OCEANOGRAPHY

3. Marine Provinces

notes from the textbook, integrated with original contributions

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Introduction

- A flat, muddy ocean bottom?
  - For a long time, not much was known about the ocean

For centuries, the sea was shown on maps as a blank space between landmasses, which cartographers decorated with fantastic monsters to make up for the absence of other detail.

The Carta Marina (1539) by the Swedish topographer Olaus Magnus fills the otherwise empty ocean with strange creatures.

a flat, muddy ocean bottom?

- The answer is NO: there are three main marine provinces
  - continental margins
  - deep-ocean basins
  - mid-ocean ridges

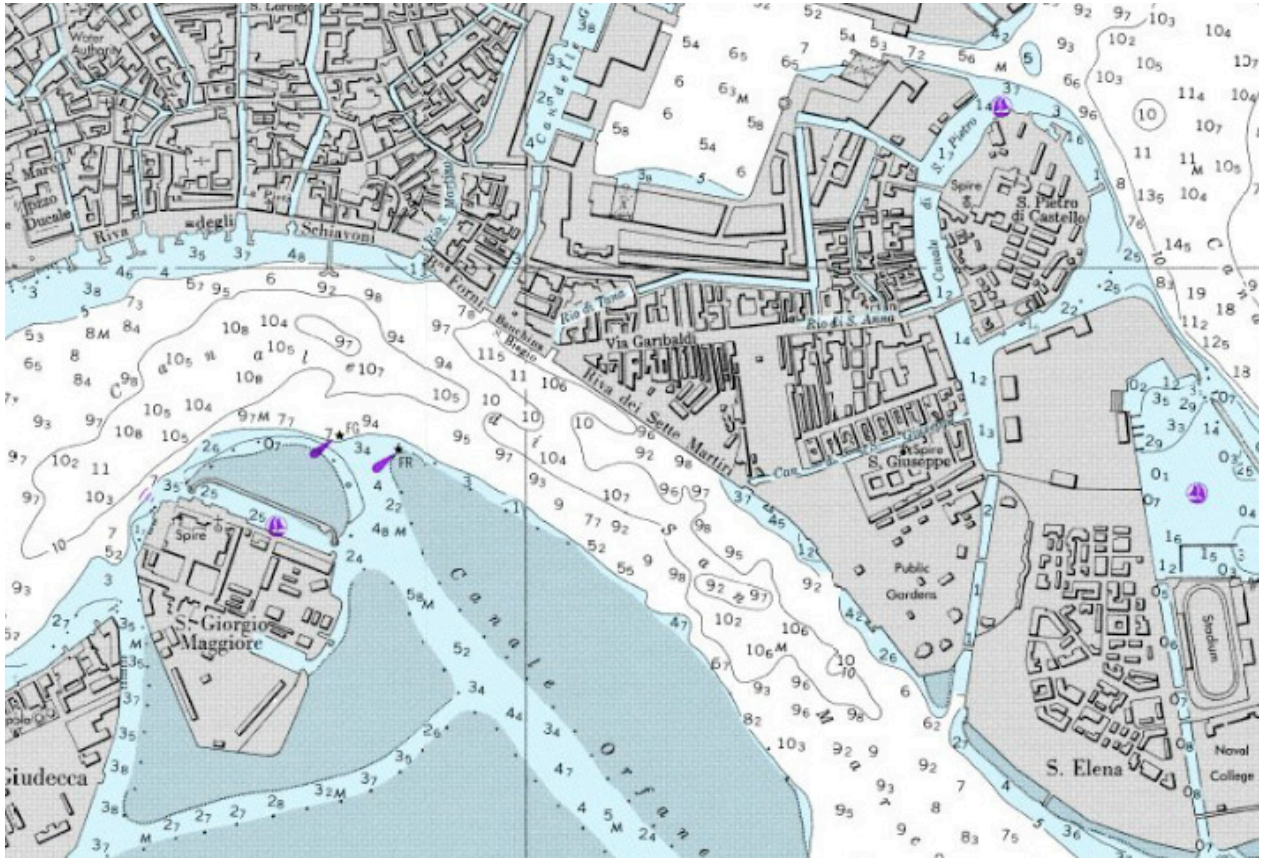
- This chapter describes
  - the bathymetry of the ocean and
  - its geographic and geologic features

3.1 - Bathymetry

- Bathymetry is the measurement of ocean depth (from the surface to the sea floor)
  - Soundings
  - Echo Soundings
  - Use of Satellites
  - Seismic Reflection Profiles

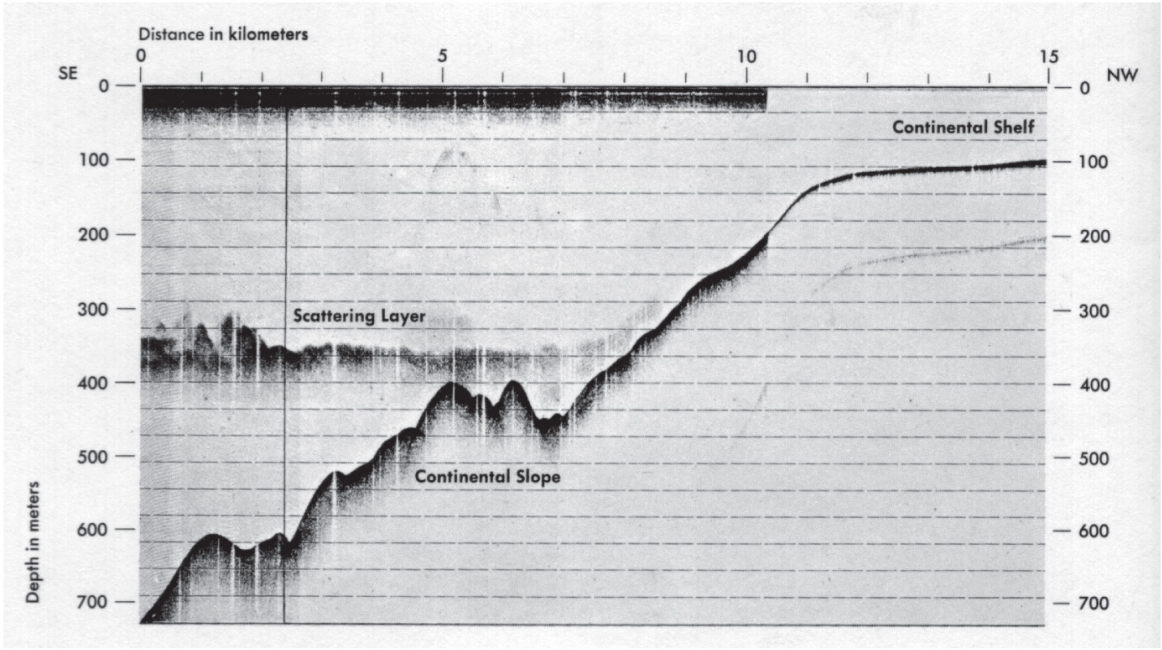
Soundings

- hand measurements done using a line with a heavy weight (fathom = 1.8 m)
- random measurements
- more accurate in harbors for navigation
- systematic measurements starting in 1872
  - first realized ocean bottom is not flat and lifeless



Echo Soundings

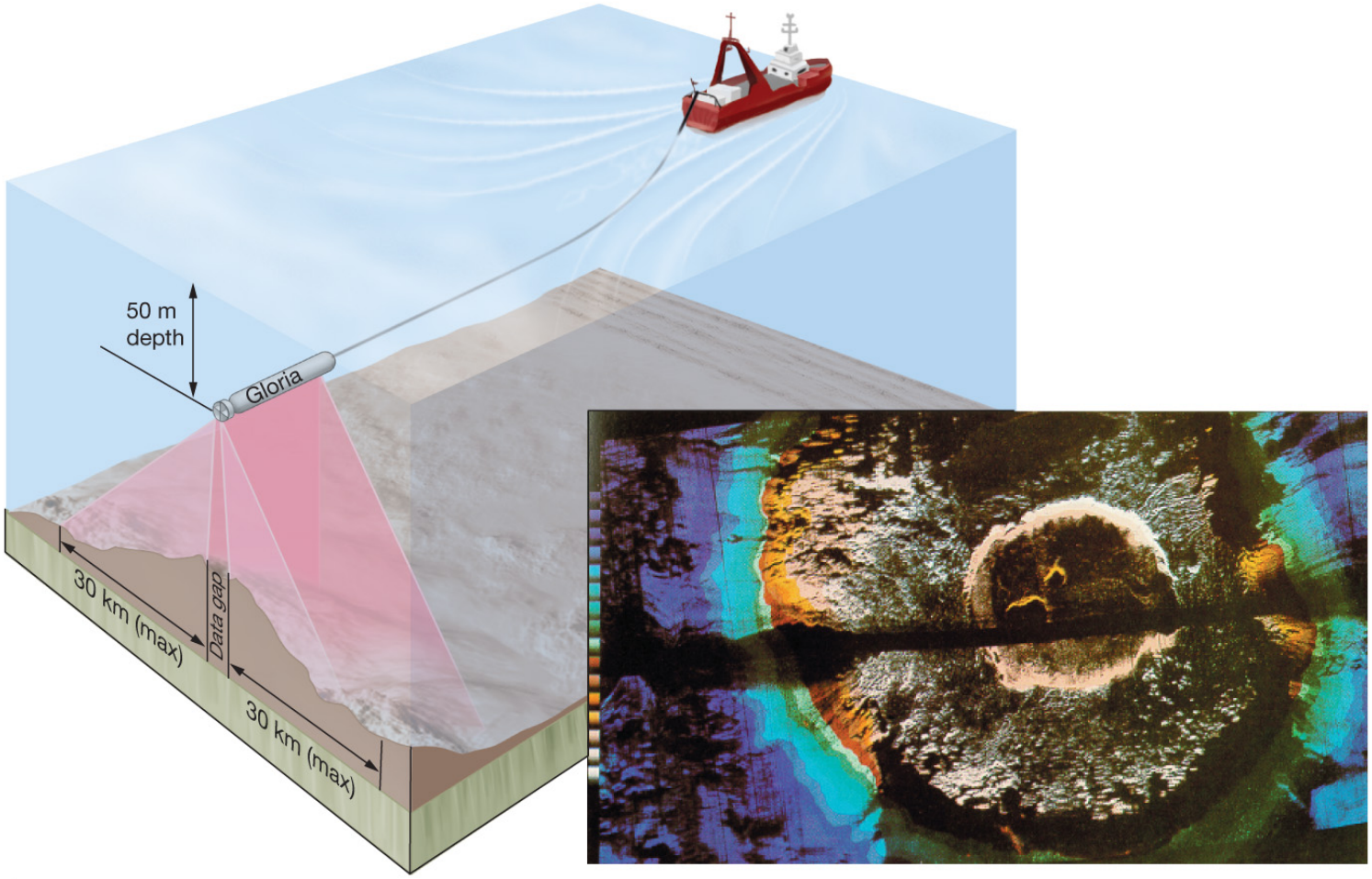
- An echo sounder sends a sound signal (ping) from a ship downward
- the ping bounces off any density difference
- Lacks detail
- May provide inaccurate view of sea floor



