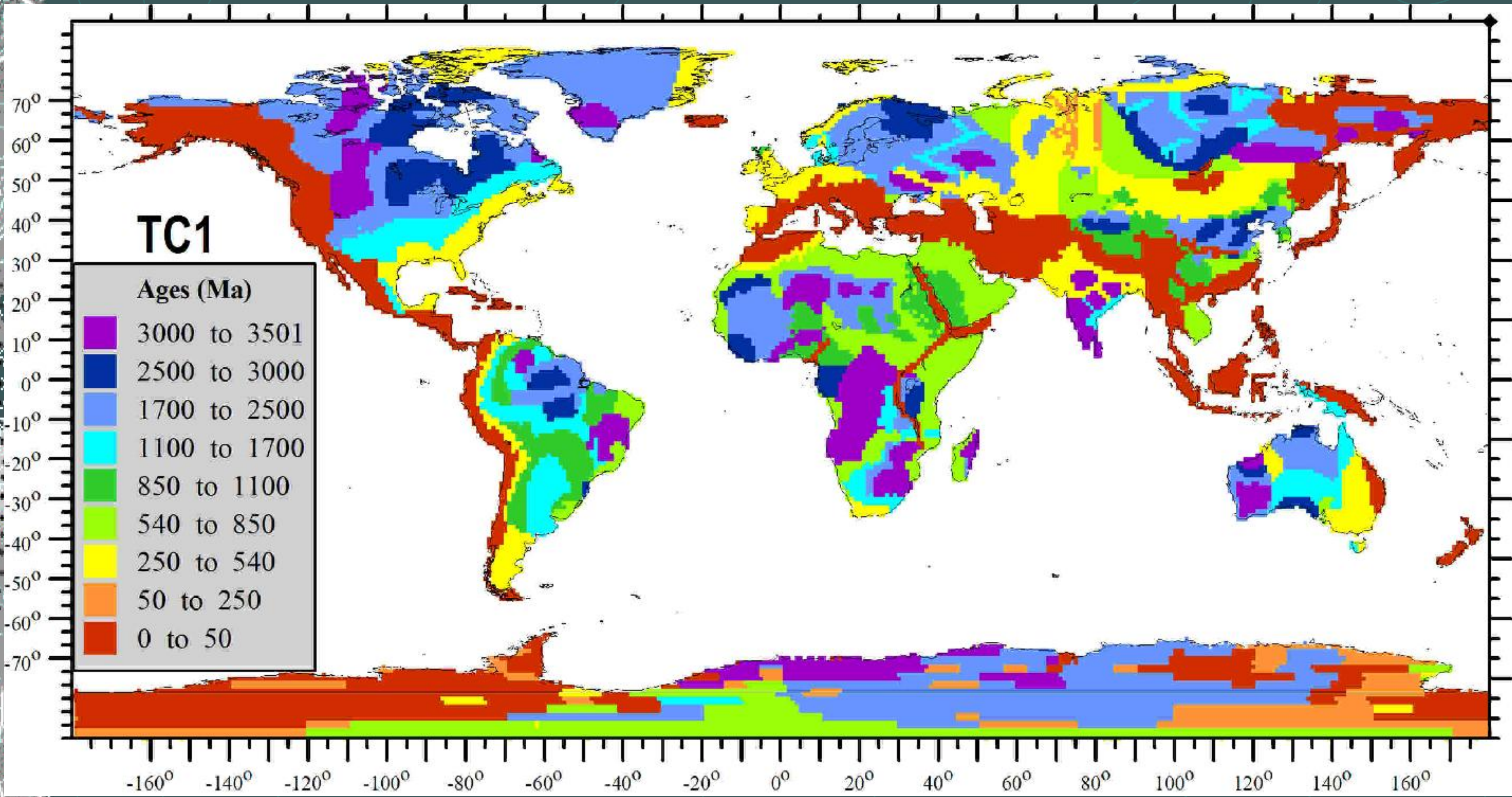
- Oceanic lithosphere is youngest at mid-ocean ridges and oldest along margins of ocean basins – no older than 200 myo!

Major Crustal Provinces



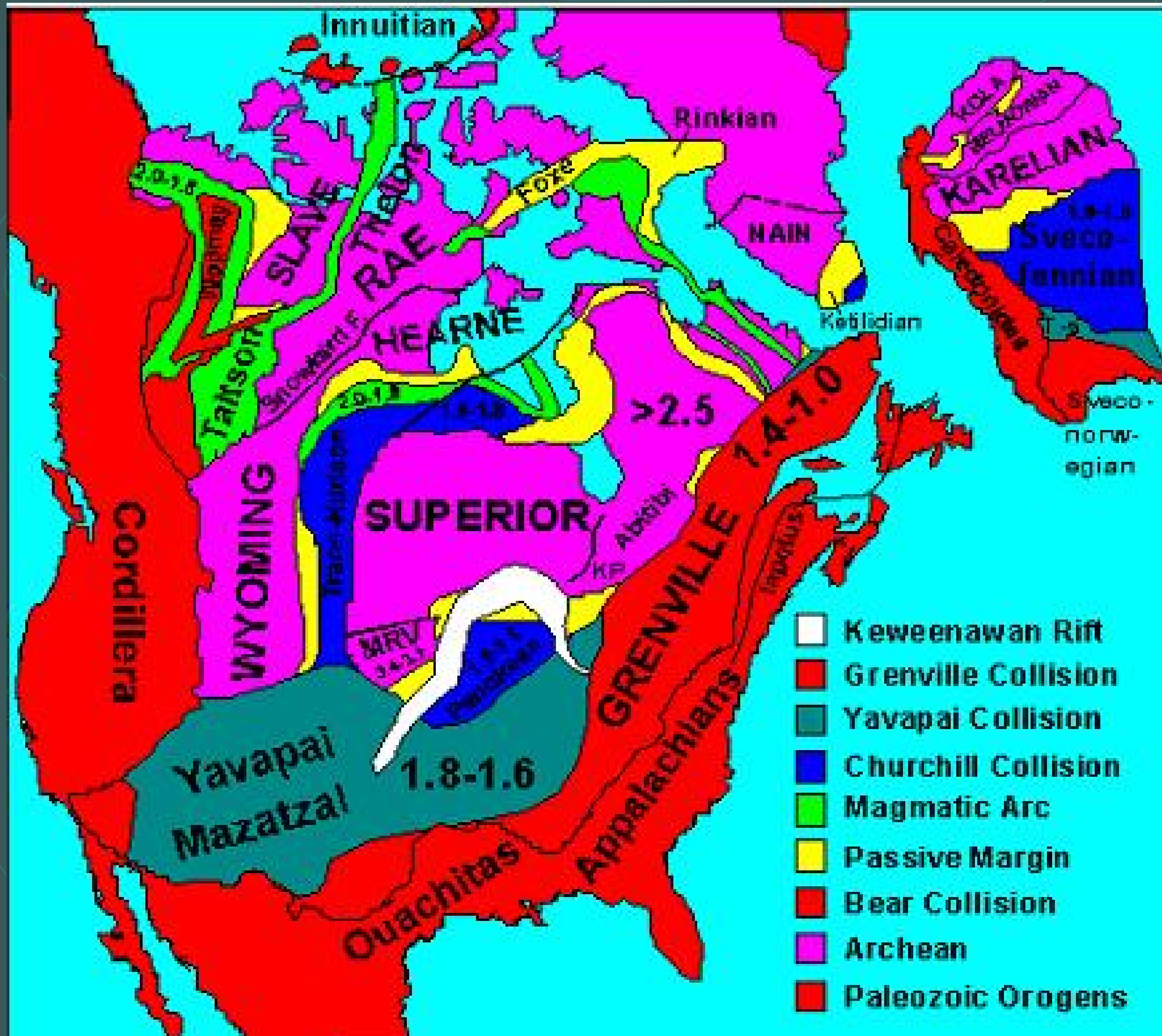
- Black-circled regions are called “shields” or “cratons” – Precambrian rock that make up the cores of continents

Age Profiles of Continents



- Continental lithosphere is oldest in center and youngest along continental margins – the oldest rocks are up to 3.8 byo!

