JOURNEY TO THE CENTER OF THE EARTH

Visualization Technologies 1 Final Project

Fall 2019

Ellen Bechtel

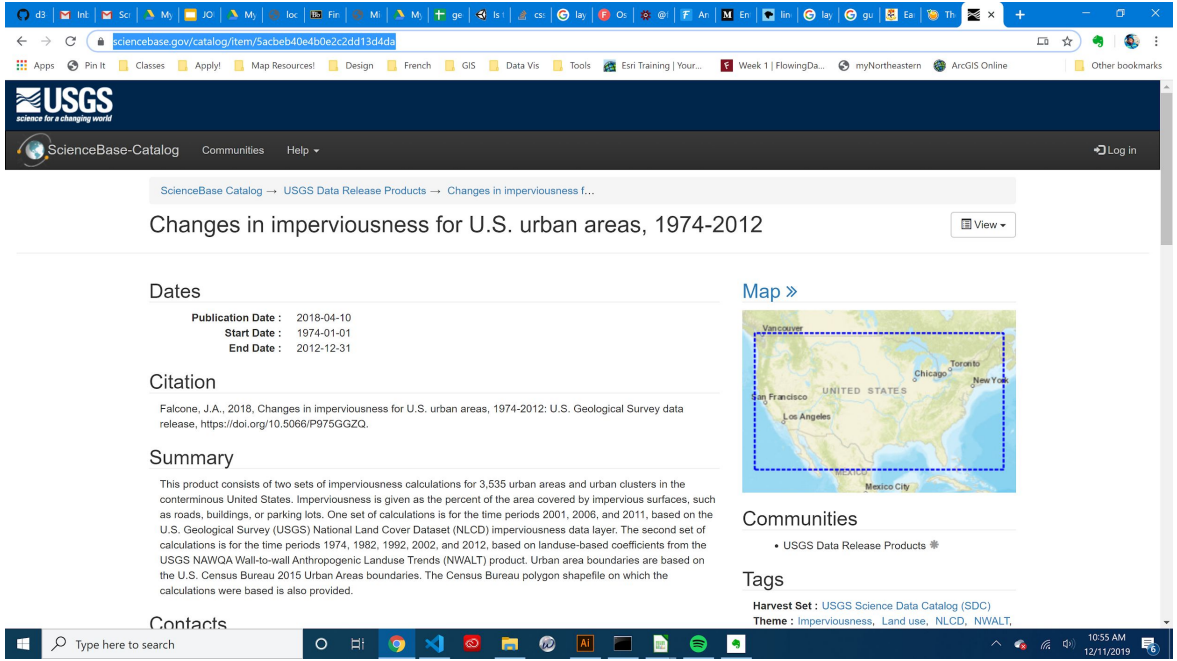
Goals

- Make a cool, fun visualization about geology, specifically (because I'm interviewing for a position at the United States Geological Survey and want to show them something relevant).
- Learn how to use scrolling as a trigger for events to happen
- Learn how to use Javascript to control styling better
- Do better styling in CSS, generally
- Try a whole bunch of stuff just to see if I can make them happen!

Initial Thoughts - Imperviousness

The USGS has made a model of the change in city imperviousness - that's an important measure for determining soil erosion, stormwater runoff, and general urban changes. It's super interesting!

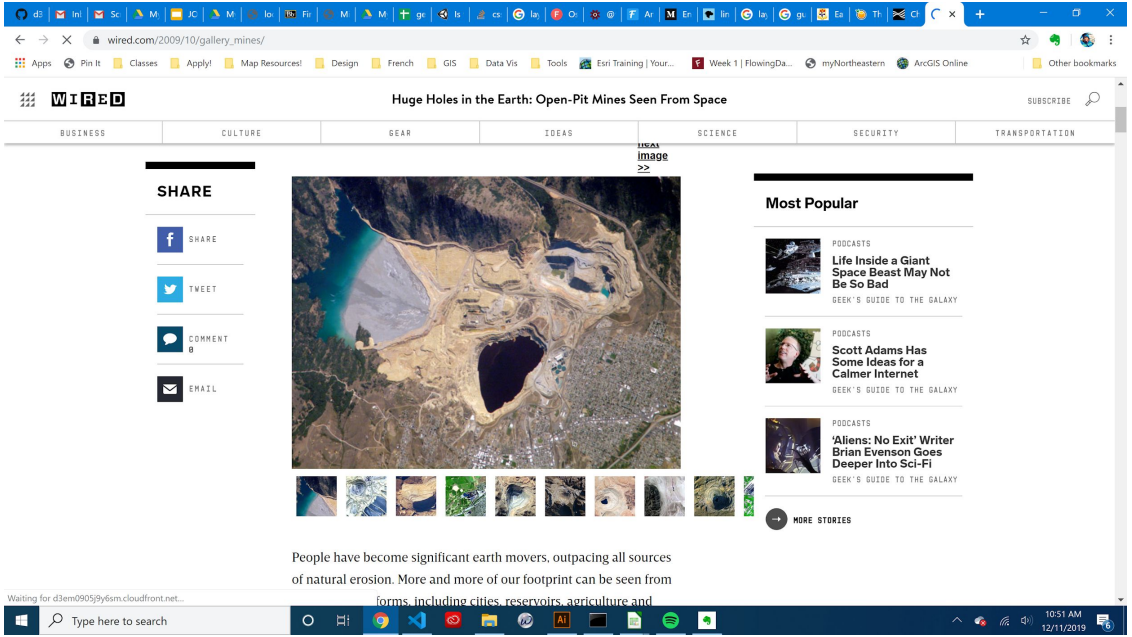
Data found here:
https://www.sciencebase.gov/catalog/item/5acbeb40e4b0e2c2dd13d4da



Initial Thoughts - Superfund Sites

I'd love to make a Superfund Sites explorer. What do these sites really look like? I love seeing aerial imagery, and I've been really struck by open-pit mine explorers from Google Earth.

