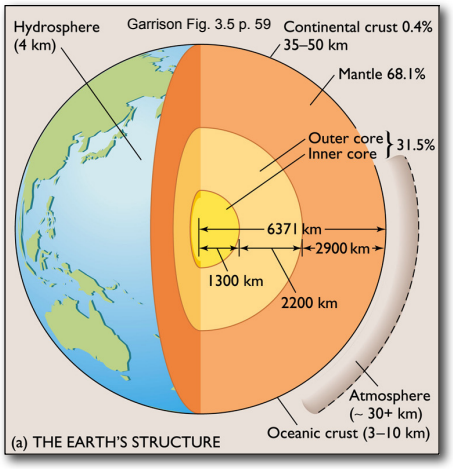
Journey to Center of Earth

- Types of rocks that make up the Earth
- Internal layers of the Earth
- Ocean sediments



Rocks at the Earth Surface

- Igneous:
  - Cooled directly from liquid rock (magma)
- Sedimentary
  - Formed from small particles (sediments) that sink to the sea floor
    - Compressed to form rock (lithified)
- Metamorphic
  - Igneous or sedimentary rocks altered in shape and chemistry by pressure, heat, and bending

Igneous Rocks

- Liquid rock is called:
  - Magma below the Earth's surface
  - Lava on the Earth's surface
- Classified by two properties
  - Color
    - Indicates density
  - Size of crystal grains
    - Indicates where it formed
- Online study guide to igneous rocks:
  - http://volcano.und.edu/vwdocs/vwlessons/lessons/Igrocks/Igrocks1.html

What Does Color Tell Us?

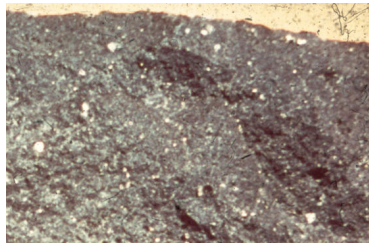
- Density
  - g/cm^3 (water = 1)
  - Denser rocks are darker in color
- Chemical composition
  - Inclusion of heavier elements makes rock denser
  - Heavier elements are darker in color

Color, Density, & Chemistry

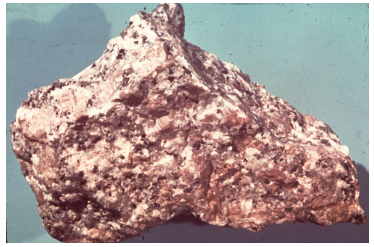
- Dense and dark color
  - More heavy, dark-colored elements: iron (Fe) and manganese (Mn)
  - Referred to as “Basic,” “Sima” and “Mafic.”
- Less dense and lighter color
  - More light & light-colored elements: Si, aluminum (Al), and magnesium (Mg)
  - Referred to as “Acidic,” “Sial” and “Felsic.”
- Both are mostly silicon (Si)

Color, Density, & Chemistry

- A denser, darker rock: Basalt

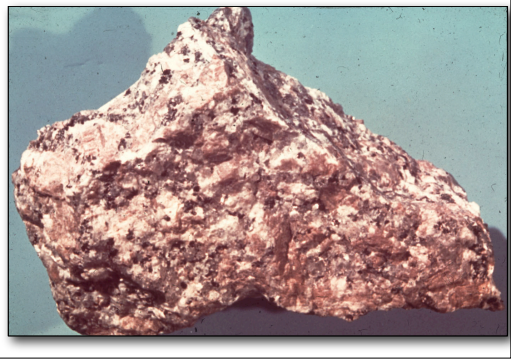


- A less dense, lighter rock: Granite



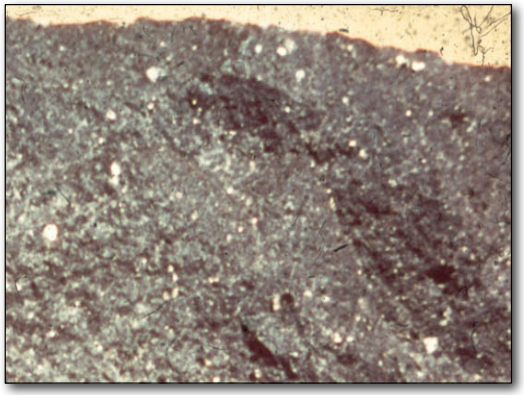
Grain Size

- Reveals where rock cooled from magma
- Coarse grains = visible to naked eye
  - Slow cooling—time for large crystals to grow
  - Deep in Earth
  - Insulated from air & water
  - *Intrusive* into existing rock layers
- Granite



