Tags
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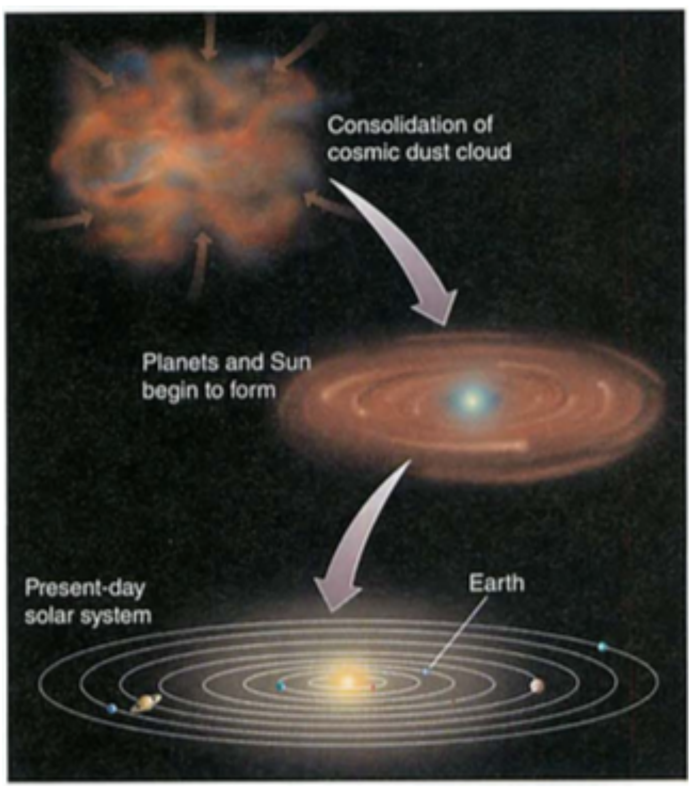
Modules 24-25 earth and soils

Module 24: Earth Science
Key points:

- **All elements up to Iron on the periodic table came from the big bang**
- **Earth was formed from materials created by first generation stars going supernova**
- **The core of the earth is made up of a rotating solid core surrounded by a liquid core**
- **The inner core creates our magnetic field, which reverses periodically**
- **Layers: crust-mantle-outer core-inner core**
- **Uranium in the core produces heat that travels to the surface by convection**
- **Tectonic plates on the surface move on top of the sticky asthenosphere because of this convection**
- **Spreading zones are were these plates are created, subduction zones are where they dive under others**
- **Subduction zones create trenches in the ocean and andesitic volcanoes (sticky lava, pointy cones)**
- **Hot spots in the crust can create basaltic volcanic islands like the one we are on (runny lava, broad cones)**
- **Earthquakes include P (primary, compression) waves and S (secondary, shear) waves**
- **P waves are faster and go through solids and liquids, S waves only travel through solids**

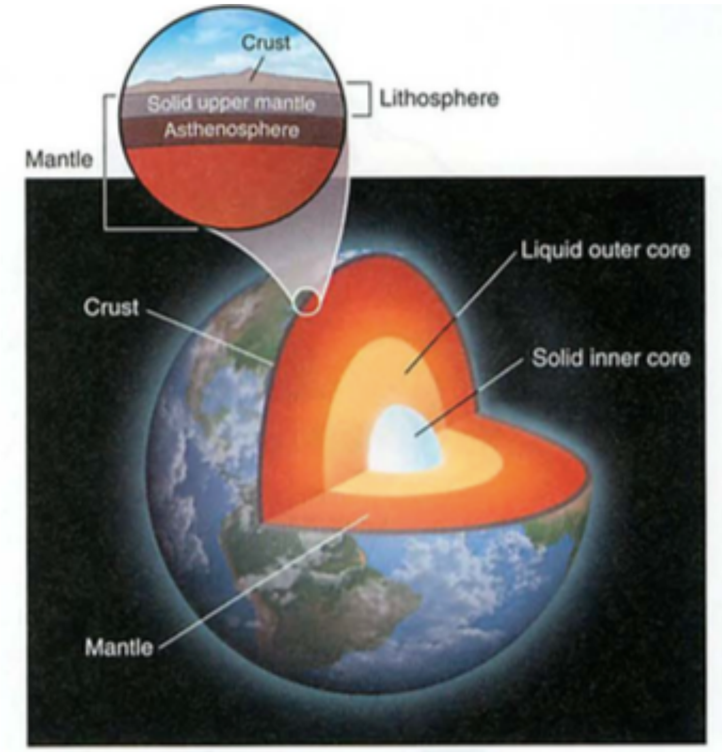
First, there was the big bang (see the cute video here: https://www.youtube.com/watch?v=xzAOhyOtfqc)
The only thing at first was Hydrogen, which is just a proton and an electron, sometimes a neutron making isotopes of Hydrogen
Stars formed from this hydrogen, and through fusion created all of the elements up until Iron (Fe)
Look this up on your periodic table------https://ptable.com/#Properties
Eventually, these stars expanded and then collapsed...
Smaller stars became neutron stars or various versions of these

Huge ones (15x our sun size) exploded and created all of the elements after Fe (check the periodic table again)
so,
Any element in you below Fe on the table came from an exploding star
cool...
NASA and other folks are really interested in two things now: exoplanets (planets outside our solar system) and asteroids
https://www.cnn.com/2020/10/23/world/asteroid-bennu-sample-update-scn-trnd/index.html
Why?
Well, if we know what asteroids are made of, we have a clue about what materials (e.g. water) that were around when the solar system formed.
From this info, we can look for those elements in other solar systems, and look for life there.
Back to our earth...

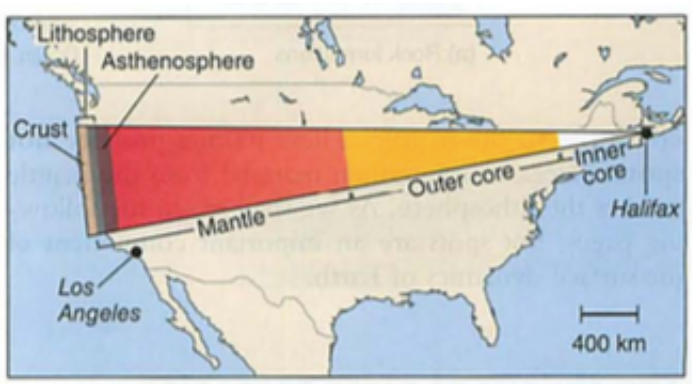


This is how our solar system formed. Our earth was molten for a long time, then cooled to become solid-mostly.
Since it is also made up of Uranium and other things that combine to create heat, our planet is still really hot deep down.
A minister named Ussher (https://en.wikipedia.org/wiki/Ussher_chronology) worked

backwards from the molten state to solid state of the earth to guess that the earth was created one Sunday afternoon in 4004 BC.
We was not stupid, he just did not know about Uranium, and our molten core...
Here's what we know the earth to look like (check this out on your globes too):
Layers: (onion boy)
Core-Mantle-Crust-think of an apple



(a) Earth's vertical zonation



The core is actually two bits: solid inner iron and nickel, liquid outside that bit. It spins, giving us a weak magnetic field which switches direction every few thousand years.
Remember this, it comes up later...
How do we know this? Nuclear bomb testing and our global seismic sensor network.
How?

Two key clues about the earth came from military conflict: one from WWII and another from the cold war, when everyone was building bigger and bigger bombs.

First the cold war part:

We set up seismic sensors called seismographs all over the world to spy on Russian and Chinese nuclear ("A-Bomb", fission) and thermonuclear ("H-Bomb", Fusion) bomb testing to see how powerful they were.