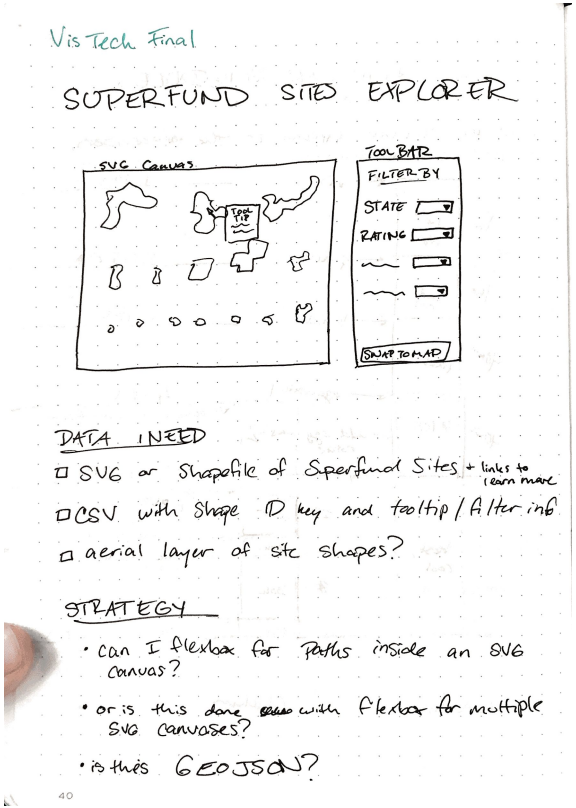
What would this look like if I made SVG shapes of all the outlines of Superfund Sites? I could order / sort them somehow, filter them by certain qualities, and tooltips could tell me more about them.



Initial Thoughts - Superfund Sites

However, turns out that the owners of superfund sites don't like the public knowing too much about the details of their hazardous waste sites.

I can find points, but no outlines. The points are interesting, but not what I'm most interested in visually. I'll have to return to this idea another time.



What about simple datasets that just aren’t well visualized or conceptualized?

Like the layers of the earth?!

The scale of the earth is hard to comprehend

As a geologist by training, a lot of the science about the earth deals with some really huge, incomprehensible numbers.

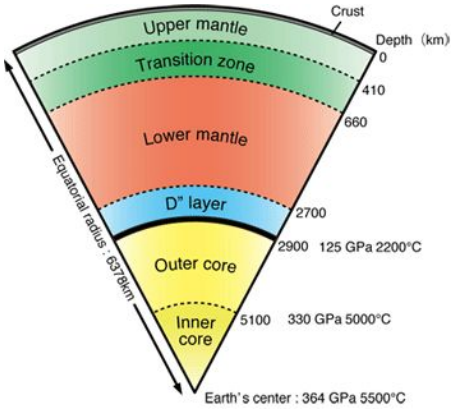
Billions of years! Millions of kilometers! Giga Pascals!

The scale of the earth - and the universe, for that matter - is truly amazing. We are such tiny specks on this grand hunk of molten rock, floating on a tiiiiiiiny film of frozen crystals.

And current diagrams of this scale don't nearly do it justice.

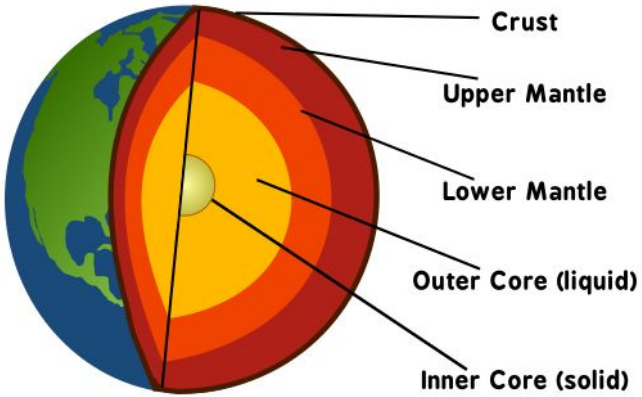
Current Visualizations are frankly, terrible

Japan Synchrotron Radiation Research Institute (JASRI)



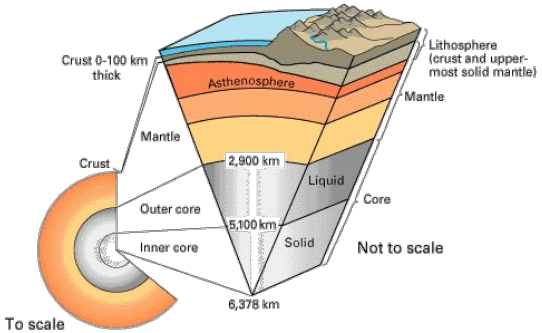
That color scheme, ugh! And why is there Pressure and temperature information only at a few locations?

"Easy Peasy Homeschool"



Why is the core off center? Where's the citation on the webpage?

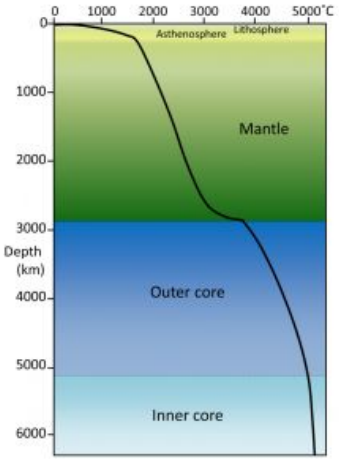
USGS, 1999



Reading the scale here is an afterthought - it would take some good thinking to realize that that cust is not actually that thick.