Echo Soundings

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

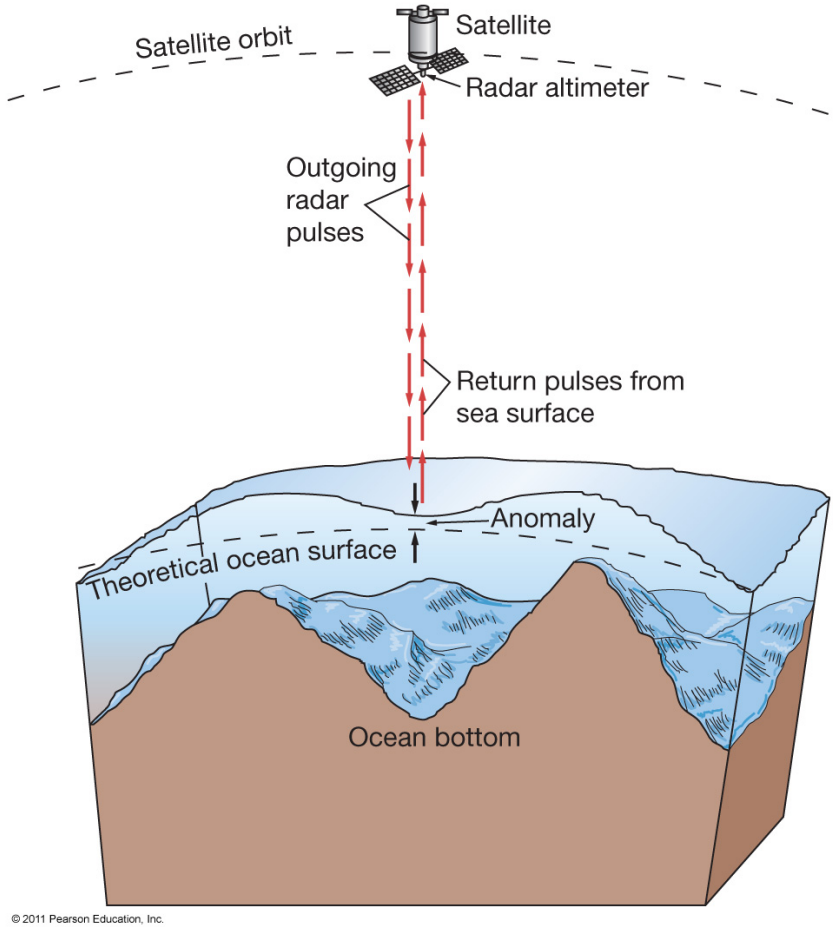
- Modern Acoustic Instruments
  - Multi-beam echo sounder
    - Seabeam
  - Side Scan Sonar (*so*und *na*vigation and *r*anging)
    - Can be towed behind ship to provide very detailed bathymetric strip map



Side-scan sonar image of a volcano with a summit crater about 2 km (1.2 mi) in diameter in the Pacific Ocean

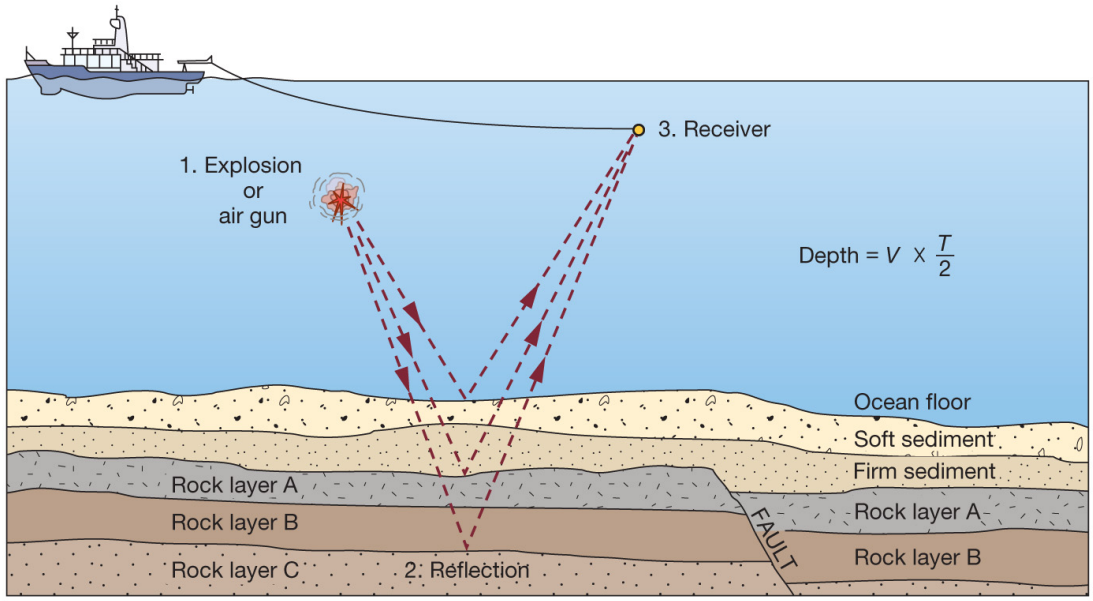
Satellites: Sea Floor Mapping from Space

- Uses satellite measurements
- Measures sea floor features based on gravitational bulges in sea surface
- Indirectly reveals bathymetry



Seismic Reflection Profiles

- Allow to know ocean structure beneath sea floor (also used on land)
- Use air guns to produce strong, low-frequency sounds
- Sounds penetrate rocks and reflect off boundaries between different layers



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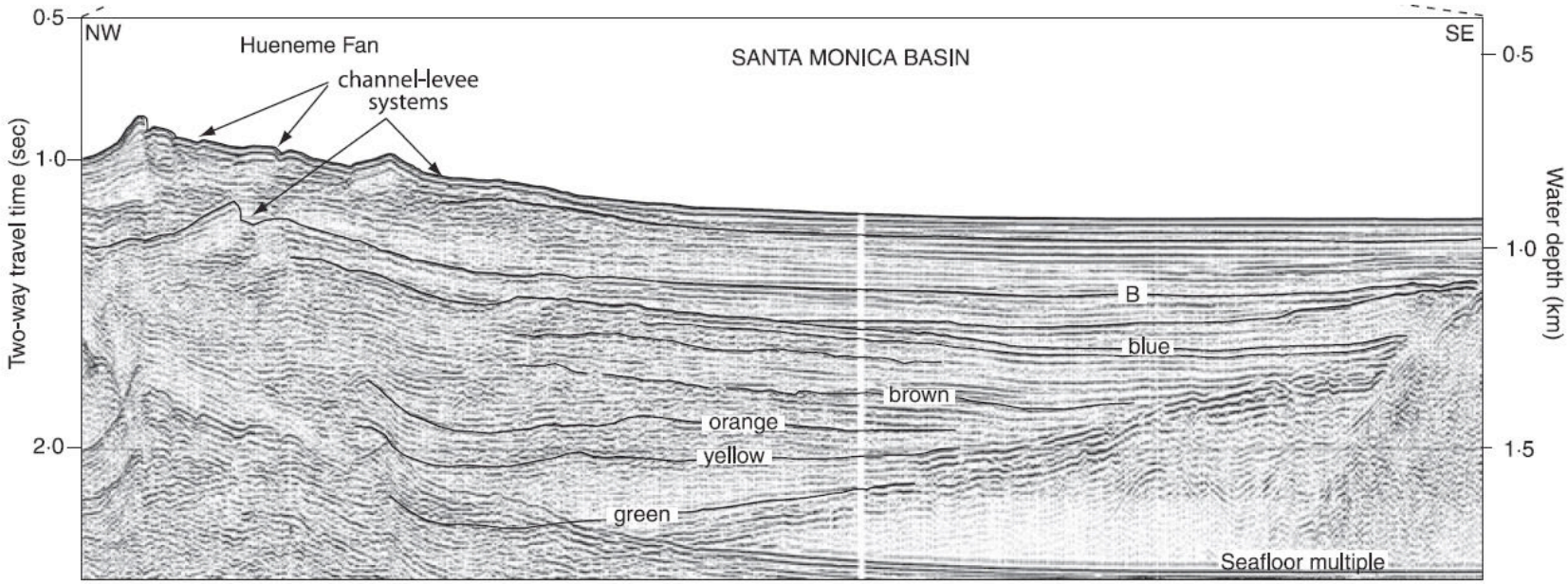
Seismic Reflection Profiles

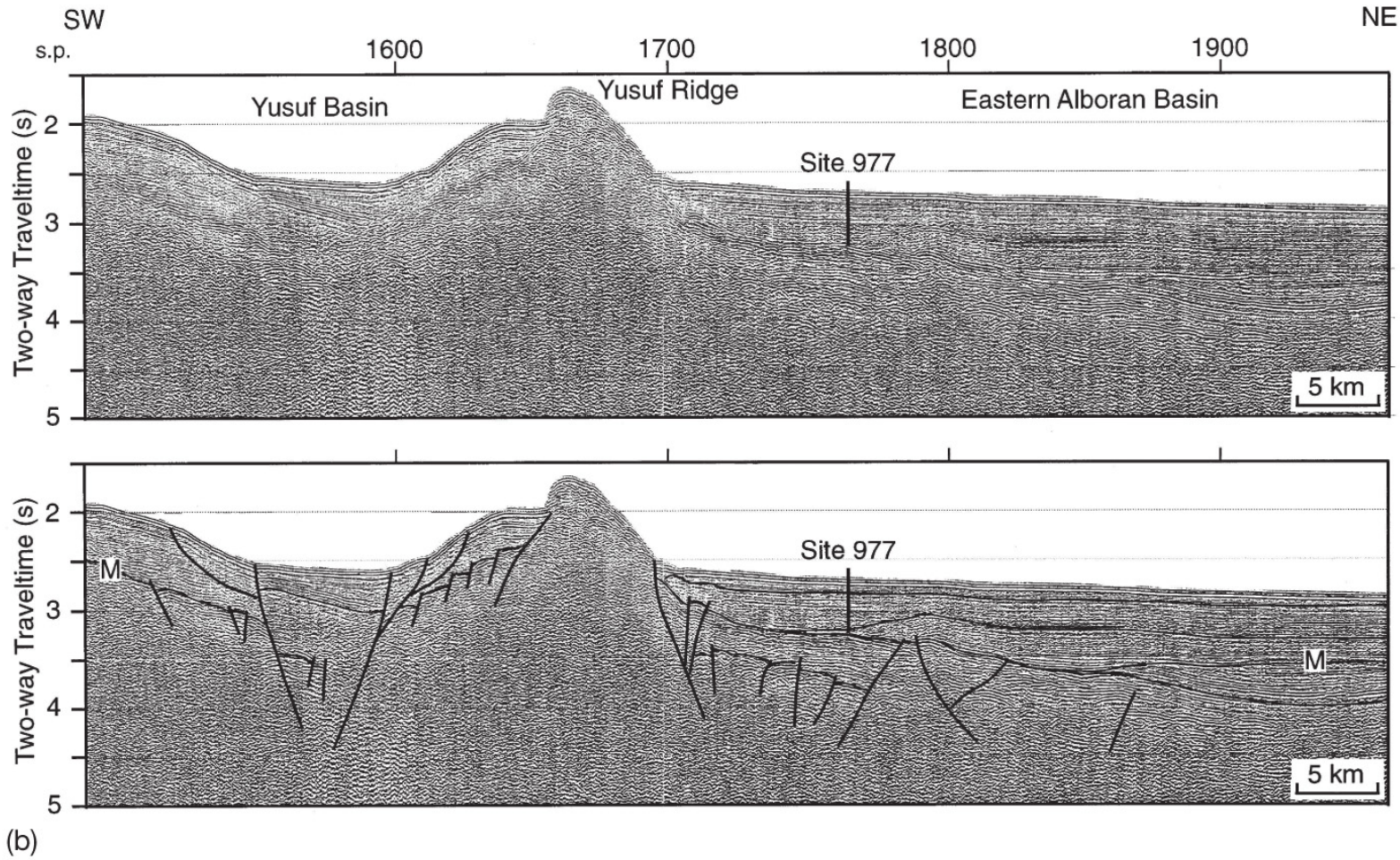
- Details the ocean structure beneath sea floor