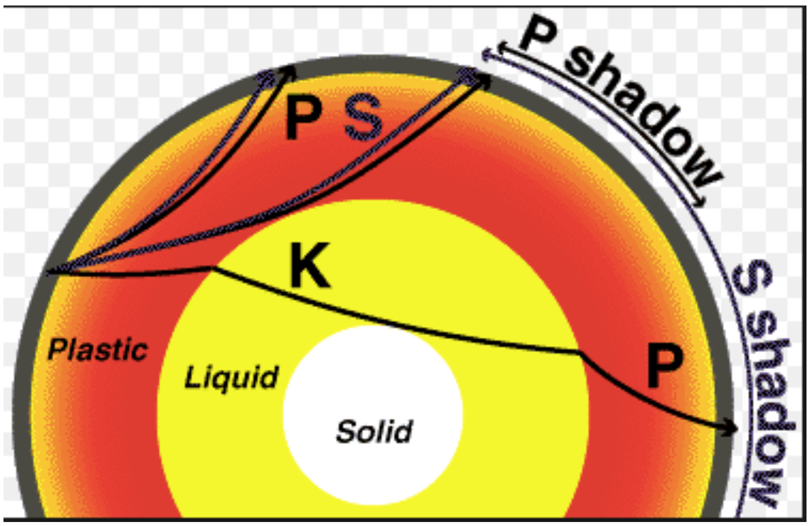
You next need to know that there are two main types of earthquake wave: P or "primary" waves which are compression waves. and S waves "secondary waves" that are transverse, like shaking a slinky.

P waves are faster, and go through solids or liquids, but at slightly different velocities.

S waves are slower, and can only travel through solids.

So,

Here's what they saw:



This data was found by spying on atomic bomb tests in the 1950s, not because we wanted to know about the guts of our planet...

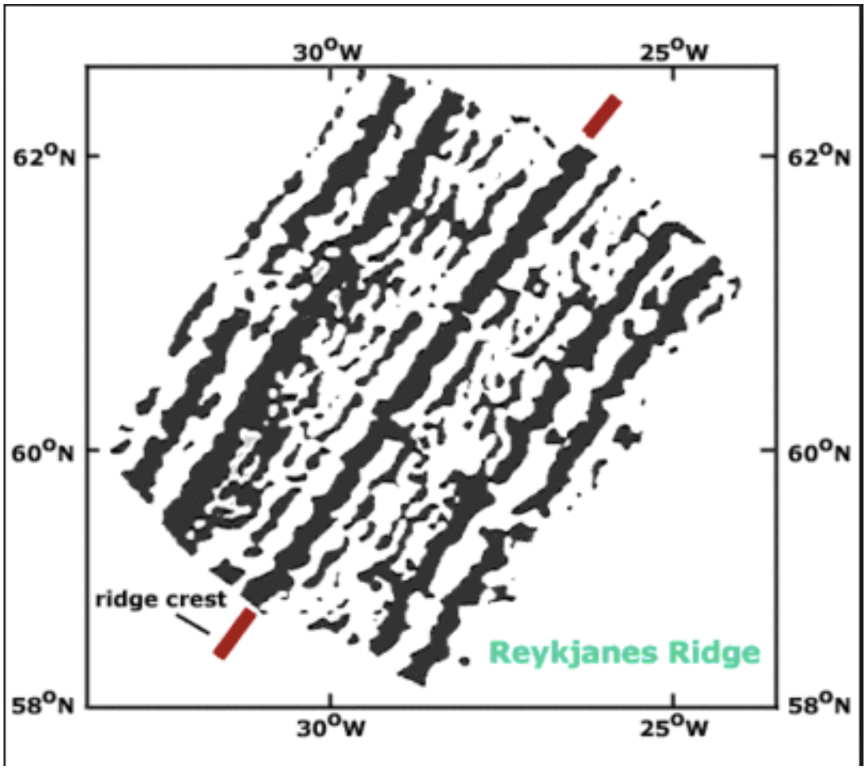
Now, to the WWII part...

Submarines like to hide underwater, so planes and ships can't find them.

So, during WWII, our side tried dragging little magnetic sensing torpedo thingys from behind their ships, hoping to detect submarines. (they later used airplanes too).

Here's what they found:

What the heck is this?



This might help:

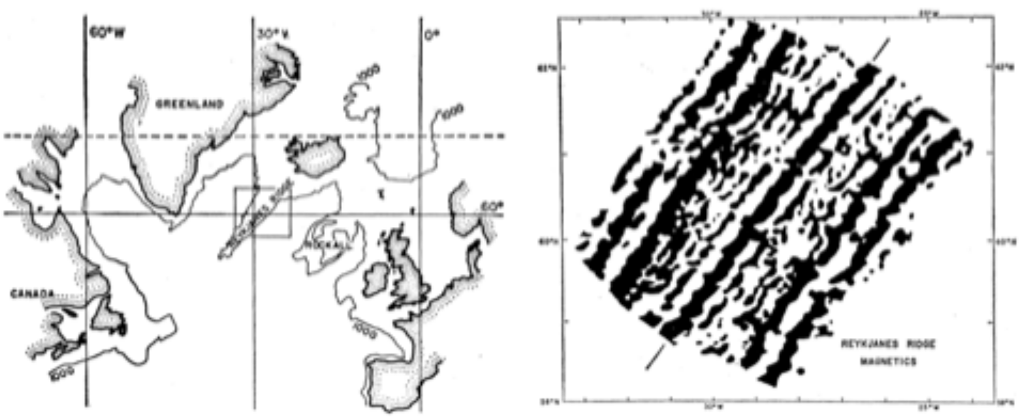


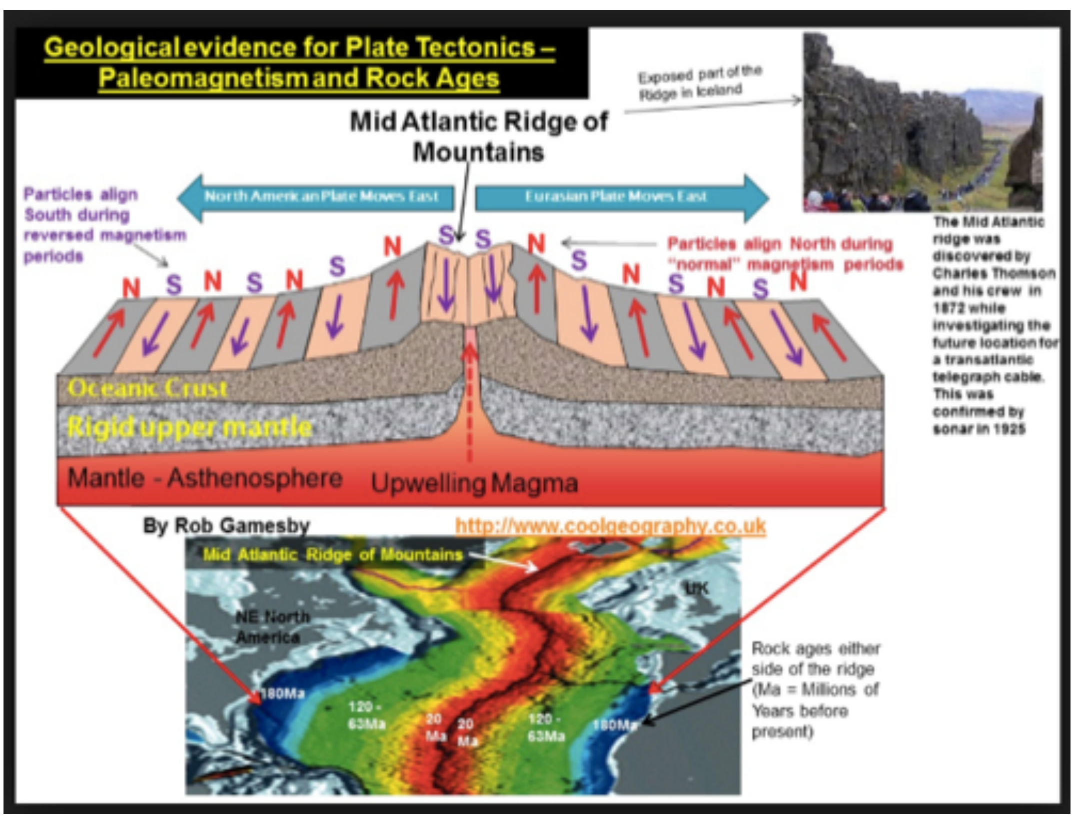
Fig. 2 (left). The location of Reykjanes Ridge, southwest of Iceland, and the area of Fig. 3. The 1000-fathom submarine contour is shown, together with the 500-fathom contours for Rockall Bank. Fig. 3 (right). Summary diagram of the magnetic anomalies observed over Reykjanes Ridge (see Fig. 2). Straight lines indicate the axis of the ridge and the central positive anomaly (*17*).

