EPSC 201 – LECTURE 11 – FEBRUARY 16 2016

Preparing for Earthquakes

We can’t stop them but we can be ready for them.

- Train the community in earthquake preparedness
- Run preparedness drills
- Educate individuals on safe behaviour and responses
- Keep viable stores of emergency supplies

Practice Question: All else being equal, which building would more likely survive a large earthquake?

Answer: One whose foundation is built on an exposure of granite bedrock. If you have hard bedrock, the seismic waves go faster and their amplitude does not increase. If you build on granite, you are more likely to be in better shape on something less hard or dense. Wet clay or sand means there is a possibility for liquefaction when it gets shaken by seismic waves.

Practice Question: Which statement about the distribution of earthquakes at convergent plate boundaries is correct?

Answer: Hypocenters occur in the Wadati-Benioff zone, down to a depth of about 670 km below the surface.
Note: Earthquakes can occur in both plates – a lot do occur in the subducting plate, but you also do get earthquakes on the surface of the overriding plate. You get <u>deep</u> earthquakes in the subducting plate.

Practice Question: With existing technology, is it possible to predict earthquakes to within a few days?

Answer: False – we can predict long term or very shortly after a pre-shock.

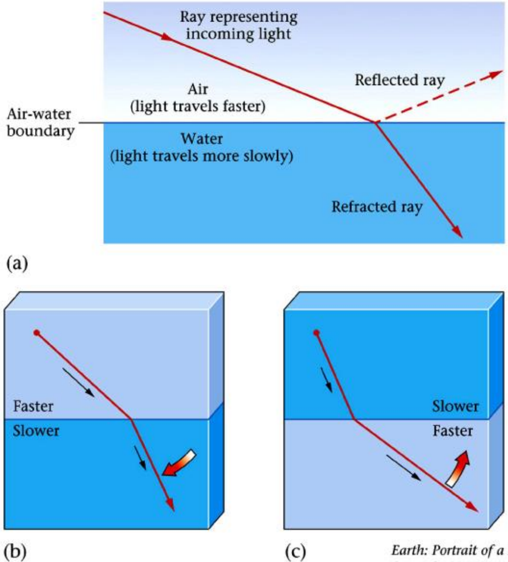


FIGURE C.5

Earth: Portrait of a Planet, 2nd Edition
Copyright (c) W.W. Norton & Company

Interlude D: Seismicity and the Earth’s Interior

Seismic waves will travel at different speeds through different materials which is how we know what we know about the Earth’s interior.

Refraction

A wave will refract (bend) direction and speed when it encounters a new boundary/material. Some part of the wave does get reflected back.

