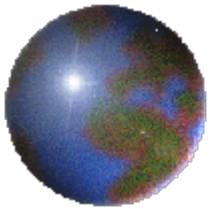
Introduction to Physical Geology

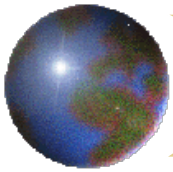


Chapter 11
Ocean Basins

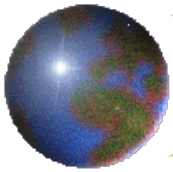
By Dr. Jia Hui

School of Earth Sciences and Engineering

Xi'an Shiyou University



Content



The Earth's Oceans

- Oceans cover about 71% of the Earth's surface.
- The Pacific Ocean is the largest and deepest ocean.
- The sea floor is about 5 kilometers deep in most parts of the ocean basins.
- The size of an ocean basin changes over geologic time.
- Oceans profoundly affect the Earth's climate.

11.1 The Ocean Floor Is Mapped by Bathymetry

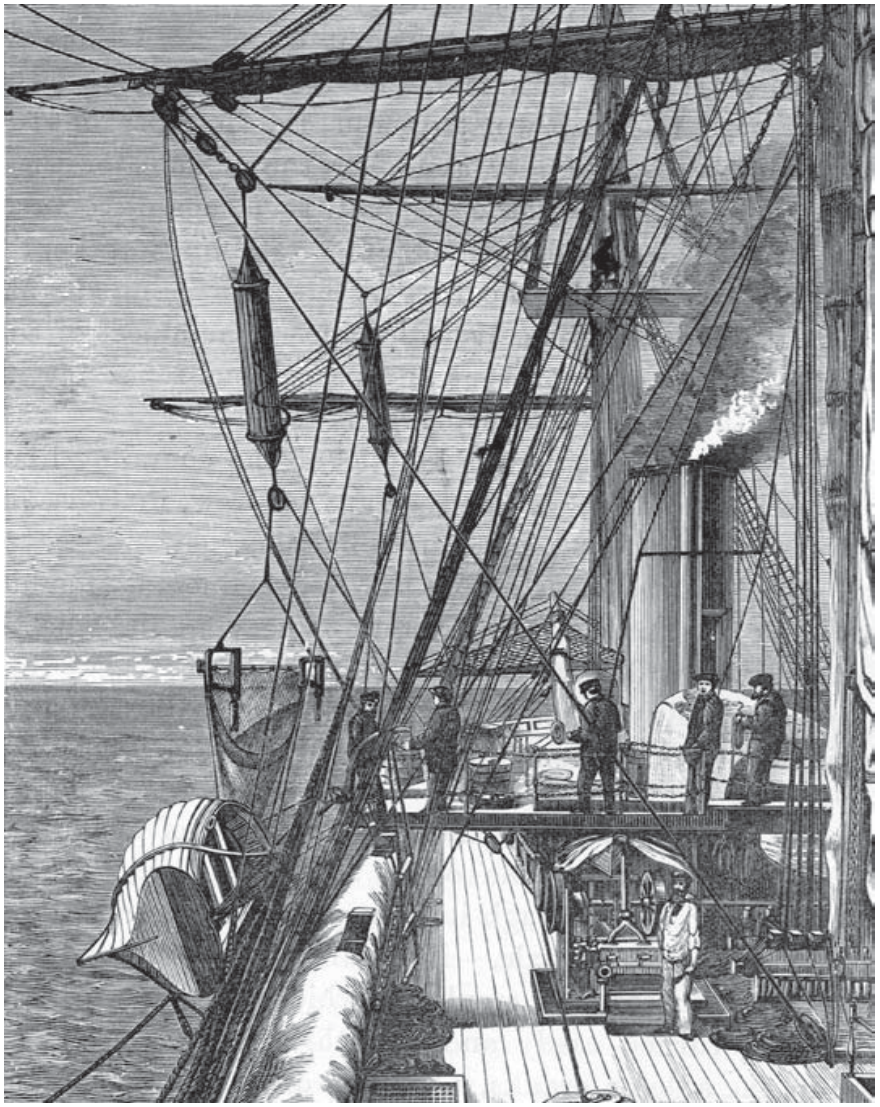
Bathymetry: The discovery and study of ocean floor contours.

- Posidonius : The earliest-known bathymetry studies were carried out in Mediterranean by him in 85 B.C.E.

- In the 1870s, the researchers aboard HMS C*hallenger* added the innovation of a steam-powered winch to raise the line and weight.

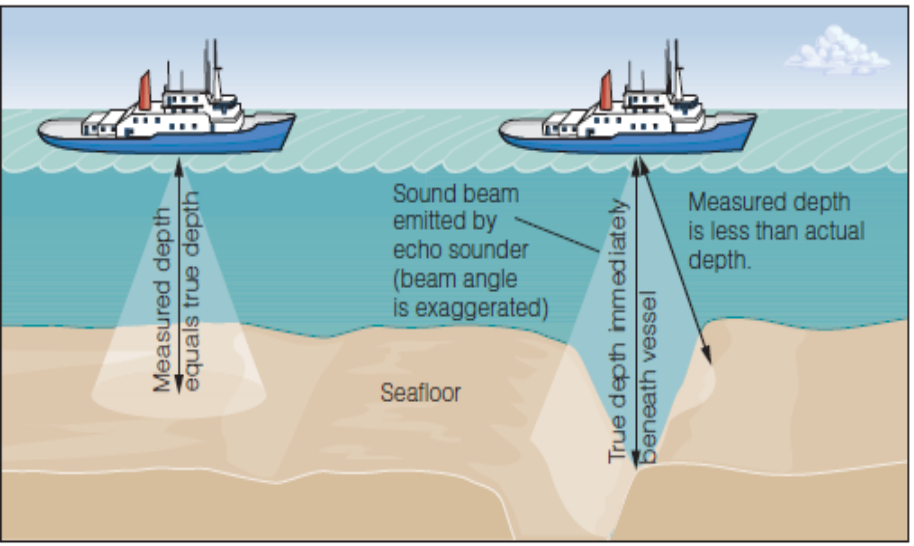
- In June 1922, an echo sounder made the first continuous profile across an ocean basin aboard the USS S*tewart*, U.S.

11.1 The Ocean Floor Is Mapped by Bathymetry



Seamen handling the steam winch aboard HMS *Challenger*

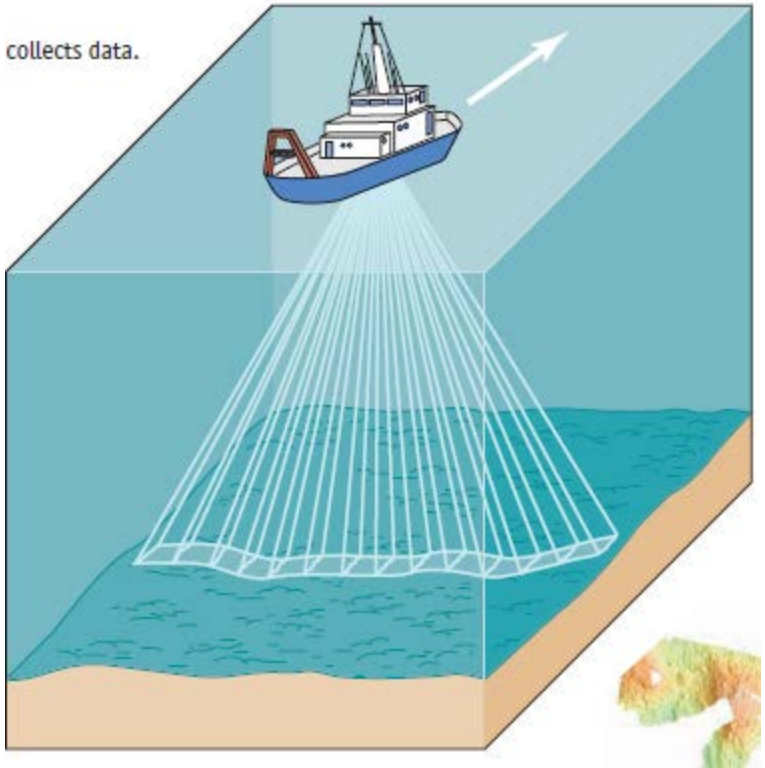
11.1 The Ocean Floor Is Mapped by Bathymetry



The accuracy of an echo sounder can be affected by water conditions and bottom contours

A multibeam echo sounder uses as many as 121 beams radiating from a ship's hull

The **echo sounder** is commonly used to map sea-floor topography. It emits a sound signal from a research ship and then records the signal after it bounces off the sea floor and travels back up to the ship.

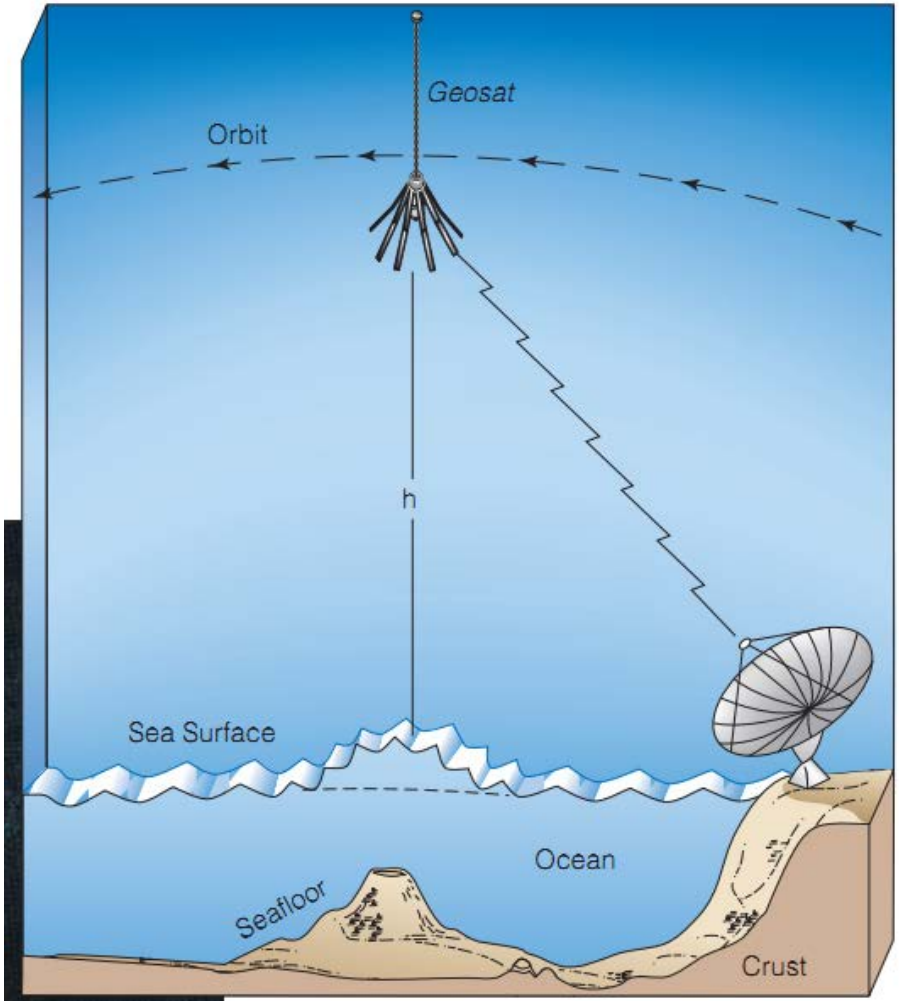


Bathymetry

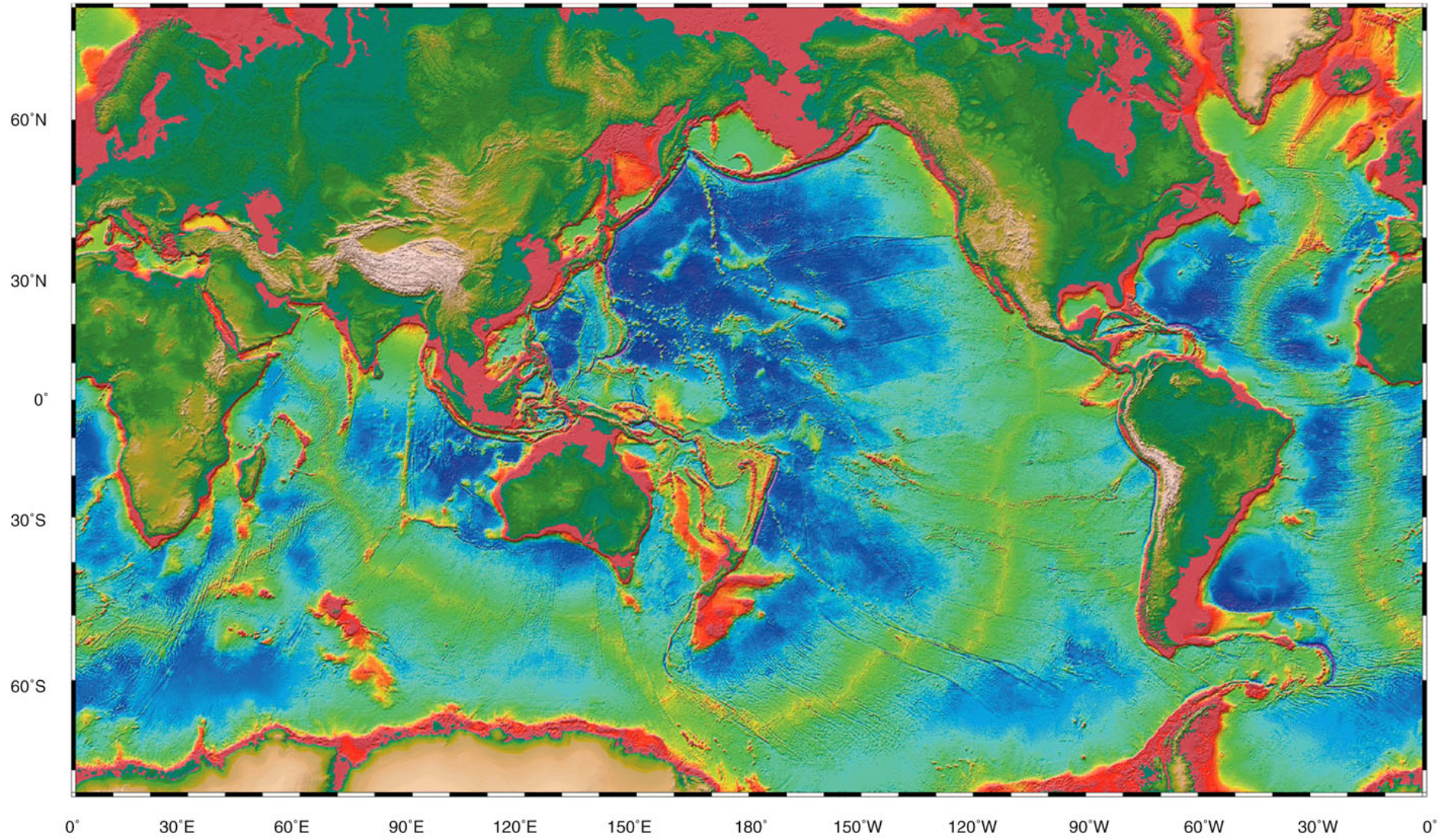
- LADS (shallow water)
  - Laser airborne depth sounder
  - Fixed winged aircraft/ GPS
  - Operating depth of 0.5-70m
- Gravity measurements
  - Changes in sea surface elevation
    - Seamounts +5m and ridges +10m
    - Trenches -25-30m
- Satellite altimetry
- Side-scan sonar