Other visualizations of the data are also very science-y

Physical Geology, Steven Earle



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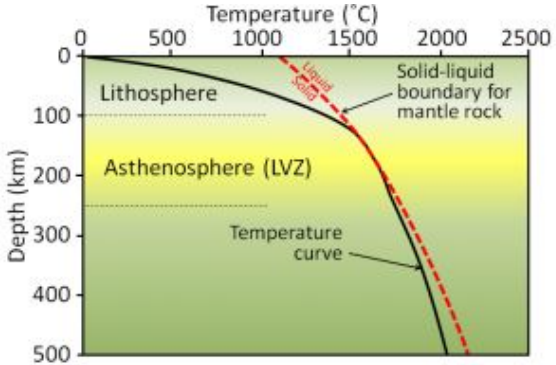

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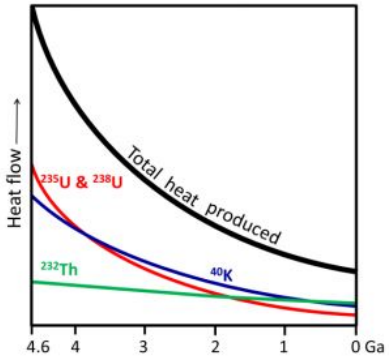

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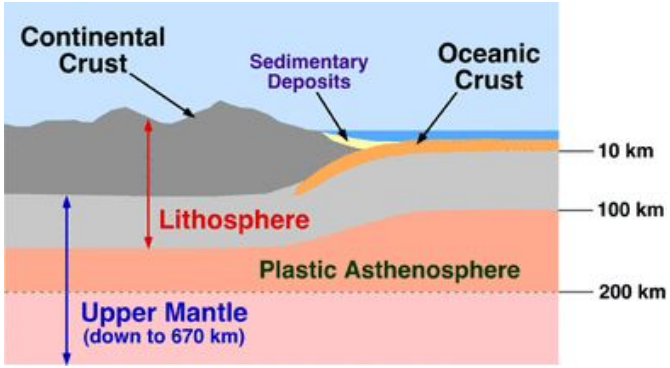
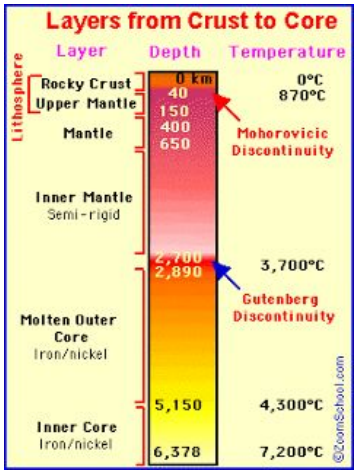
And the lingo is confusing

Herculea Jones



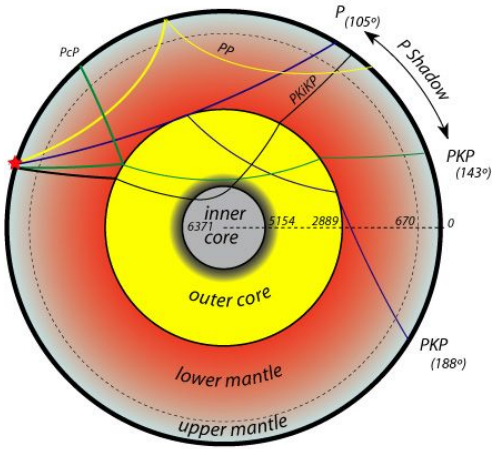
So what's the gray layer inside the Lithosphere? And why do the lithosphere and mantle overlap?

Geology IN



While the gradient is useful, the temperatures are just...wrong? Where's the citation?

University of Sydney



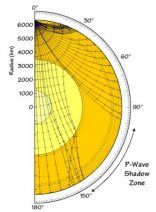
What the heck are these lines? And the labels? And the units?!

The data is either very rough, or hidden deep in scientific papers.

(This is why I love data viz, by the way - I think science should be far more accessible!)

Key Contributions to Plate Tectonic Theory and Solid Earth Geophysics

Beno Gutenberg was a driving force behind the acceptance of seismology as an international science of earthquake detection and study. In the year 1913, Gutenberg proved the existence of the Earth's core. He recognized that the P-wave shadow zone was due to the refraction and reflection of primary waves by the Earth's molten core. He also found that the S-wave shadow zone resulted from the complete absorbtion of the secondary waves by the liquid core. This information allowed him to calculate that the Earth's core began at 1800 miles (2880 km). Eventually, this core-mantle boundary was named after him and is known as the Gutenberg Discontinuity (www.bookrags.com). He is also well known for editing and contributing to the *Handbuch der Geophysik* (Mitchell).



P-wave Shadow Zone

(Image: http://earthquake.usgs.gov/learn/glossary/images/shadow_zone.gif)

During the years of 1931-1939, Gutenberg worked on a series of papers with Charles Richter, a noted physicist after which the "Richter Scale" is named. Their article *On Seismic Waves* provides basic information on the travel times of several seismic phases through the Earth's interior. They also described

Crust and Mantle vs. Lithosphere and Asthenosphere

Why do we use two names to describe the same layer of the Earth? Well, this confusion results from the different ways scientists study the Earth. Lithosphere, asthenosphere, and mesosphere (we usually don't discuss this last layer) represent changes in the mechanical properties of the Earth. Crust and mantle refer to changes in the chemical composition of the Earth.

Lithosphere and Asthenosphere
The *lithosphere* (*litho*:rock; *sphere*:layer) is the strong, upper 100 km of the Earth. The lithosphere is the tectonic plate we talk about in plate tectonics. The *asthenosphere* (*a*:without; *sthenos*:strength) is the weak and easily deformed layer of the Earth that acts as a "lubricant" for the tectonic plates to slide over. The asthenosphere extends from 100 km depth to 660 km beneath the Earth's surface. Beneath the asthenosphere is the *mesosphere*, another strong layer.

Crust and Mantle
The *crust* is a chemically distinct layer at the surface of the Earth. Crustal material contains lighter elements like Si, O, Al, Ca, K, Na, etc... Feldspars (Anorthite, Albite, Orthoclase) are comon minerals in the crust ($CaAl_2Si_2O_8$, $NaALSi_3O_8$, $KALSi_3O_8$). The crust may be divided into 2 types: oceanic and continental. Oceanic crust is usually 5-10 km thick and continental crust is 33 km thick on average. Beneath the crust is the mantle. The *mantle* is made up of Si and O, like the crust, but it contains more Fe and Mg. Thus, Olivine (Fe_2SiO_4-Mg_2SiO_4) and pyroxene ($MgSiO_3$-$FeSiO_3$) are abundant in the mantle. The mantle extends to the core-mantle interface at approximately 2900 km depth. Thus, the mantle contains the lower portion of the lithosphere, the asthenosphere, and the mesosphere. The crust is made of the upper portion of the lithosphere.