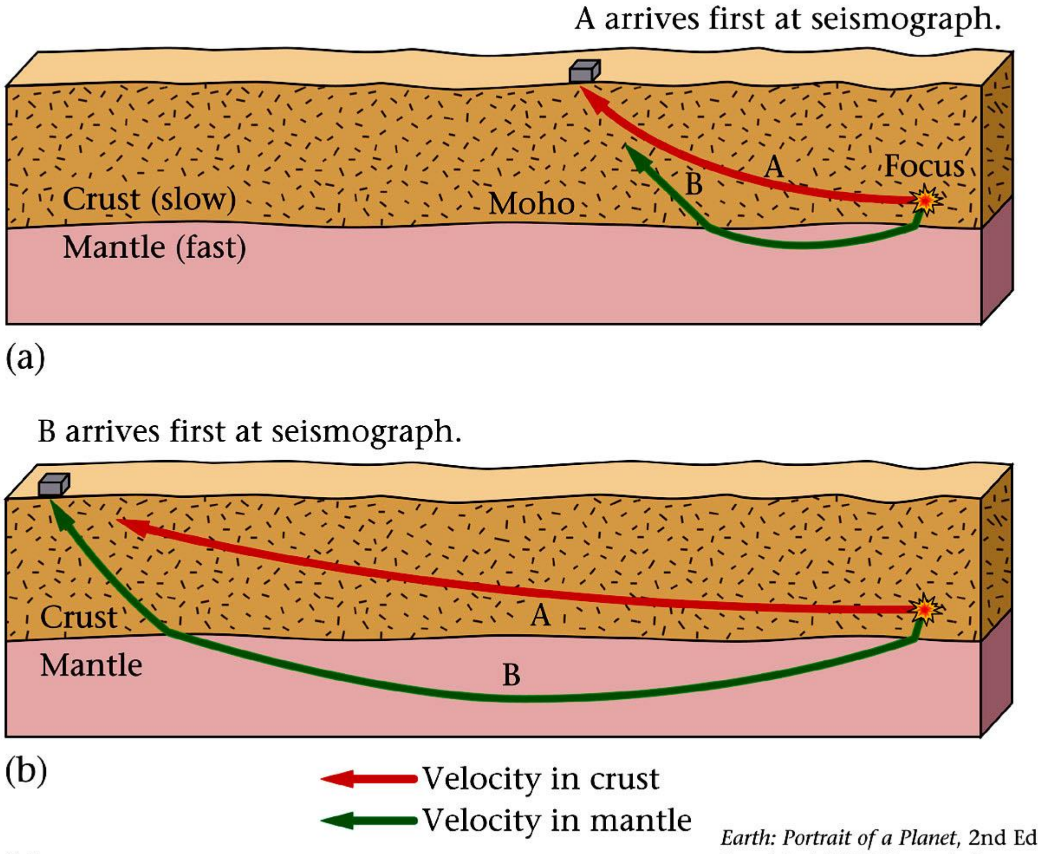
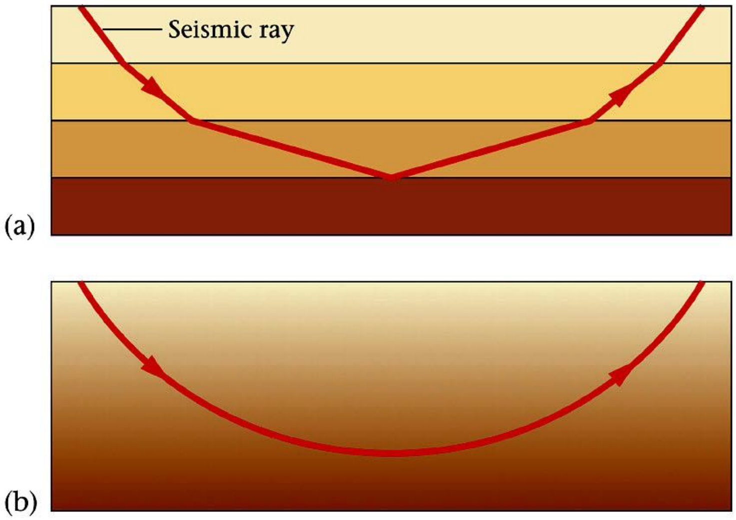


FIGURE C.6

Earth: Portrait of a Planet, 2nd Edition
Copyright (c) W.W. Norton & Company

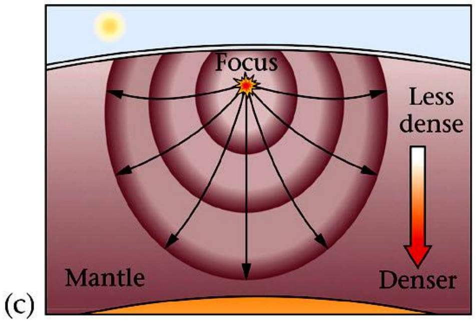
Note: Seismic waves travel in 3 dimensions, outward from a point.

In a) the red line indicates a wave reaching a seismograph. The green line indicates a wave which refracted when it traveled from the crust to the mantle, and refracted again when it traveled from the mantle to the crust. Red and green lines will reach the seismograph at different times. Seismic waves travel slower through the crust and faster through the more dense mantle. If the seismograph is placed closer to the focus of the earthquake, in a), the wave through the crust will reach the seismograph faster. But in b), if the travel distance to the seismograph is larger, then the wave in the mantle will reach the seismograph first.



If the wave travels through different materials (a), we observe a segmented travel path, whereby the wave refracts between each new material. In this case, we can determine layers because we get reflected waves.

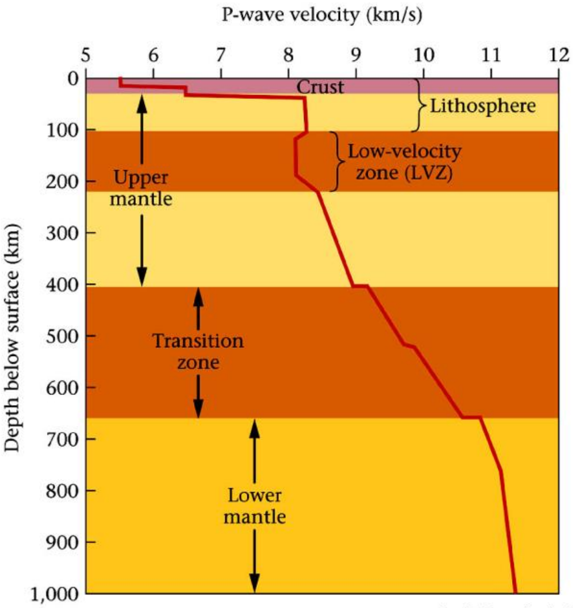
If there is a gradual increase in density of the material (b), the wave will slowly bend. In this case, we will not get a reflected wave.