AGE PROFILE OF NORTH AMERICA



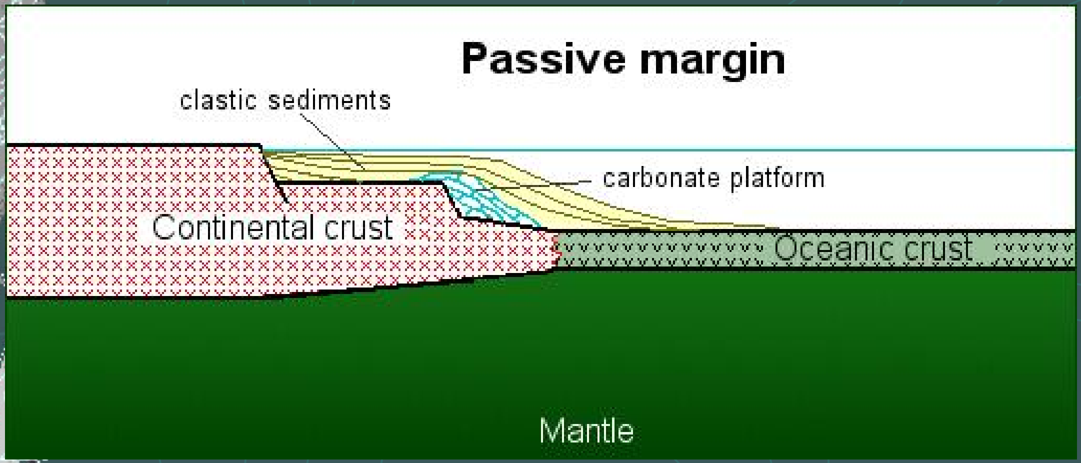
Tectonic Provinces of North America: (Ages are in **Billions** of Years)

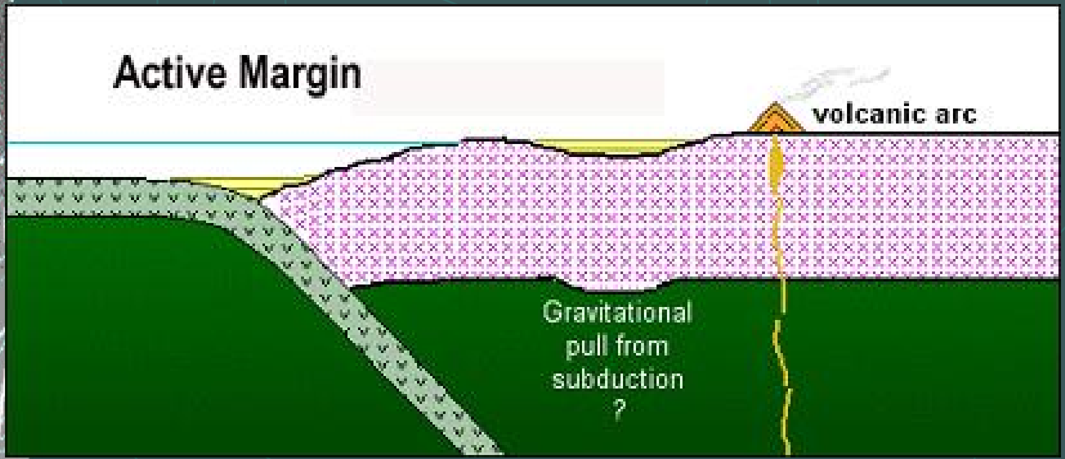
Continental Margins of the World

Submerged continental margins are shown in pale orange color

Two Types of Continental Margins

- **Passive** = Constructive = Atlantic Type
- **Active** = Destructive = Pacific Type