Click for a full-size image

Ok, let's break this down: between England and the US, they found stripes of North then South weak magnetic fields.
When they got to the middle of the Atlantic (about where Iceland is on the map above), the pattern reversed.
Huh?

That's what they said too...
Remember the shifting magnetic field every few thousand years?
As the magma came out of the earth in the molten state, it solidified in the magnetic field of that time, so the newest lava was along the center of the ocean (under Iceland too).

Ok, now shift quickly to a meteorologist named Alfred Wegener. Meteorologist is a fancy name for a person who studies the weather.
He cut out the continents on a map (like, with scissors) and noticed that South America and Africa fit nicely together.
Try this on your globe----
Everyone in the geology community told him he was nuts.
He later froze to death in Greenland, but I digress...
Then, these strange magnetic stripe thingys showed up from the ships dragging those magnetic torpedoes.
...and it proved he was RIGHT:
Remember how hot is was in the earth core?
That heat rises to the surface as magma (say like Dr. Evil), just like the Hadley, Ferrel and Polar cells do:



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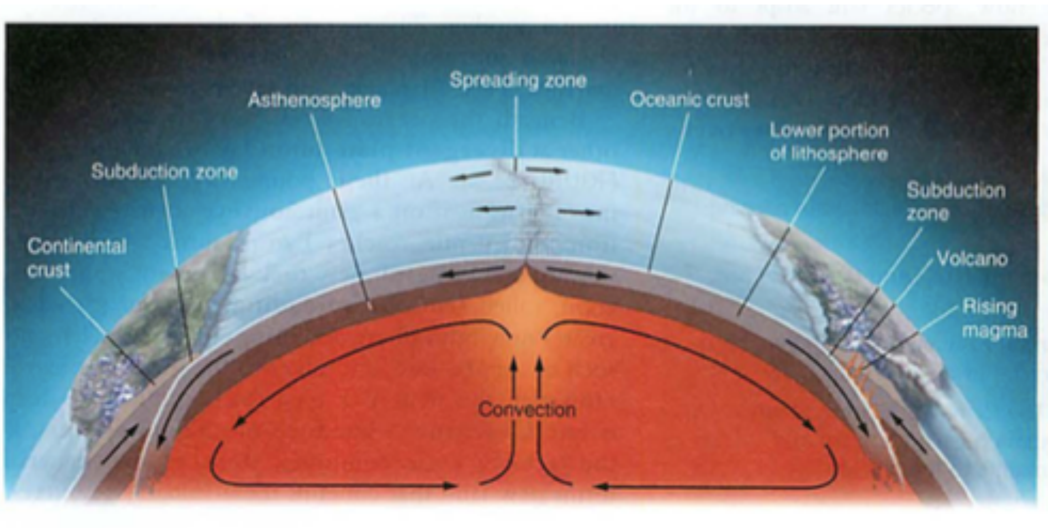
Remember the earth's magnetic field changing?



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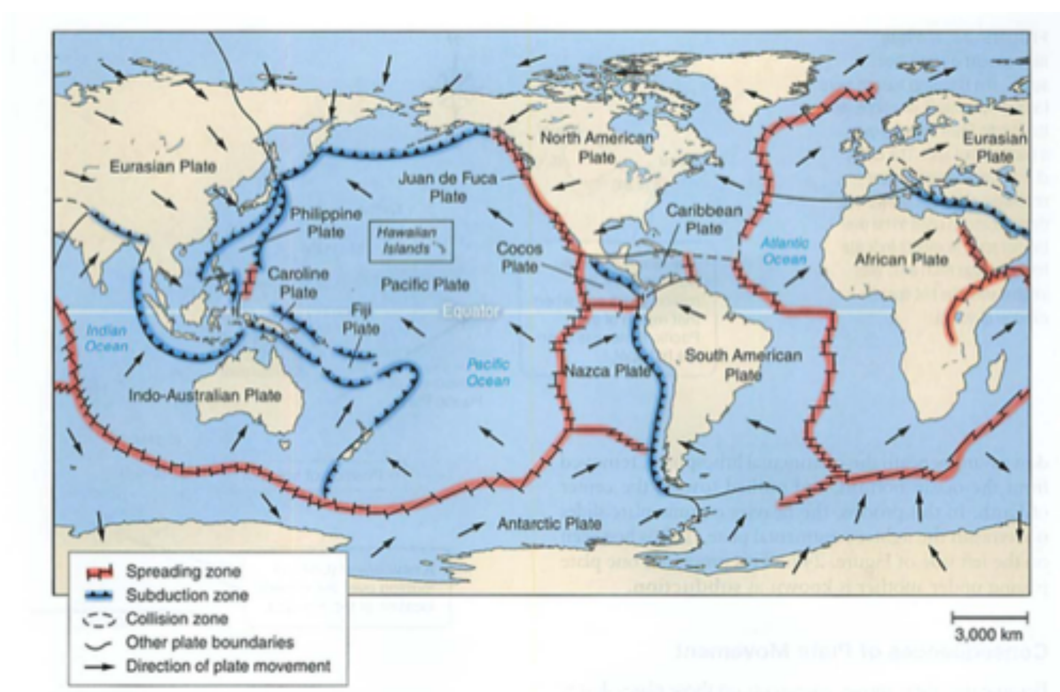
Check out this diagram: note the red (spreading) and the blue (subducting), esp. look at Chile---->



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So, connecting all of these dots, the plates are floating on the magma, some created at the mid-Atlantic ridge, others diving down under others in subduction zones.

...what about those subduction zones?

What mountains are in Chile?

