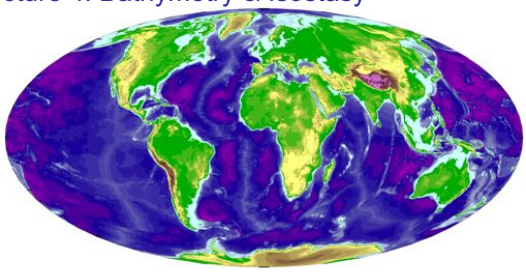
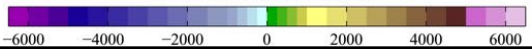
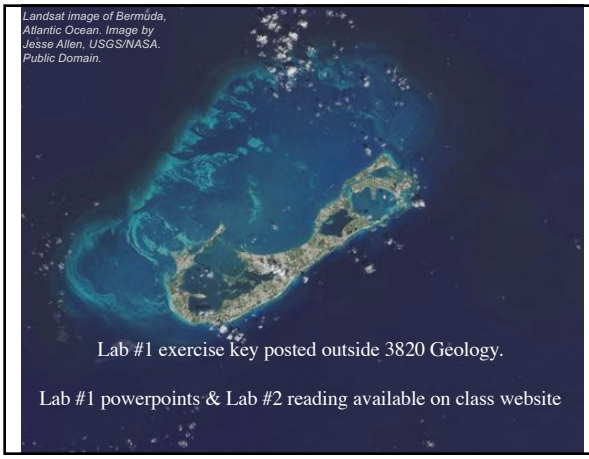
Introduction to Oceanography

Lecture 4: Bathymetry & Isostasy



Plumbago, wikimedia commons, C C A S-A 3.0



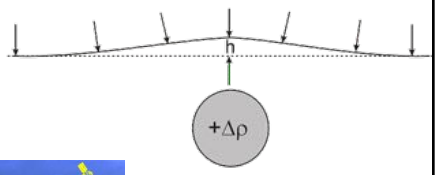


Landsat image of Bermuda, Atlantic Ocean. Image by Jesse Allen, USGS/NASA. Public Domain.

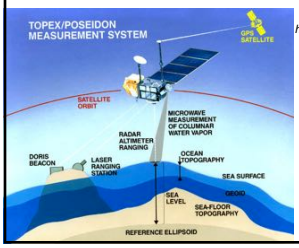
Lab #1 exercise key posted outside 3820 Geology.

Lab #1 powerpoints & Lab #2 reading available on class website

Satellite radar mapping (gravity)



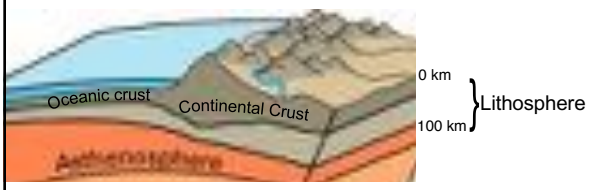
http://principles.ou.edu/earth_figure_gravity/geoid/geoid.gif



NASA/JPL image, Public Domain. http://topex-www.jpl.nasa.gov/technology/technolog

Oceanic vs. Continental Crust

- Bimodal elevation distribution due to
  - Continental Crust
    Vs.
  - Oceanic Crust

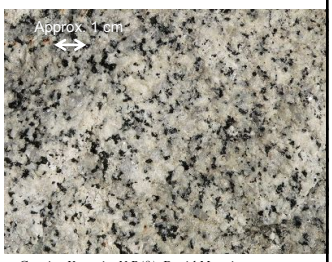


Adapted from USGS image, Public Domain

Continental Crust: Granitic

- Continents typically made up of the rock granite
- Density: 2.7-2.8 gm/cm^3
  - density = mass/volume
- Light in color, coarse in texture
  - Yosemite/ Mt. Whitney rock

Granite hand specimen

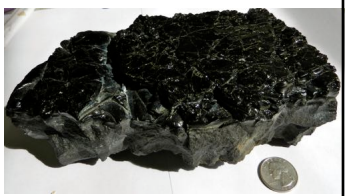


Granite, Yosemite N.P.(?), David Monniaux, Wikimedia Commons, Creative Commons Att. S-A 3.0