The Inner and Outer Core
The core-mantle interface is a change in mechanical properties (rock to liquid) and composition (Mg, Fe silicates to liquid Fe metal). At the outer-inner core interface we believe there is a slight compositional change and a mechanical change from liquid to solid. Most likely, the outer-inner core transition is from a liquid to a "fudgey" substance and not as "solid" as the mantle. Inner and outer core are used with both crust and mantle, and lithosphere and asthenosphere to describe the Earth's structure.

Inferences about the interior of the Earth, so far from being all inferior to those in the 'exact' sciences, range from those which are indeed flimsily based to inferences that are now as well established as commonly accepted results in standard physics.
K. E. Bullen, The Earth's Density (1975)

7.1 Generalities

All the information we have about the inaccessible interior of the Earth is embodied in Earth models which, if they are well constrained by observations and physical laws, are, at least in some respects, open to as little doubt as accepted tenets of, for instance, astronomy.

The previous chapters were devoted to laying the groundwork of the physics and thermodynamics that apply to the materials constituting the deep Earth, emphasizing the contribution of laboratory experimentation. We are now in a position to summarily present the recent view of the inner Earth that results from the conjunction of these physical constraints with a corpus of ever-improving geophysical observations.

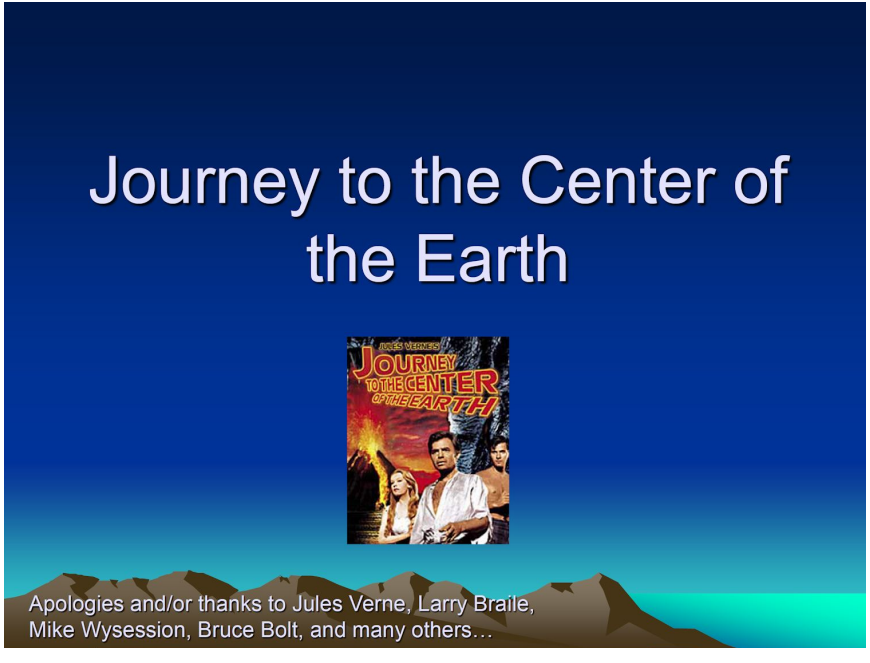
We will follow the traditional, and convenient, habit of separately considering seismological, thermal and compositional (mineralogical) Earth models. It must, of course, be kept in mind that they strongly interact (Fig. 7.1).

The seismological models are based on velocity–depth profiles determined from the travel-time–distance curves for seismic waves and on periods of free oscillations (see Bullen and Bolt, 1985 and, for a clear elementary presentation, Bolt, 1982). Due to the development of world-wide networks of three-component broad-band seismographs, there are more and more data, of better and better quality. At the initiative of the

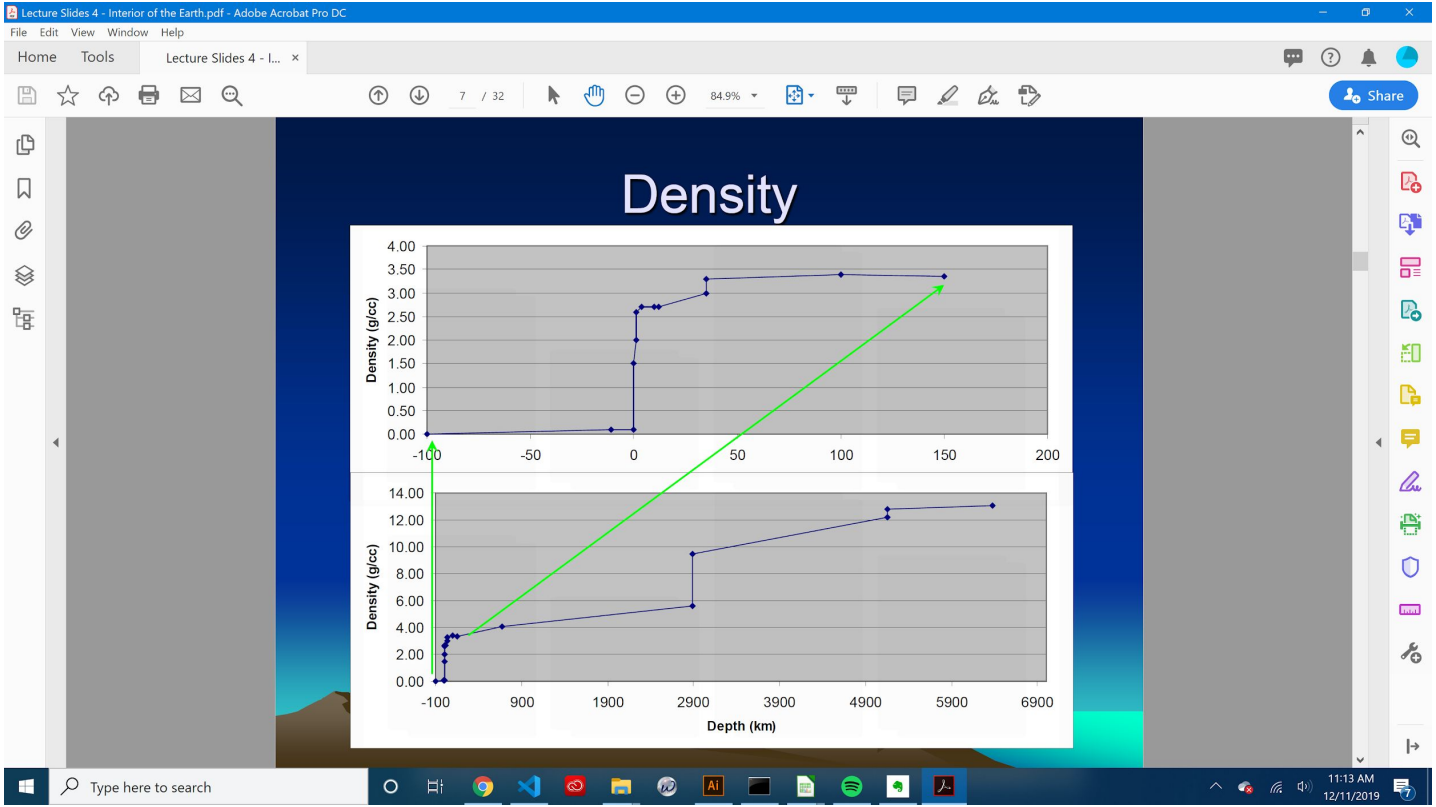
So I asked Professor Dr. Timothy Bechtel, who teaches geophysics at Franklin & Marshall College, for the best dataset he has.