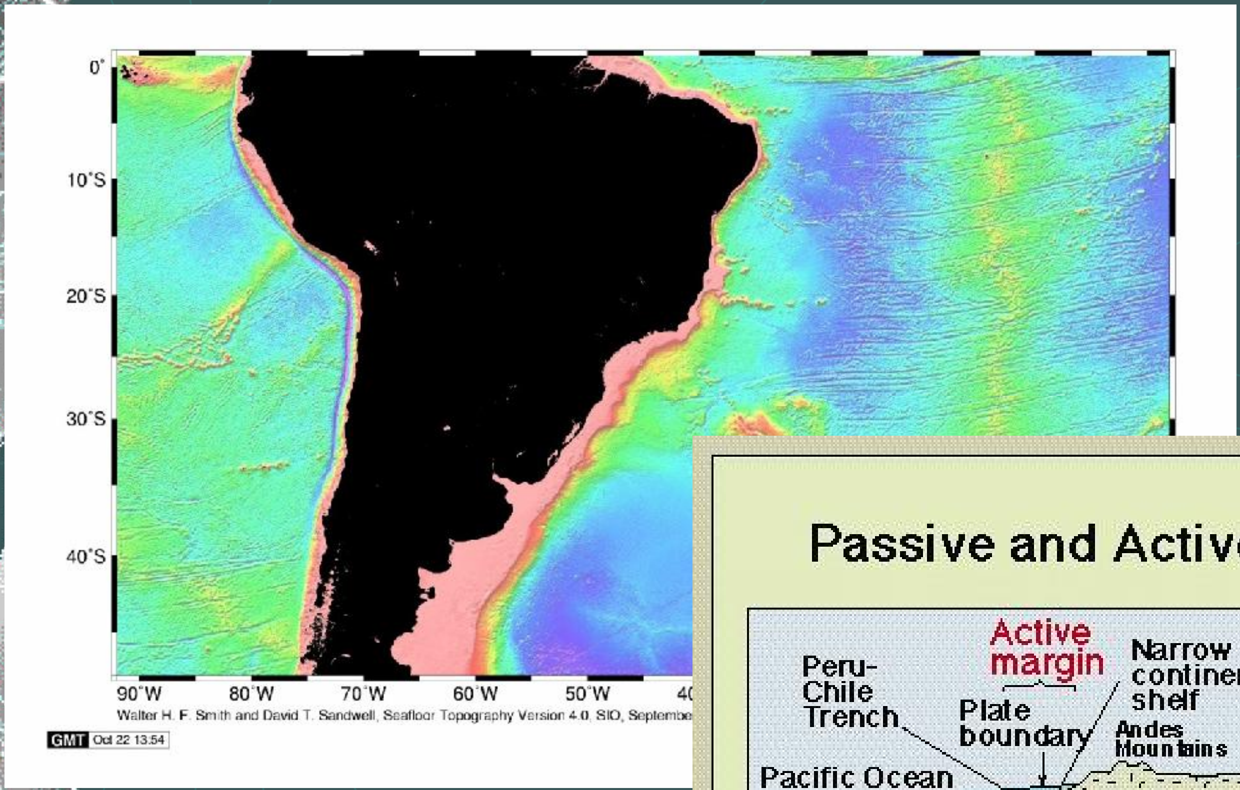
Passive Margins

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

Active Margins

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

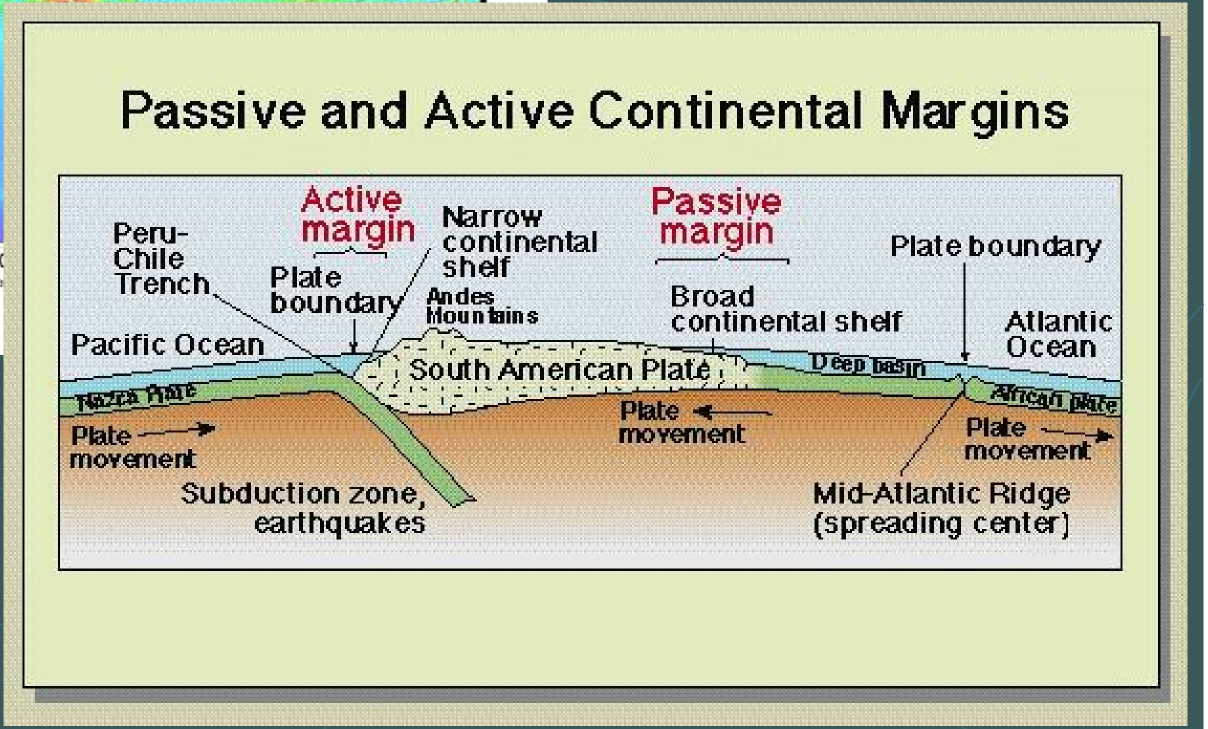
Active versus Passive Margins



Excellent Example:
South America

Active = West Coast