Oceanic Crust: Basaltic

- Ocean crust made up of basaltic rock
- Density: 2.9-3.0 gm/cm^3
- Basalts are typically about 0.2 gm/cm^3 denser than granites
  - about 7% denser

Basalt hand specimen

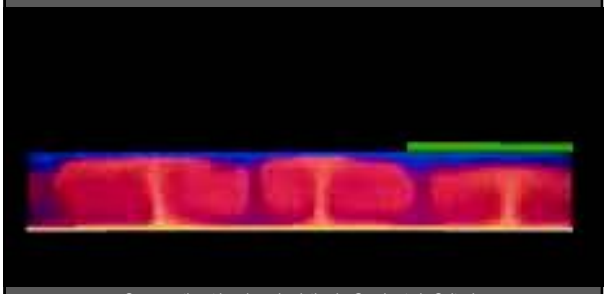


Mid-ocean ridge basalt, East Pacific Rise, photo by E. Schauble, Sample courtesy A. Schmitt

Oceanic vs. Continental Crust

- Continental Crust
  - 30-40 km thickness
- Oceanic Crust
  - 5-10 km (thinner) & denser than CC
- Crust underlain by denser mantle
  - ~ 3.3 gm/cm^3
  - ~ 15% denser than crustal materials
  - Can flow at depths below ~100 km, i.e. in the asthenosphere.

QUESTIONS?



Supercontinent breakup simulation by Gurnis et al., Caltech, http://www.gps.caltech.edu/~gurnis/Movies/Science_Captions/aggdisp.html

What is Buoyancy?

- Archimedes' Principle: A solid will sink into a fluid until the displaced fluid's mass is equal to the mass of the solid.

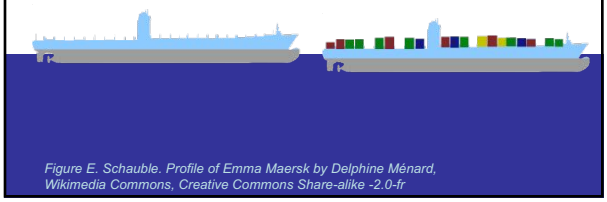


Figure E. Schauble. Profile of Emma Maersk by Delphine Ménard, Wikimedia Commons, Creative Commons Share-alike -2.0-fr

What is Buoyancy?

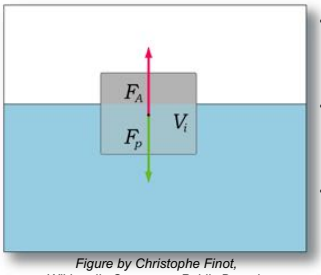


Figure by Christophe Finot, Wikimedia Commons, Public Domain

- Any object in a fluid will be pushed up as the fluid tries to fill in the space taken up by the object.
- At rest, a buoyant object will sit so that the mass of fluid it displaces equals the mass of the object.
- The downward force of gravity on the object is balanced by the restoring force from gravity pushing fluid into the displaced volume.

1) Low density materials don't have to displace as much fluid to match their mass, so they float higher
2) Thicker pieces of material have more volume left over after displacing their mass, so they float higher

Isostatic Balance

- Blocks of lithosphere (crust + uppermost mantle, ca. 100 km thick) **float** atop the plastic asthenosphere

Which is more like continental lithosphere?

Which is more like oceanic lithosphere?

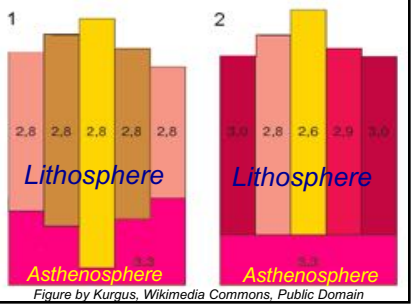
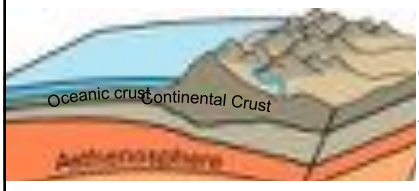