A seismic reflection profile form northern Santa Monica Basin

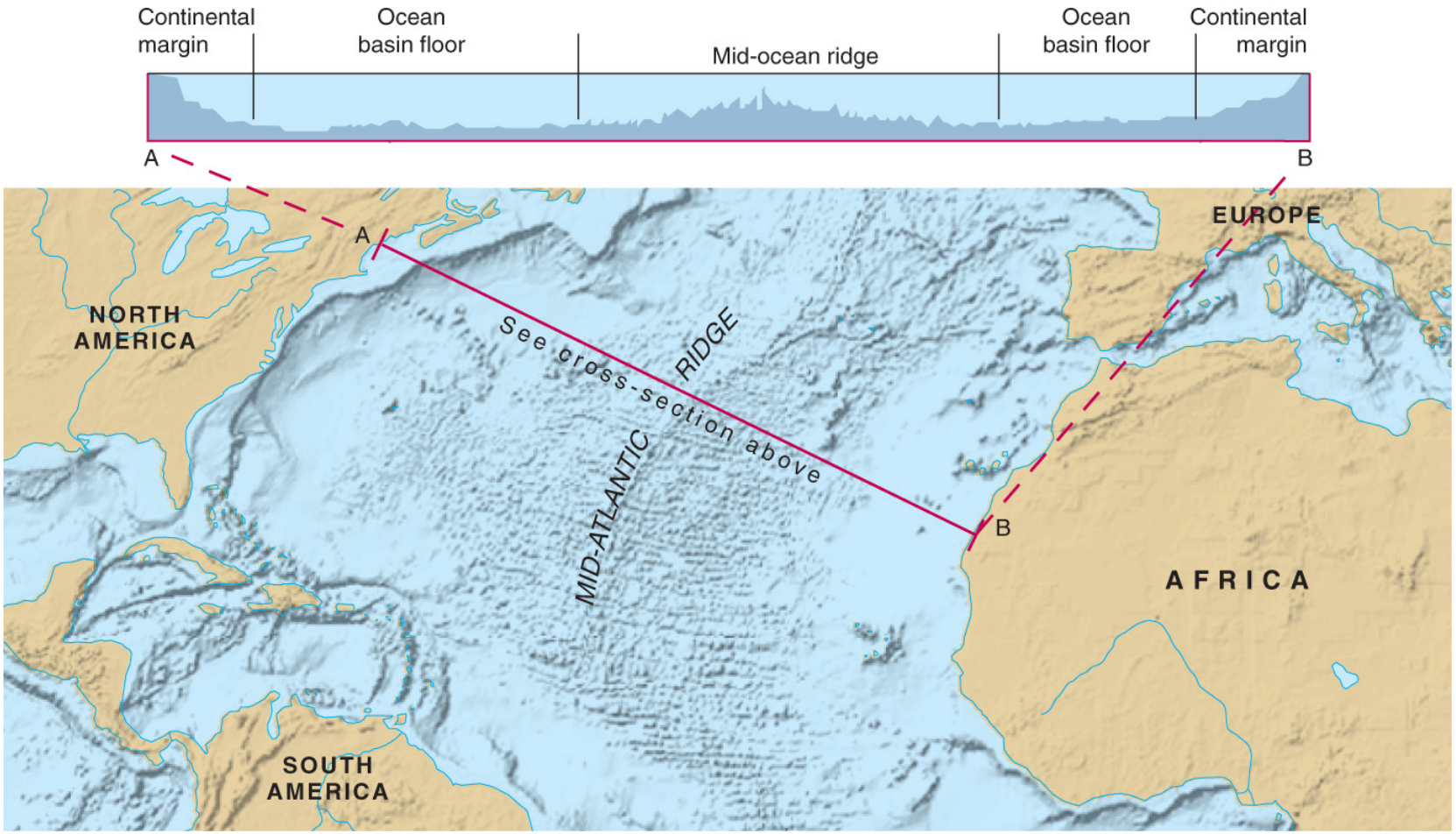
From Normark, W.R., D.J.W. Piper, and R. Sliter, 2006, Sea-level and tectonic control of middle to late Pleistocene turbidite systems in Santa Monica Basin, offshore California: Sedimentology, v. 53, p. 867-897. Explore online: http://pubs.usgs.gov/of/2006/1180/index.html

Seismic Reflection Profiles



Ocean Provinces

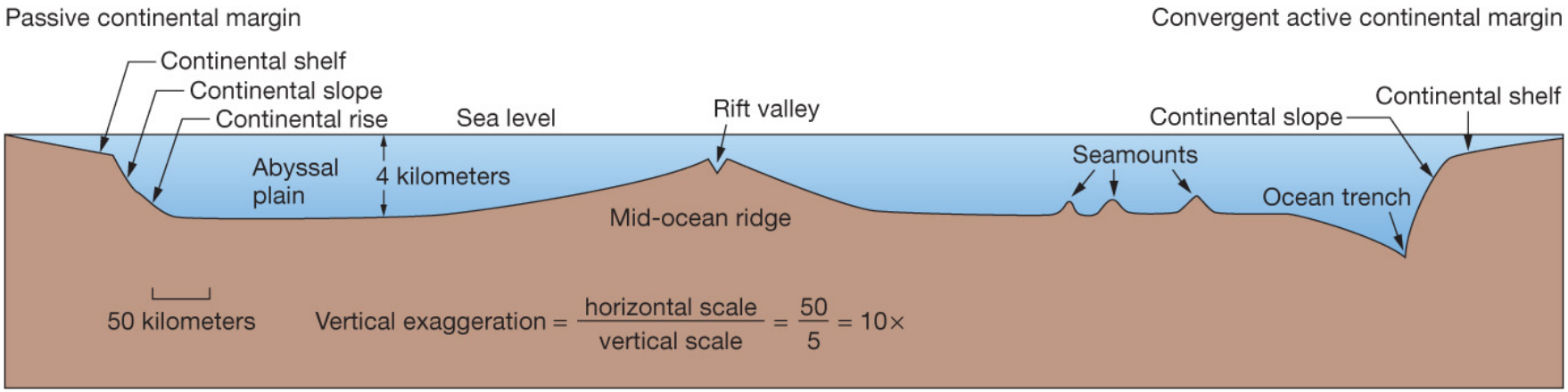
- There are three major Ocean provinces:
  - Continental margins
    - Shallow-water areas close to shore
  - Deep-ocean basins
    - Deep-water areas farther from land
  - Mid-ocean ridge
    - Submarine mountain range



3.2 – Features of Continental Margins

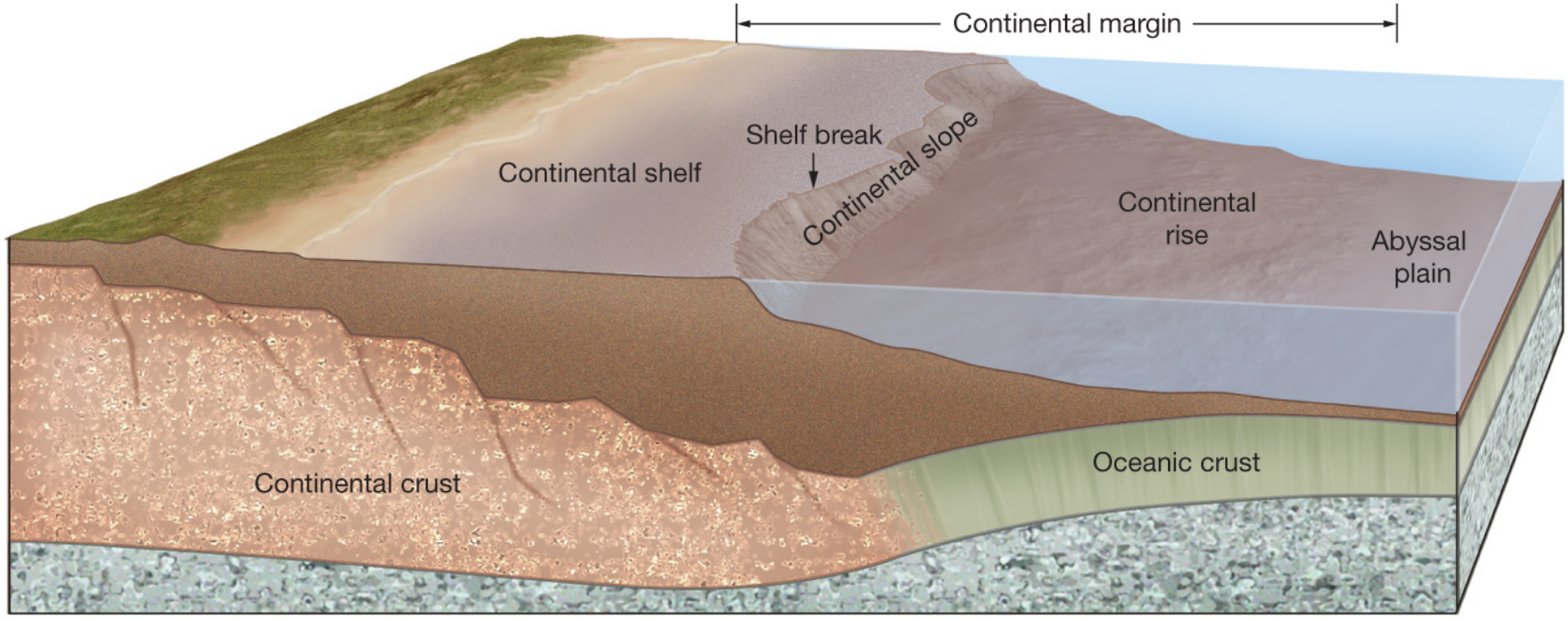
- Two kinds of Continental Margins:
  - Active Continental Margins
    - Associated with convergent or transform plate boundaries
    - Tectonic activity
  - Passive Continental Margins
    - Not close to any plate boundary
    - No major tectonic activity

- Continental Margins features include:
  - the Shelf
  - the Slope
    - incised by Submarine Canyons
    - where Turbidity Currents run
  - the Continental Rise
    - not found in Active Continental Margins