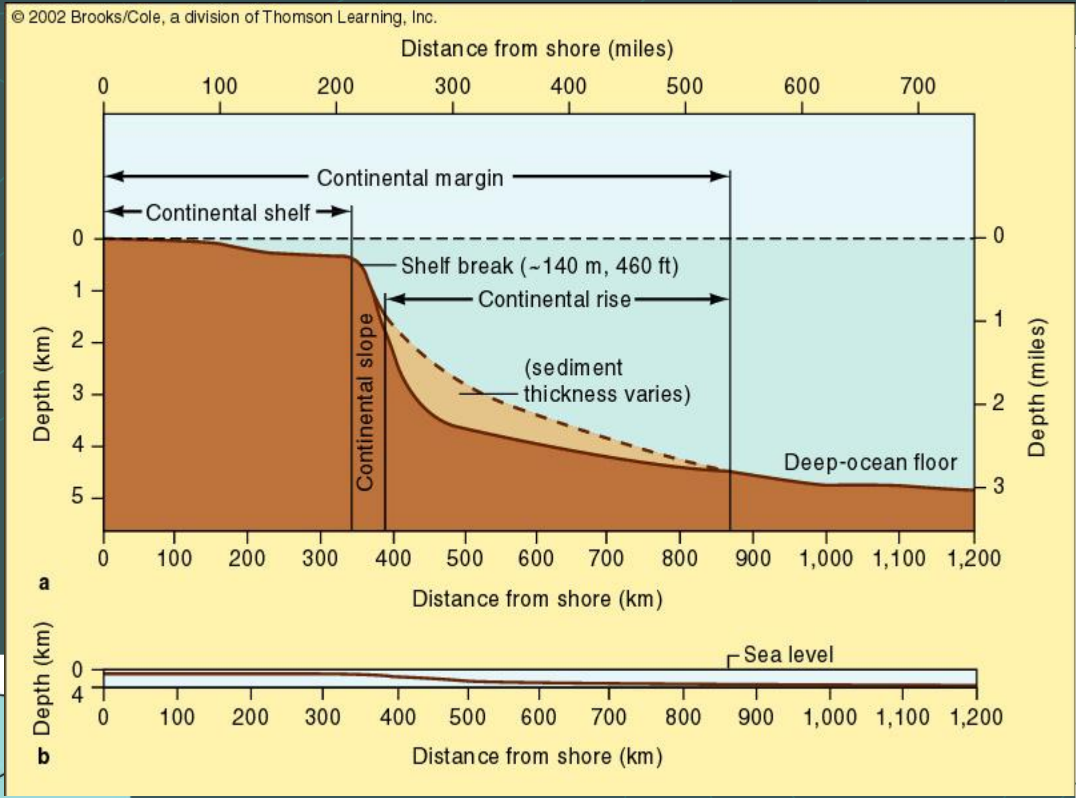
Passive = East Coast

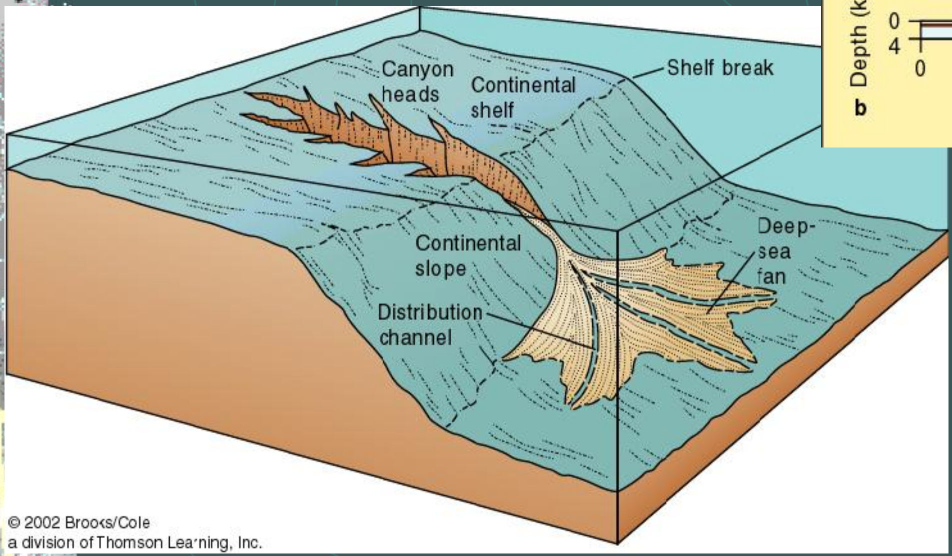


Continental Margin Features

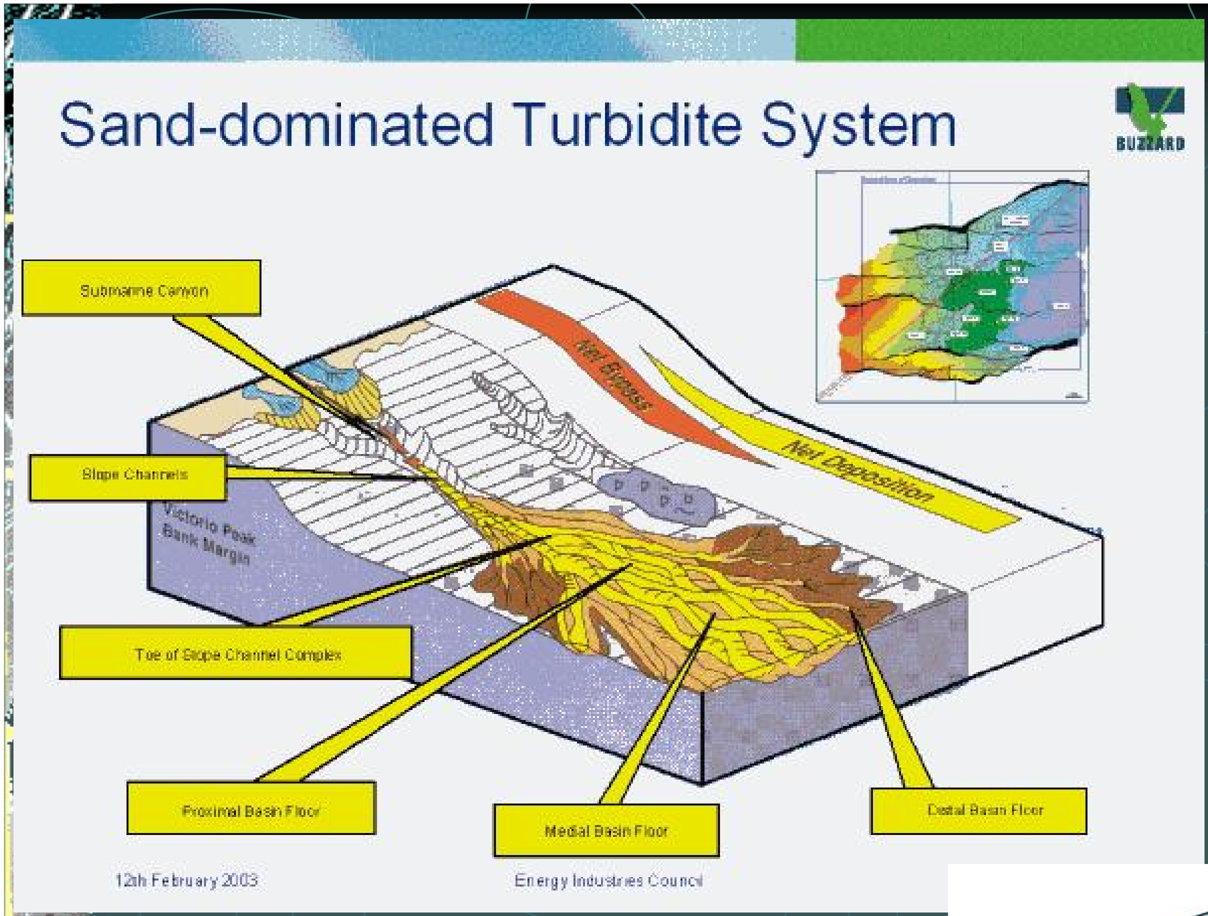
Major Features

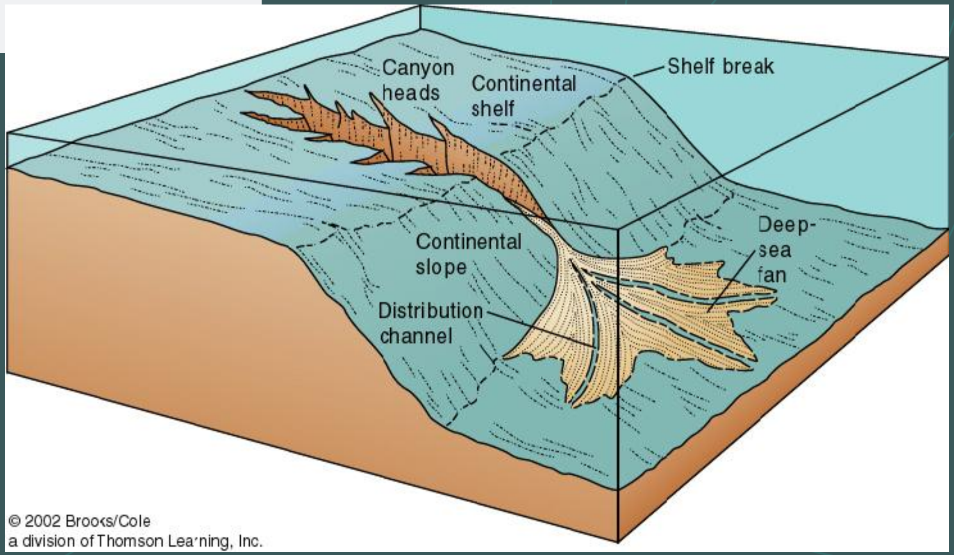
- Continental Shelf
- Continental Slope
- Slope Break
- Continental Rise
- Submarine Canyons