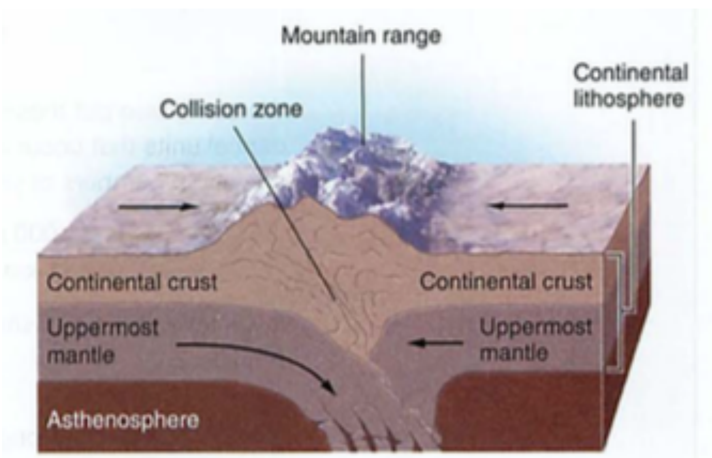
Volcanoes are the key:

Two kinds of volcanoes: **Andesitic** (pointy), **Basaltic** (runny, look out your window)

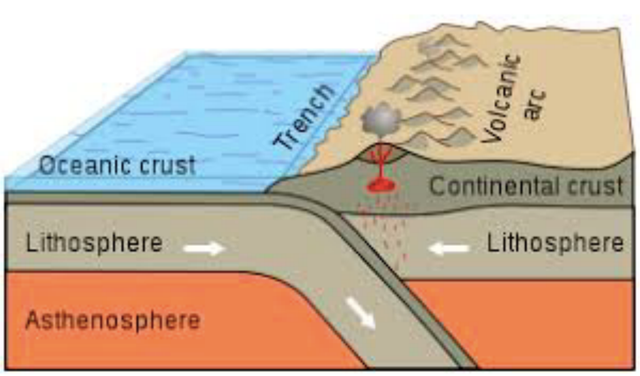
Andesite-from pressure and heat as plates subduct (sticky, high silica content, e.g. Andes mountains)

Basalt-from ocean crust, lots of water, makes for weak, runny magma, formed as magma pushes through watery ocean plates

Subduction zones:



(b) Formation of the Himalayas



Note the sticky stuff boiling up in red-this is why the Andesitic volcanoes are sticky, and always found near subduction zones (Andes, Cascades, Japan, Italy, etc.)

Note also the trench where the subduction zone goes down: this is the origin of the

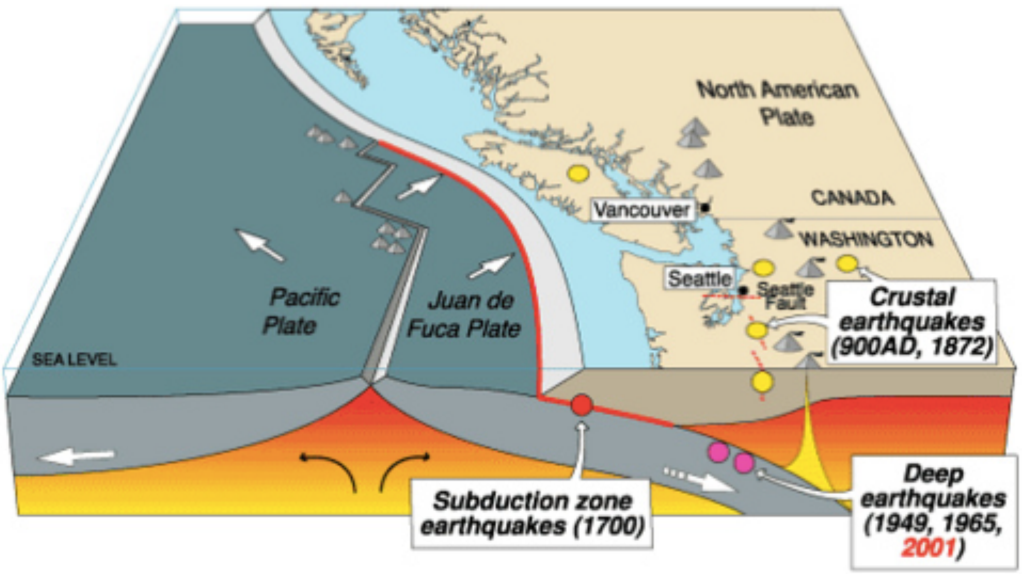
Chilean/Peruvian trench we covered in the El Nino notes, as well as the deepest part of the ocean: the Marianas Trench, which is 7 MILES deep. Whoa!

Let's review the geological players:
Magma-(Dr. Evil voice here: https://www.youtube.com/watch?v=yVo1S52xdpI)
Asthenosphere-"sticky rock" (from Greek ἀσθενής *asthenḗs* 'weak' + "sphere")
Lithosphere-floating rock (litho = stone) (Ancient Greek: λίθος [*lithos*] for "rocky", and σφαίρα [*sphaira*] for "sphere")
Continents-even more floaty, made of lighter rock (granite) that formed from the interaction of magma with oceans

Plates are large, float on the Asthenosphere
Continents are like rafts on the Asthenosphere, more buoyant than the plates
The plates can slide under each other (subduction zones), crash into each other (Himalayas), next to each other (transform faults), and are formed at spreading zones (divergent boundaries)

Neato. What about those earthquakes?
Check this out:

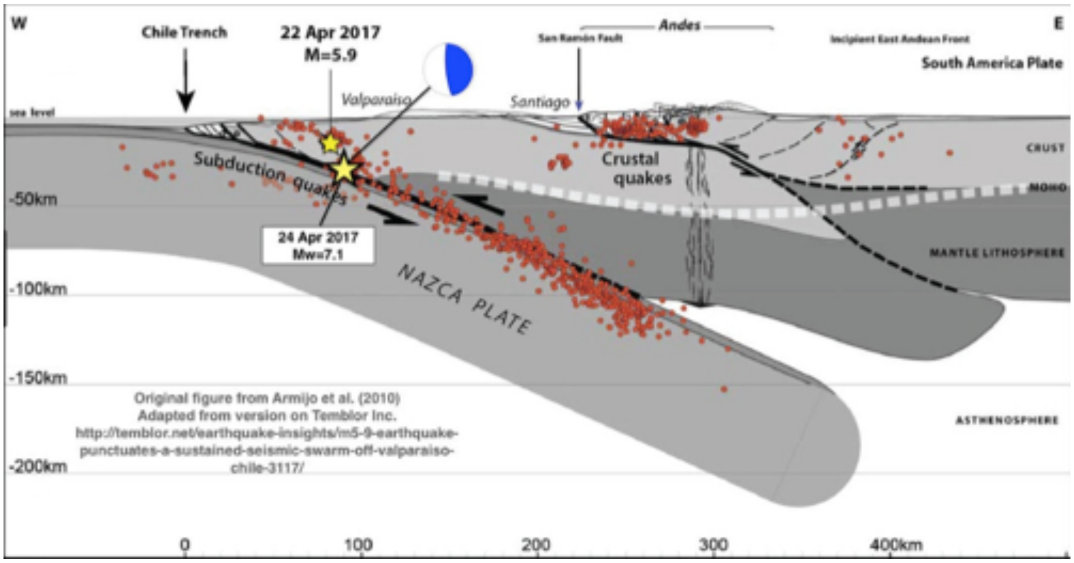
Cascadia earthquake sources



Source	Affected area	Max. Size	Recurrence
Subduction Zone	W.WA, OR, CA	M 9	500-600 yr
Deep Juan de Fuca plate	W.WA, OR,	M 7+	30-50 yr
Crustal faults	WA, OR, CA	M 7+	Hundreds of yr?

Click for a full-size image

Historic data shows subduction zone quakes that would create a tsunami 1000' high or more on the Pacific northwest coast, flooding everything west of I-5.



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Look at all of the earthquakes (red dots) as the plate subducts

Two things to take-away about subduction zones:

1. subduction zones create ANDESITIC (pointy) volcanoes, which are high in silica, and sticky like thick pancake batter.
2. subduction zones create lots of deep-focus earthquakes.