11.1 The Ocean Floor Is Mapped by Bathymetry

Satellites can be used to map seabed



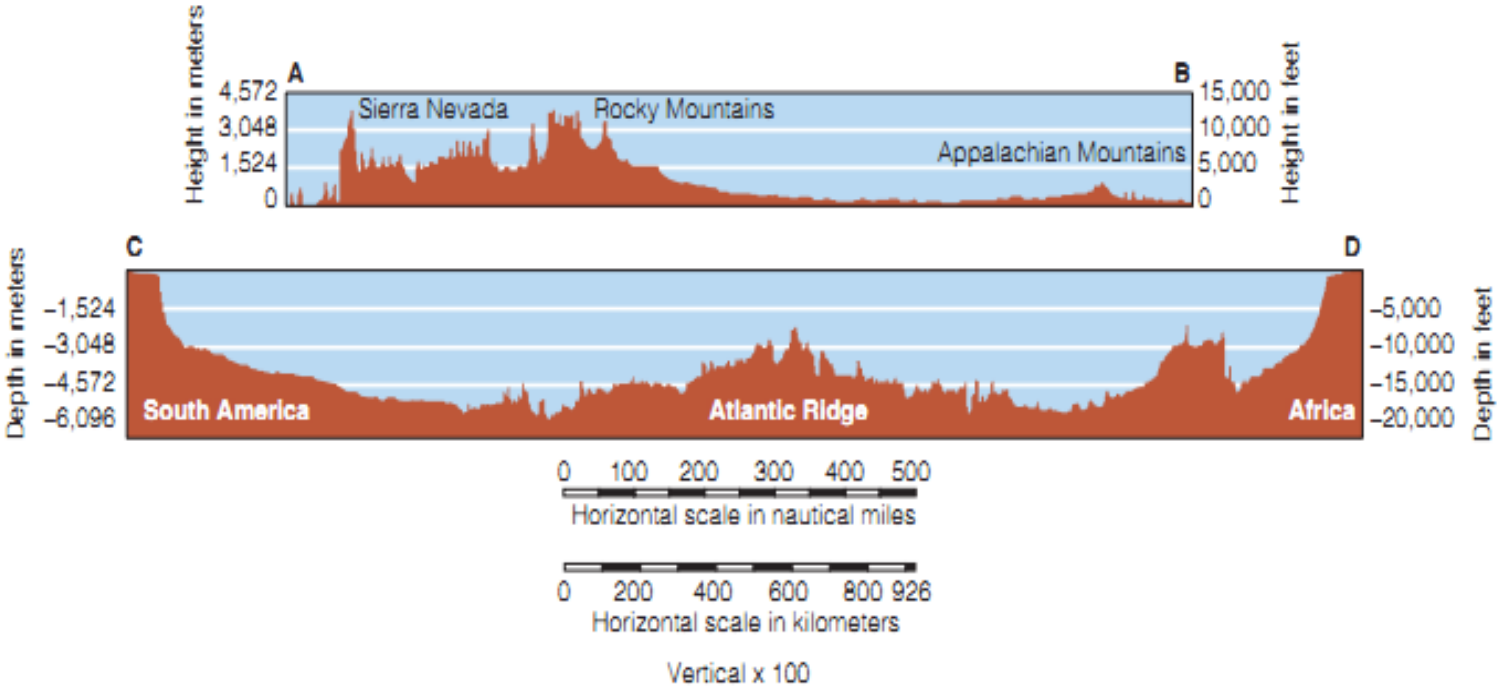
Marine Gravity Anomalies by Satellite Altimetry



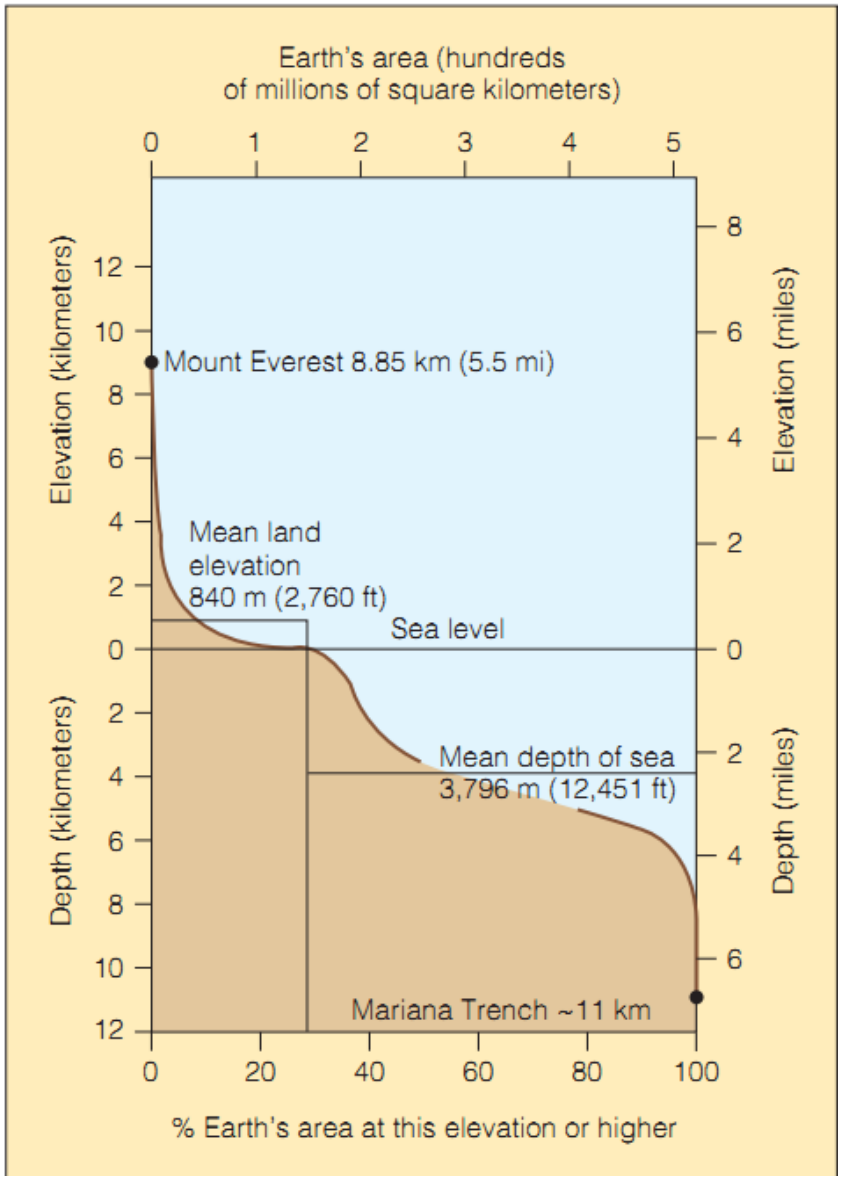
11.2 Ocean-Floor Topography Varies with Location

How would you characterize the general shape of an ocean basin?

Ocean basins are not bathtub-shaped. The submerged edges of continents form shelves at basin margins, and the center of a basin is often raised by a ridge.



11.2 Ocean-Floor Topography Varies with Location



A graph showing the distribution of elevations and depths on earth

Bathymetry of the Sea Floor

- Continental Margin
  - Continental shelf (Flat- 10-1500km, 65km; 20-500m deep)
    - Continental shelf break
  - Continental slope (Steep)
    - Submarine canyons
      - Turbidity currents and turbidites
  - Continental rise
- Ocean Floor
- Ridges, Rises and Trenches

11.2 Ocean-Floor Topography Varies with Location

continental margin: the submerged outer edge of a continent

(passive continental margin and active continental margin)

continental shelf :the shallow, submerged extension of a continent

continental slope: is the transition between the gently descending continental shelf and the deep-ocean floor

continental rise :Along passive margins, the oceanic crust at the base of the continental slope is covered by an apron of accumulated sediment

11.2 Ocean-Floor Topography Varies with Location

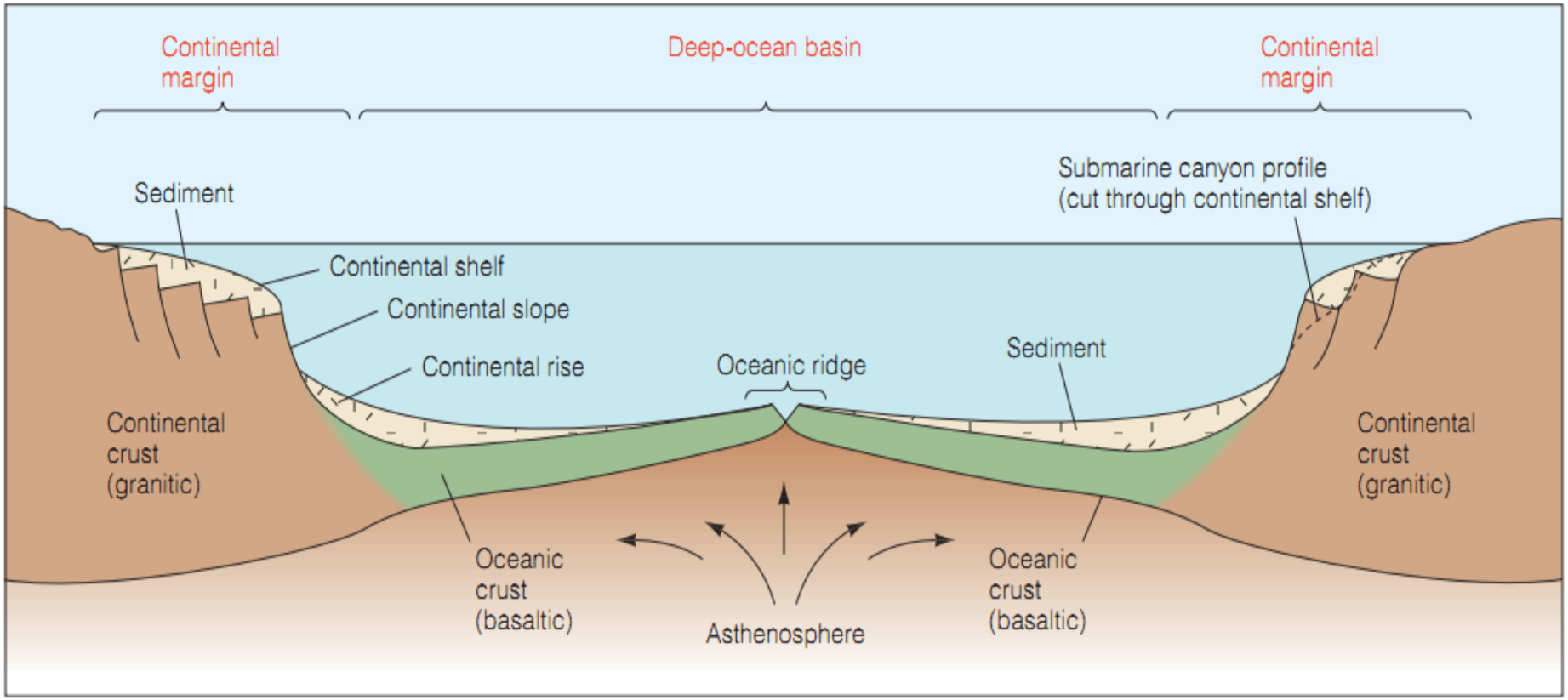
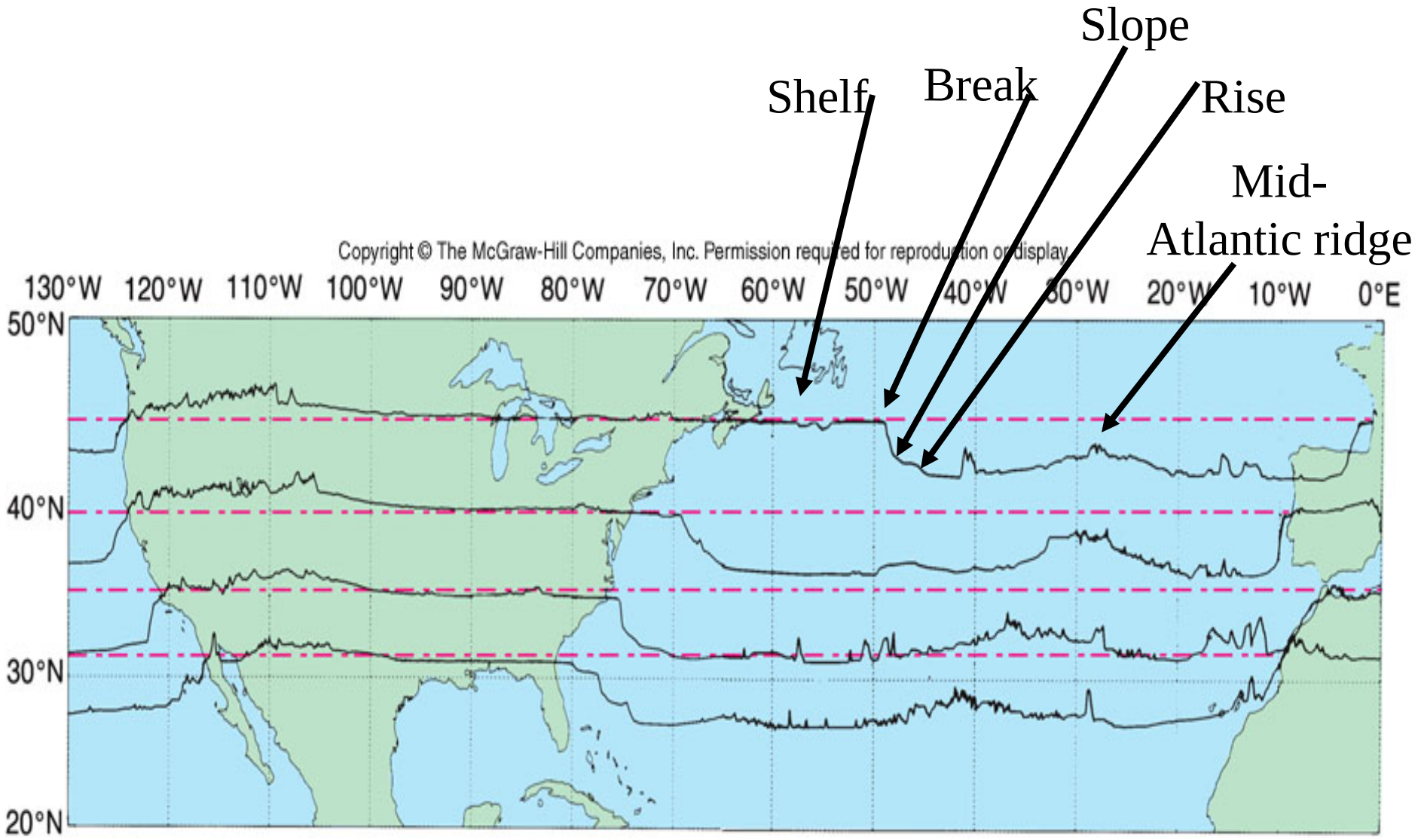


Figure 4.7

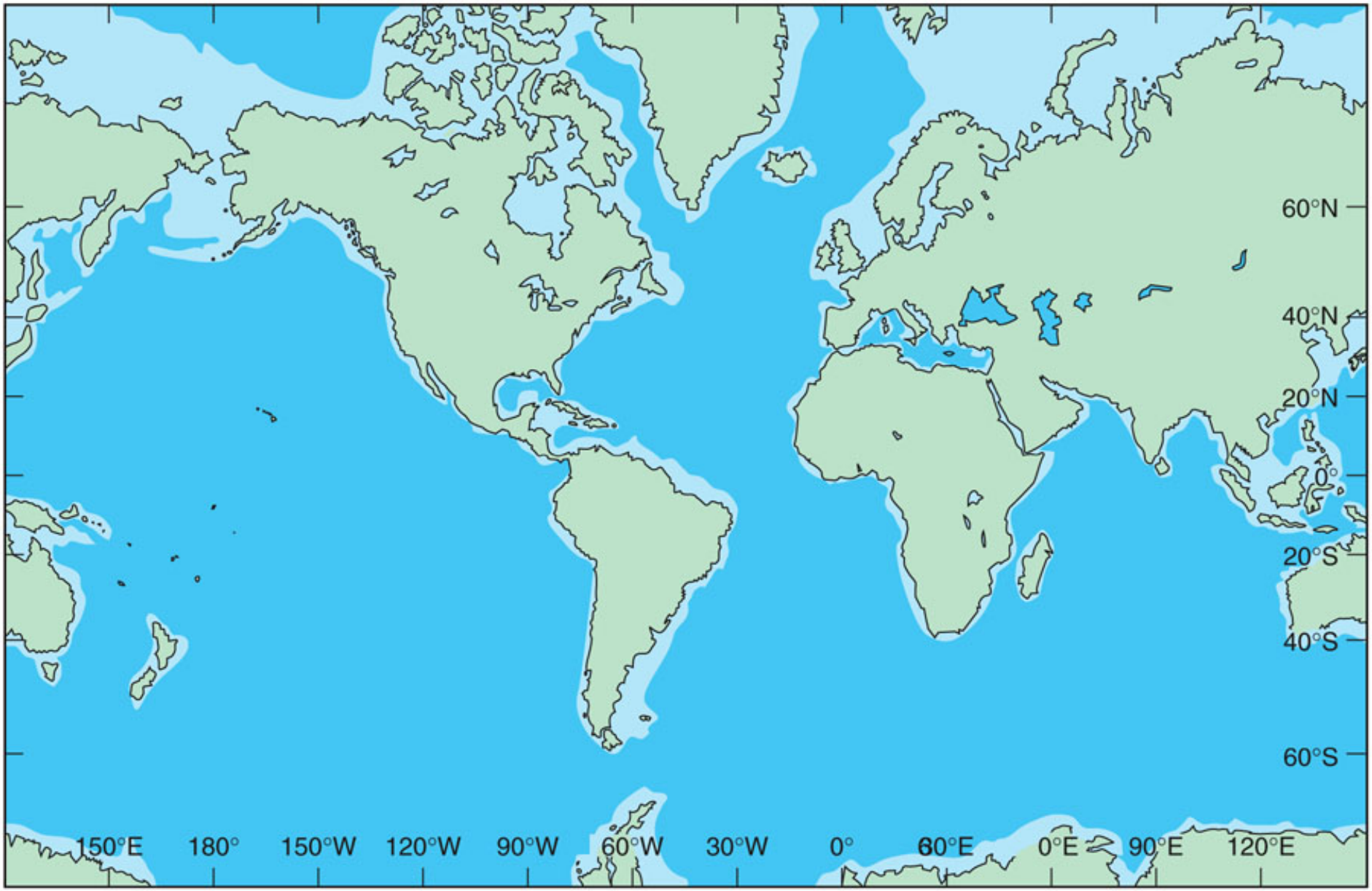
Cross section of a typical ocean basin flanked by *passive continental margins*. (The vertical scale has been greatly exaggerated to emphasize the basin contours.)