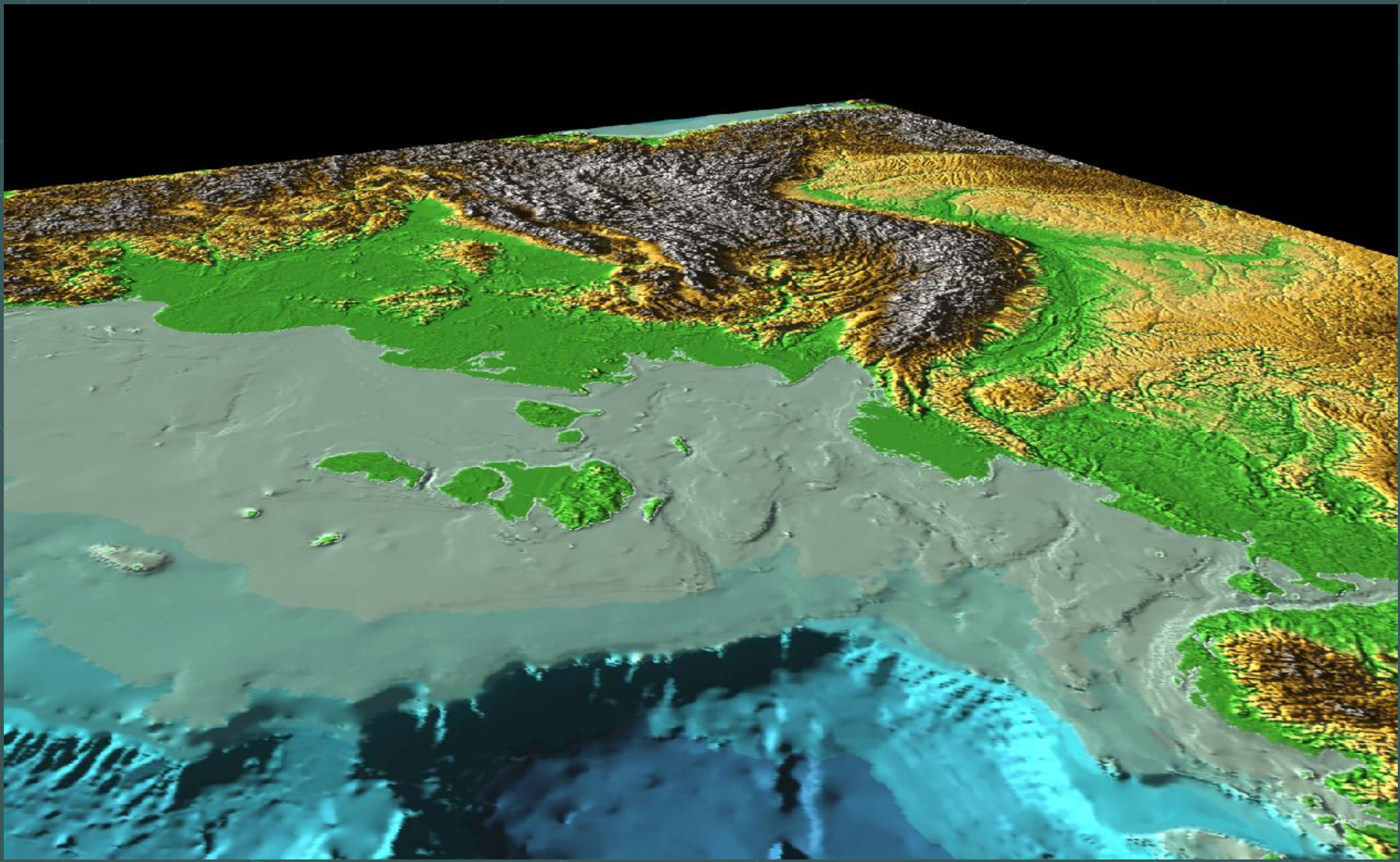


Turbidity Sedimentation





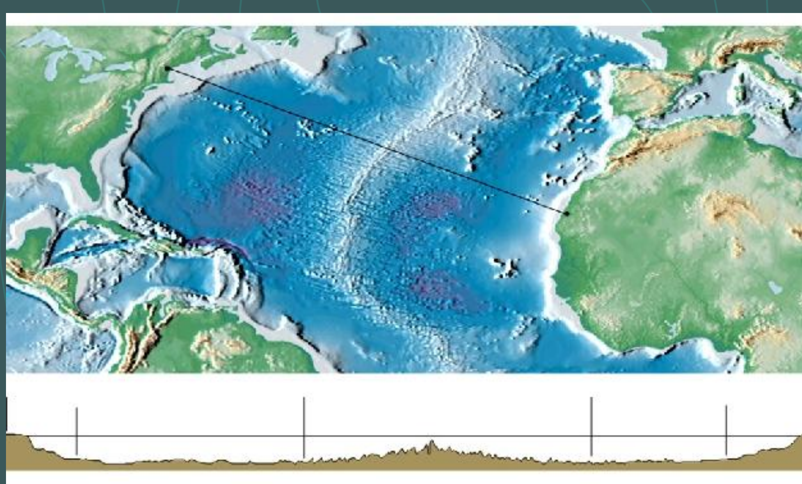
Passive Continental Margin

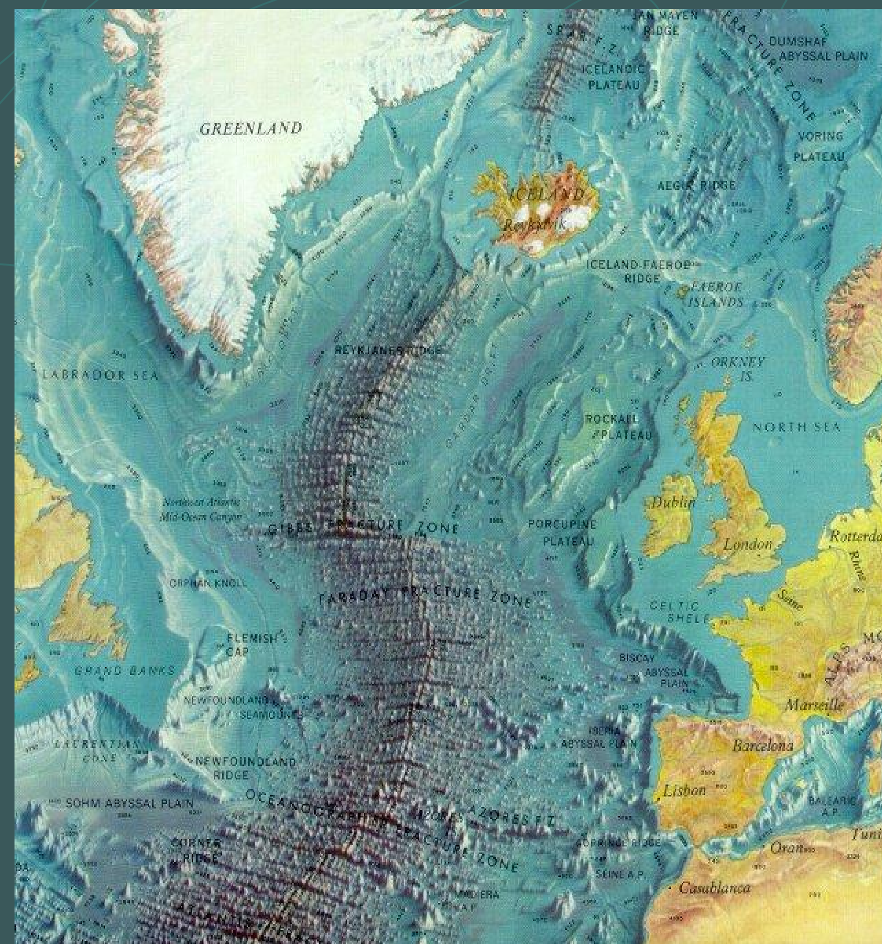


Example: Eastern Siberia -- Arctic Ocean Basin

Earth's Deep-Sea Basin Features

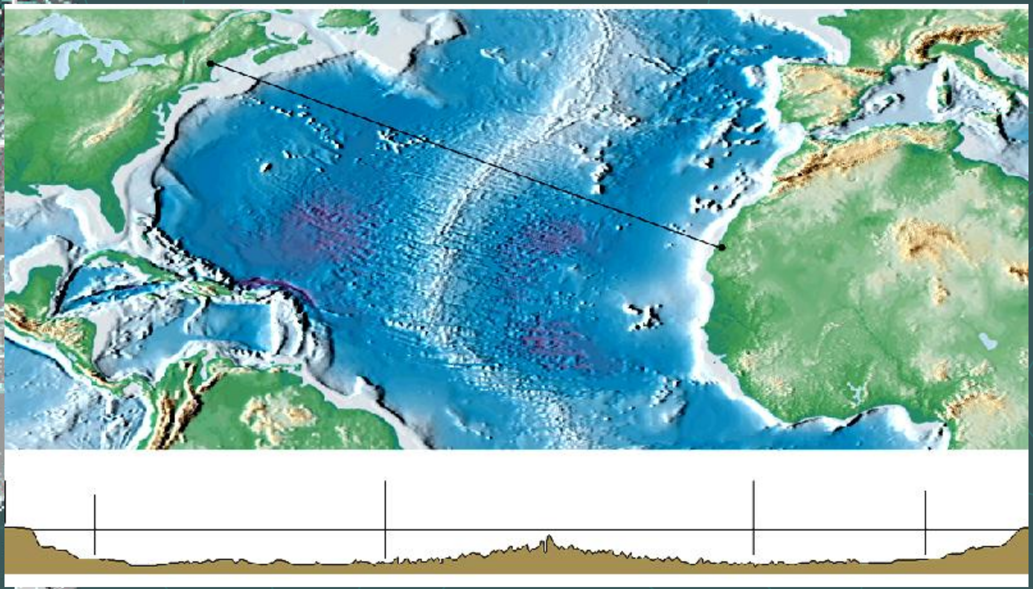
- Mid-Oceanic Ridge and Transform Fracture Systems
- Abyssal Hills and Plains
- Seamounts and Guyots
- Oceanic Islands and Plateaus
- Trenches and Island Arcs