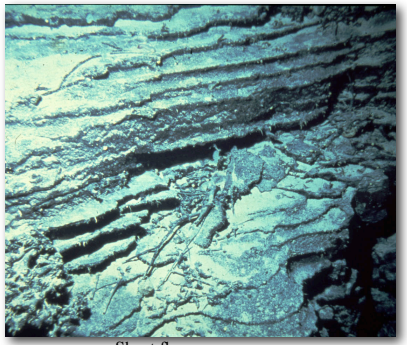
Grain Size

- Fine grains = invisible to naked eye
  - Rapid cooling—no time for crystals to grow
  - At Earth surface
  - Exposed to air or water
  - *Extrusive* atop existing rock
- Basalt



Examples of Basalt

- Lava flow under water
- Rapid cooling

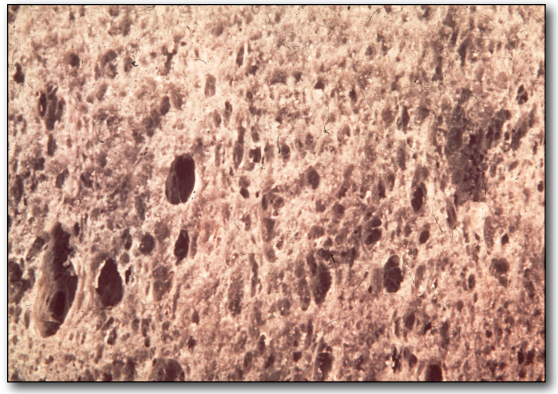


Sheet flow

"Pillow lava"

Fine-Grained "Felsic" Rock

- Lava with same composition as granite exploded into air
- Light color
- Very rapid cooling
- Frozen gas bubbles
- Pumice



The Rock Families

- "Granite family"
  - Granite = coarse; Rhyolite = fine
  - Density = 2.8 g/cm^3
- "Basalt family"
  - Basalt is fine; Gabbro = coarse
  - Density = 3.0 g/cm^3
- Very dense "Ultramafic"/"Ultrabasic" rocks
  - Olivine, pyroxene below Earth's surface

The "Hybrid" Rock Family

- Mixtures of Granite & Basalt families
  - Basaltic magma erupting through granitic rock
  - Intermediate in density and color
  - Occurs under specific geologic conditions
- Andesite—fine-grained
  - Mt. St. Helens
  - Explosive combination
- Diorite—coarse-grained

Categories of Igneous Rocks

	Continental Crust: Felsic, Sial (**Silicon-Aluminum**)	Intermediate & Mixtures		**Oceanic Crust**: Mafic, Sima (**Silicon-Magnesium**)
Density	**≃ 2.8**	≃ 2.9		**≃ 3.0**
Silica (SiO_2) content	70-78%	62-70%	54-62%	45-54%
Color	**Lighter.....Darker**			
Coarse-grained (intrusive, **slow subsurface cooling**)	**Granite**	Granodiorite	Diorite	Gabbro
Fine-grained (extrusive, **rapid surface cooling**)	Rhyolite	Dacite	**Andesite**	**Basalt**

Internal Structure of Earth

- How do we know what is inside the Earth?

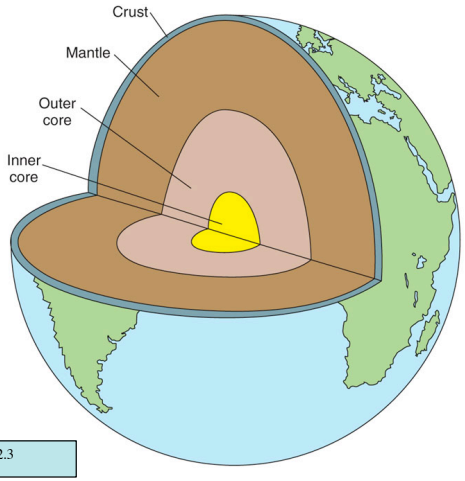


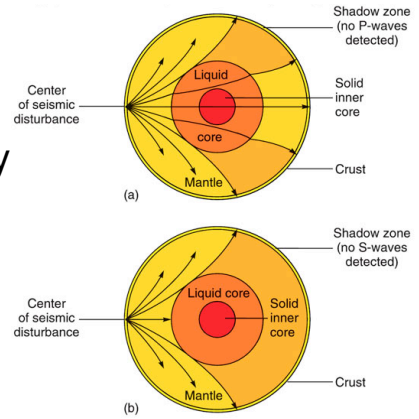
Figure 2.3

Probing the Earth's Interior

- Seismic waves generated by earthquakes
  - P=primary (push-pull or pressure) waves
    - Travel through solid and liquid but bend when passing through changes in density
  - S=secondary (snake) waves
    - Cannot pass through liquid
  - Both waves travel slowly through soft (warm) layers & faster through hard (cold) layers