11.2 Ocean-Floor Topography Varies with Location



Computer Drawn Topographic Profiles

Continental Shelves



11.3 Continental Margins May Be Active or Passive

Note that active margins coincide with plate boundaries but passive margins do not.

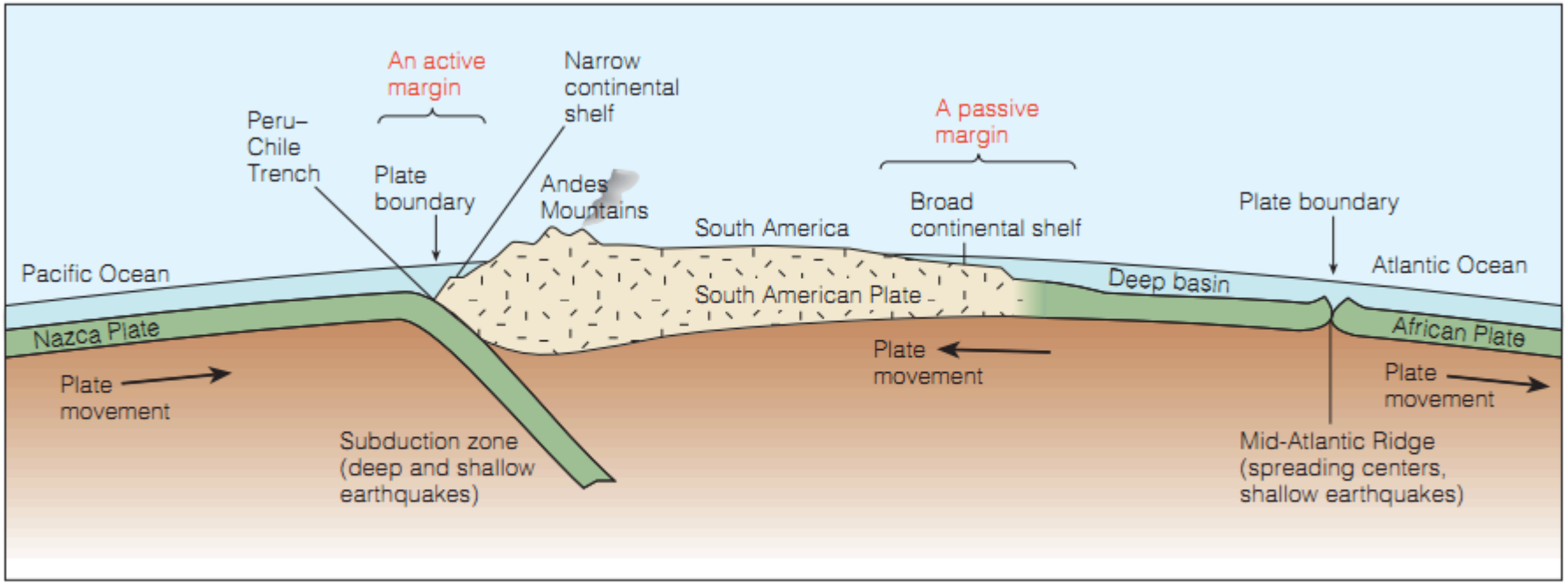
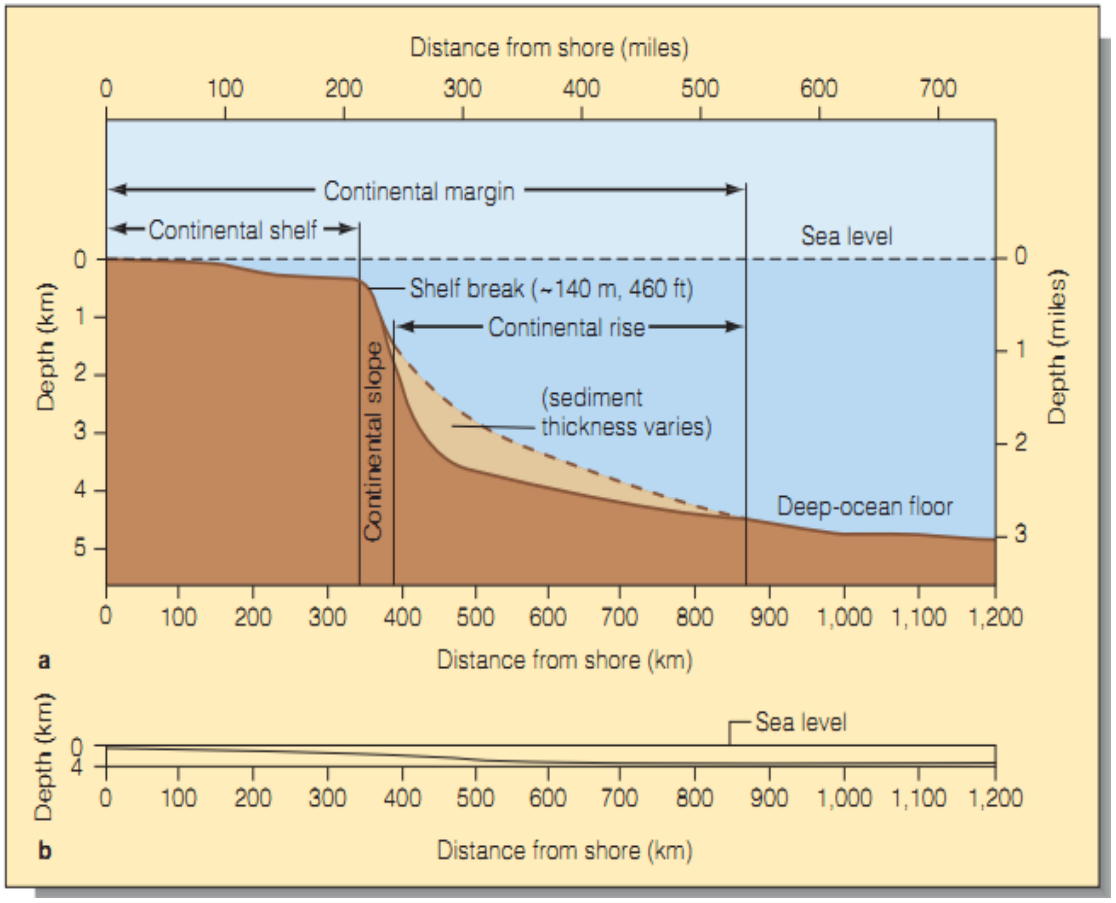


Figure 4.8

Typical continental margins bordering the tectonically *active* (Pacific-type) and tectonically *passive* (Atlantic-type) edges of a moving continent. (The vertical scale has been exaggerated.) Look at Figure 4.4e for a different view of the same area.

The shelf at the passive margin is broad, but the shelf at the active margin is very narrow

11.3 Continental Margins May Be Active or Passive



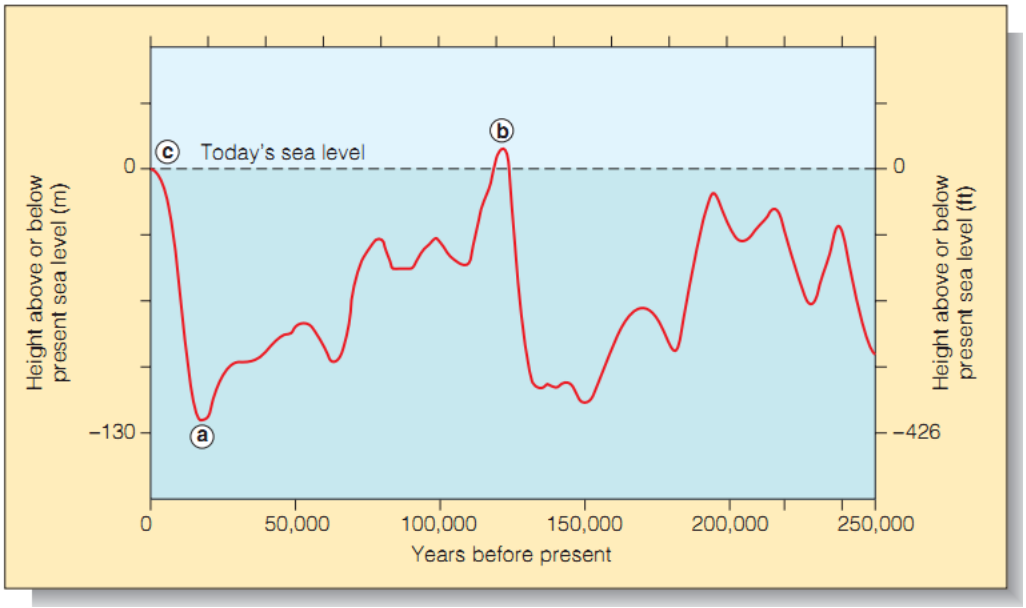
The broad shelf extends far from shore in a gentle incline, typically 1.7 meters per kilometer

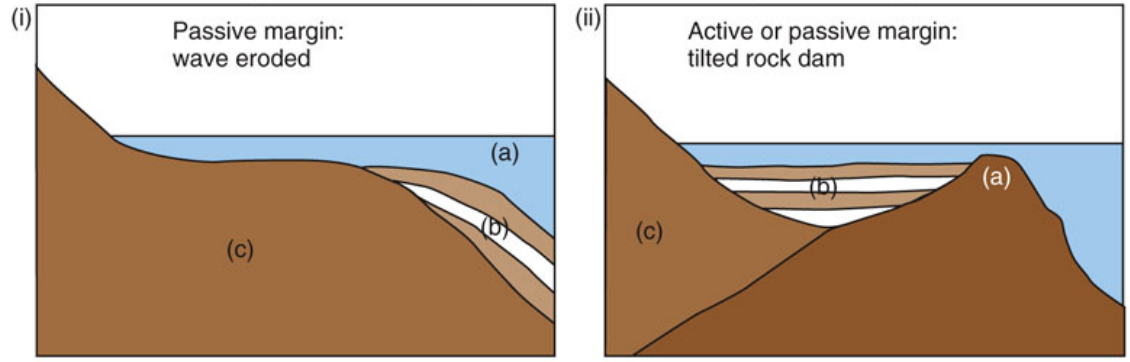
The features of a passive continental margin

11.3 Continental Margins May Be Active or Passive

The continental shelves have been the focus of intense exploration for natural resources

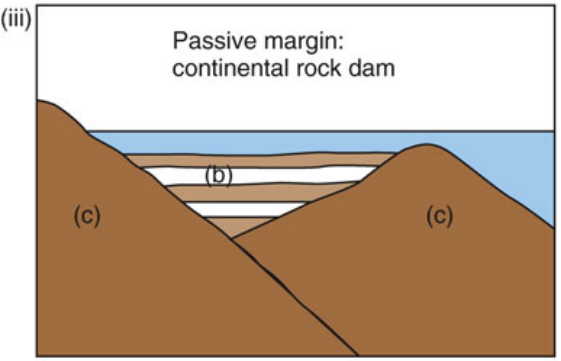
Because of their gentle slope, continental shelves are greatly influenced by changes in sea level



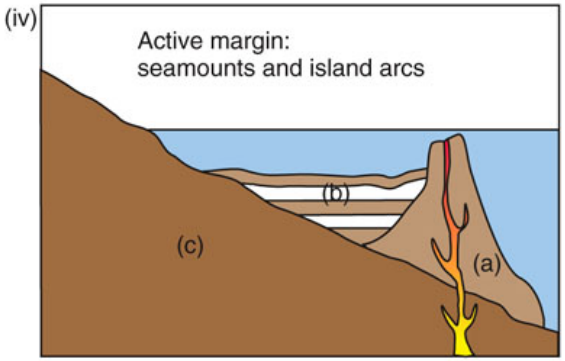


(a) Wave-cut terrace
(b) Water-deposited sediments
(c) Surface continental rock

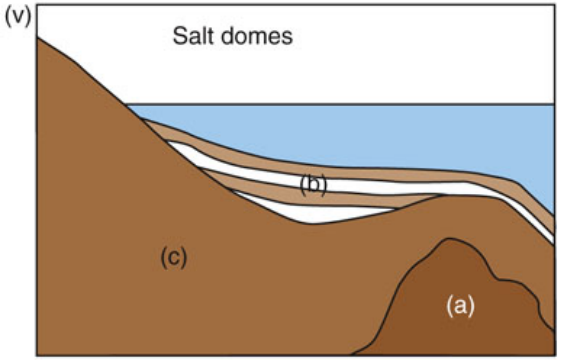
(a) Wave-eroded island
(b) Water-deposited sediments
(c) Surface continental rock



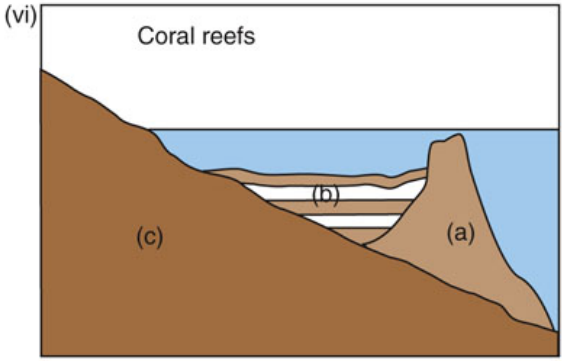
(b) Water-deposited sediments
(c) Surface continental rock



(a) Underwater volcano
(b) Water-deposited sediments
(c) Surface continental rock

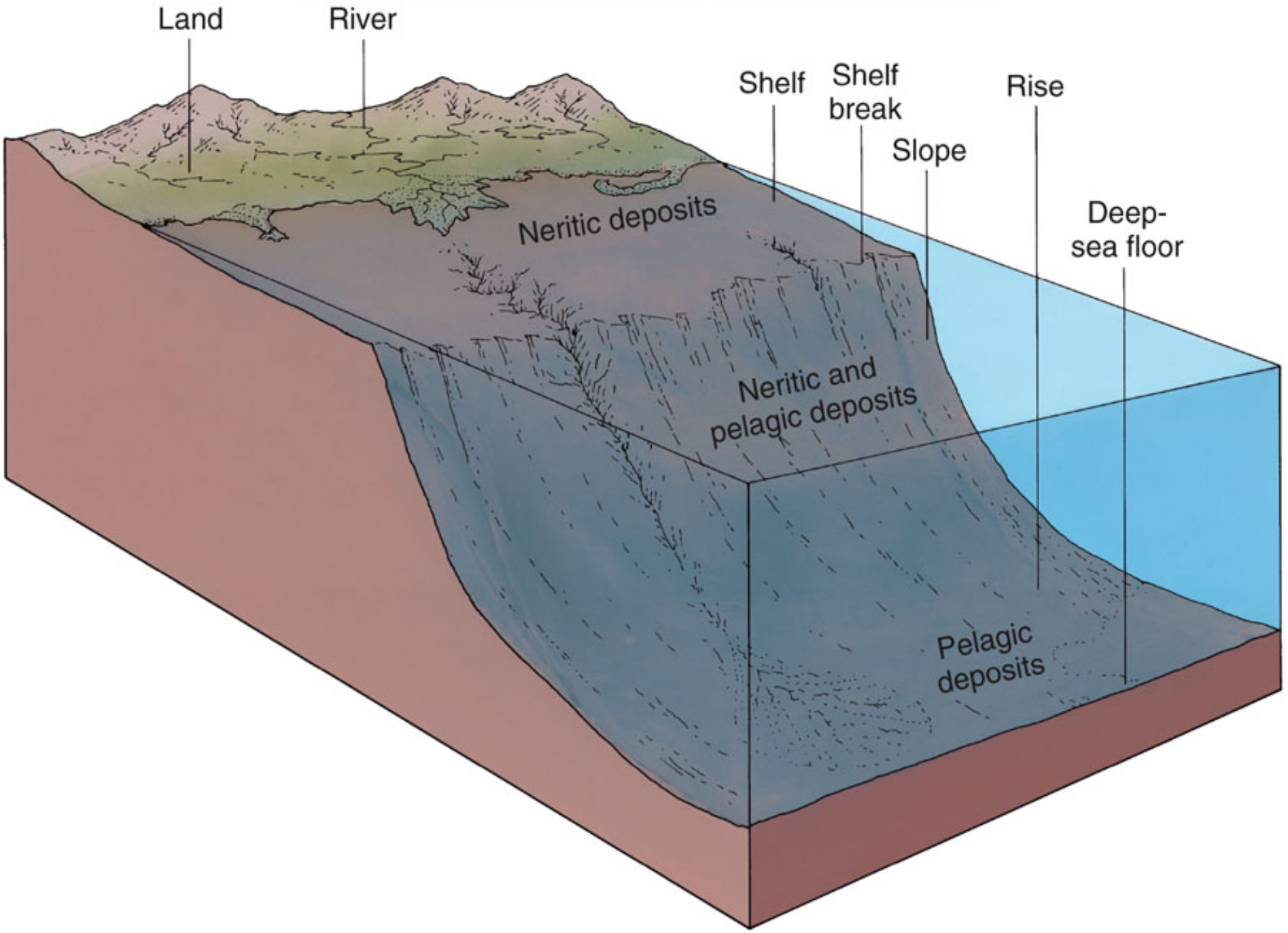


(a) Salt dome
(b) Downwarped river deposits
(c) Surface continental rock



(a) Coral reefs
(b) Water-deposited sediments
(c) Surface continental rock

Formation of Shelves by trapping of land derived sediments



11.3 Continental Margins May Be Active or Passive

Submarine canyons cut into the continental shelf and slope, often terminating on the deep-sea floor in a fan-shaped wedge of sediment