Curved rays in a mantle whose density increases gradually with depth

Earth: Portrait of a
Copyright (c) W.W. N

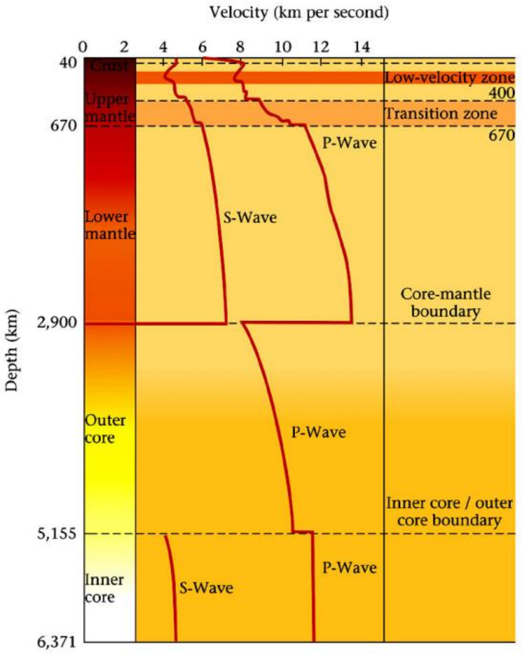
Application of seismology: Seismic waves can be used to map out local regions for building something or to see what is below us in a shallow region of the crust.



Earth: Portrait of a Plan
Copyright (c) W.W. Norton

P-waves are the first wave to arrive, S-waves are the second to arrive.

P-wave velocity: As you move down into the Earth, you get denser materials, and so the wave speed increases. Between 100-200 km depth into the Earth, there is a Low-Velocity zone (LVZ). There is an increase, and then suddenly there is a decrease in velocity – it turns out P-waves slow down when it travels in liquid, and in this zone, the temperature and pressure conditions are such that there is a small amount of melt that happens in the mantle, so there is a little more liquid material in this layer compared to the other layers in the mantle. Also, sharp transitions are observed between major layers.



Earth: Portrait of
Copyright (c) W.W.

S-wave velocity: travels slower than the P-wave. Looks analogous to the P-wave until the outer core, where it stops – there are no S-waves in the outer core. The outer core is liquid (this is how we found out the outer core is liquid).

Evidence for a liquid core: P-wave behaviour

From a given focus point, if we look at the pattern at where we can measure the P-wave, there are shadow zones, where the P-wave does not reach the surface: Between 103°-143°. From this, we know that the seismic waves are refracting from a center to create these shadow zones. The size of this shadow zones depends on how the seismic waves bend when they enter the core. Looking at this pattern, it was hypothesized that there was a core. However, we now know there is an inner and outer core.

Evidence for a liquid core: S-wave behaviour

If we look at the pattern of measured S-waves at the surface, we have a very large shadow zone that wraps around the back of the earth (relative to the focus). If S-waves could travel through the core, then we would see them arrive on the other side, but they don't, so this means there is a boundary stopping them. This lead us to hypothesize that there must be a liquid layer which is stopping them (S-waves to do not travel through liquid). Another element is that we observed P-waves being reflected back out from the interior of the core, which suggested that the core is divided into the materials – inner (solid) vs outer (liquid) core.

Geotherm and melting curve

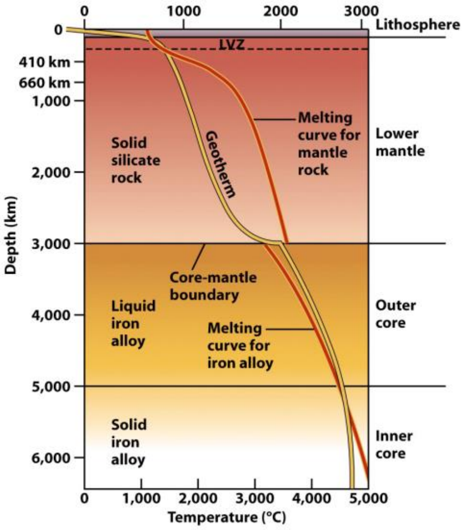


Figure D-11c Earth: Portrait of a Planet 3/e
© 2008 W. W. Norton & Company, Inc.

We know the outer core is liquid, but why is it liquid with all that pressure? Geotherm describes how temperature changes with depth in the Earth and temperature increases with depth (actual temperature in a layer).