Passive Continental Margins

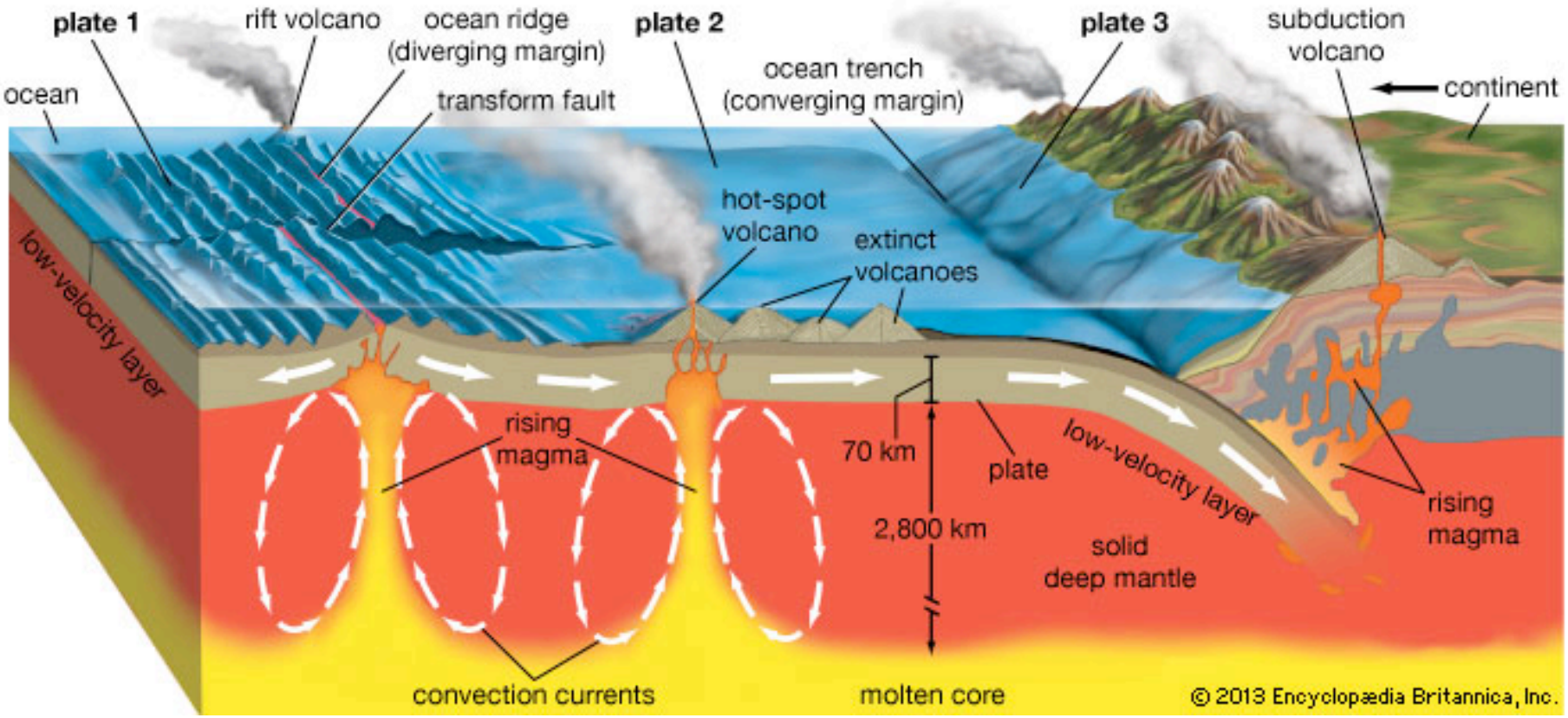
- Not close to plate boundary, hence no tectonic activity
- Part of the continental crust (not oceanic)
- Usually produced by rifting of continental landmasses and continued seafloor spreading
- Include the complete suite: shelf, slope and rise



Active Continental Margins

- Convergent
  - Oceanic-continent convergent plate boundaries
  - Active continental volcanoes
  - Narrow shelf
  - Offshore trench
- Transform
  - Less common
  - Transform plate boundaries
  - Linear islands, banks, and deep basins close to shore

Active Continental Margin: Convergent

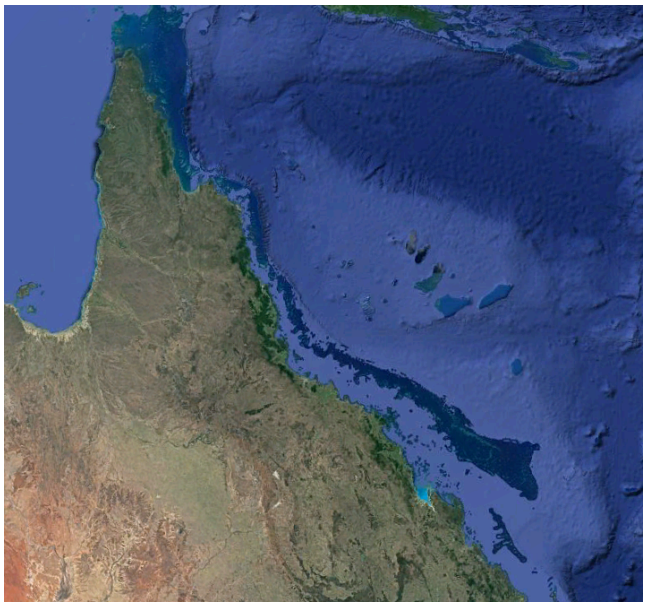


Active Continental Margin: Transform

Continental Shelf

- generally flat zones from coastline to shelf break
- can contain islands, reefs, raised banks
- on continental crust (that is, the shelf IS part of continent)

islands offshore California
(continental borderland)



the Great Barrier Reef
offshore Australia

- Shelf width can go from 10s of meters to 1500 km
- Average shelf depth is 135 m (350 m in Antarctica)
- Average slope of shelf is 1/10 of a degree

- Shelf can be exposed or flooded depending on icehouse/greenhouse times

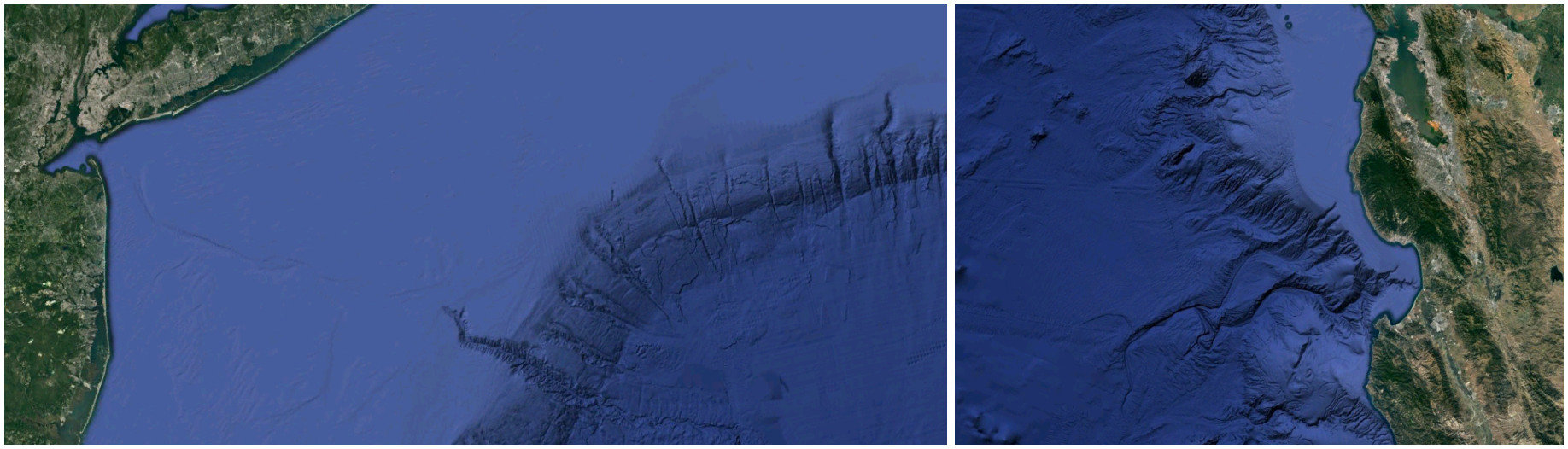
compare the width of the shelf along the western (active) and the eastern (passive) margin of North America

The widest shelf in the world (Russia, with Siberia and Kamchatka peninsula is to the left, Alaska and the Aleutian Islands to the right and the bottom of the picture)

Continental Slope

- extends from Shelf Break to the Deep Ocean
- from 1 to 5 km of vertical relief (up to 15 km if on active margin, where trenches are located)
- slope angle between 1° and 25°

- incised by submarine canyons



Left: submarine canyons along the eastern passive margin of North America (by New York, NY)
Right: submarine canyons along the western active margin of North America (by San Francisco, CA)

Submarine Canyons

- Most of them are only on the shelf, and NOT directly offshore rivers
- Narrow, deep, V-shaped in profile
- Steep to overhanging walls
- Extend to base of continental slope, 3500 meters below sea level.
- Created on the slope and possibly expanding over time backward onto the continental shelf

Hueneme, Santa Monica and Redondo submarine canyons in Santa Monica Bay

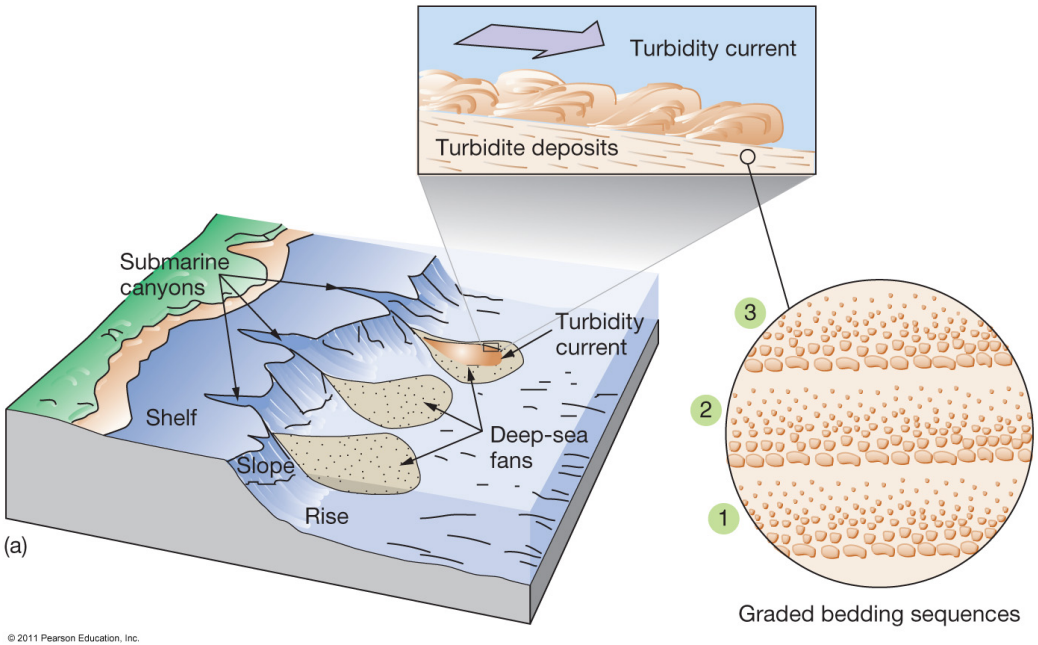
Submarine Canyons

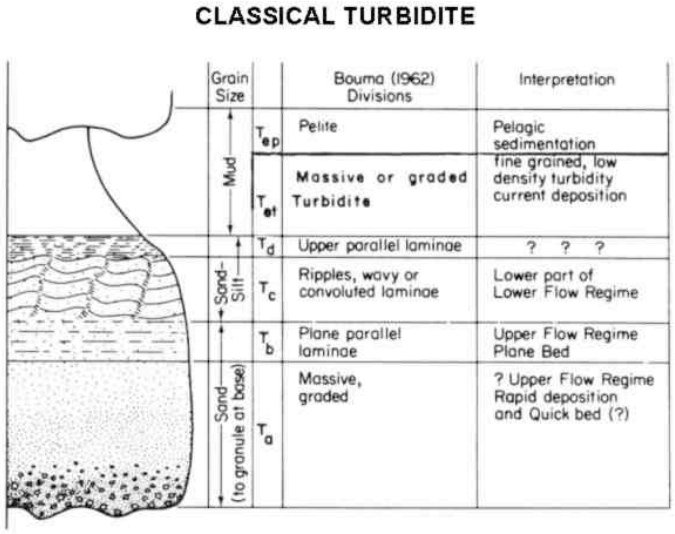
- Carved by turbidity currents (underwater density currents that carry sand and mud to the ocean bottom starting for the shelf)