Probing the Earth's Interior

- P=primary (push-pull or pressure) waves refract with changes in density
- S=secondary (snake) waves pass only through solid layers



"Shadow zones" reveal inner layers

The Three-layered Earth

- If Earth was a candy, what would it be?
  - Brittle candy shell
  - Toffee middle layer
  - Liquid inner layer
  - Hard candy or nut center

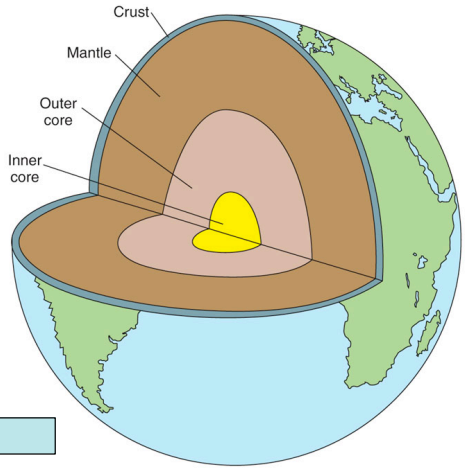


Figure 2.3

The Three-layered Earth

- Seismic waves and other data tell us:
  - Crust
    - 2 Sublayers
  - Mantle
    - 3 sublayers
  - Core
    - 2 sublayers

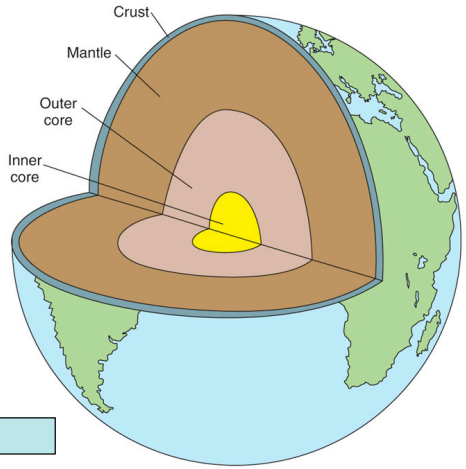
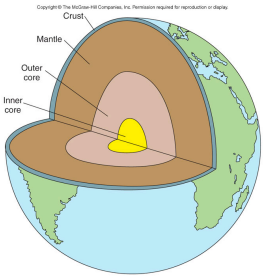


Figure 2.3

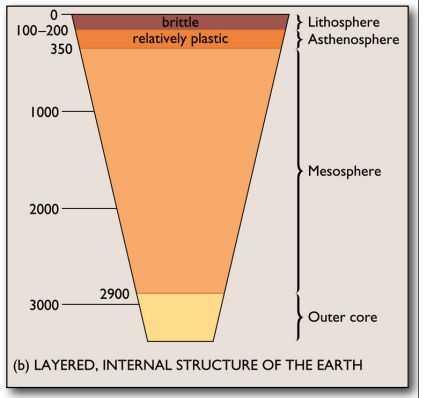
The 2-Layered Core

- Inner (solid) core
  - Density 13 g/cm^3
  - Density of liquid mercury is 13
- Outer (liquid) core
  - Density 11 g/cm^3
  - Density of solid lead is 11.5
- Composed mainly of iron (Fe) & nickel (Ni)



The 3-layered Mantle

- Upper (rigid) mantle attached to crust
- Middle (plastic, ductile or "putty-like") asthenosphere
- Lower (solid) mantle (Mesosphere)
- Mg-Fe silicates ("ultramafic")

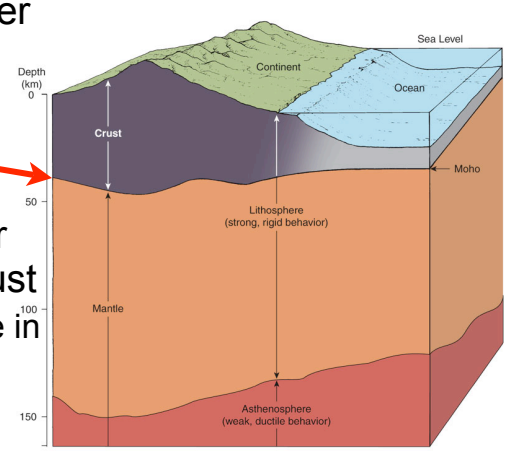


Layers of the Earth's Interior

Layer		Depth (km)	State	Composition	Density (g/cm^3)
Lithosphere	Crust	0-10, 0-65	Solid		
	Continental	0-65	Solid	Al silicates	2.7
	Oceanic	0-10	Solid	Mg silicates	3.0
Moho					
	Mantle	10/65-2900		Mg-Fe silicates	(4.5)
	Upper	10/65-70/150	Solid	Mg-Fe silicates	3.2
	Asthenosphere	70/150-250/700	Ductile	Mg-Fe silicates	3.4
	Mesosphere	250/700-2900	Solid	Mg-Fe silicates	5.6
	Core	2900-6370		Fe & Ni	
	Outer	2900-5300	Liquid	Fe & Ni	11.5
	Inner	5300-6370	Solid	Fe & Ni	13.0