Figure by Kurgus, Wikimedia Commons, Public Domain

Elevation of Continents vs. Oceans



Oceanic Crust: Thinner & Denser

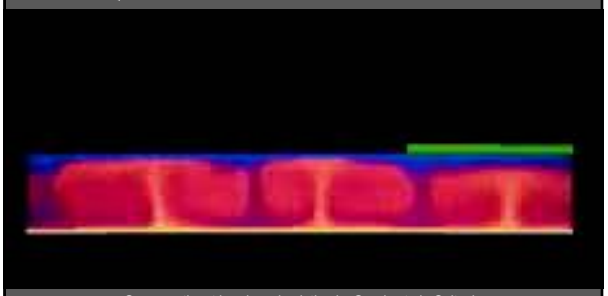
Continental Crust: Thicker & Lighter

Adapted from USGS image, Public Domain

Oceans vs. Continents

	OCEANS	CONTINENTS
Average Elevation	–3800m	+840m
Surface Area	71%	29%
Crustal Distribution	59%	41% (Margins)
Crustal Thickness	5 - 10 km	30 - 70 km
Density	3.0 gm/cm^3	2.7 gm/cm^3

QUESTIONS?



Supercontinent breakup simulation by Gurnis et al., Caltech, http://www.gps.caltech.edu/~gurnis/Movies/Science_Captions/aggdisp.html

Morphology of the Oceans

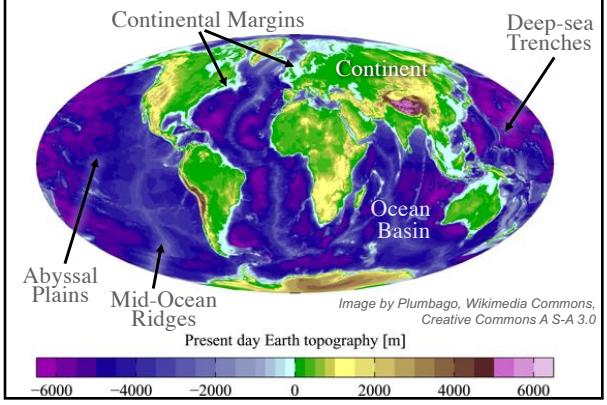


Image by Plumbago, Wikimedia Commons, Creative Commons A S-A 3.0

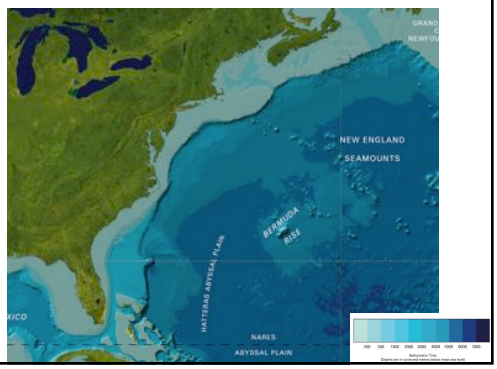
Continental Margins

- Two Types
  - Atlantic style "passive" margins
    - Broad flat shelves
    - Examples are Florida, Virginia
  - Pacific style "active" margins
    - Narrow shelf adjacent to a deep-sea trench
    - Examples are Chile, Japan

Distances and depths of margin features are variable. Active margin features are narrower and extend deeper than on passive margins.

Passive Margins (Atlantic-style)

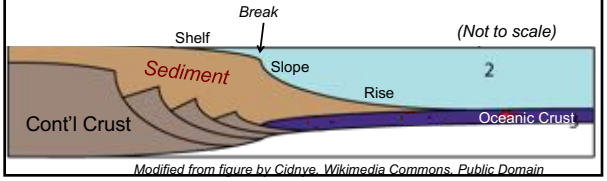
Broad continental shelf, gradual transition to deep ocean.