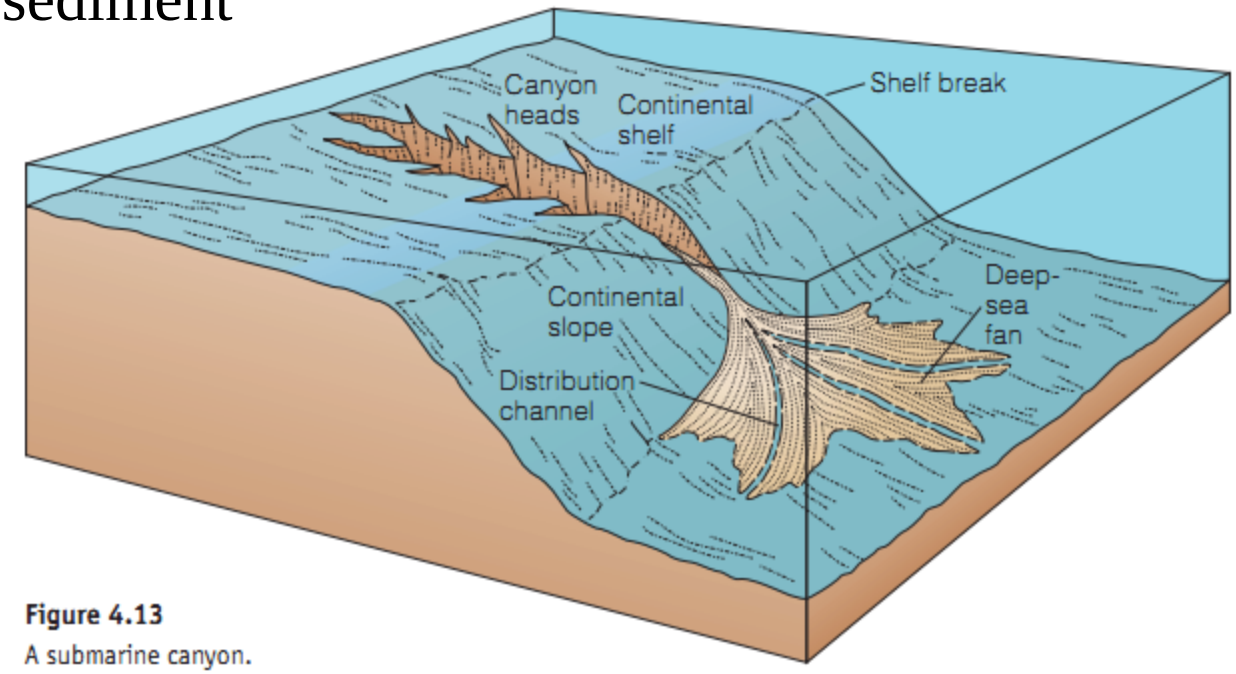
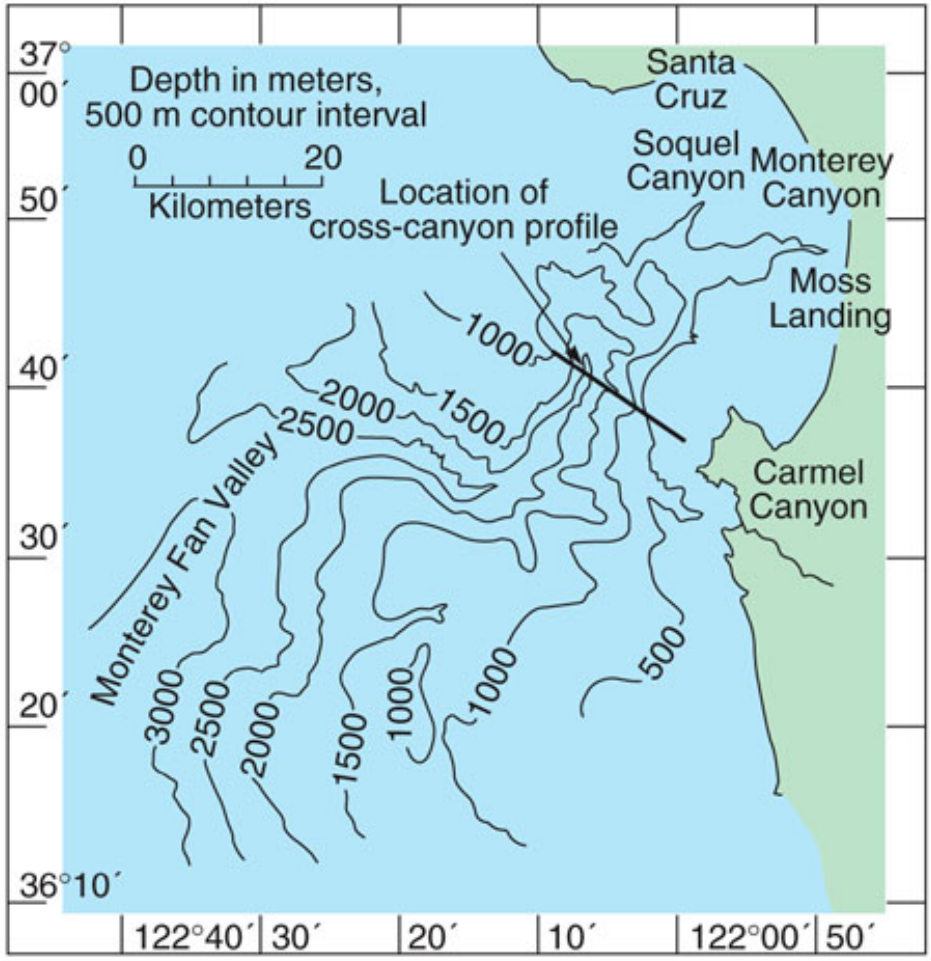


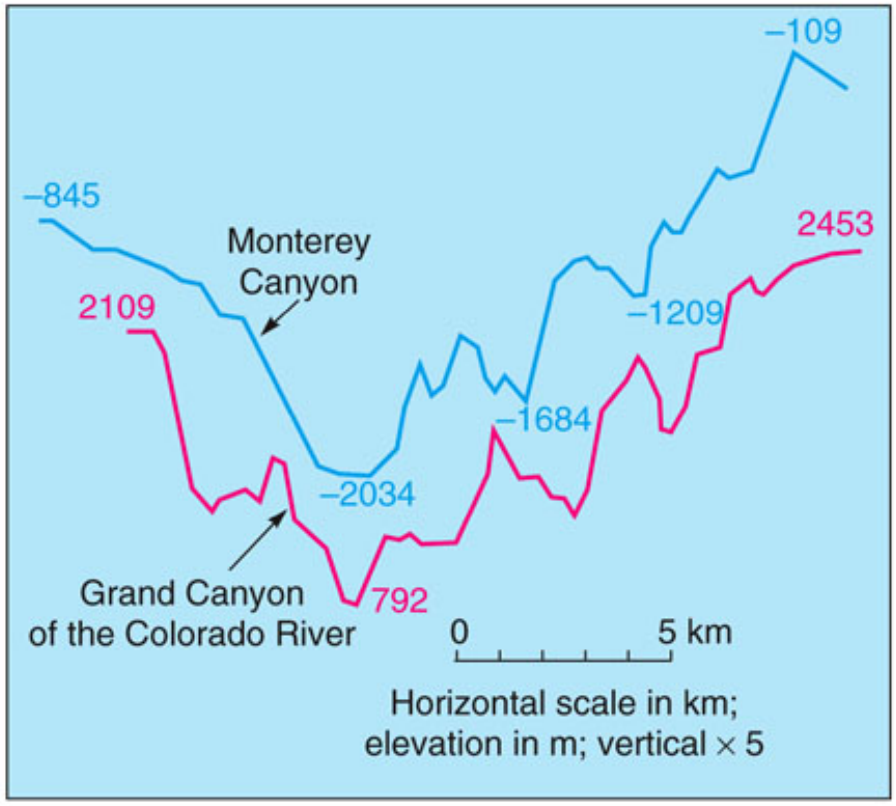
Figure 4.13
A submarine canyon.

At its lower end, a submarine canyon commonly leads into an **abyssal fan** (sometimes called a **submarine fan**), a large, fan-shaped pile of sediment lying on the continental rise. Most submarine canyons occur where large rivers enter the sea.

11.3 Continental Margins May Be Active or Passive



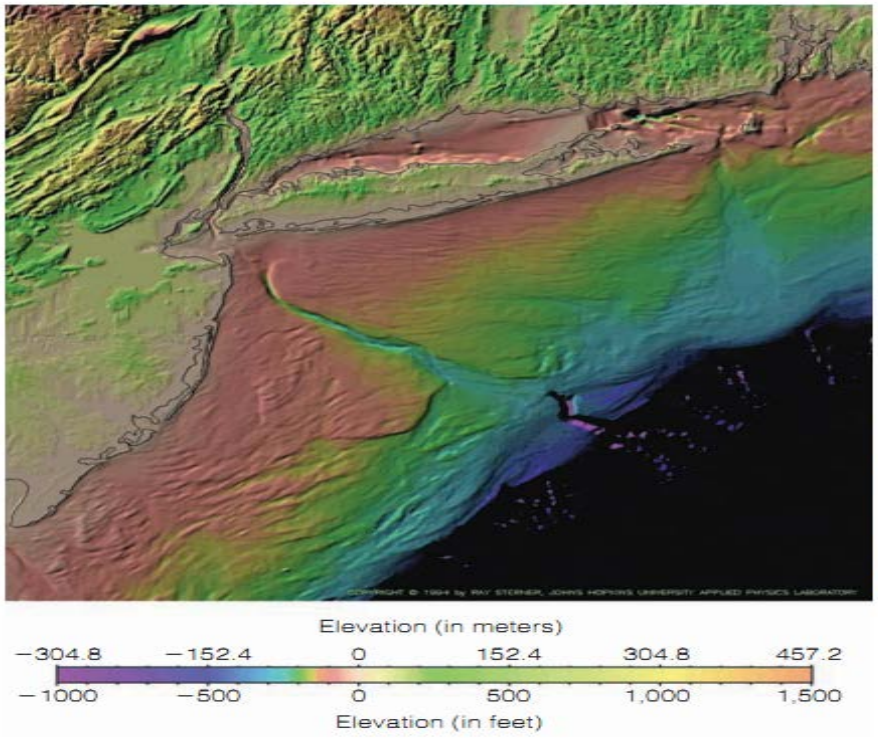
(a)



(b)

Turbidity Currents- 90km/hr, 300kg of sed in suspension

11.3 Continental Margins May Be Active or Passive

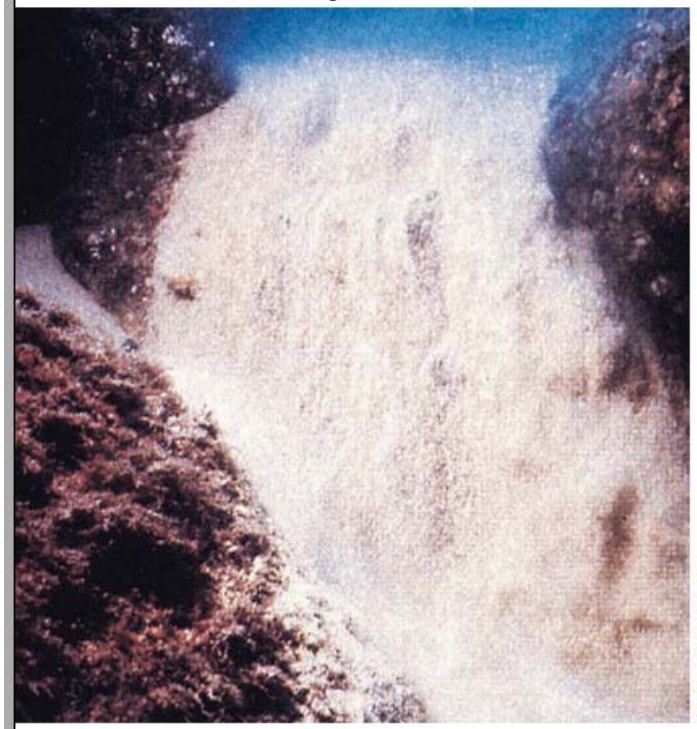


Ray Sterner, Johns Hopkins University

What, then, caused the submarine canyons to form?

turbidity currents

Local landslides or sediment liquefaction triggered by earth-quakes sometimes causes an abrasive underwater “avalanche” of sediments. These mass-movements of sediment, called turbidity currents.