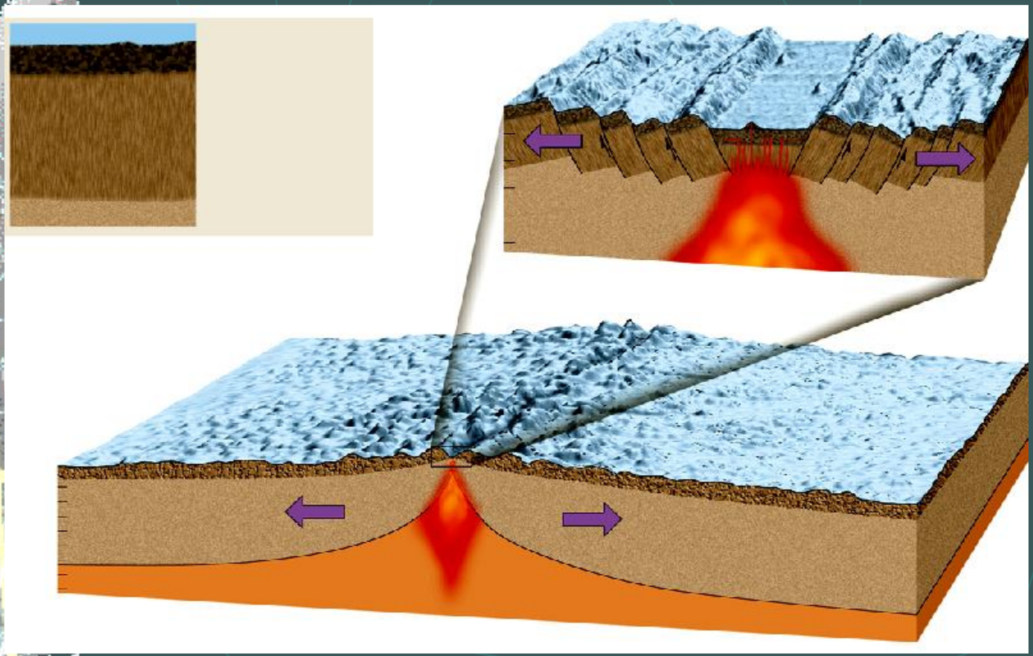




Profile: North Atlantic Ocean Basin

Mid-Ocean Ridge and Fracture Systems

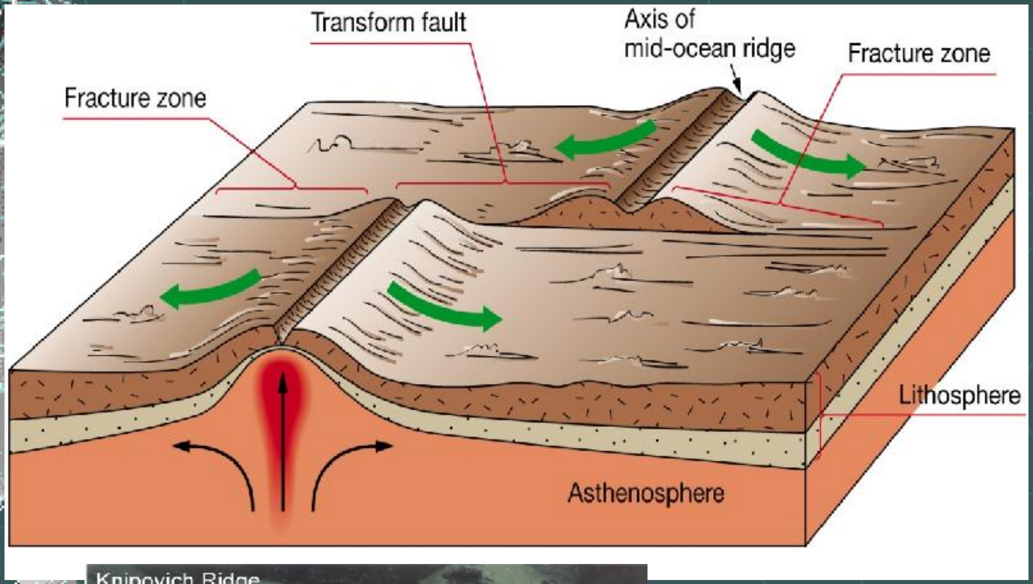


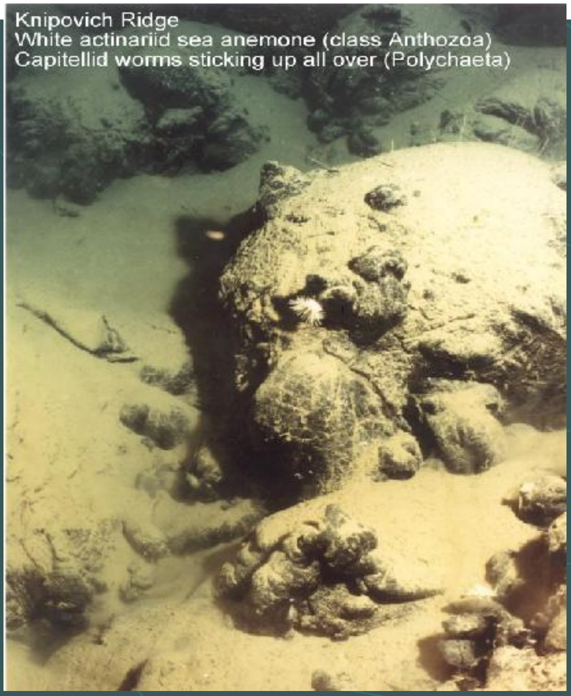


Key Points

- 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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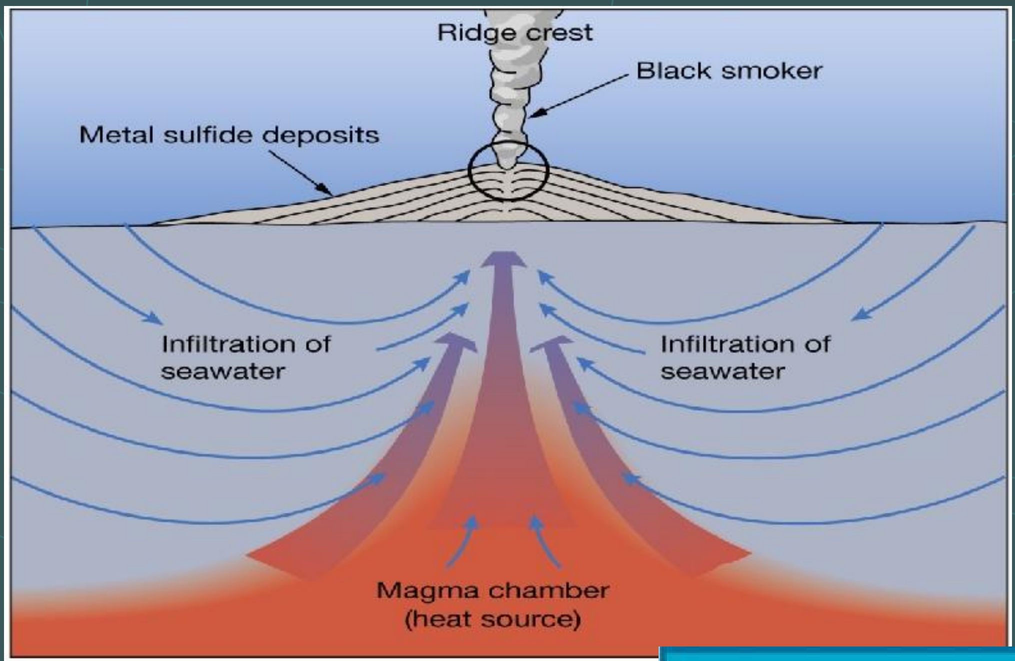
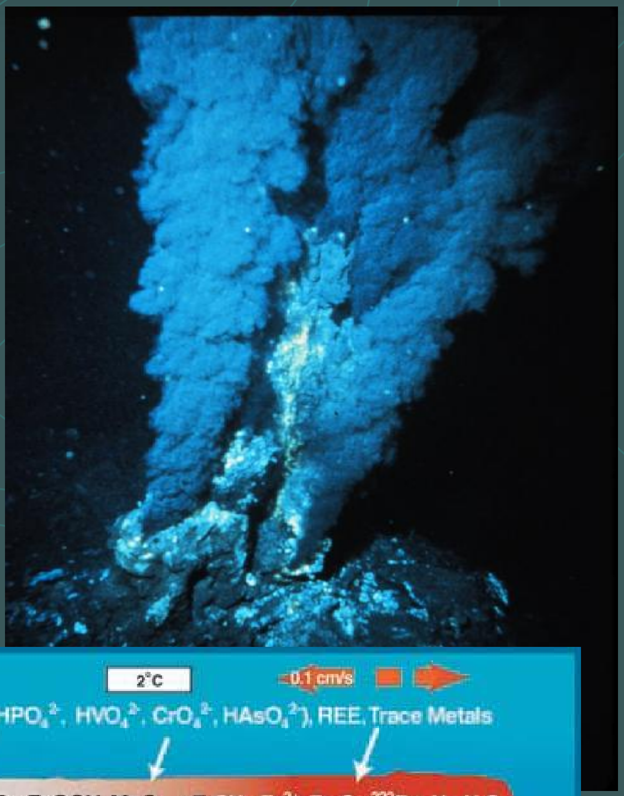
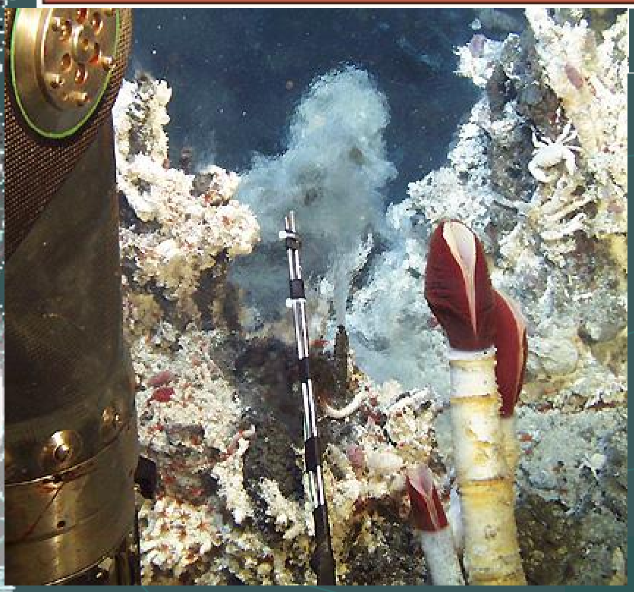
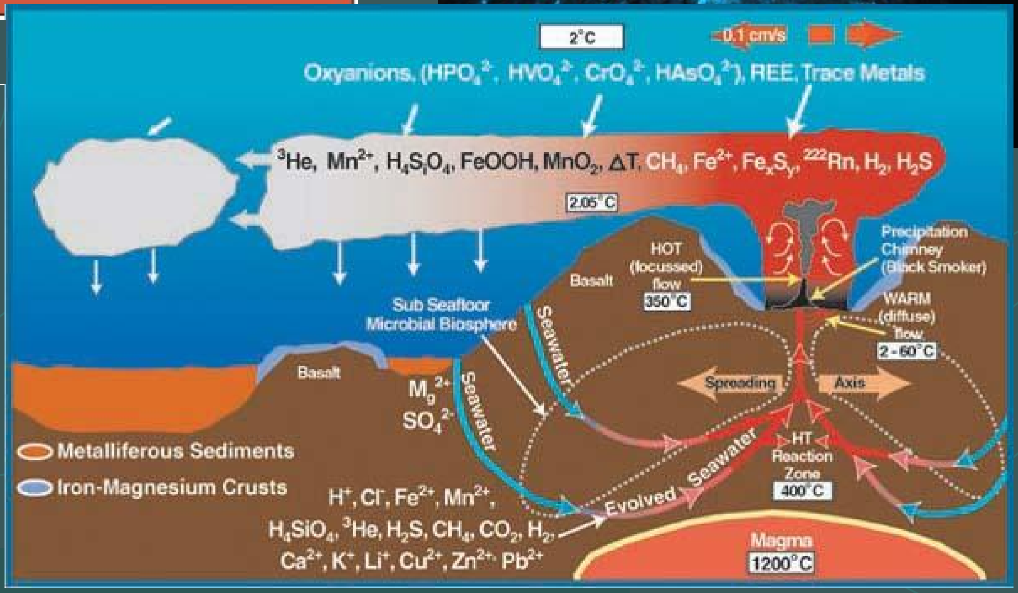
Mid-Ocean Ridge Hydrothermal Vents