(Spoiler, he's my dad, and he loves decorating with powerpoint)

The full powerpoint is included in the ./data folder



He had all the data, collected from his colleagues



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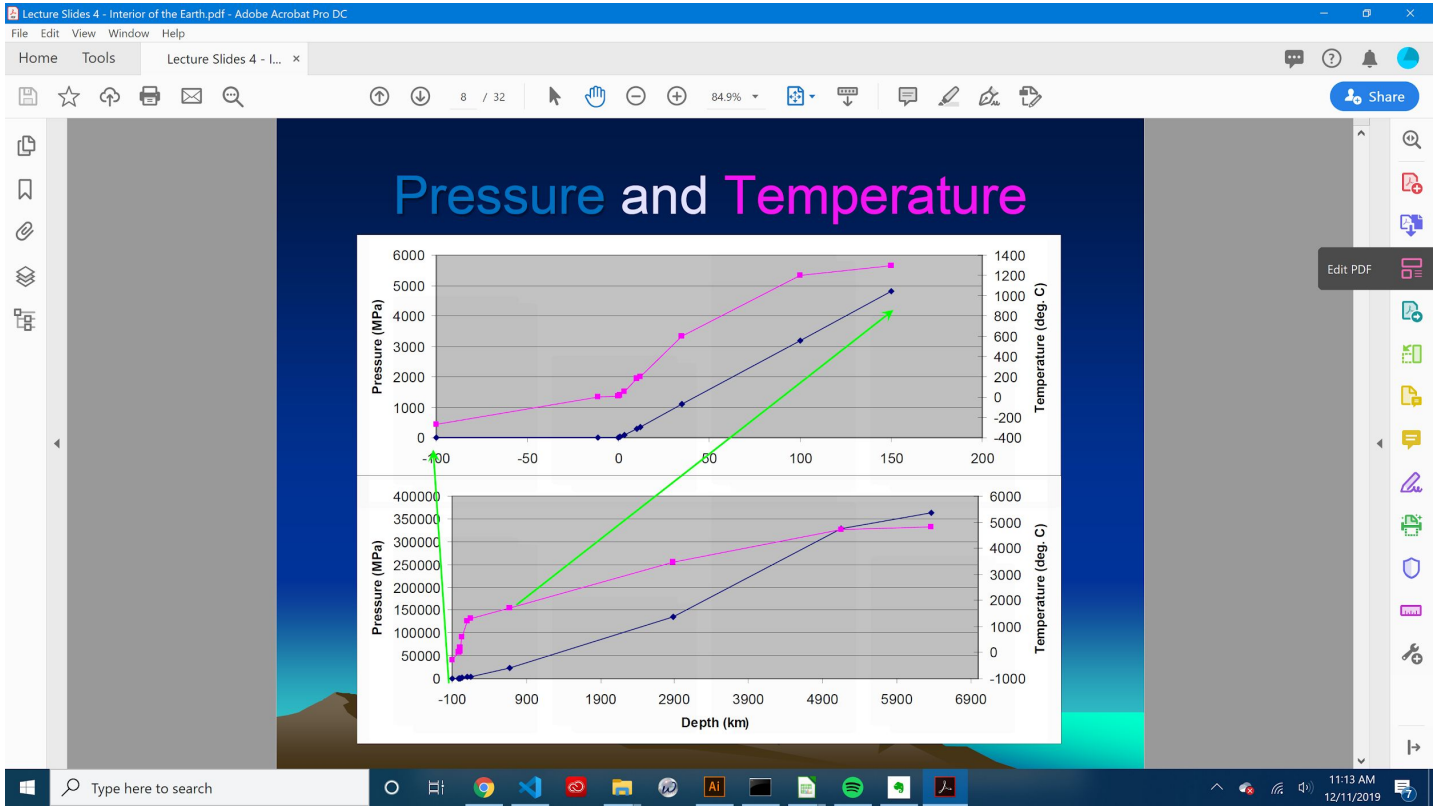
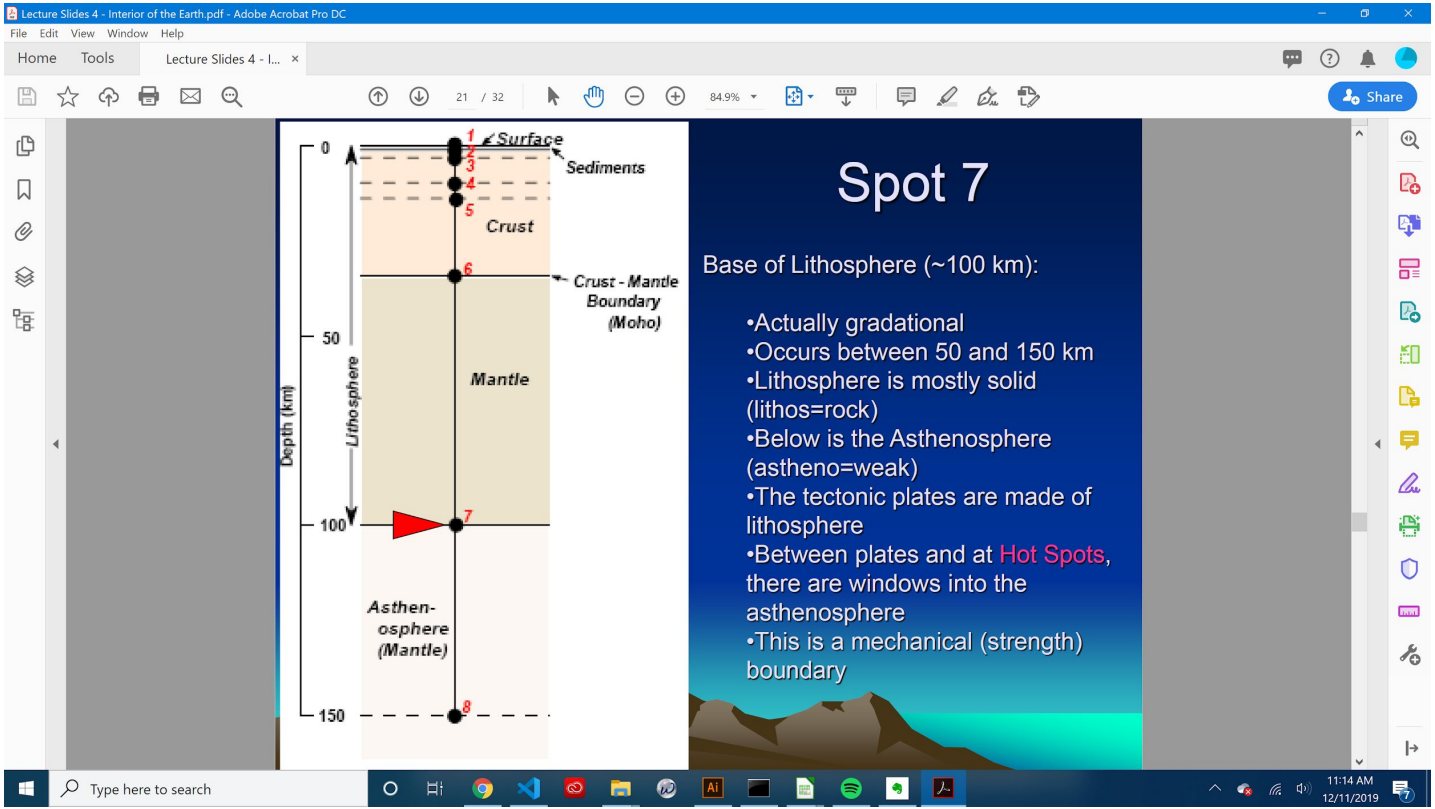