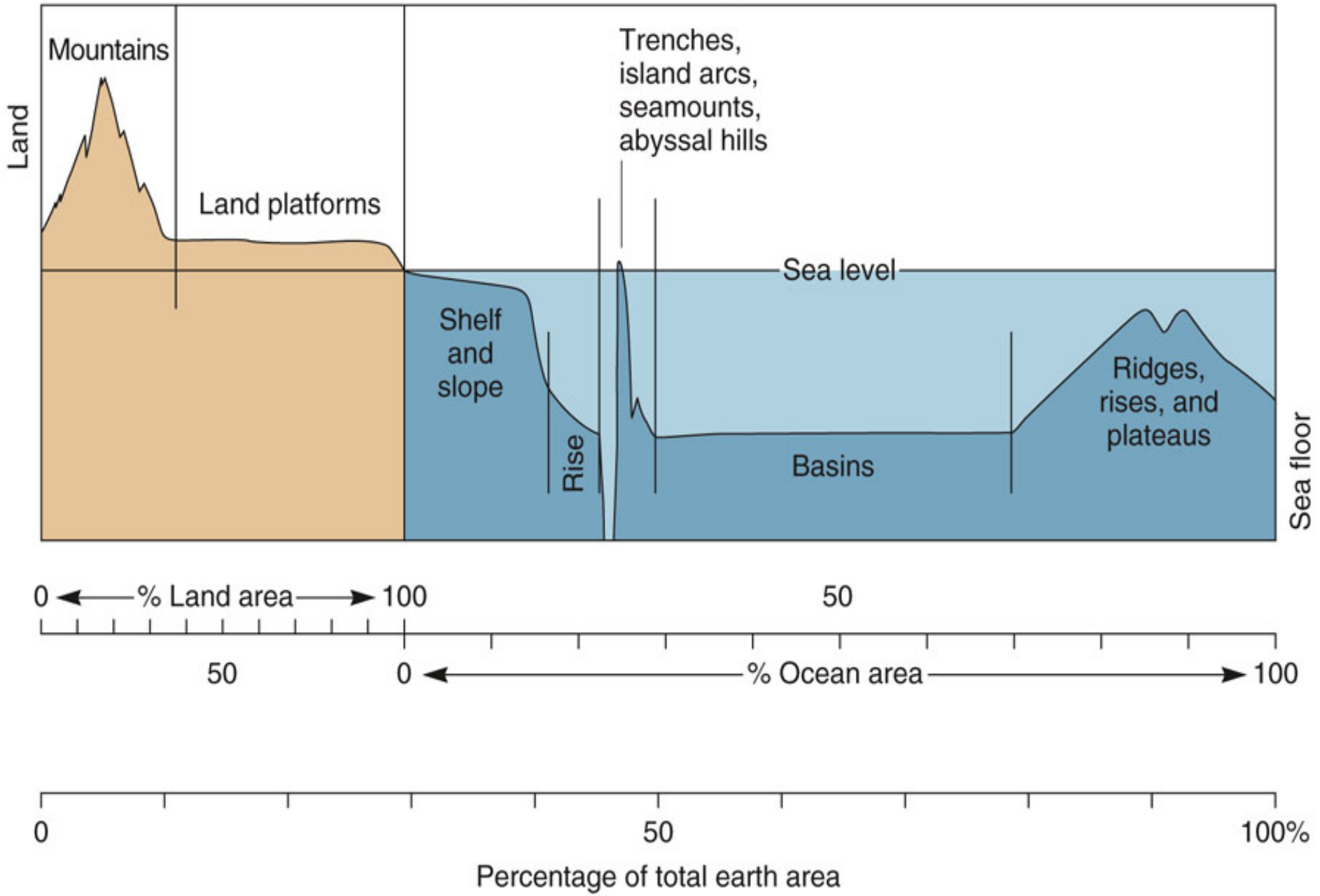


U.S. Department of the Navy

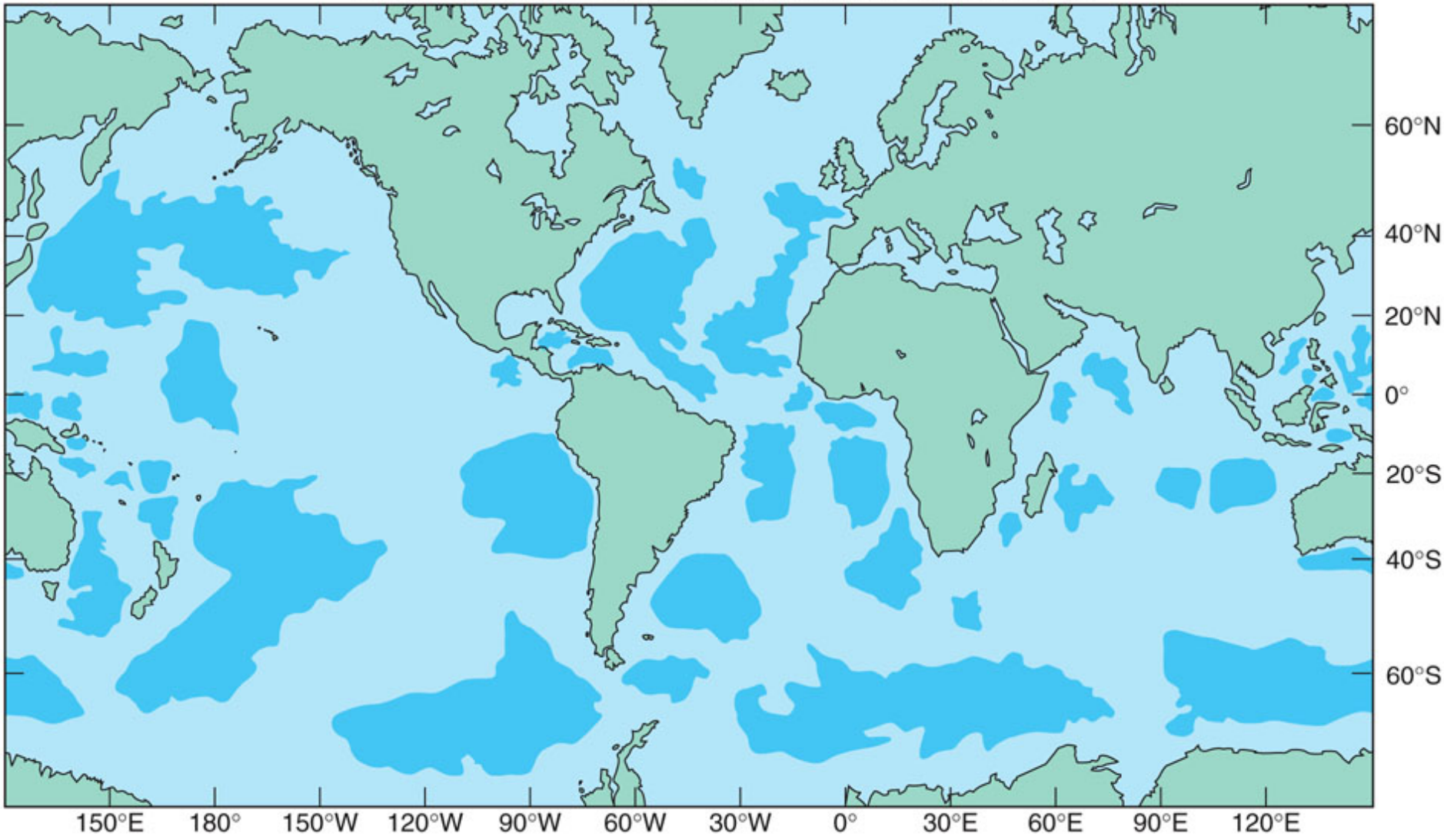
Figure 4.15
A continuous cascade of sediment at the head of San Lucas submarine can-yon (off the coast of Baja California, Mexico), which may be eroding the narrow gorge in conjunction with occasional turbidity cur-rents. About 100,000 cubic meters of sand slip down this canyon every year.

11.4 The Topology of Deep-Ocean Basins Differs from That of the Continental Margin

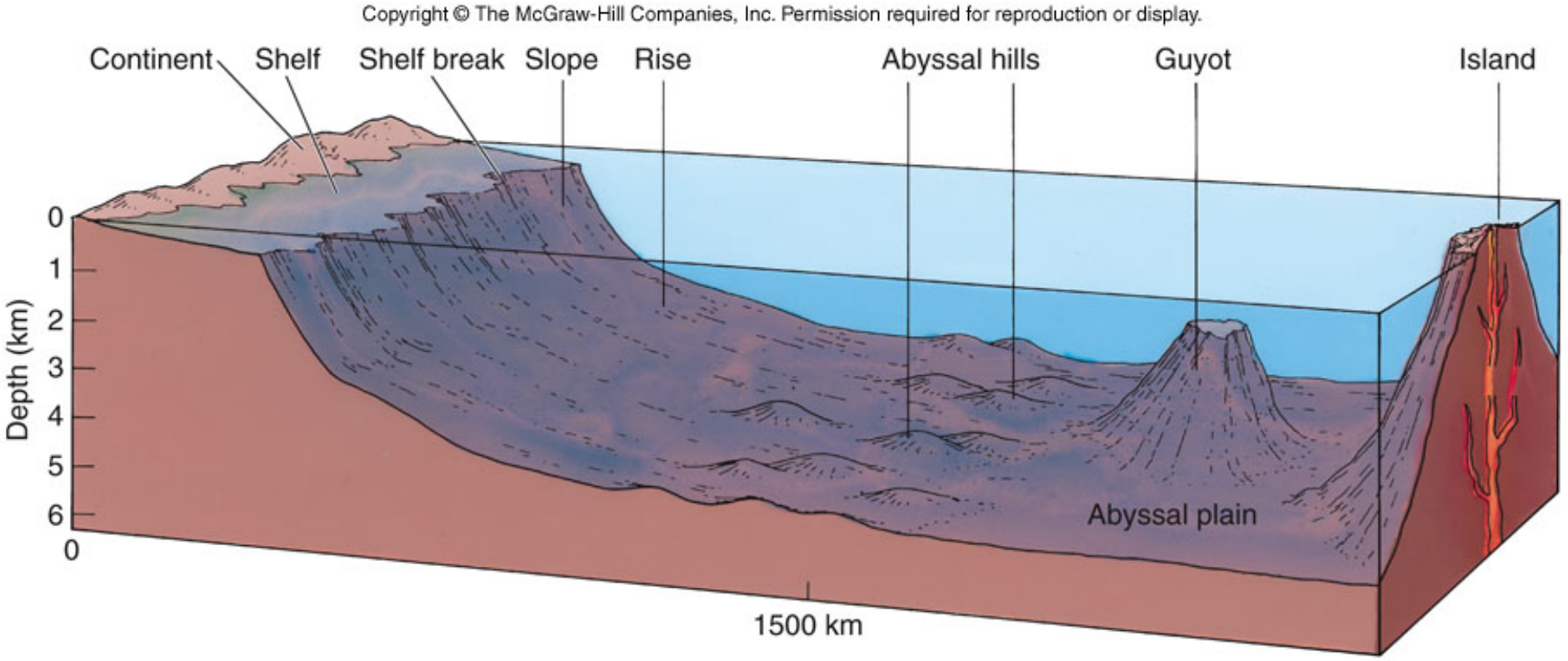
- Ocean Floor
  - Deep seafloor (4000-6000m cover 30% of Earth's surface)
  - Abyssal Plain (Flat)
    - Pelagic sediments and turbidites
  - Abyssal hills and seamounts & Guyots
    - <1000m high; steep sided volcanoes
    - Found on 50% Atlantic and 80% Pacific seafloor
    - Some become atolls
- Ridges, Rises and Trenches
  - 65,000km mountain range
  - Challenger Deep (Mariana Trench 11,020m)



Major Ocean Basins

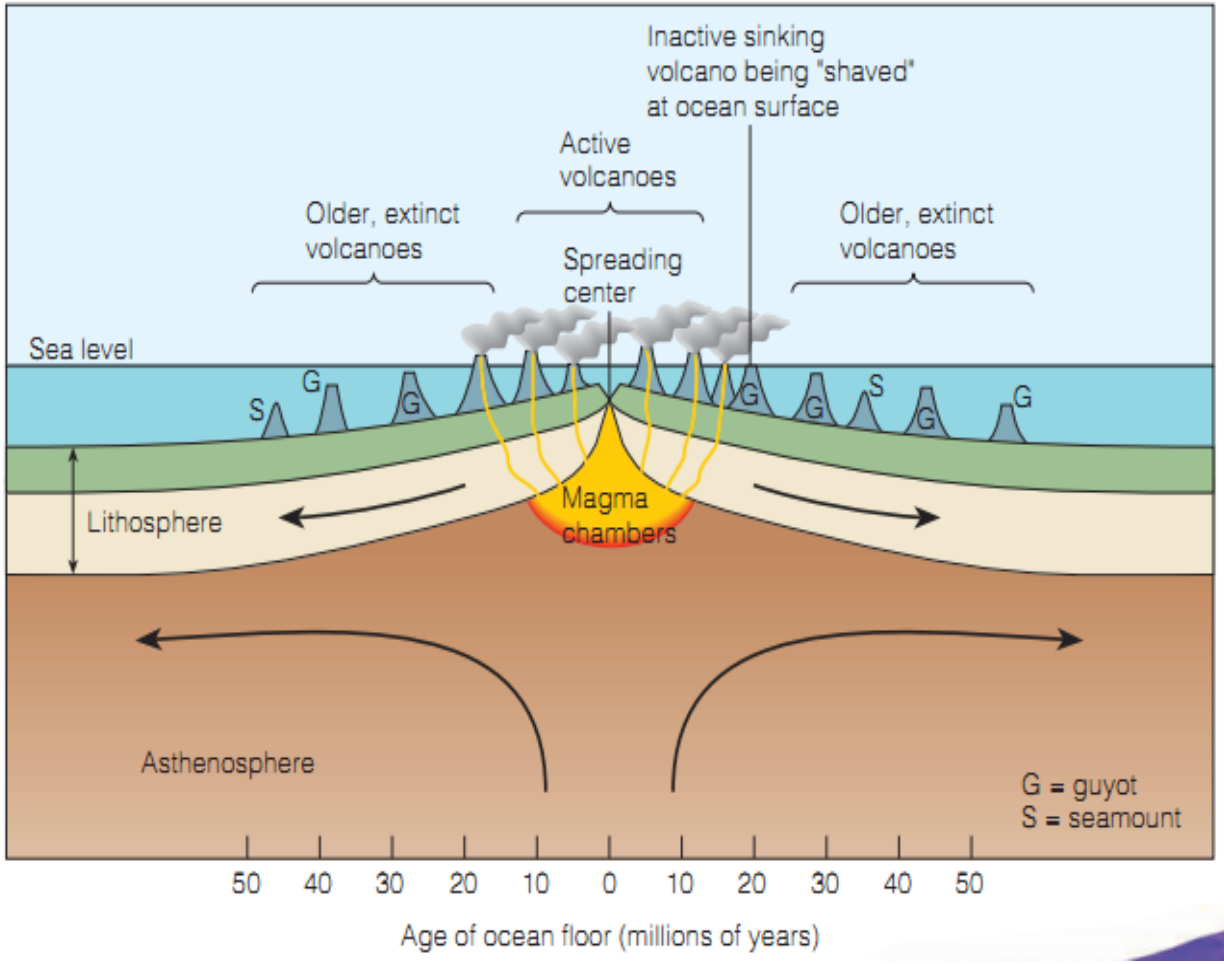


11.4 The Topology of Deep-Ocean Basins Differs from That of the Continental Margin



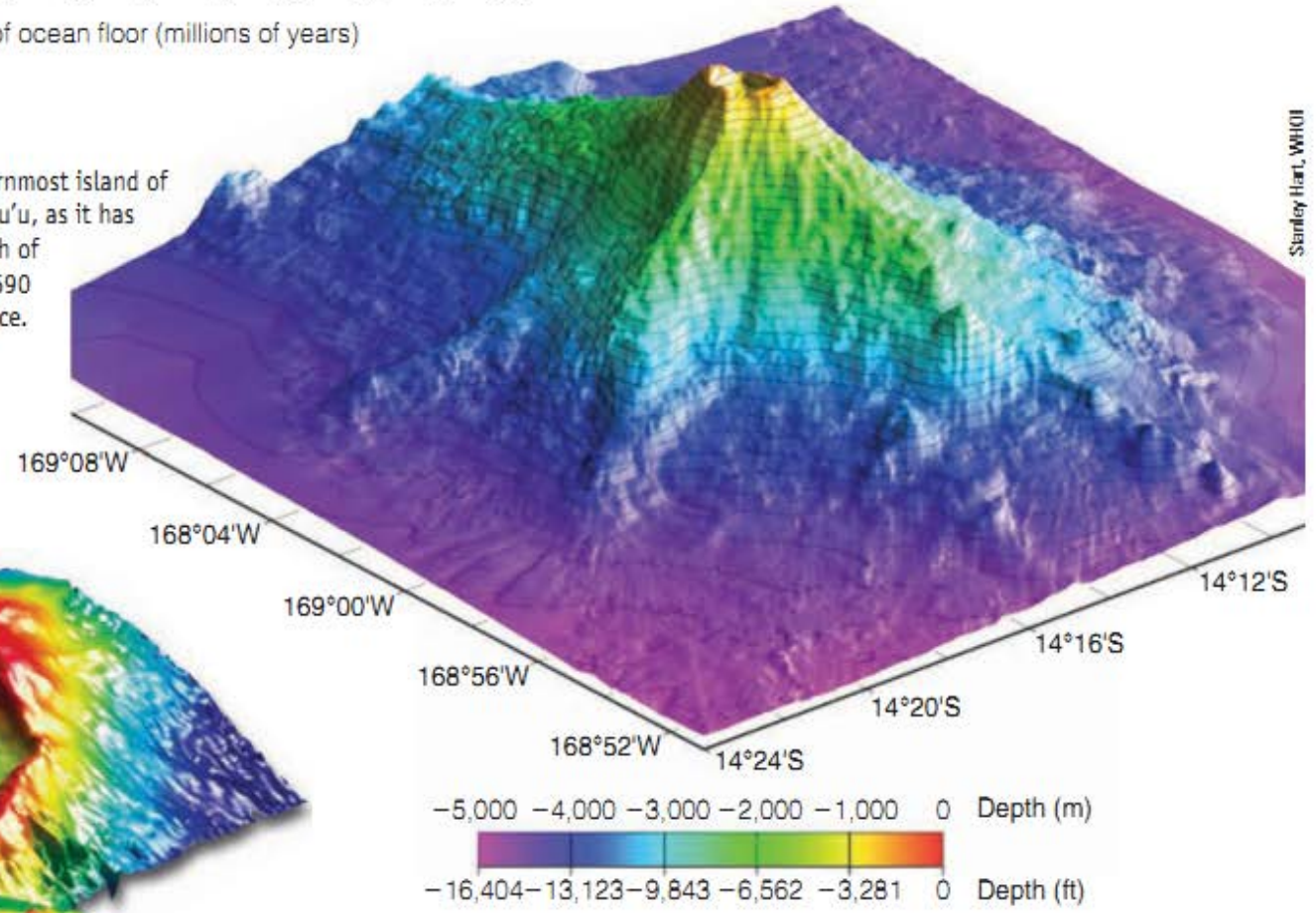
11.4 The Topology of Deep-Ocean Basins Differs from That of the Continental Margin

The process by which guyots (G) and seamounts(S) form

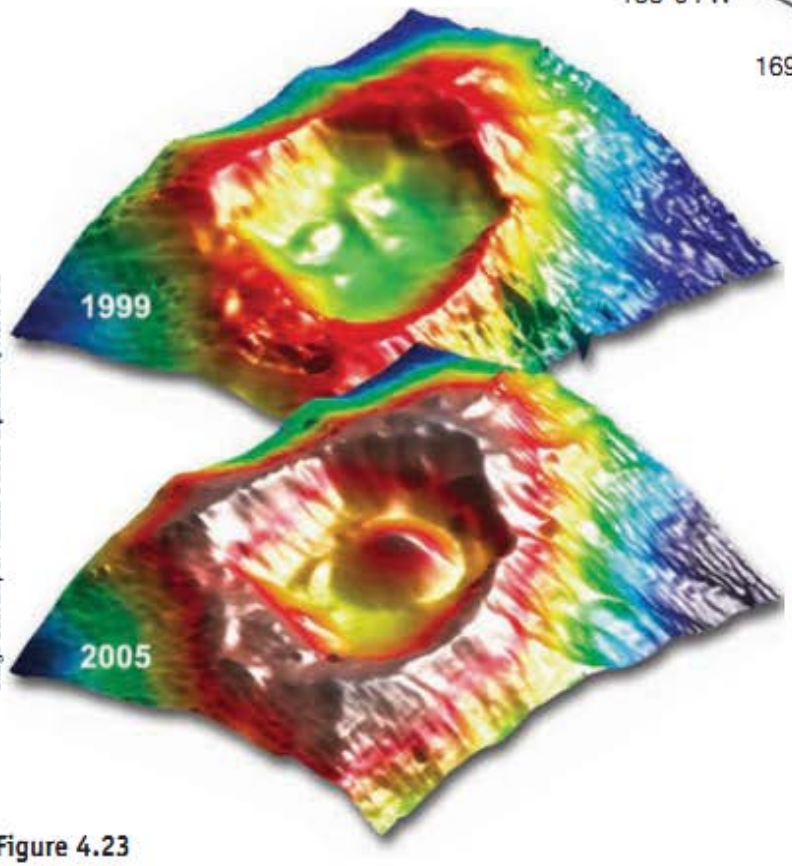


(a) The process by which guyots (G) and seamounts (S) form. Guyots have flat tops because they were once tall enough to be eroded by waves at the ocean's surface. Seamounts have a similar origin but retain their more pointed volcano shape because they never reached the surface.