- Sand and mud come form land, move on the shelf, and can be moved down the canyon by oversteepening, shaking by earthquakes, hurricanes, flooding from land

Turbidity Currents

- Currents deposit turbidites
  - graded beds
  - organized in a “Bouma Sequence”
  - graywacke sandstones



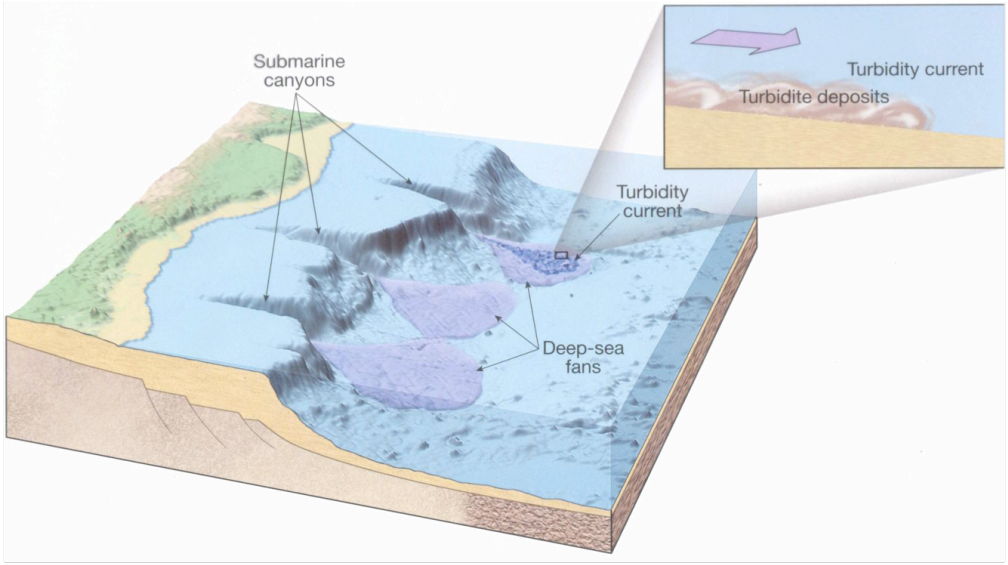


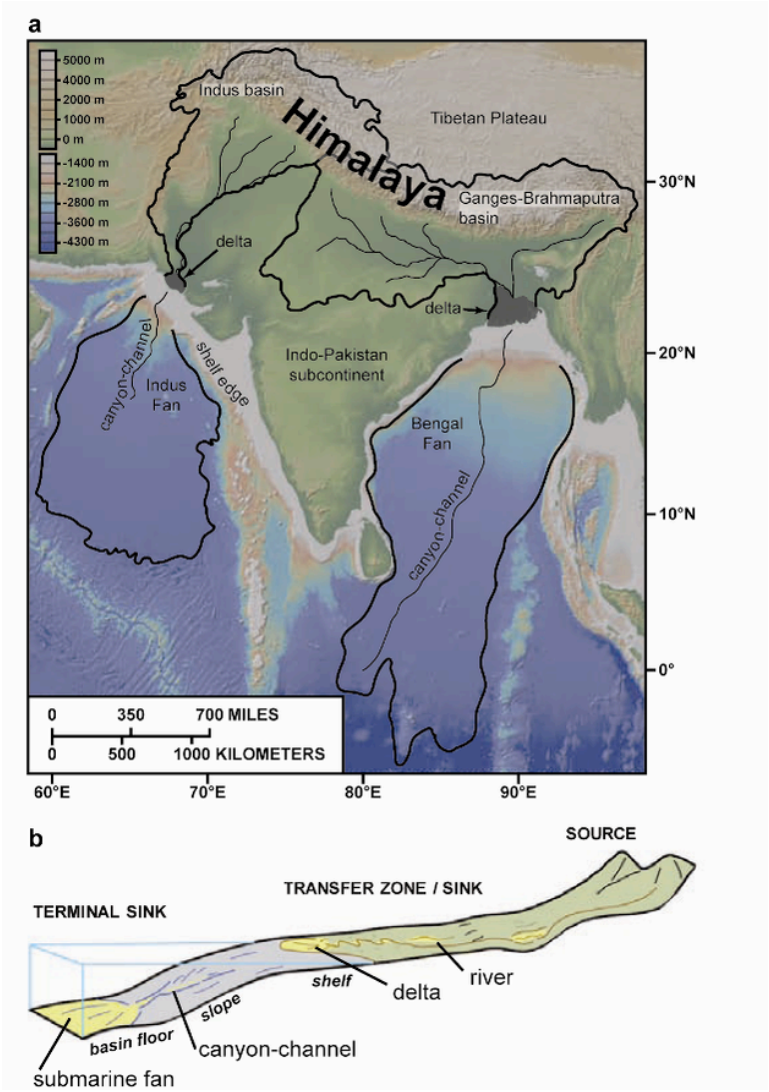
Turbidites

Deep-marine turbidite deposits from the Northern Apennines of Italy

Continental Rise

- Turbidites leaving submarine canyons are deposited at the base of the continental slope
- They form abyssal fans, which would coalesce into the continental rise
- The continental rise marks the transition between the slope and the abyssal plain of the deep ocean

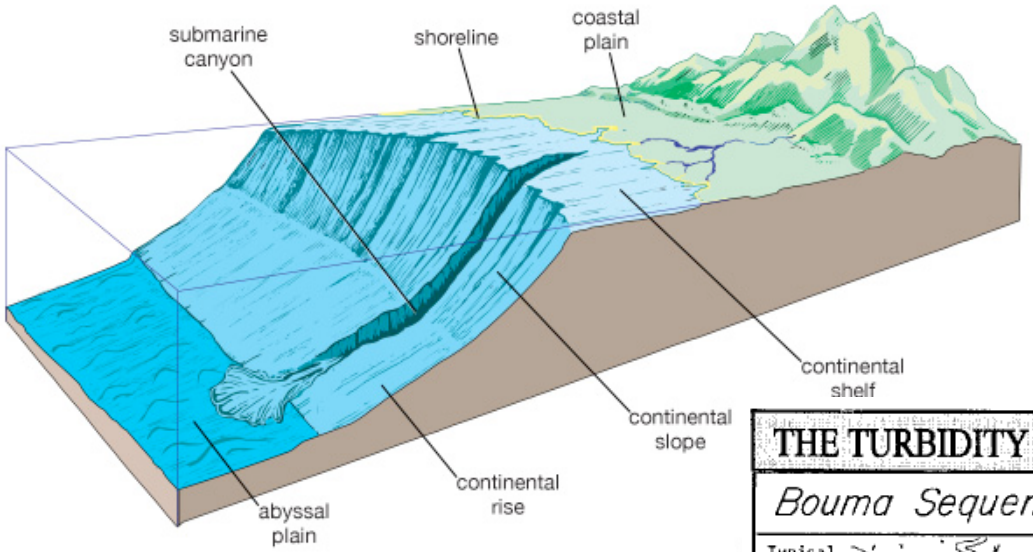


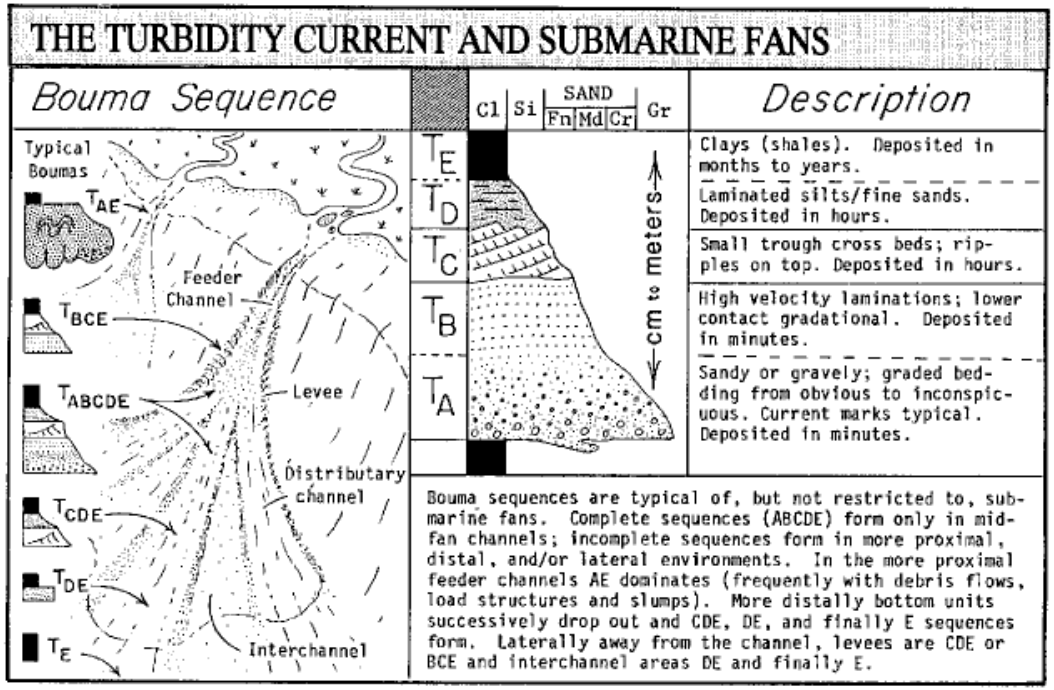


The biggest submarine fans of the world: the Indus and the Bengal fans, in the Indian Ocean

the Abyssal Fan and the Continental Rise:

morphology and Bouma Sequence structure



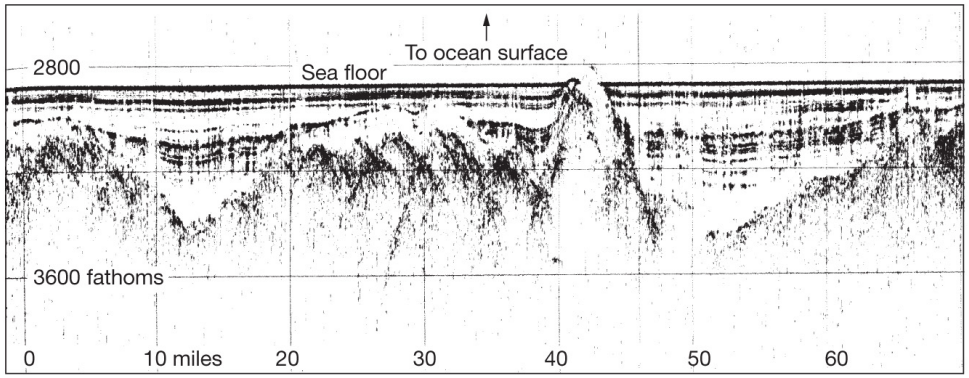


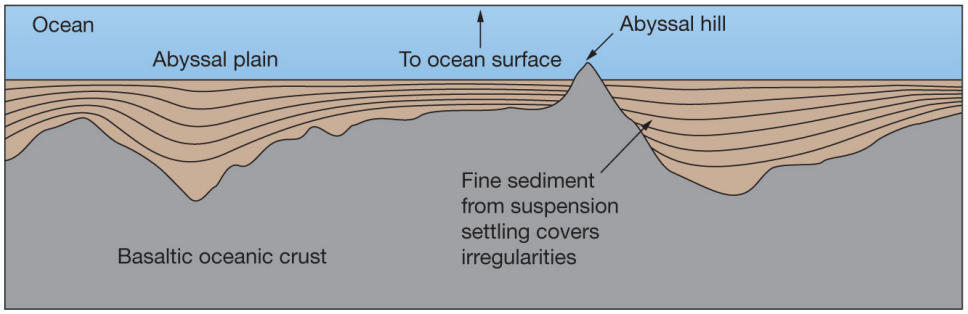
3.3 – Features of Deep-Ocean Basins

- Deep oceans lie beyond the continental rise and include the following provinces:
  - Abyssal Plains
  - Volcanic Peaks of the Abyssal Plains
  - Ocean Trenches and Volcanic Arcs

Abyssal Plains

- Ocean bottom, extending from base of continental rise
- Deepest and flattest regions on Earth
- Average depth between 4500 and 6000 m
- Roughness of oceanic crust is covered (blanketed) by fine particles of sediment slowly settling on it (pelagic sediments + turbidites)
- Well-developed in Atlantic and Indian oceans (lack of trenches)





Volcanic Peaks of the Abyssal Plain

- Poke through sediment cover

- Below sea level:
  - Seamounts (called tablemounts, or guyots, if with a flattened top)
    - are 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

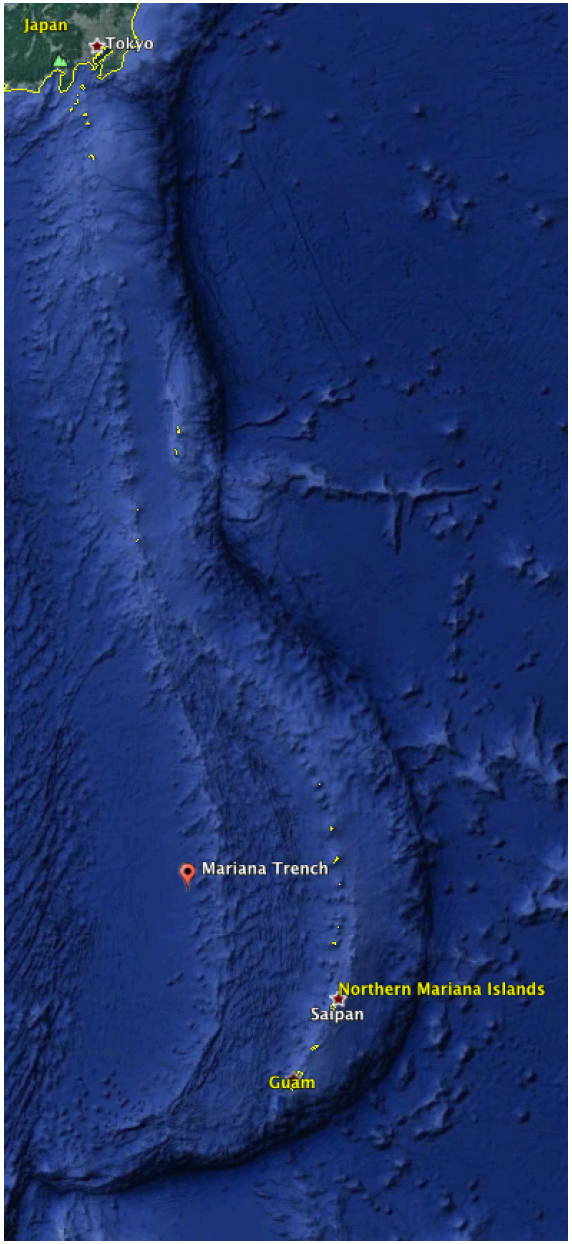
- Abyssal Hills provinces in the Pacific Ocean

- Most abyssal hills from stretching of oceanic crust during sea-floor spreading at a Mid-Ocean Ridge
- Possible relationship between sea-level (glaciations) and production of abyssal hills

Ocean Trenches

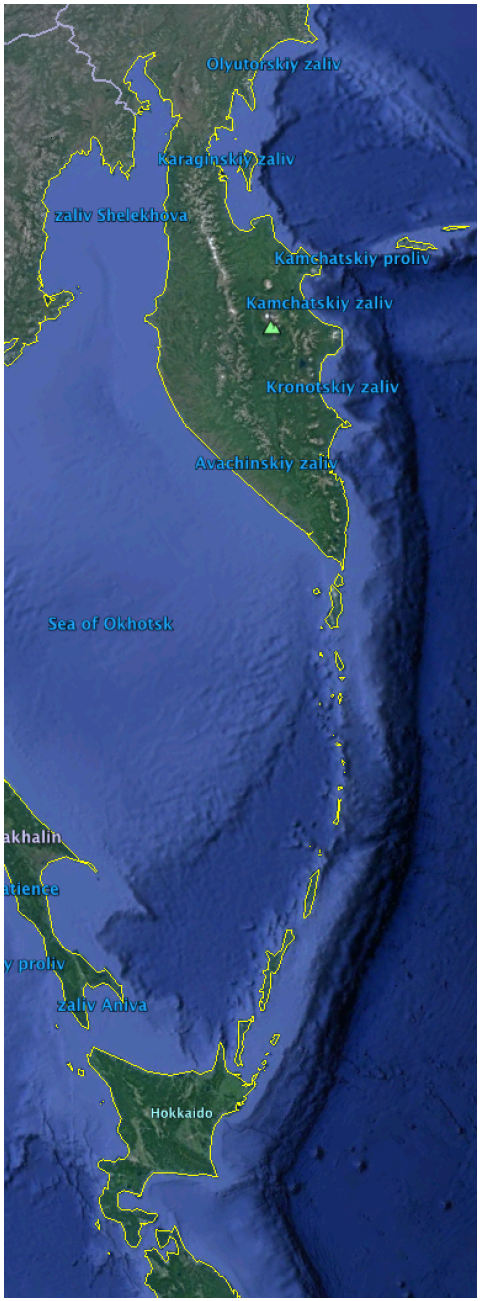
- Along active margins the slope descends into a long, narrow, steep-sided **ocean trench**

- Ocean trenches are caused by the collision of two plates along convergent boundaries
  - Deepest part of oceans
  - Most in Pacific Ocean
  - Deepest trench: Mariana Trench at 11,022 m (36,161 ft)



Volcanic Arcs

- landward side of a trench rises as a volcanic arc
  - island arcs (e.g. Japan, Aleutian Islands)
  - continental arcs (e.g. Cascades, Andes)



the Pacific Ring of Fire

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

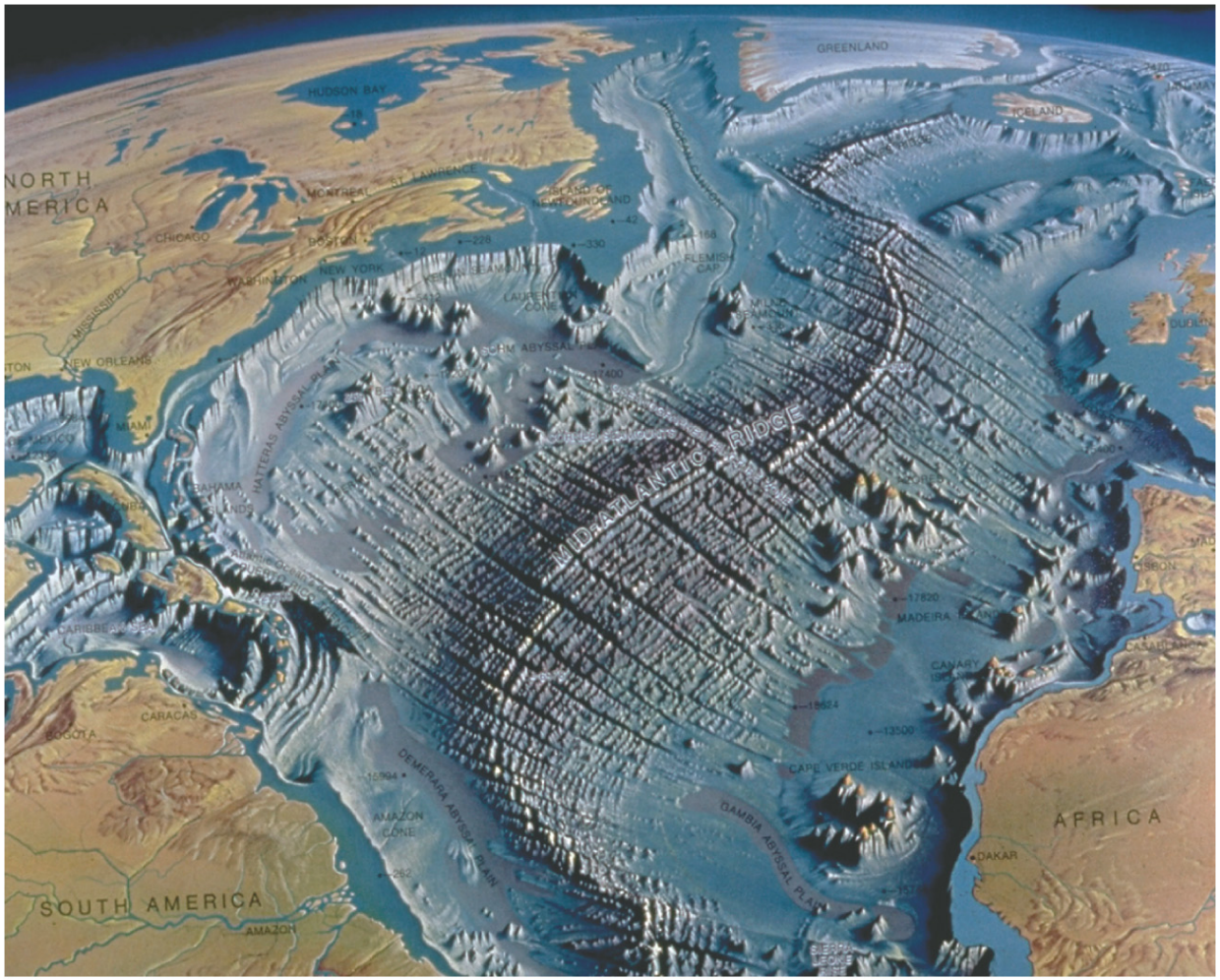
Name	Depth (km)	Width (km)	Length (km)
South Sandwich	8.4	90	1450
Puerto Rico	8.4	120	1550