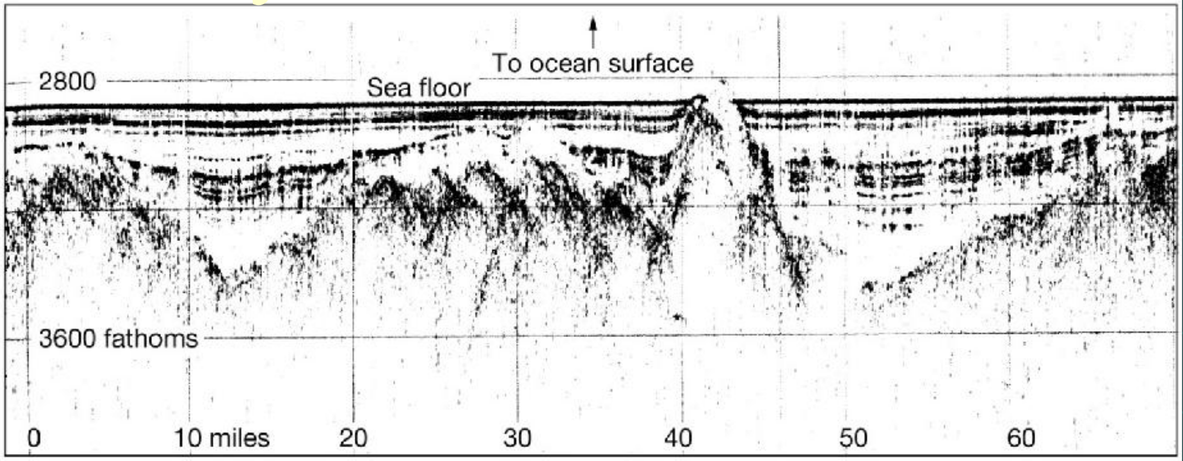


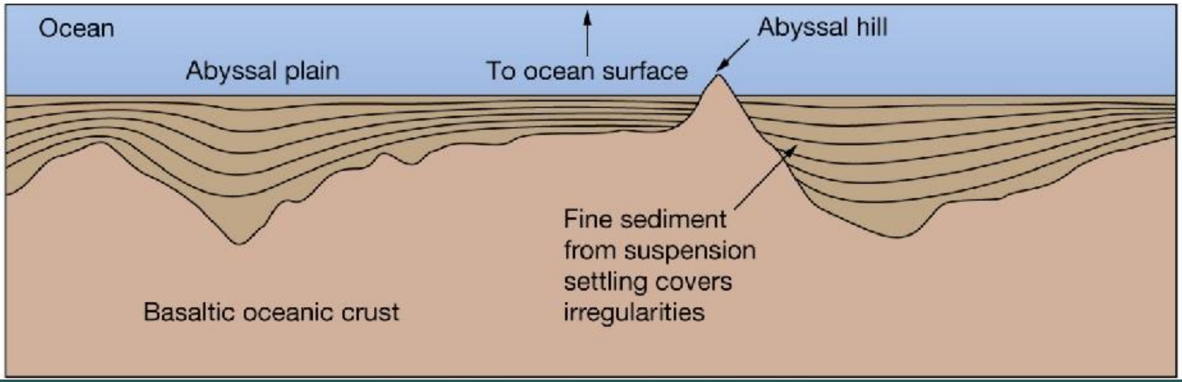






Abyssal Plains and Hills





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

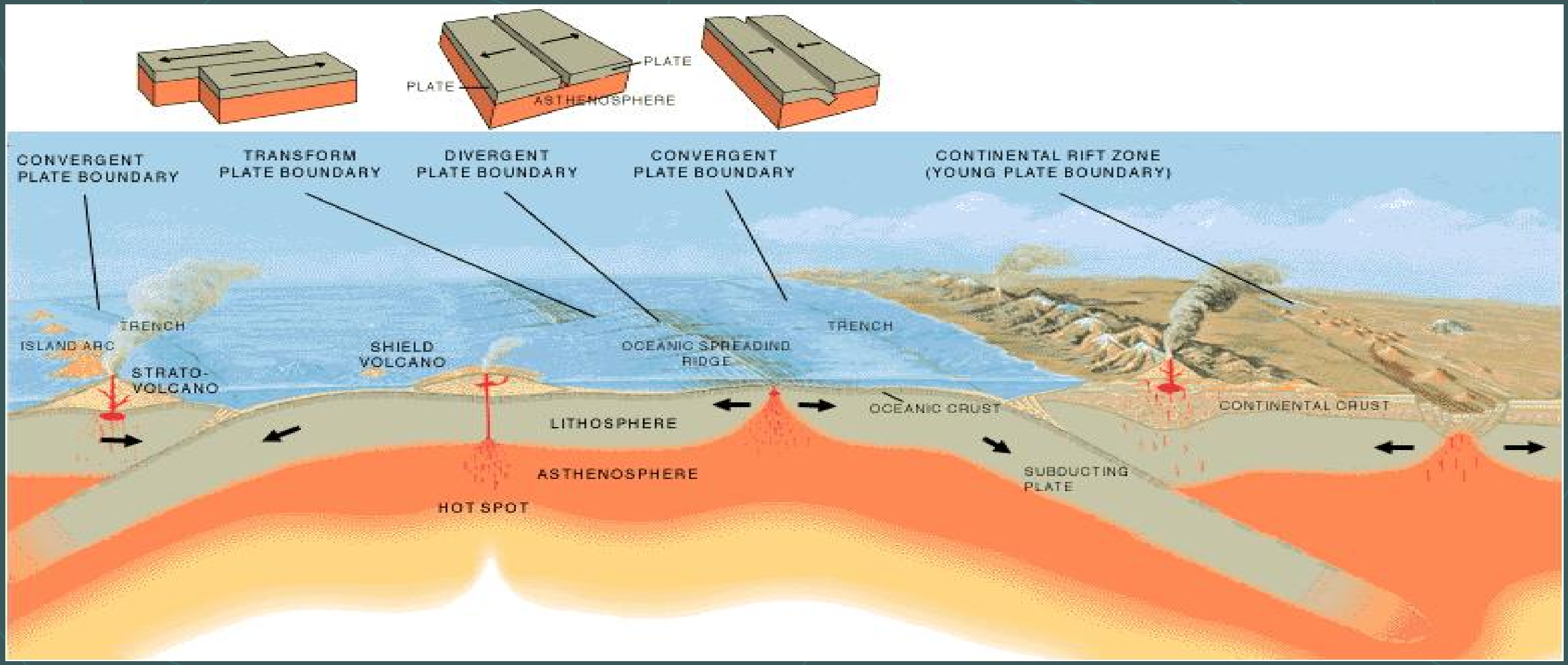
Abyssal Plains and Hills

Key Points

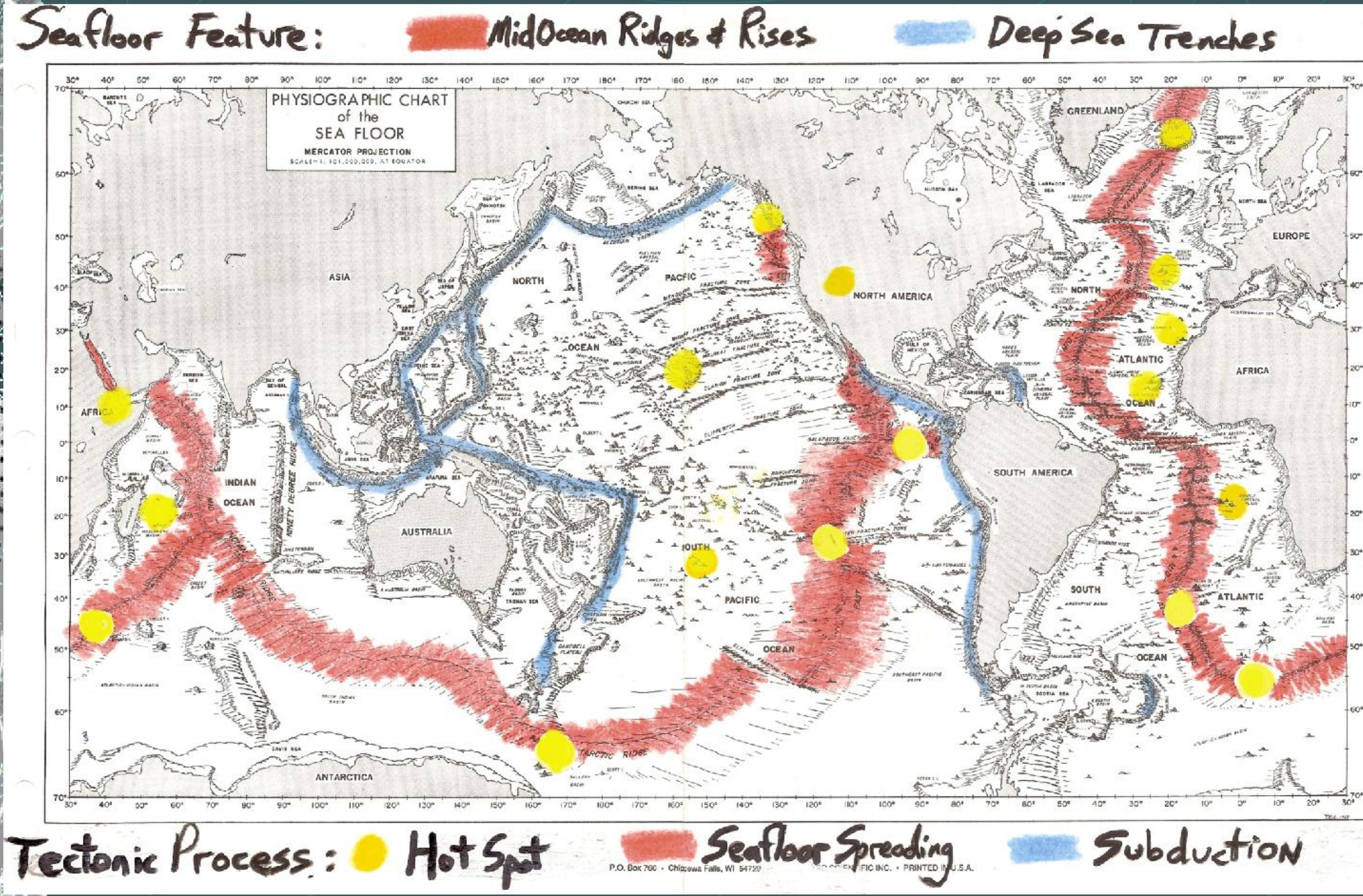
- Abyssal sediments are predominately clays and oozes
- Soft pelagic sediment is loaded with benthic organisms
- Benthic organisms crawl over and and burrow through the sediment = Bioturbation

PLATE TECTONICS and the SEAFLOOR

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



Seafloor Ridge and Trench Map