Age of ocean floor (millions of years)



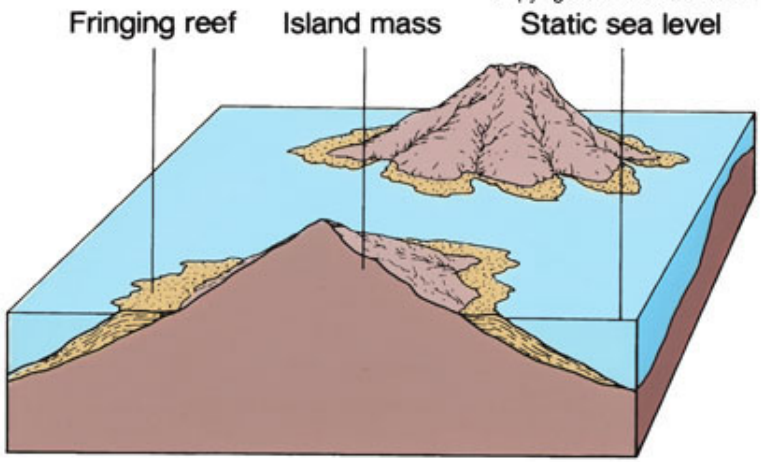
(b) An undersea volcano east of the easternmost island of the Samoan chain in the Pacific. Vailulu'u, as it has been named, rises from an ocean depth of 4,800 meters (15,700 feet) to within 590 meters (1,900 feet) of the ocean surface.



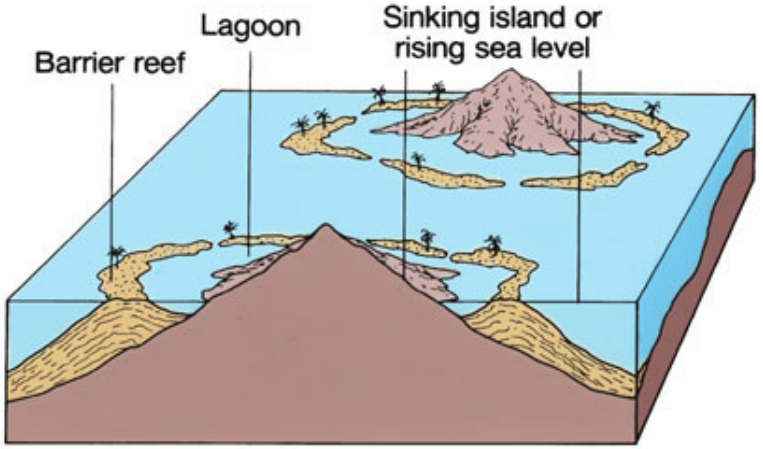
(c) A new volcano grew inside Vailulu'u between 1999 and 2005.

Figure 4.23

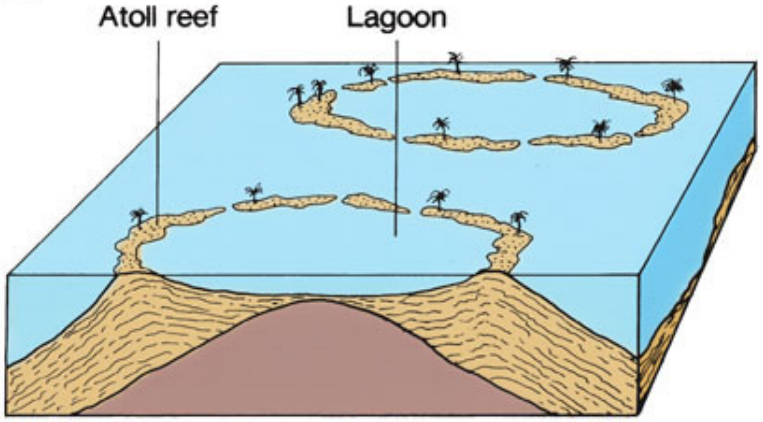
11.4 The Topology of Deep-Ocean Basins Differs from That of the Continental Margin



(a)



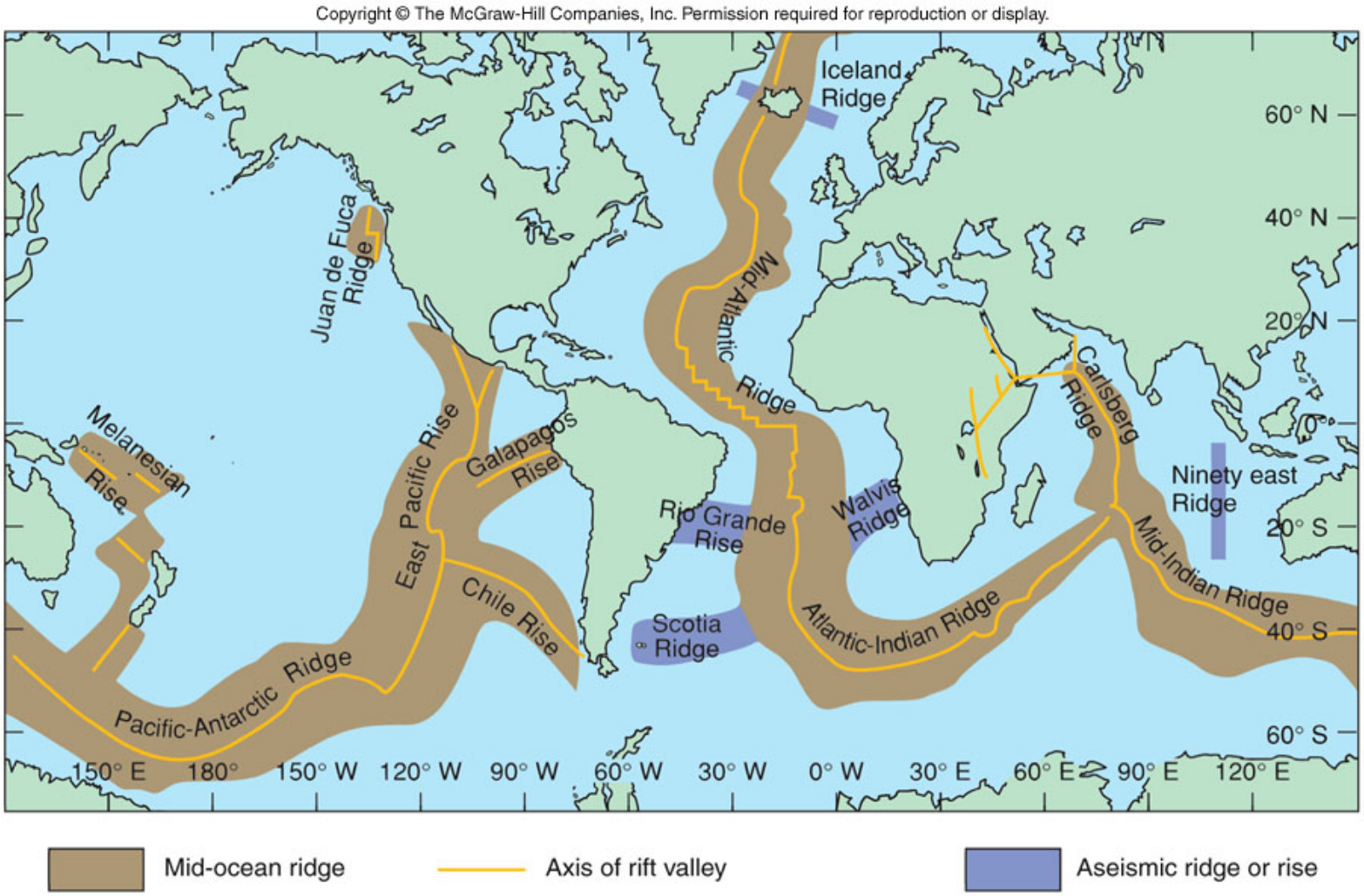
(b)



(c)

11.4 The Topology of Deep-Ocean Basins Differs from That of the Continental Margin

- An oceanic ridge is a mountainous chain of young basaltic rock at the active spreading center of an ocean

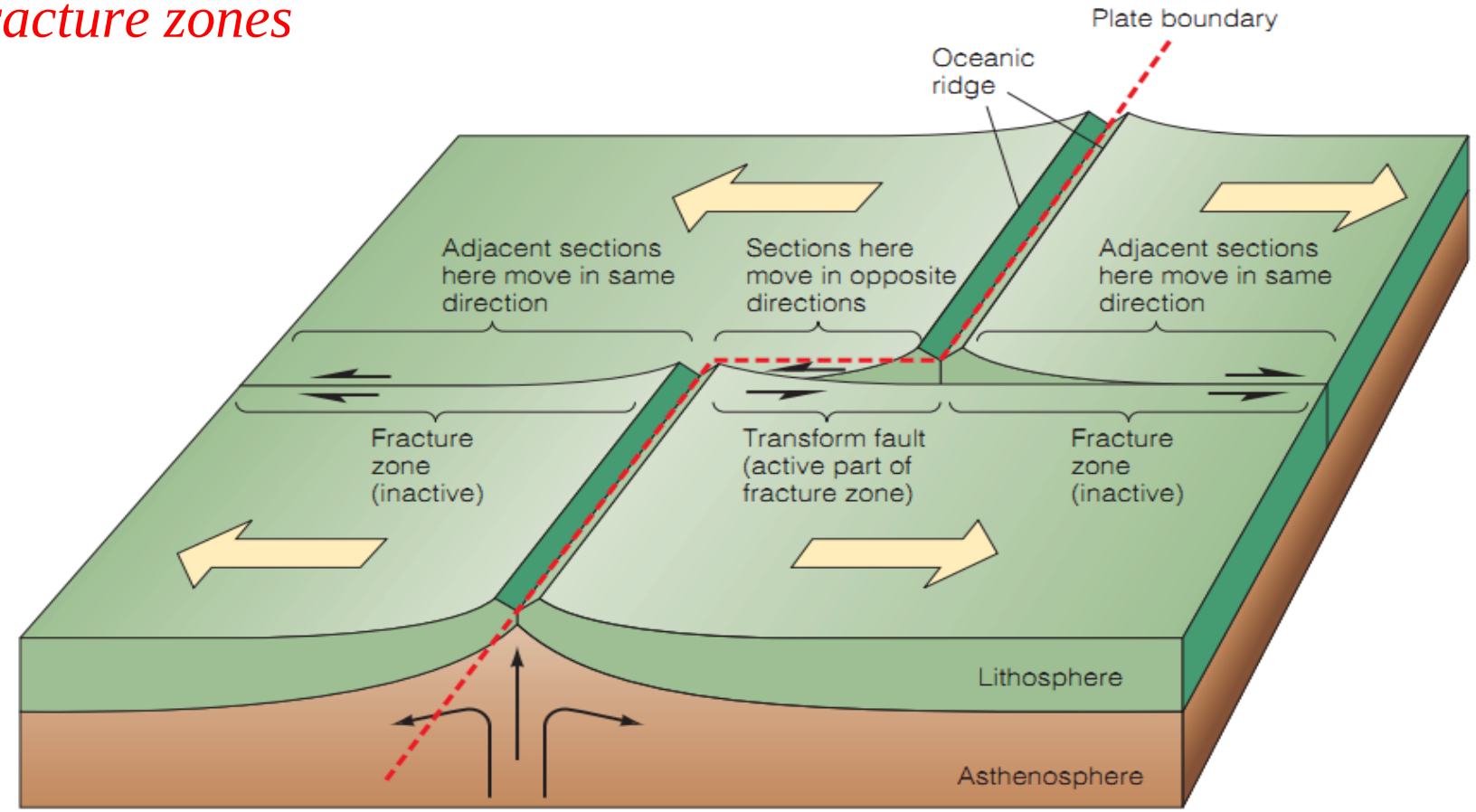



HUDSON BAY
NORTH AMERICA
MONTREAL
ST. LAWRENCE
CHICAGO
BOSTON
NEW YORK
WASHINGTON
MISSISSIPPI
ISLAND OF NEWFOUNDLAND
MID-OCEAN CANYON
ICEBERG RIDGE
ICELAND
FAEROE ISLANDS
FLEMISH CAP
KELVIN SEAMOUNT
LAURENTIAN CONE
MILNE SEAMOUNT
HOUSTON
NEW ORLEANS
SOHM ABYSSAL PLAIN
DUBLIN
HATTERAS ABYSSAL PLAIN
BERMUDA ISLANDS
OCEANOGRAPHER FRACTURE ZONE
CORNER SEAMOUNTS
MIDDLE ATLANTIC RIDGE
MIAMI
GULF OF MEXICO
BAHAMA ISLANDS
CUBA
BERMUDA RISE
MADEIRA ISLAND
CANARY ISLANDS
CASABLANCA
LISBON
MADRID
CARIBBEAN SEA
PUERTO RICO TRENCH
CARACAS
DEMERARA ABYSSAL PLAIN
AMAZON CONE
CAPE VERDE ISLANDS
GAMBIA ABYSSAL PLAIN
AFRICA
DAKAR
SOUTH AMERICA
AMAZON
SIERRA LEONE RISE
FORTALEZA
ROMANCHE FRACTURE ZONE
-46°30'
-46°
-45°30'

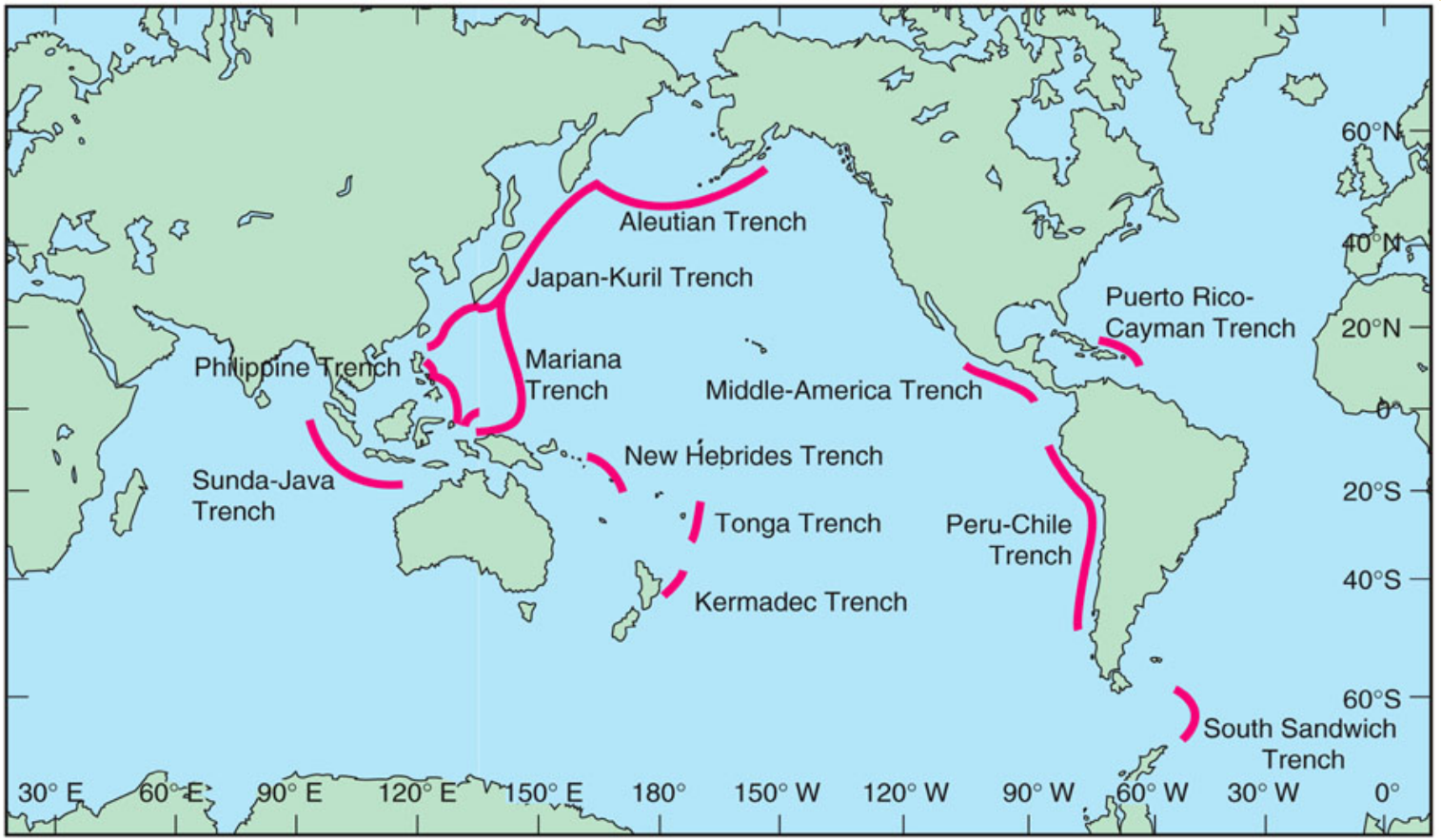
a

11.4 The Topology of Deep-Ocean Basins Differs from That of the Continental Margin

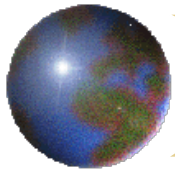
Transform faults and fracture zones along an oceanic ridge. Transform faults are fractures along which lithospheric plates slide horizontally past one another. Transform faults are the active part of fracture zones



A trench is an arc-shaped depression in the deep-ocean floor.