And a bunch of extra information



There *are* clever ways to “experience” the data

Like this fictional narrative guide to travelling to the center of the earth on someone’s personal blog.

Welcome to 3014, today is the 19th of July and it is finally it! Today mankind will attempt to travel to the centre of the Earth and discover the secret inside the core. I’m professor Baboons and I will be the person to attempt this mission with my sassy drill mobile. This vehicle is made out of a blend consisting of tungsten (a rare and hard metal that can with stand pressure and heat) and diamond it is designed to travel through any type of environment, with standing an enormous amount of heat up to 6000 degrees and can operate while under extreme pressure up to 400 gigapascals. The capacity of this vehicle is only valid for a person because the engine takes most of the space since the top speed for this monster is 1000km per hour. The reason for this to be called the drill mobile is because of the humongous drill attached to the front of the vehicle to break through hard granitic rocks and paddle through hot magma at top speed, it lights up when the engine is operating so the person will be able to see at all times under extreme dark conditions. Inside the vehicle there is an extreme AC system which will keep the temperature both exterior and interior of the vehicle at 23 degrees at all times. There is more than enough space for a person to dine, rest and plus a small bathroom. It is the perfect vehicle to travel to the centre of the Earth.

6:00pm the monitor buzzed again as the drill switched its drilling motion into a swift propeller motion. We are now inside the outer core as the temperature suddenly sky rocketed up to 5000 degrees and I am in liquid instead of the olivine green rocks. My surrounding completely changed again, illuminated by the light from the drill the liquid iron and nickel gave off a beautiful warm orange glow. I grew excited as minutes go by wanting to see more of this natural phenomenon and desperately wanting to know what lies in the core.