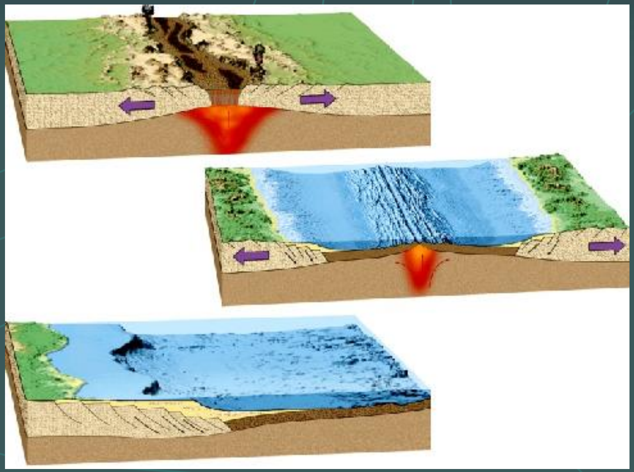


Earth Processes That Create Seafloor Features

Continental Margins

1) Features resulting from Continental Rifting

- Continental Shelf and Slope



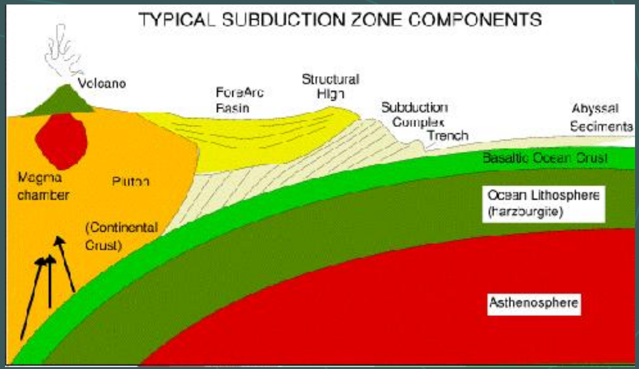
Deep-Sea Oceanic Basins

1) Features generated by Seafloor Spreading

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

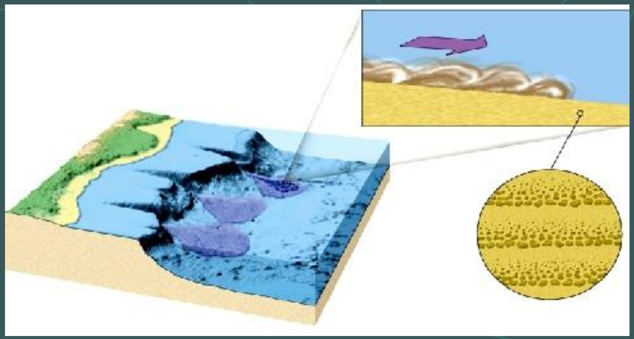
2) Features generated by Subduction

- 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
- 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

OCEAN BASINS and SEAFLOORS

Discussion