The water temperature at the bottom of a trench is slightly cooler than the near-freezing temperatures of the adjacent flat ocean floor,
reflecting the fact that trenches are underlain by old, relatively cold ocean crust sinking into the upper mantle.



4.5 The Sediment of Deep Sea Floor and Continental Margins

- Continental margins and ocean basins receive continuous supply
- Organic
  - plankton
- Terrigenous (Land)
  - Rivers, beaches
- Atmospheric
  - wind
- Space
  - tektites (meteorites)

4.5 The Sediment of Deep Sea Floor and Continental Margins

Table 3.5 Sediment Summary

Type	Source	Areas of Significant Deposit	Examples
Lithogenous (terrigenous)	Eroded rock, volcanoes, airborne dust	Dominantly neritic, pelagic in areas of low productivity	Coarse beach and shelf deposits, turbidites, red clay
Biogenous	Living organisms	Regions of high surface productivity, areas of upwelling, dominantly pelagic, some beaches, shallow warm water	Calcareous ooze (above the CCD), siliceous ooze (below the CCD), coral
Hydrogenous	Chemical precipitation from seawater	Mid-ocean ridges, areas starved of other sediment types, neritic and pelagic	Metal sulfides, manganese nodules, phosphates, some carbonates
Cosmogenous	Space	Everywhere but in very low concentration	Meteorites, space dust

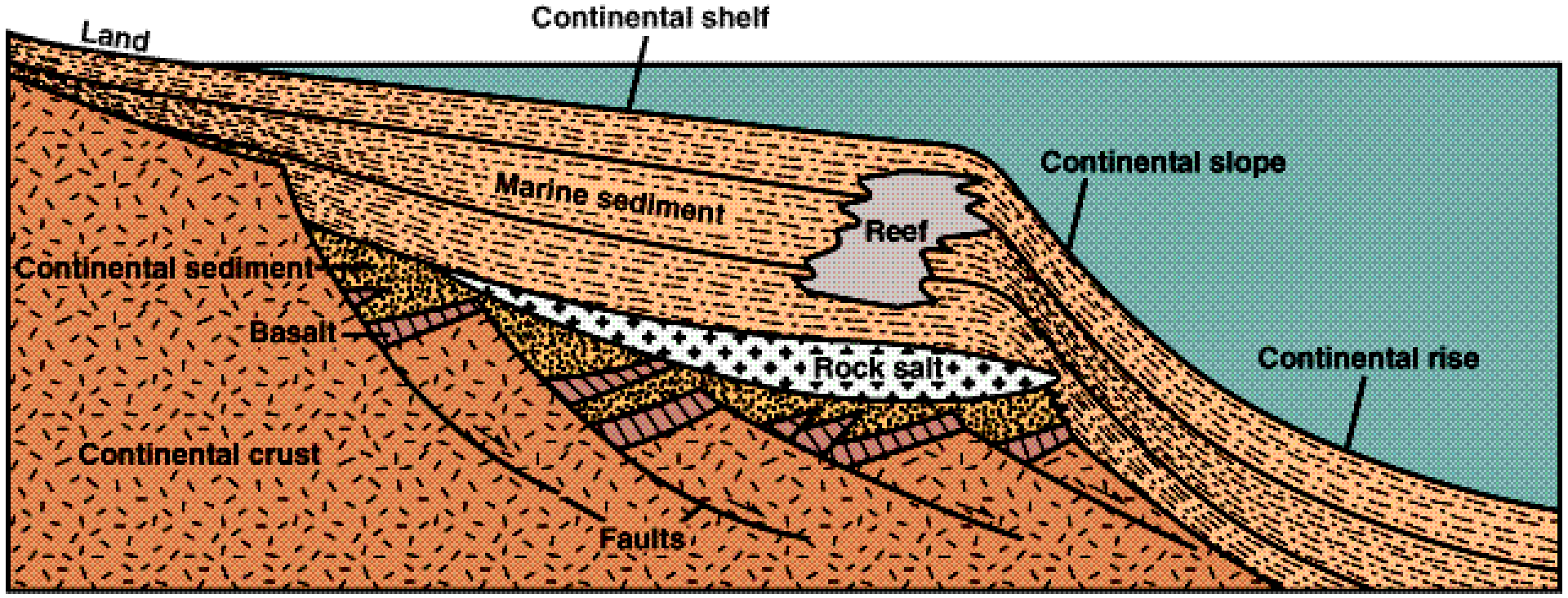
Continental Margin

- Thick Sequence of sediments (1000's m)
  - Passive margin
- Gravels, sands, muds
  - Rates of deposition vary 8m/yr in estuaries
  - 5m/1000yr quiet bays
  - Shelf and slope 10-40cm/1000yrs
- Carbonates
- Salts
- Potential for resources
  - Oil
  - Gas
  - Methane Hydrates

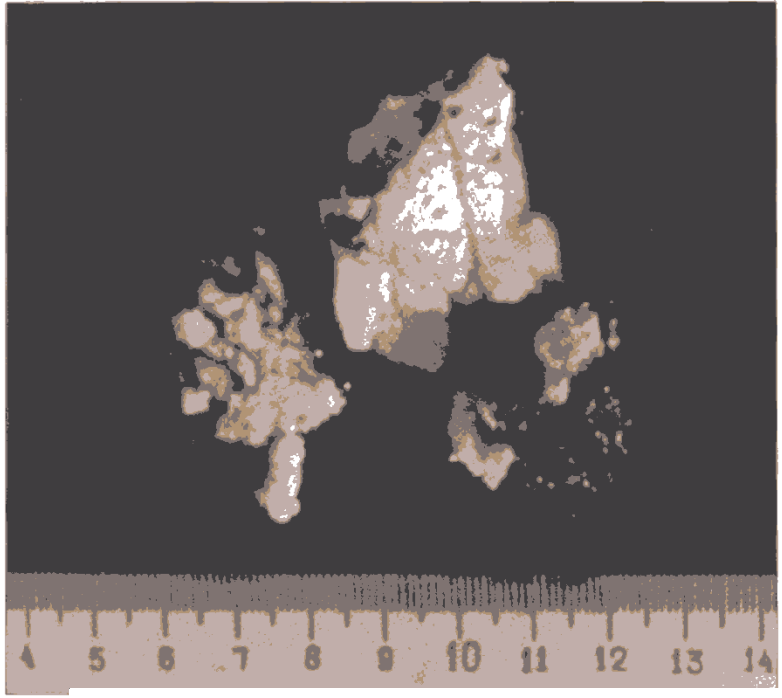
Sand and Gravel

- 1.2 billion tons/yr
- Reserves of 800 billion tons
  - US 450 billion tons
- UK & Japan take 20% from seafloor
- Other materials found within such as Fe, U, Pt, Au & Diamond
- The Tin Belt of SE Asia
- Carbonate sands

Passive Continental Margin

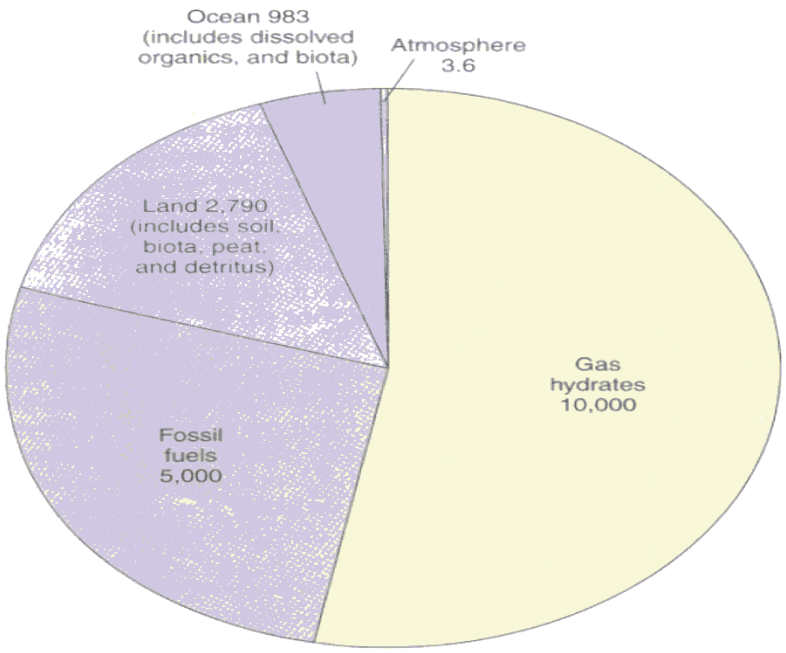


Oil and Gas account for 95% of material exploited from the sea 24.8% of oil and 20.7% gas in US came from offshore production (1997)



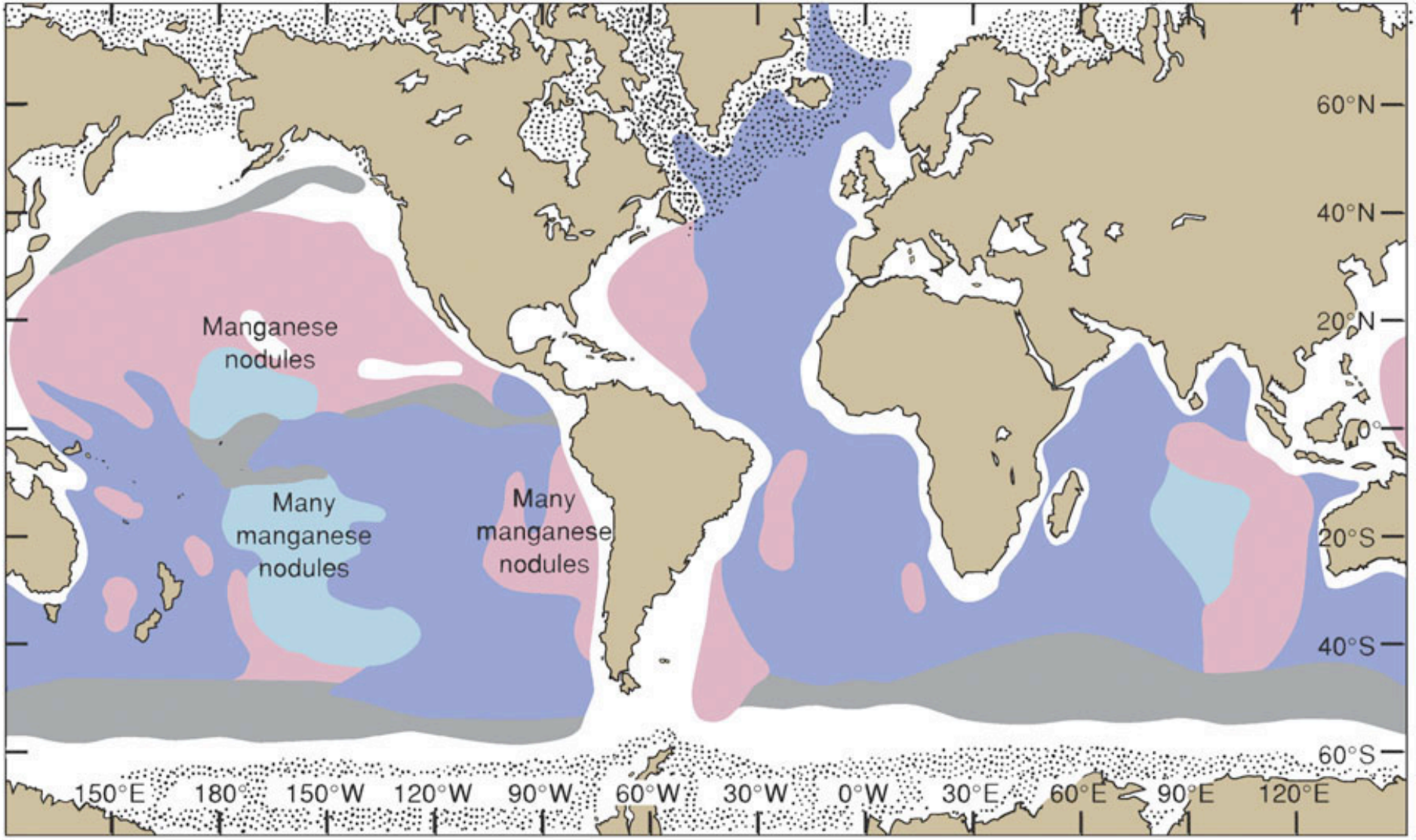
Gas Hydrates and other Gases

- Geopressurized zones
- Methane Hydrates, crystalline solids of gas and water abundant in arctic regions and marine sediments
- 1 ft^3 releases 160 ft^3 gas
- Offshore east coast area of potentially 1300 trillion ft^3 gas
- Reserves $4x10^{20}$ ft^3



Atmosphere-Wind

- Winds from deserts transfer terrigenous sediment 1000's kms into ocean basin
- Annual supply to oceans 100×10^6 metric tons
- Sahara-Caribbean connection
  - Reefs
  - Soils



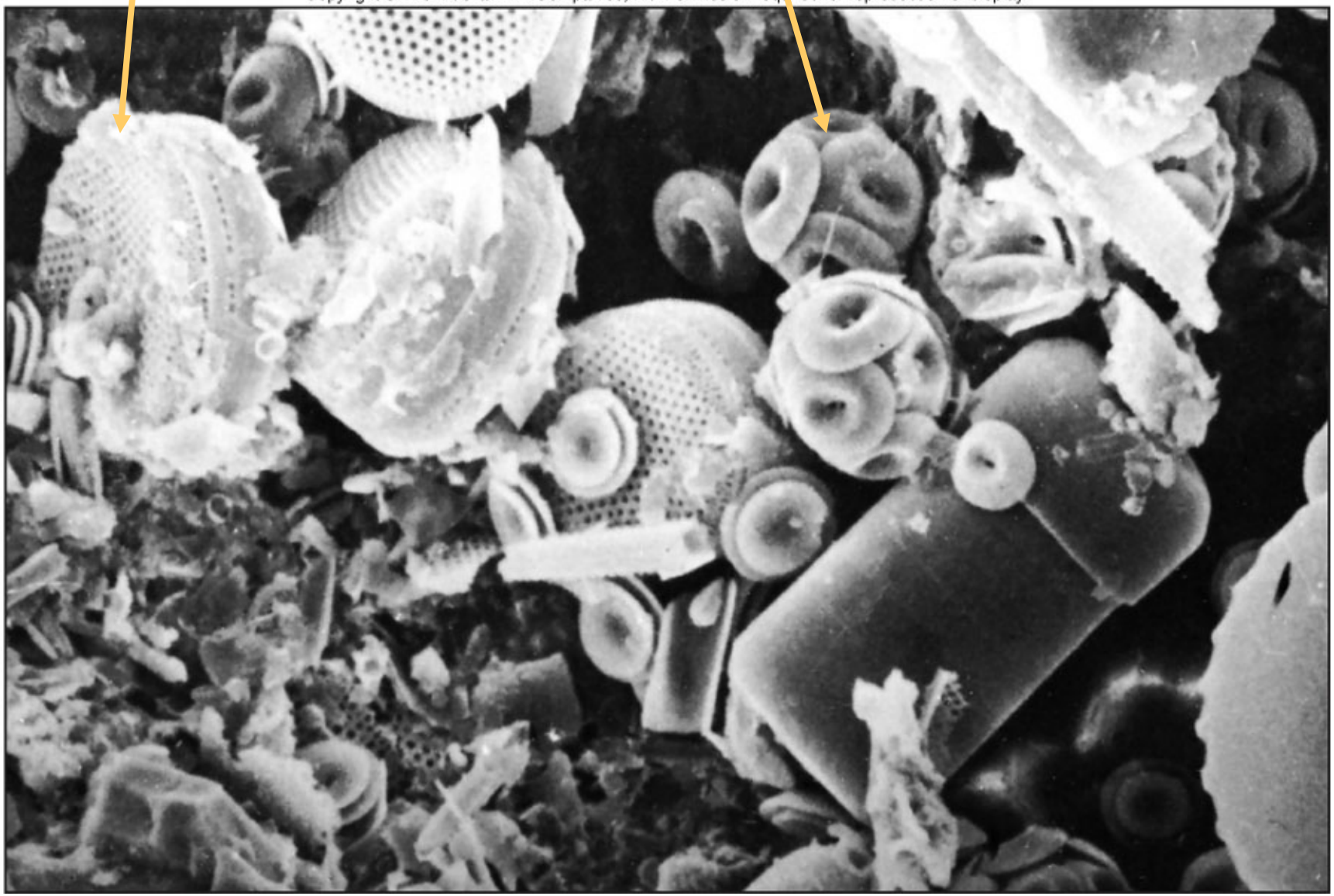
Biogenous Sediment

- Planktonic- Siliceous and Carbonate Oozes
  - Phytoplankton
    - Diatoms (silica)
    - Coccolithosphorids (carbonate)
  - Zooplankton
    - Radiolarians (silica)
    - Foraminefera (carbonate)
- Lysocline (dissolution)
  - CCD (carbonate compensation depth) <20% preservation CO_3 ~4500m
    - Atlantic (5000m)
    - Pacific (4200-4500m); Equatorial Pacific (5000m)