Indian Ocean Trenches

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

Mid-Ocean Ridges

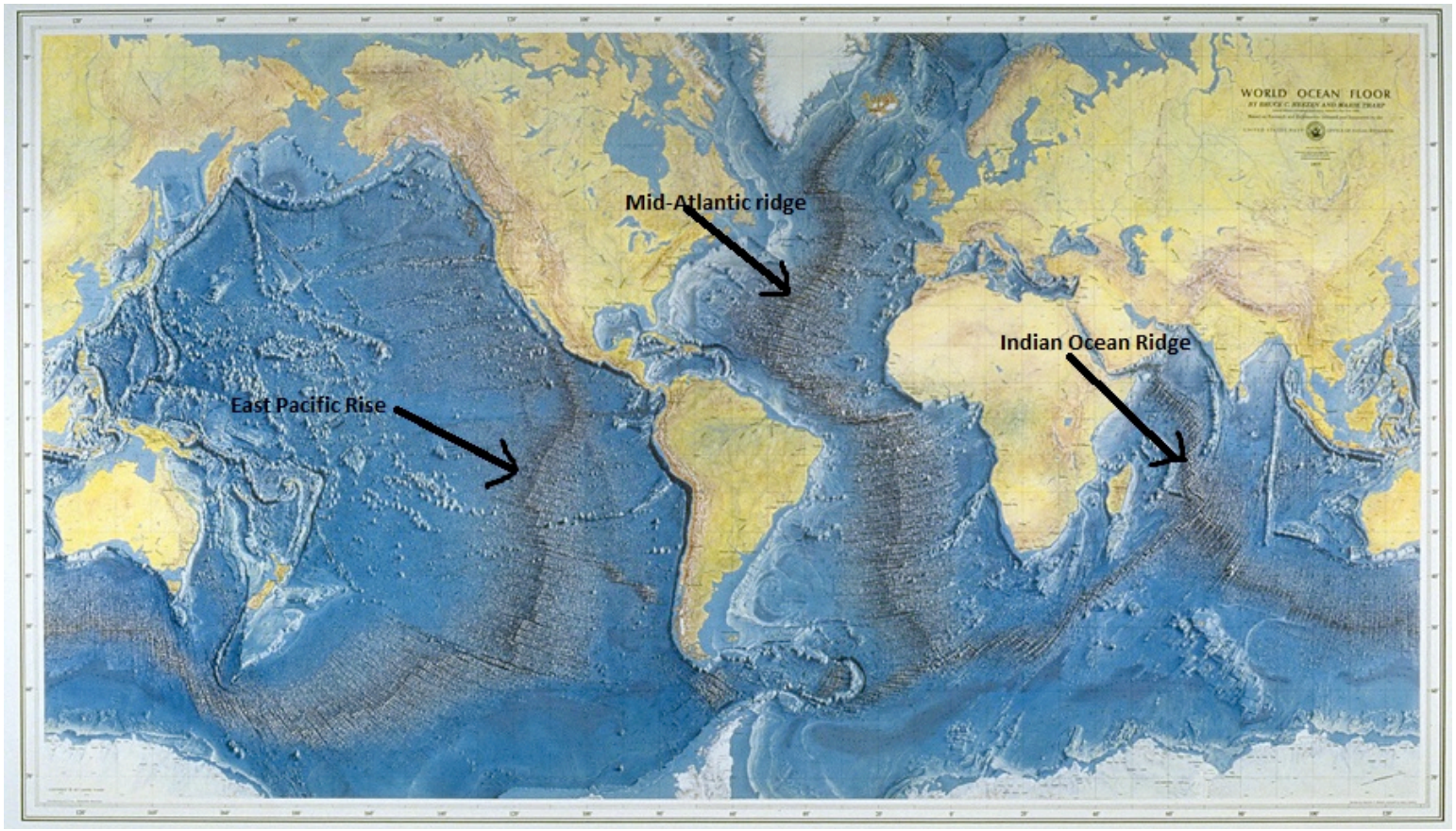
- Longest mountain chain on Earth (75,000 km)
  - broken into segments by:
    - transform faults
    - fractures



Mid-Ocean Ridges

- On average, 2.5 km (1.5 miles) above surrounding sea floor
- On average, 1000 km (~ 600 miles) wide
- Wholly volcanic (basaltic lava)
- Divergent plate boundary

- Mid-Ocean Ridges vs. Mid-Ocean Rises
  - differences in steepness, ultimately caused by different spreading rates


WORLD OCEAN FLOOR
Mid-Atlantic ridge
Indian Ocean Ridge
East Pacific Rise

Rift Valley (in the Mid-Ocean Ridge)

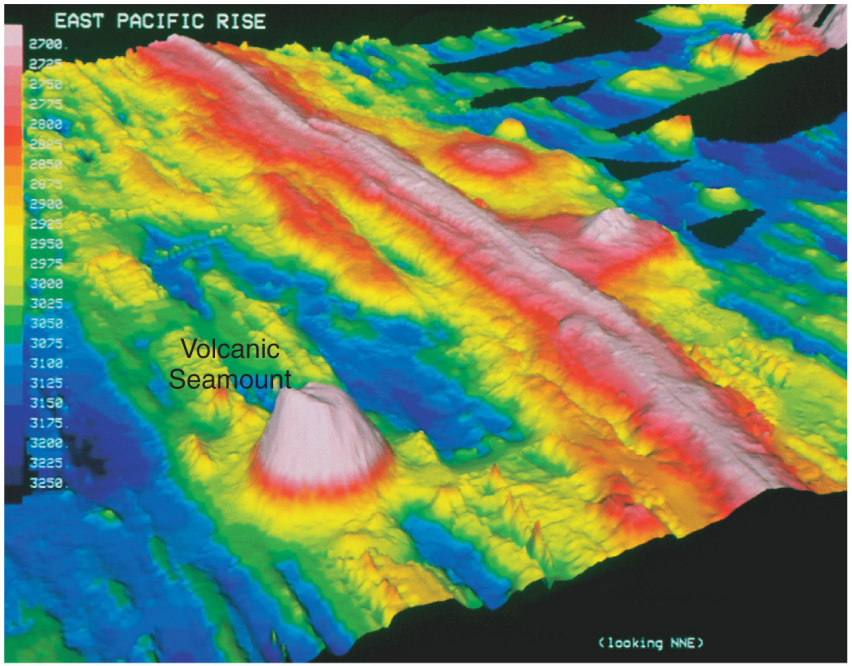
- Central rift valley downdropped by seafloor spreading
  - Fissures and faults in rift valley

The central rift in the Mid-Atlantic Ridge, outcropping in Iceland

from http://ultima0thule.blogspot.com/2010/10/ingvellir-thingvellir-atlantic-creek.html

Mid-Ocean Ridge volcanic features

- Seamounts – tall volcanoes
- Pillow lava or pillow basalt – shapes formed when hot basaltic lava quickly cools



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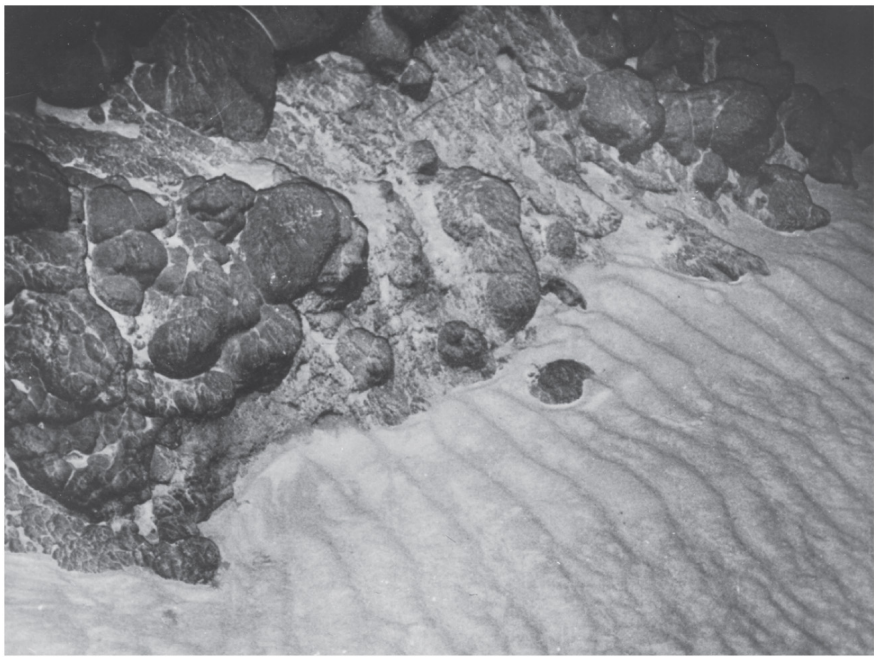