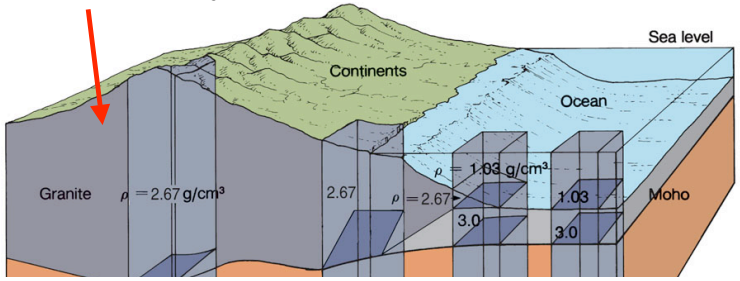
The Lithosphere

- Solid outer layer
  - Crust + Upper mantle
- Moho is boundary between upper mantle and crust
  - Abrupt change in density & chemical composition



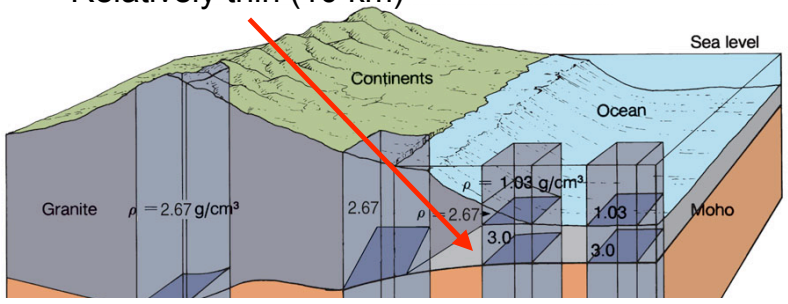
The 2-layered Crust

- Continental crust
  - Light-colored, less-dense (2.7)
  - Granite-family rocks (Sial)
  - Relatively thick (up to 65 km)



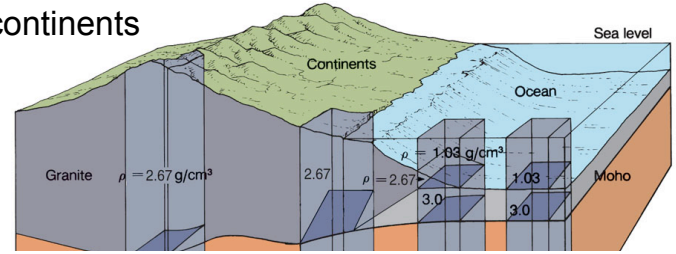
The 2-layered Crust

- Oceanic crust
  - Dark-colored, denser (3.0)
  - Basalt-family rocks (Sima)
  - Relatively thin (10 km)



The 2-layered Crust

- Continental crust extends underwater
  - Includes continental margin
  - Rise or trench is geologic boundary with oceanic crust
  - But chunks of oceanic crust found on continents

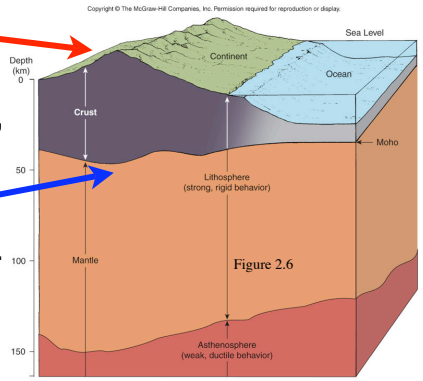


The process of Isostasy

- A form of buoyancy
- The depth at which an object floats on a denser fluid
  - I.e. wood on water, iceberg on the ocean
- "Ice-ostasy": like an iceberg
  - Most of a floating object is below the fluid surface.
  - Removing or adding weight causes the object to float higher or lower.

The process of Isostasy

- The higher a feature rises above the Earth's surface, the lower its "roots" will extend below the Earth's surface.
  - Continental crust is thickest & deepest where it is highest above the surface
  - Like an iceberg



The process of Isostasy

- Added load on crust causes it to sink
- New volcano sinks over time as the lithosphere gradually subsides atop asthenosphere