Biogenous Sediment

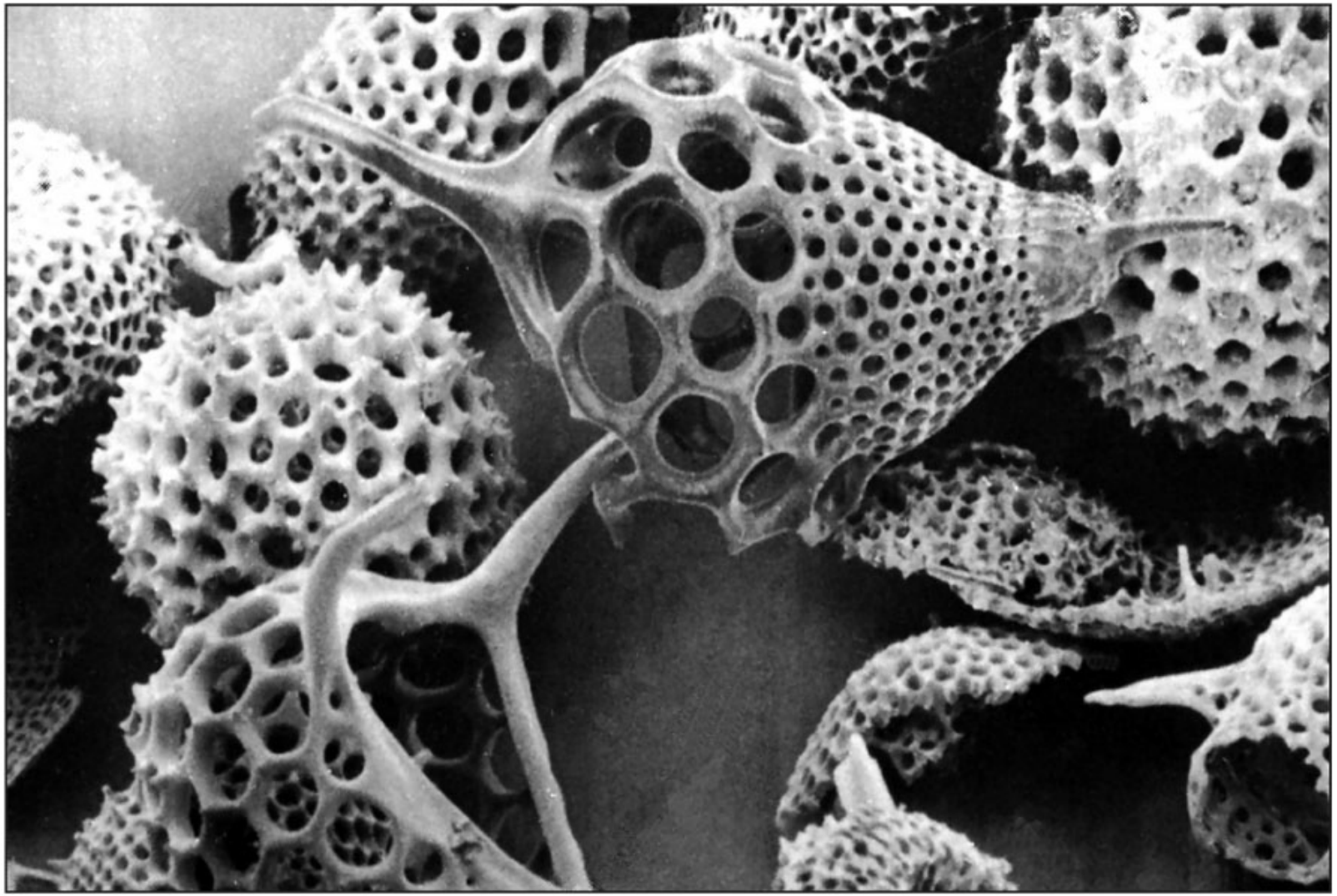
Diatoms

Coccolithosphorids

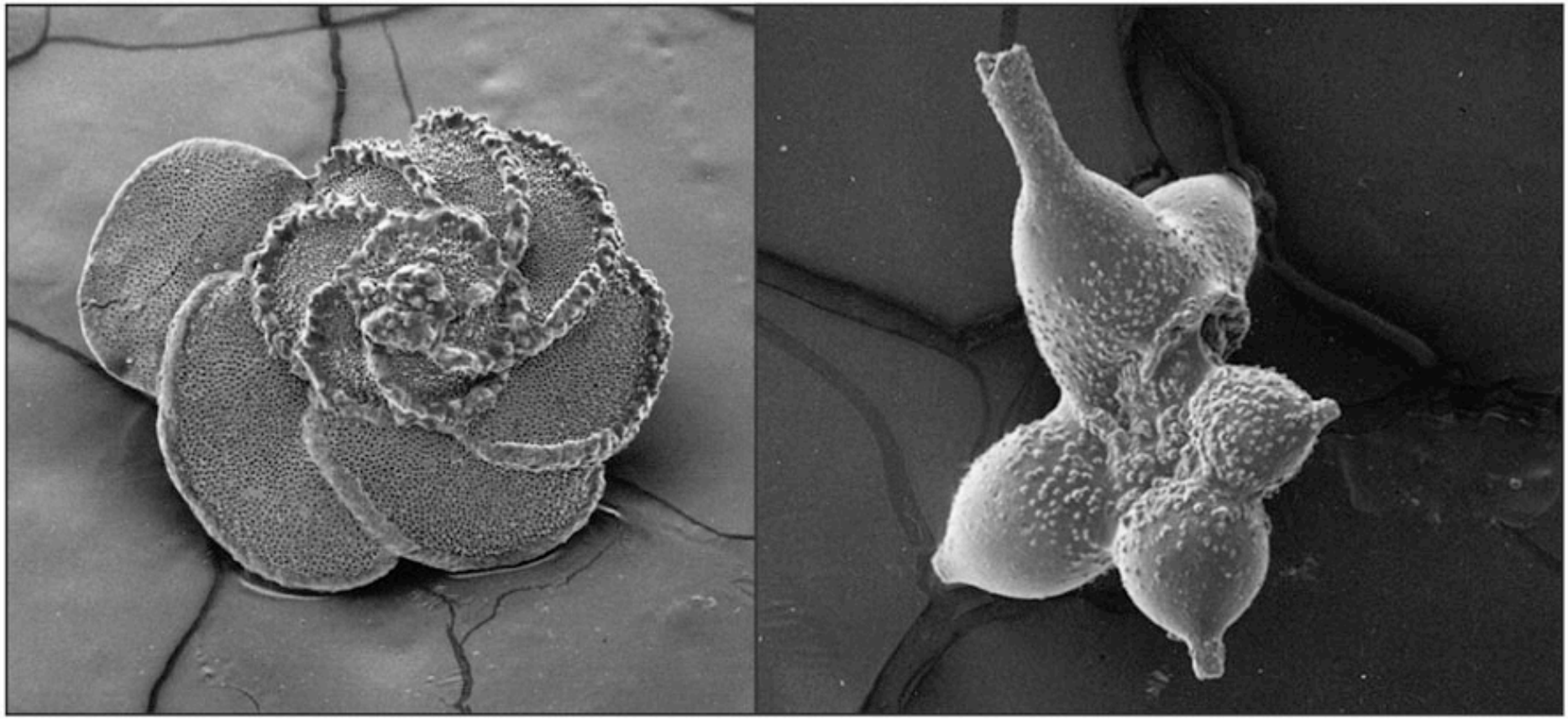


Biogenous Sediment

Radiolarians



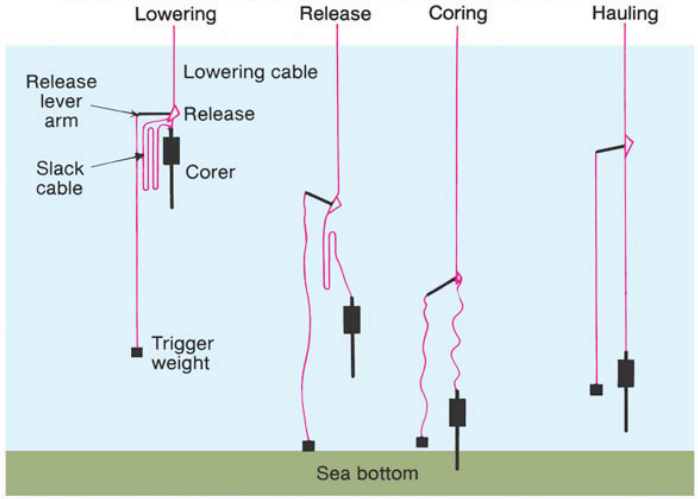
Biogenous Sediment



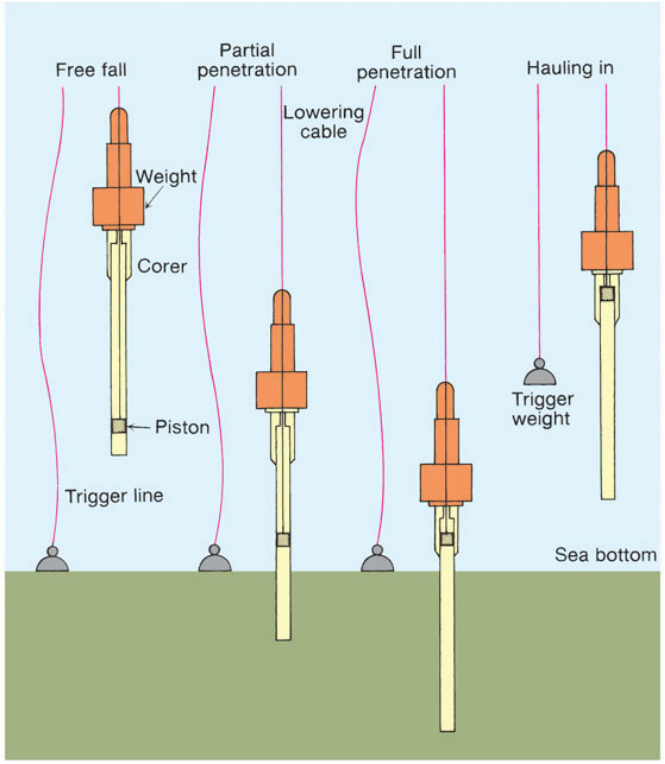
Foraminifera

Hydrogenous Sediment

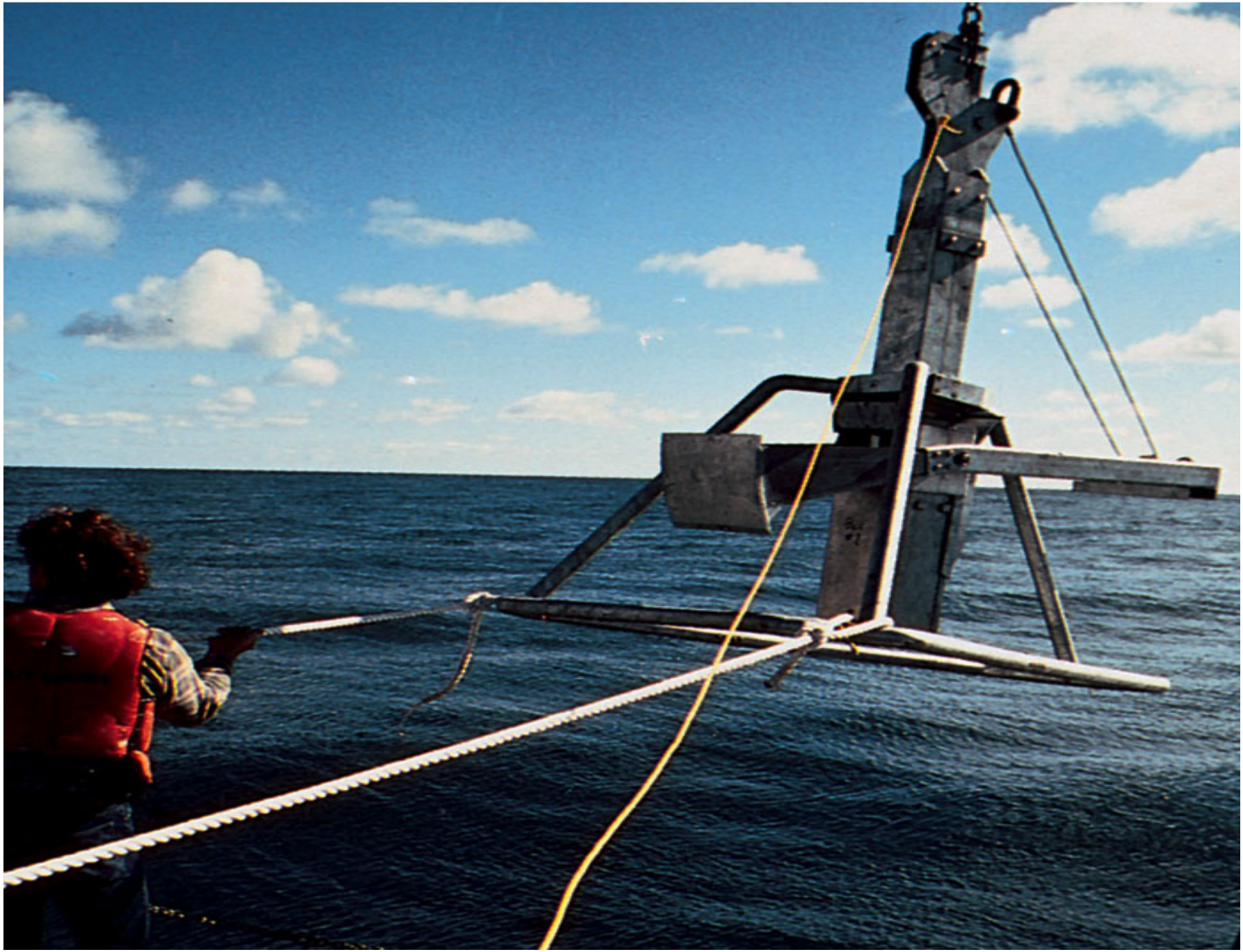
- Slow formation in water column
- Chemically precipitated
  - Carbonates (ooids, calcareous muds)
  - Phosphorites (fertilizers)
    - Continental shelf and slope
    - Reserve ~ 50 billion tons
    - Nodules or crusts
    - Due to high nutrients-upwelling
  - Salts (Mediterranean)
  - Manganese nodules
    - Concentric layering
    - High in Fe, Cu also
    - 1-10cm diameter
- Hydrothermal vents (smokers)-ores (sulfides)



(a)



(b)



Study break

Terms and Concepts to Remember

- abyssal hill, abyssal plain, active margin, bathymetry, continental margin,
- continental rise, continental shelf, continental slope, fracture zone,
- guyot, hydrothermal vent, ice age, island arc,
- ocean basin, oceanic ridge, passive margin, seamount, shelf break,
- submarine canyon, transform fault, trench,
- turbidity current,

Study break

- 1. Echo sounders bounce sound off the seabed to measure depth. How does that work?
- 2. How does a continental margin differ from a deep-ocean basin?
- 3. What are submarine canyons? Where are they found, and how are they thought to have been formed?