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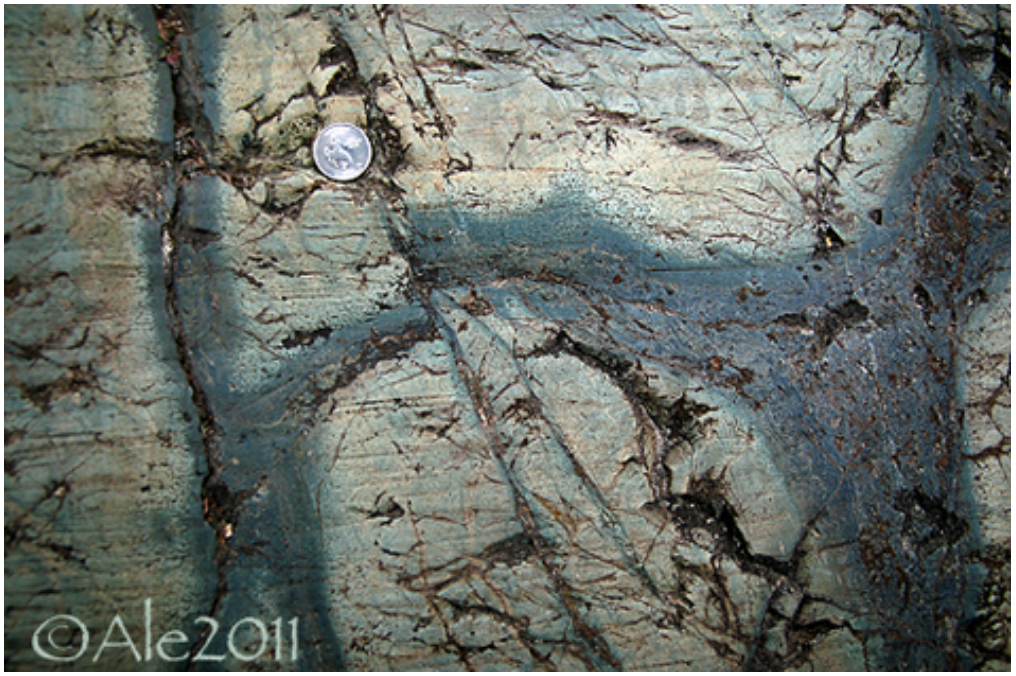
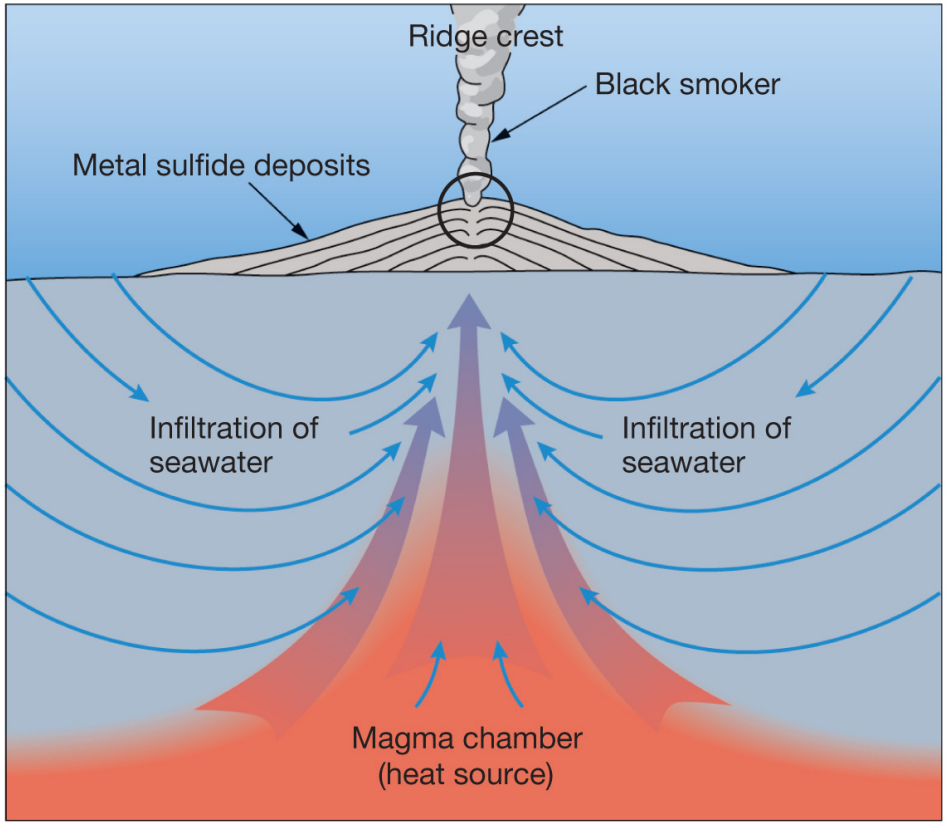
Pillow Basalt from the
South Pacific Seafloor



Precambrian Pillow Basalt
from Gilbert, Minnesota

Hydrothermal Vents

- Sea floor hot springs
- Foster unusual deep-ocean ecosystems able to survive without sunlight (chemosynthetic bacteria and related food chain)
  - Warm water vents temperatures below 30˚C (86˚F)
  - White smokers temperatures from 30 to 350˚C (86–662˚F)
  - Black smokers temperatures above 350˚C (662˚F)



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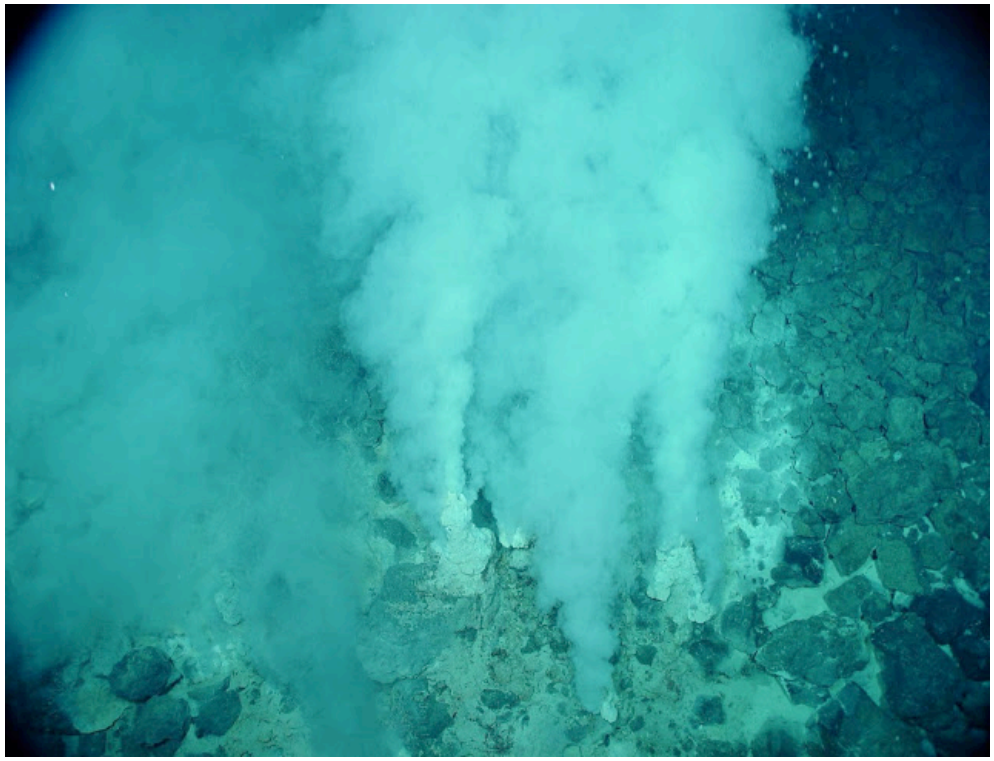
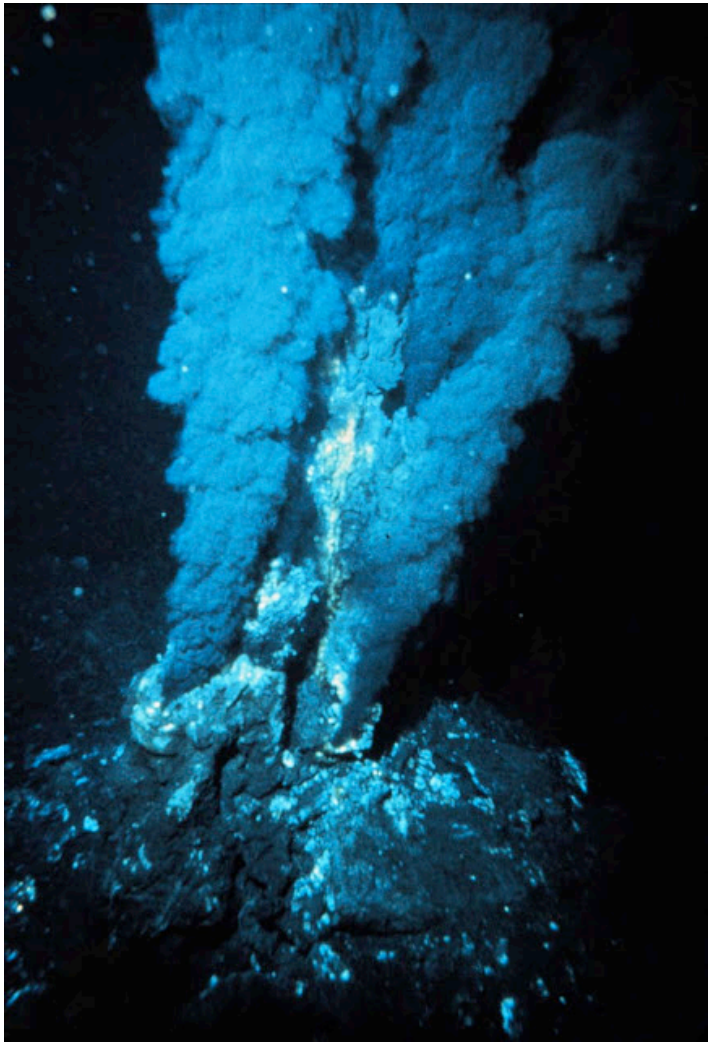
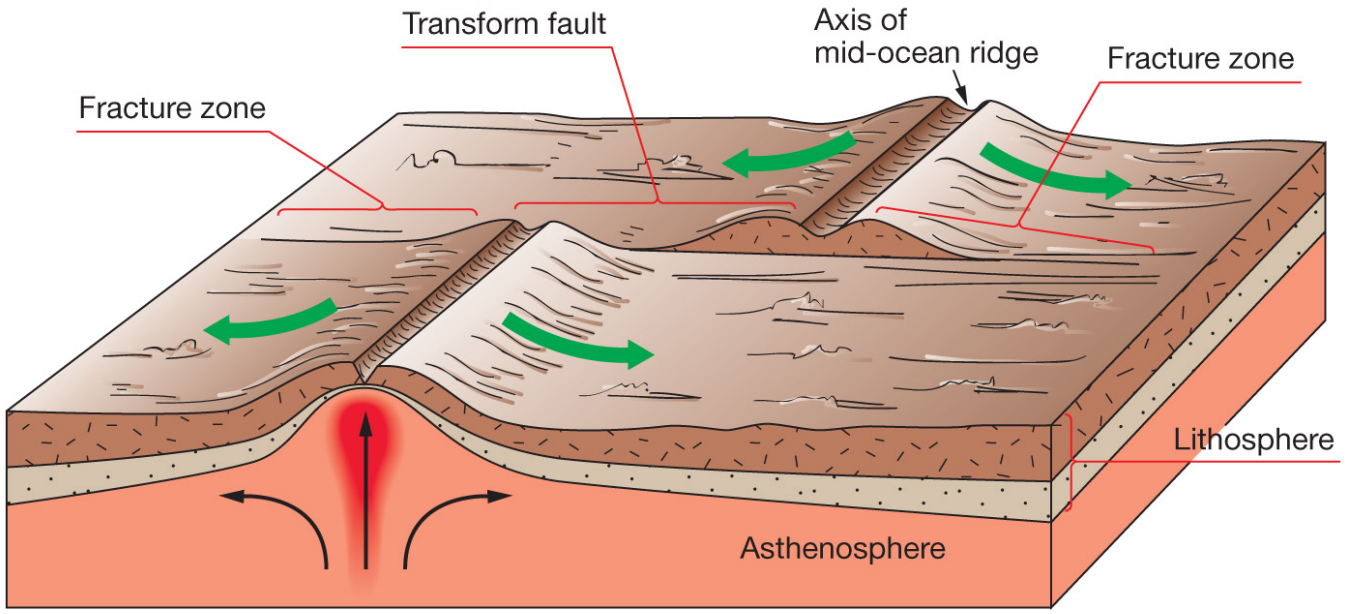




Above: white smokers; to the right: black smokers

Both images from http://www.thisismyheaven.com/2011/06/hydrothermal-vent.html

Fracture Zones and Transform Faults



	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

- Oceanic Islands ate unusually tall features that reach from the sea floor all the way above sea level

- There are three types of Oceanic Islands, all of them volcanic in origin:
  - Islands associated with volcanic activity along a **mid-ocean ridge** (Iceland, Azores)
  - Islands associated with **hot spots** (Hawai'i)
  - Islands that are part of **island arcs** (Japan, Aleutian Islands, Caribbean Islands)

  - Islands that are part of continents (Channel Islands, Vancouver Island, Sicily, Sardinia, Britain, Chiloe, etc.) are not considered as a true type of oceanic islands

Marine Provinces

the end