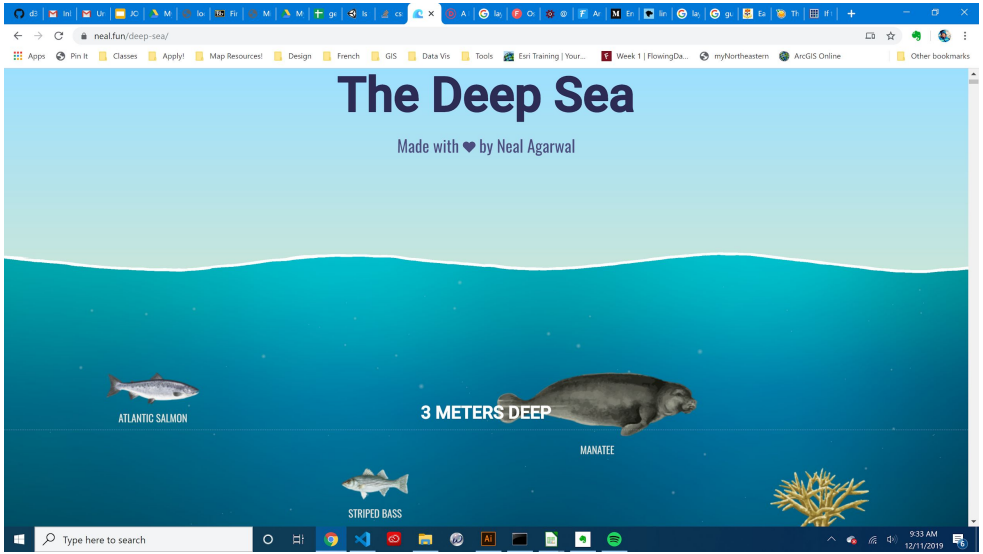
https://geologyportfoliokxz.weebly.com/layers-of-earth.html

There *are* clever ways to “experience” the data

Or this cake at https://www.youtube.com/watch?v=NAHY6965o08

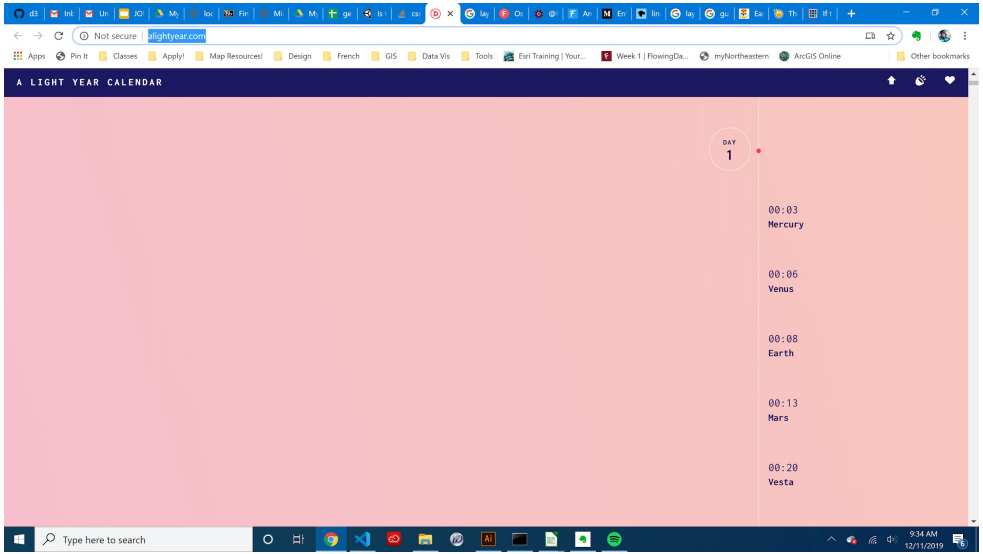
And there are several web platforms that show scale extremely well.

Like this Deep Sea scroller at https://neal.fun/deep-sea/



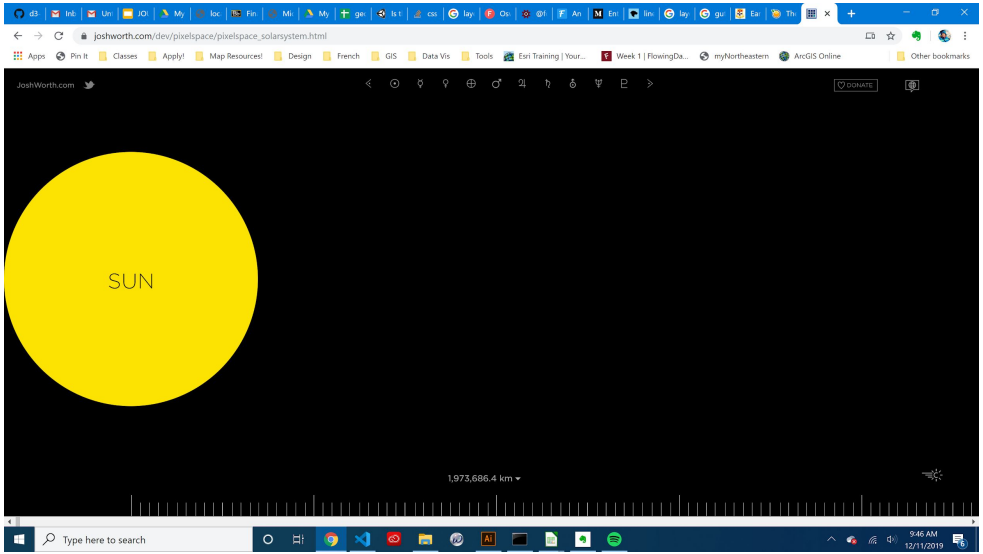
And there are several web platforms that show scale extremely well.

Or this light year calendar at http://alightyear.com/

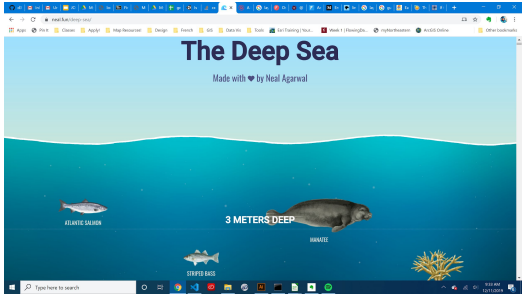


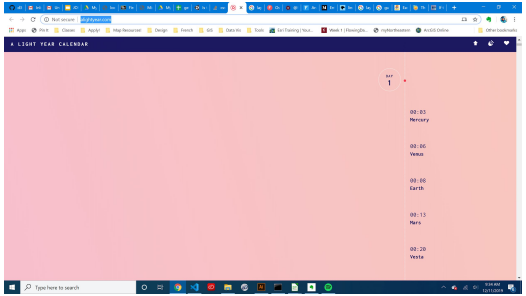
And there are several web platforms that show scale extremely well.