The red line describes the melting curve for rock inside the Earth (when rock will melt at a particular depth). If the geotherm is to the left of the melting curve then the material is solid, if the geotherm is to the right of the melting curve then there are high enough temperature for melting.

In the mantle, the geotherm is to the left of the melting curve which means that the temperature at this depth is not high enough for melting. In the outer core, the geotherm crosses over the melting curve and so temperature are high enough for melting. The geotherm crosses back when you go into the inner core (solid).

Chapter 3 Minerals and Crystals

World's largest known mineral crystals (gypsum – $CaSO_4 \bullet 2H_2O$) Chihuahua, Mexico.

A mineral: A naturally occurring solid, formed by geologic processes, that has a crystalline structure and definable chemical composition.

- Natural occurring
- Formed geologically (mostly)
- Solid
- Crystalline Structure
- Definite chemical composition
- Inorganic (few exceptions)

Naturally occurring: A true mineral is created by natural processes.
Humans can recreate natural processes to make minerals – these are called synthetic minerals.

Formed by geological processes:

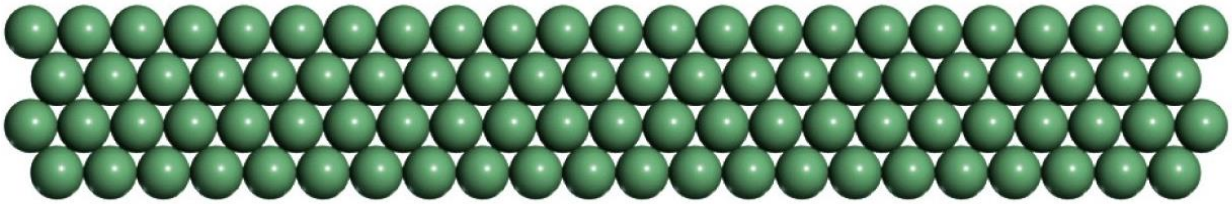
- Freezing from a melt
- Precipitation from a dissolved state in water
- Chemical reactions at high pressures and temperatures

Subtle distinction: living organisms can create minerals – called biogenic minerals to emphasize this special origin.

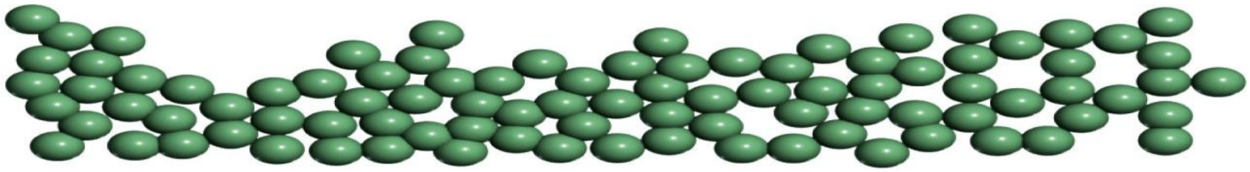
- Vertebrate bones (apatite)
- Oyster, mussel, and clam shells (aragonite)
- Other skeletal types
- Our own tooth enamel (apatite)

They are solid: A state of matter which can maintain its shape indefinitely. Minerals are solids, not liquids, or gases.

Crystalline Structure: Atoms in minerals are arranged in a specific order. The atomic pattern is called a crystal lattice.



A solid with disordered atoms is called a glass. Lacking a crystalline structure, glasses are not minerals.



Definite Elemental Composition: Minerals can be defined by a chemical formula. Same elemental composition of 2 pieces = same mineral.

Simple:

- Ice – H_2O
- Calcite – $CaCO_3$
- Quartz – SiO_2

Complex:

- Biotite – $K(Mg, Fe)_3(AlSi_3O_{10})(OH)_2$
- Hornblende – $Ca_2(Fe^{2+}, Mg)(Al, Fe^{3+})(Si_7Al)O_{22}(OH, F)_2$

Mostly Inorganic: Organic compounds contain C-H bonds. Other elements may be present (O, N, S) – these are common products of living organisms. Most minerals are NOT organic – do not contain C-H bonds.

Minerals:

- More than 4000 minerals are known
- Most are rare but the common minerals make up most of the rocks and sediments on the Earth
- ~50-100 new minerals discovered annually which need to be approved by an International Commission
- Names reflect discovery locality, discoverer, important property, important person, important institution
- Many have a McGill connection

Why study minerals?

Minerals are the building blocks of the planet:

- Minerals make up all of the rocks and sediments on Earth
- Understanding Earth requires understanding minerals

Minerals are important to humans

- Industrial minerals: raw materials for manufacturing
- Ore minerals: sources of valuable metals
- Gem minerals: attract human passions