Bathymetry from GEBCO world map, http://www.gebco.net, educational use expressly

Passive Continental Margins

- "Drowned" continental sediments pile up adjacent to the continents
- Comprised of:
  - Continental Shelf
  - Shelf Break
  - Continental Slope
  - Continental Rise



Modified from figure by Cidnye, Wikimedia Commons, Public Domain

Continental Shelf

- **Shelf**: terraces of sediment
- Width: variable,
  ~10 km (active)
  ~100's km (passive).
- Slope ≤ 0.5º
  Very flat
- Ends at the **Shelf Break**
  Occurs at average water depth
  approx. 140 m (variable)

Figure from NOAA Ocean Explorer, http://oceanexplorer.noaa.gov/technology/tools/mapping/media/GulfofMexico.jpg Public Domain

Continental Slope

- Beyond Shelf Break is the **Continental Slope**
- Much steeper, ~4º
- Depths: to ~3-4 km
- Typical width ~20 km

Figure from NOAA Ocean Explorer, http://oceanexplorer.noaa.gov/technology/tools/mapping/media/GulfofMexico.jpg Public Domain

Continental Rise

- At the base of the continental slope
- Slope lessens
- Depths: from ~2km - 5km
- Width: ~ 100-1000 km
- Sedimentary "apron" or "fan"

Bathymetry from GEBCO world map, http://www.gebco.net, educational use expressly allowed.

Turbidity currents and the slope

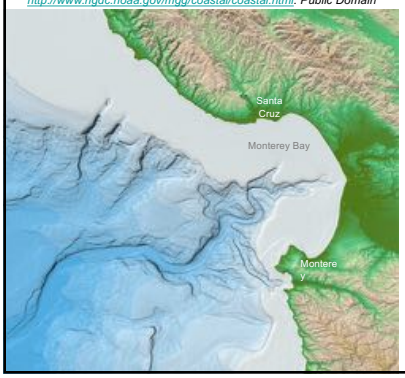
Active Margins

- A steeper, narrow margin, usually bordered by a deep sea trench.
- Particularly common around the Pacific Ocean.

Bathymetry from GEBCO world map, http://www.gebco.net, educational use expressly allowed.

Submarine Canyons

Image from Divins, D.L., and D. Metzger, NGDC Coastal Relief Model, http://www.ngdc.noaa.gov/mgg/coastal/coastal.html. Public Domain



- Erosional incisions through shelf and slope
- Transport sediments from the rise out onto abyssal plains
  - Turbidity currents
    - Transport sediments onto Abyssal Plains

Submarine Canyons, carved by debris flows and turbidity currents, not rivers

Movie by AGU & Lai et al. Morpholydraulics Imaging Laboratory, National Cheng Kung University, Taiwan. http://blogs.agu.org/geospace/2016/05/24/watch-underwater-canyons-take-shape-real-time/

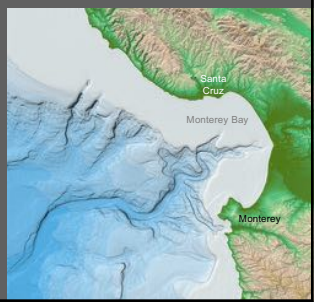


Image from Divins, D.L., and D. Metzger, NGDC Coastal Relief Model, http://www.ngdc.noaa.gov/mgg/coastal/coastal.html. Public Domain

Deep-Sea Trenches

Depths: 5 - 11 km

Widths: 30 - 100 km

Associated with volcanism and island arcs

- i.e., the Andes and the Aleutians, respectively

Also associated with the strongest and deepest earthquakes on the planet

Passive Margin

Same image credit as prevous slide.

Active Margin

Deep-Sea Trenches

The Ring of Fire – Trenches, earthquakes and volcanoes concentrated along the Pacific, including active margins.

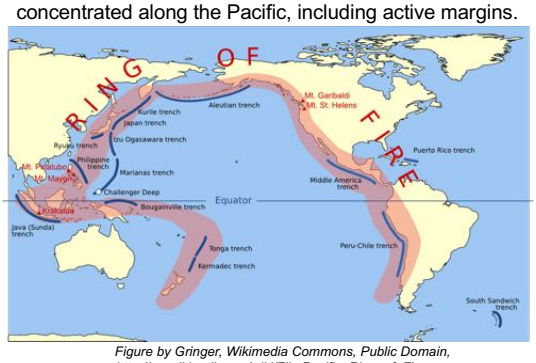


Figure by Gringer, Wikimedia Commons, Public Domain, http://en.wikipedia.org/wiki/File:Pacific_Ring_of_Fire.svg