We are lucky enough to live on an island with several active or dormant volcanoes. We live on top of a "hot-spot":

Hot spots:

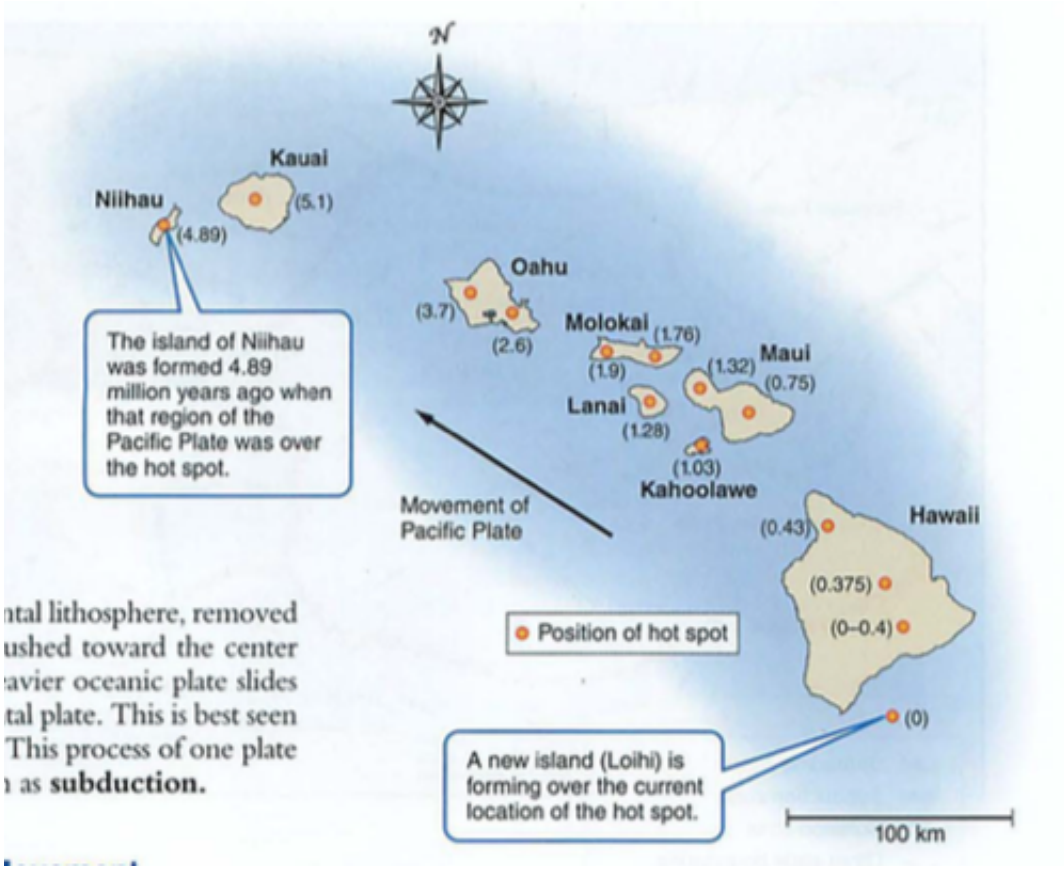
Usually in the middle of an oceanic plate, but can also be mid-continent (e.g. Yellowstone supervolcano caldera)

Hot spots-basalt-low silica content which melts easier (e.g. look out the window)

Look at the Hawaii island chain on google earth (underwater version)

While you are at it, look for the Nuuanu landslide that created a 4000' tsunami

You can also look at the Mauna Loa simulated tsunami on youtube...



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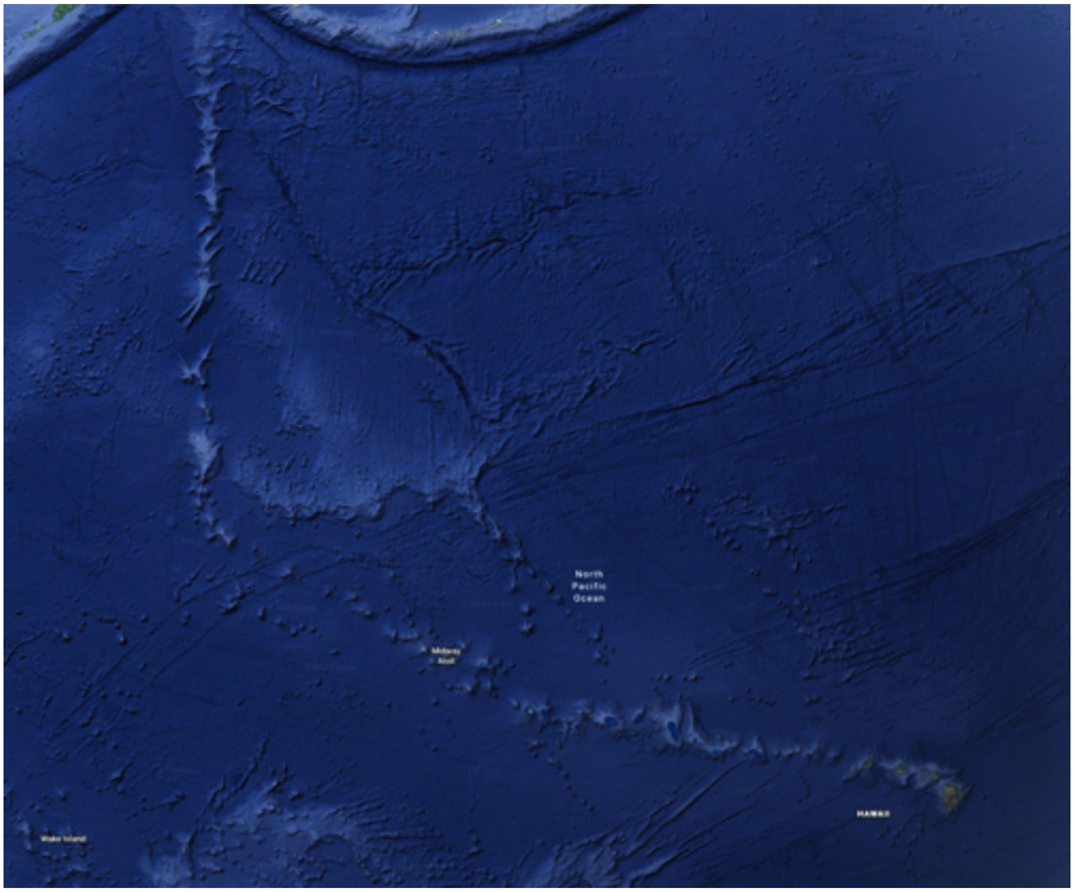
Note the tracking of the pacific plate:



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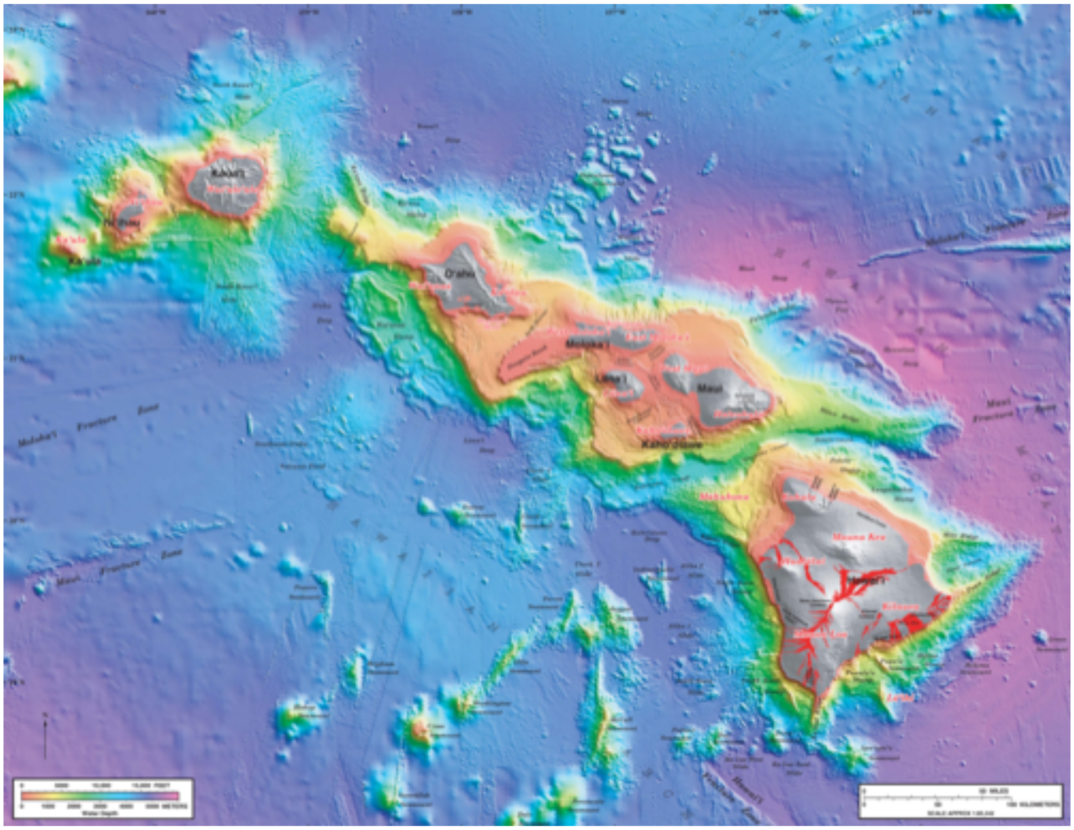
This is what happens to a shield volcano when it "calves" one side, in this case, the northeast side, in the Nuuanu landslide, one of the largest landslides on earth, causing a tsunami that deposited coral on the top of Mt. Kaala, 4055 ft. high...

Click for full-size image



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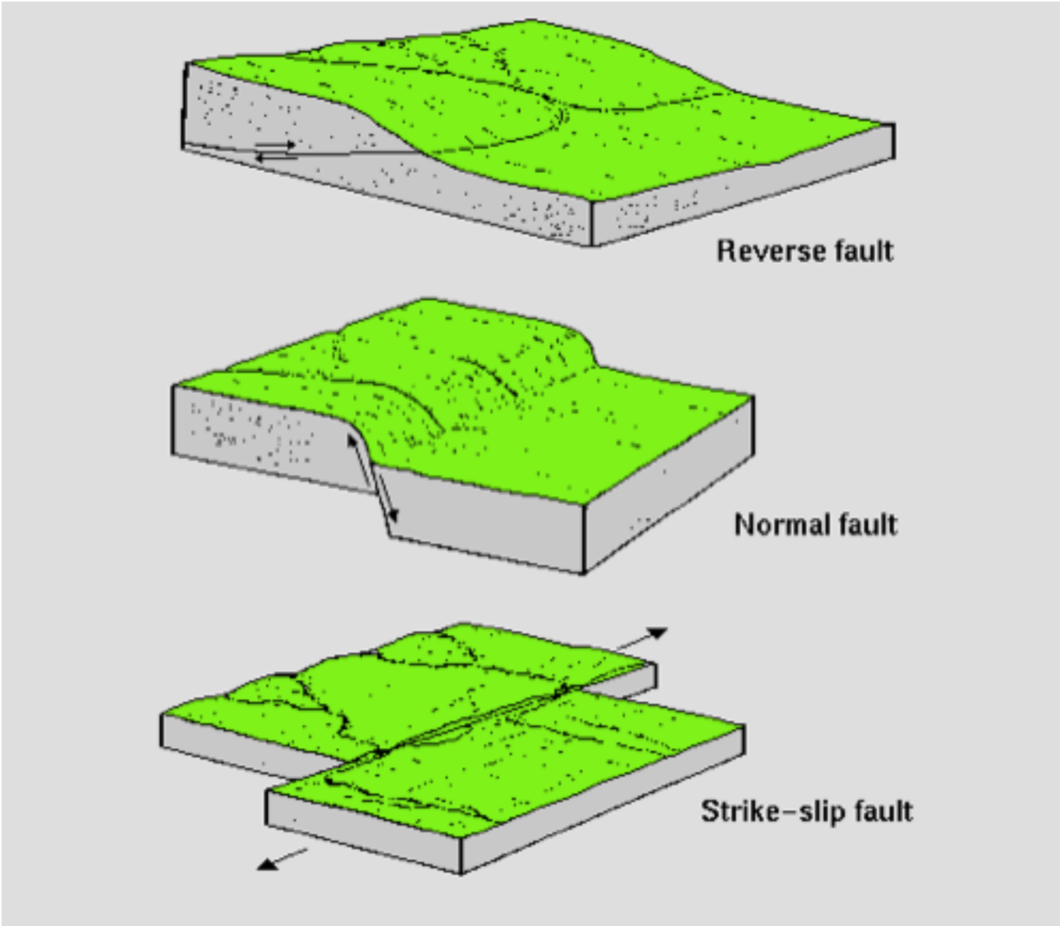
Look at the debris field North-East of Oahu...

More about earthquakes:



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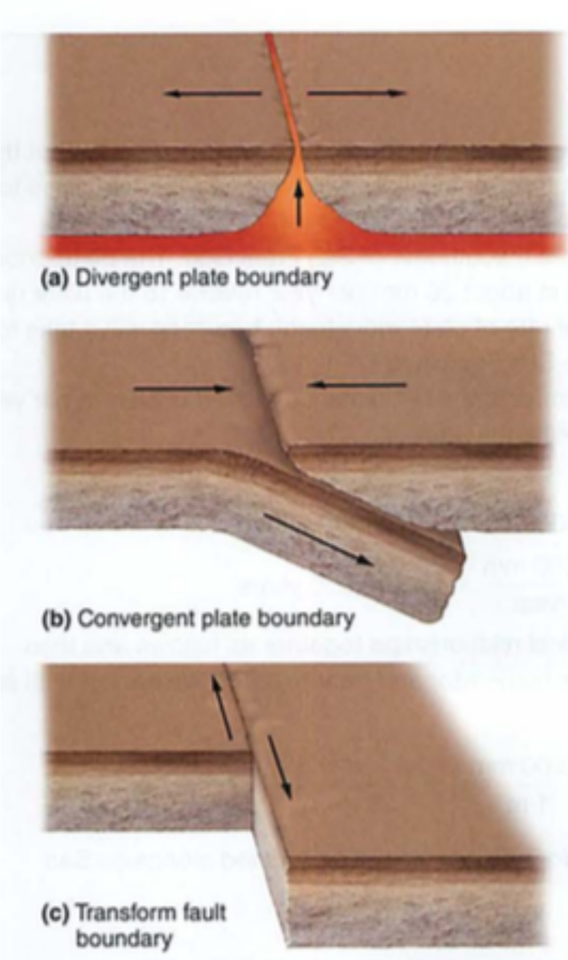
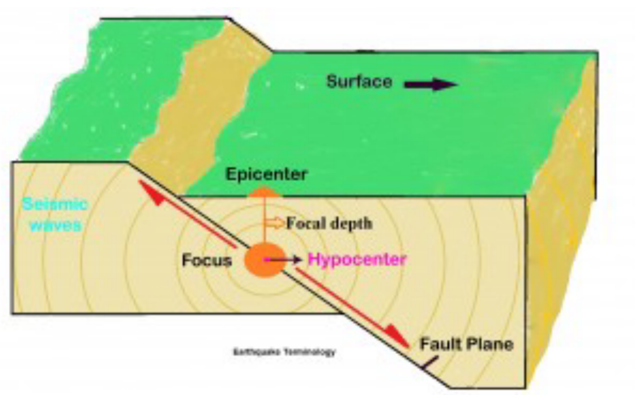
then there's the famous "not-my" fault...

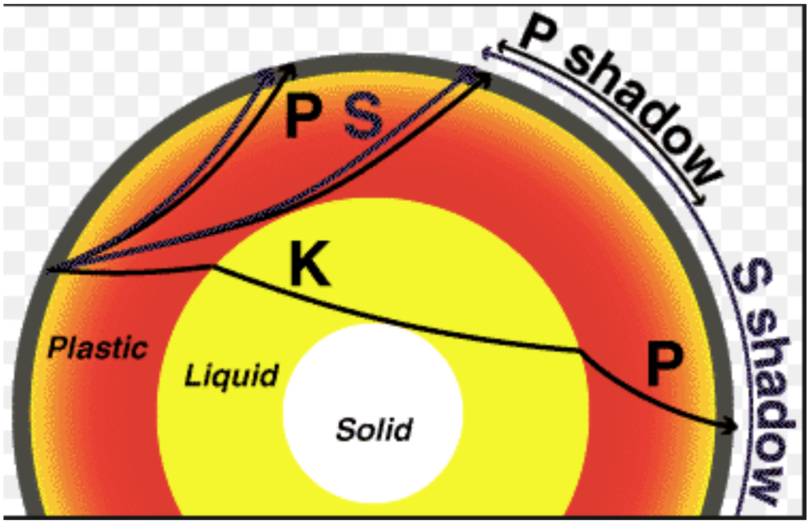


The epicenter is the place ON THE SURFACE above the hypocenter (true origin) or earthquake FOCUS. Deeper hypocentric quakes often feel "longer", while shallow hypocentric quakes feel "sharp".



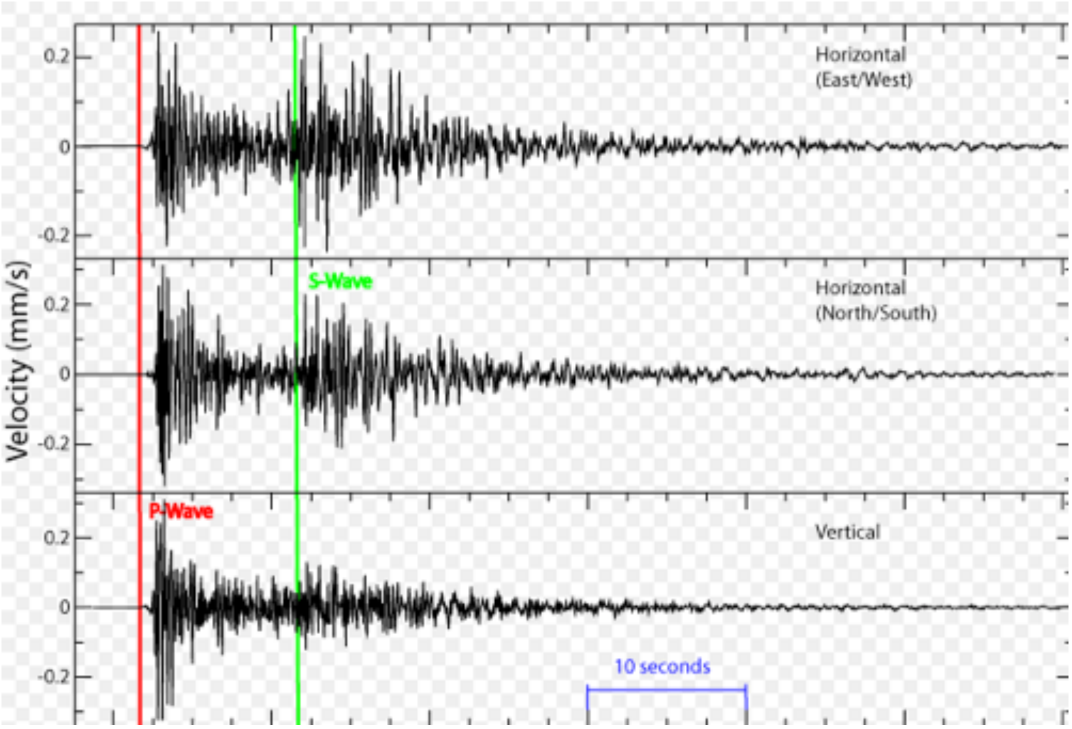
How do we find these?
Seismographs:

P waves travel by compression (comPression). These are longitudinal waves, like sound. They can travel through liquid or solid.
S waves travel by shear (Shear). These are transverse waves, like a slinky. They can only travel through solids.
Remember this?



Ok, back to earthquakes.
Suppose you have a house on posts (called "post and pier" construction). An earthquake happens some distance away. First, your house moves back and forth (P wave, much faster at 8 km/sec). After a time, your house bounces up and down from the S waves (slower at 3 km/second).
If you are far away, these are separated by different arrival times.
If you are near the epicenter, they hit at the same time...up, over, down=your house is demolished

We use this difference to calculate distance from the epicenter (and hypocenter if you are interested) using delay times on the seismograph



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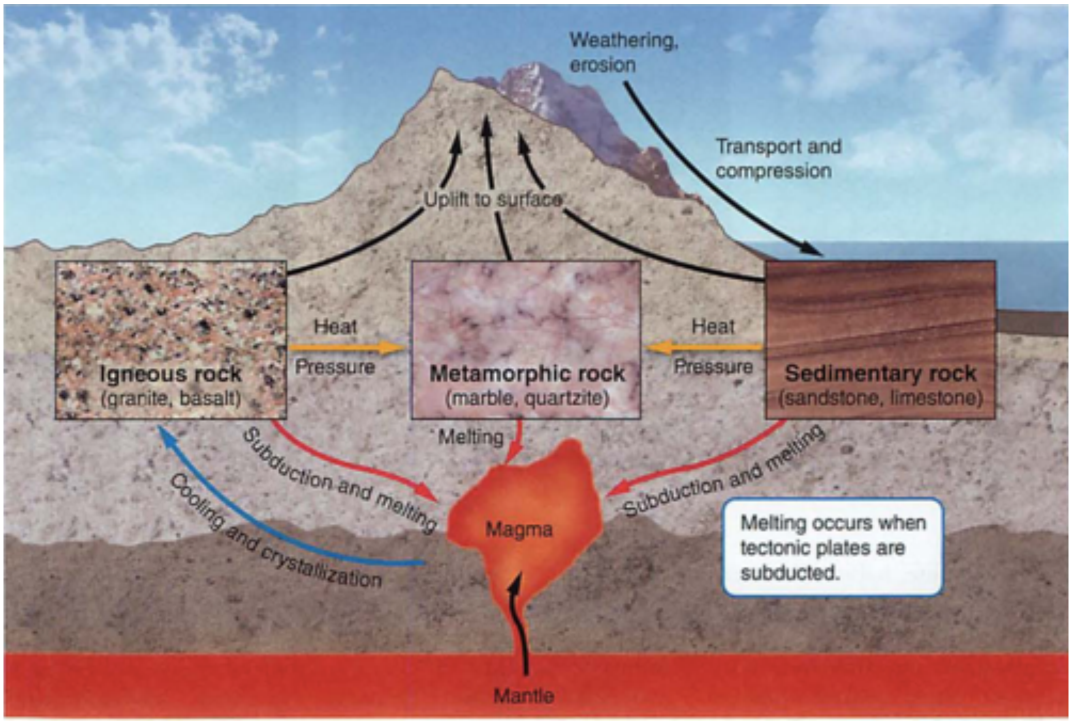
Look at the HPA seismograph here:
http://www.fdsn.org/networks/detail/PT/
and our Hawaii quakes here:
https://volcanoes.usgs.gov/observatories/hvo/hvo_earthquakes.html
Click on some earthquakes and note the depth and the seismic image.

Next: Rocks Module 25
Igneous (fire)
Sedimentary (layers)
Metamorphic (Kafka rocks, just kidding: changed by heat and pressure)



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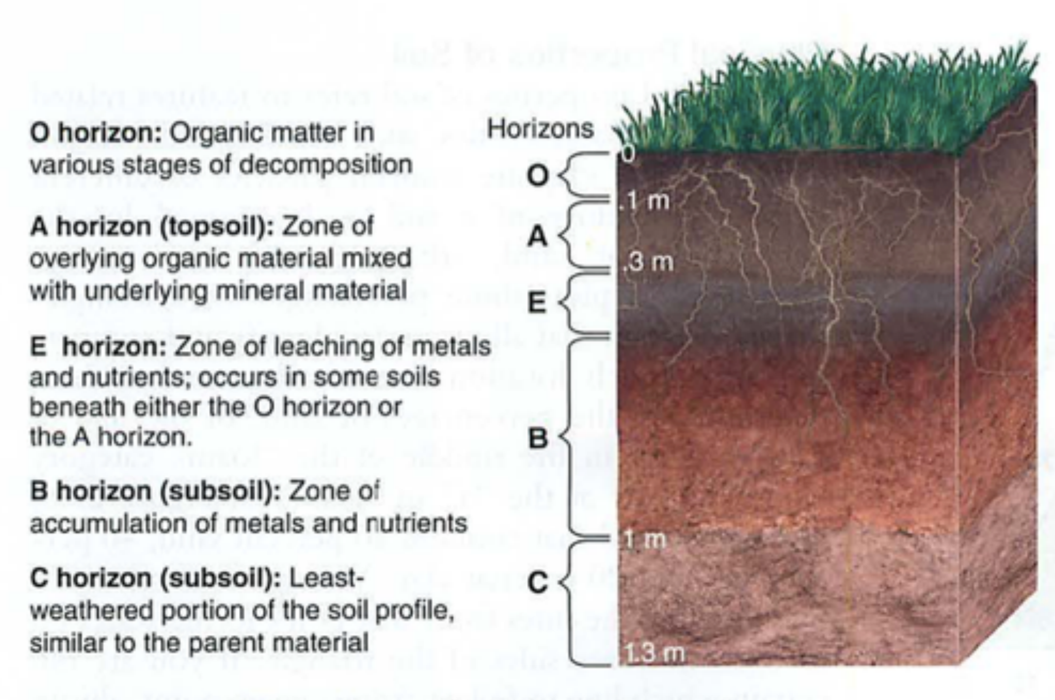
Igneous= directly from magma, and can be either basalt (low melting point, like our island or oceanic plates) or granite (lighter, what continents are made of)
Granite breaks down into light-colored sand, makes for fertile soil. Basalt (like us) can make sand too, but less fertile (e.g. black sand beach).

Sedimentary= just like it sounds, from mud, sand, or dust, usually in layers.

Metamorphic= changed by heat and/or pressure (slate, marble, or coal)

Soil-formed by weathering (chemical or physical) of parent rock
Erosion can be by water or air (wind)

Soil Horizons:



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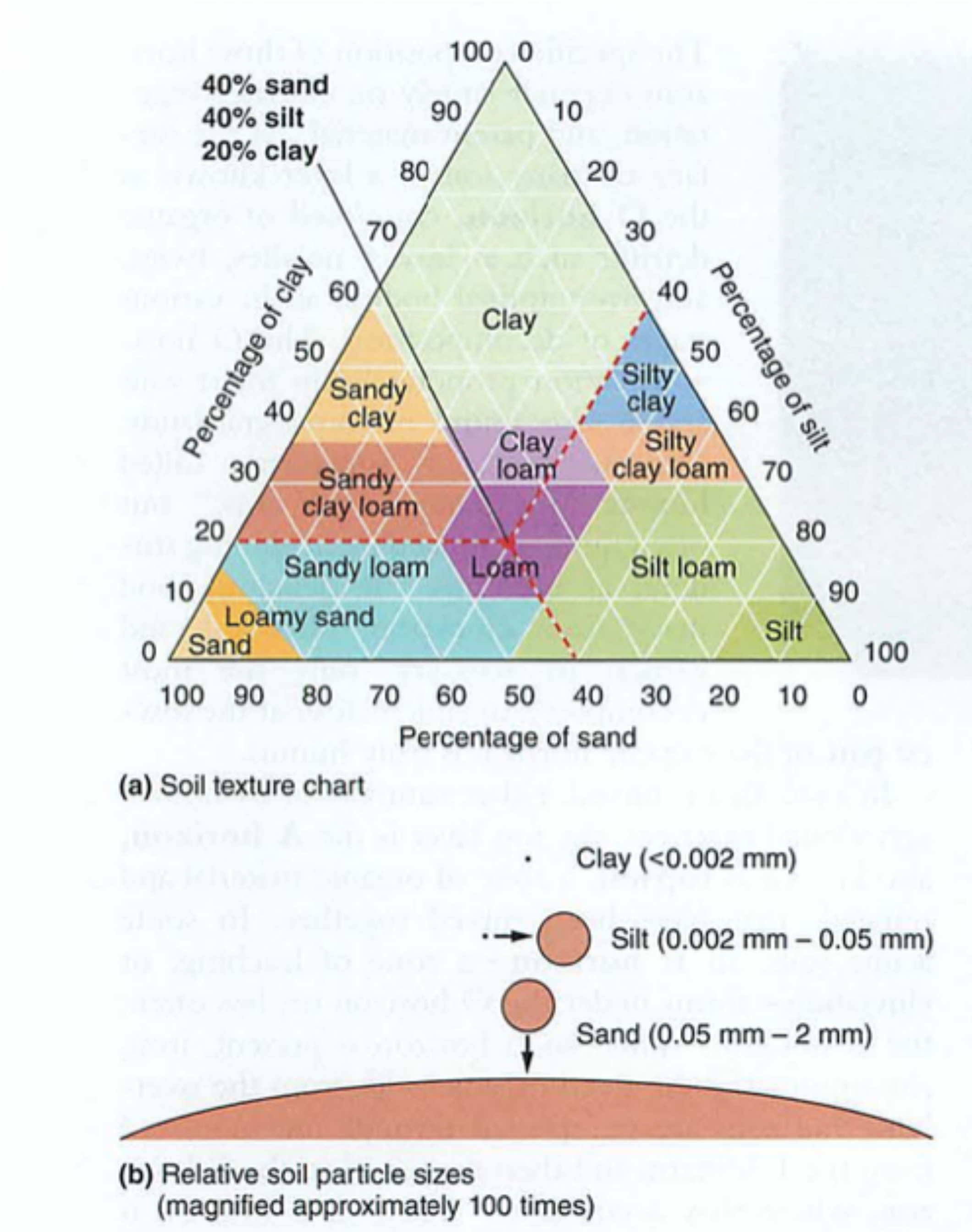

(a) Soil texture chart

(b) Relative soil particle sizes (magnified approximately 100 times)

Click for full-size image

Our Soil Sieve has 4 filters, with 5 layers:

mesh 5 = 4 mm

mesh 10 = 2 mm

mesh 60 = .25 mm

mesh 230 = 0.063 mm

Basically, most of what you find is silt and clay...