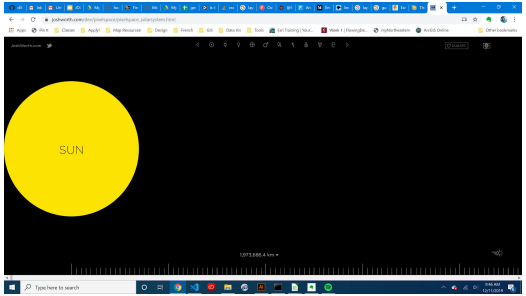
Or this solar system at https://joshworth.com/dev/pixelspace/pixelspace_solarsystem.html



They all make scale - and empty space - enjoyable







They use good design to make the numbers feel real and friendly. They use landmarks along a long scrolling path to give numbers a sense of distance or time between each landmark. And they use humor and casual-ness to make people curious and interested.

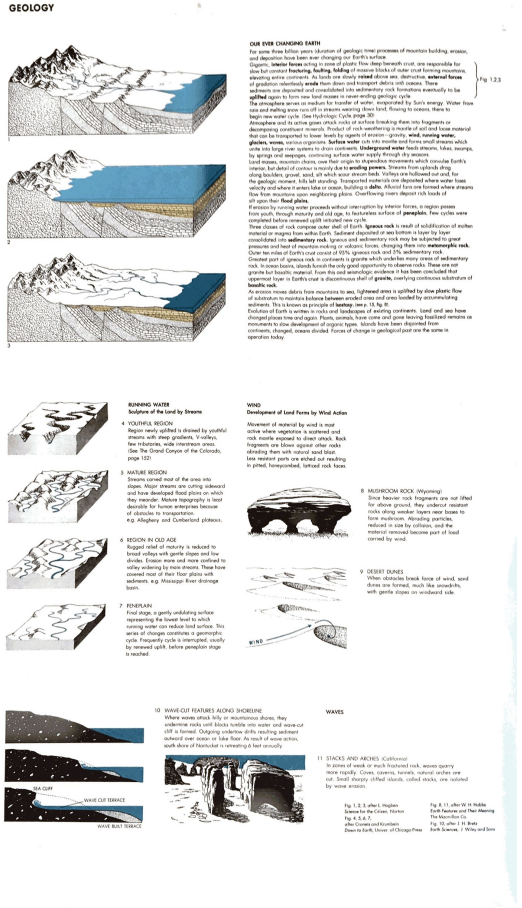
I learned a lot looking at their code - or what I could understand of it. They each did it really differently.

So I want to make one for the earth!

Design Inspiration

Herbert Bayer's World Geographic Atlas

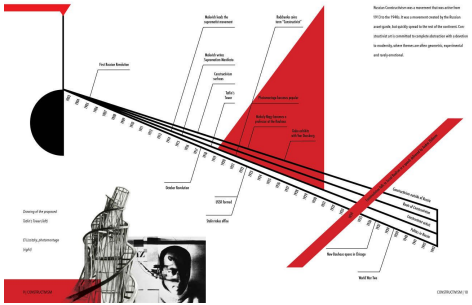
Modern type, simple colors, high contrast

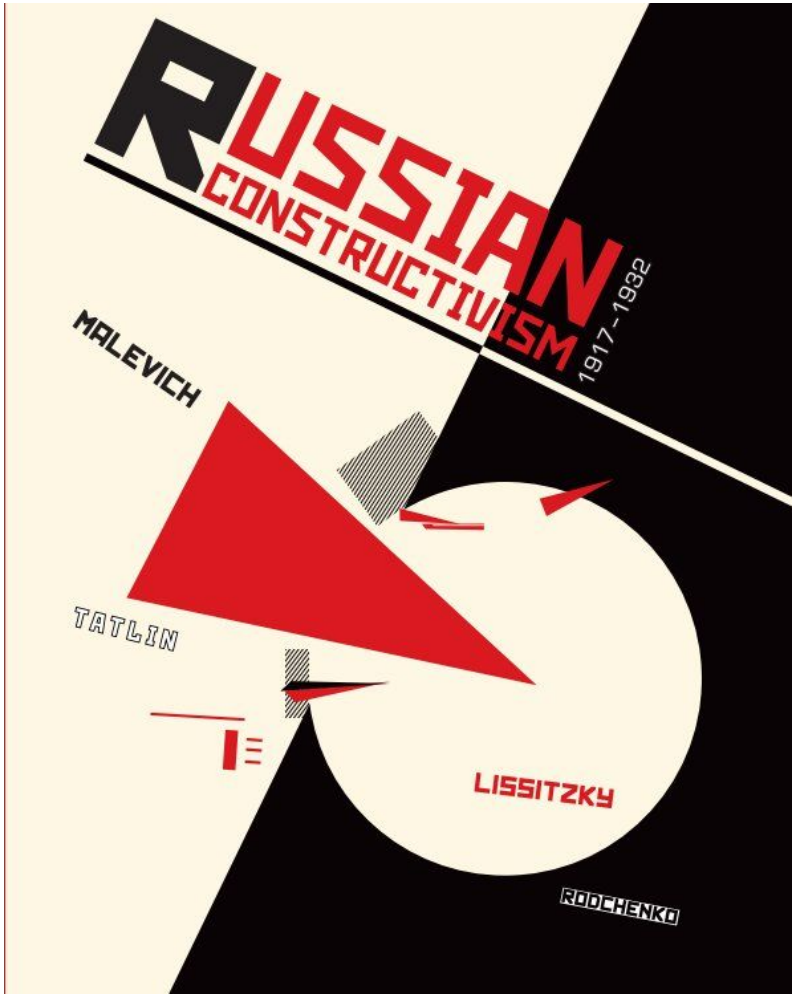


Design Inspiration

Russian Constructivism

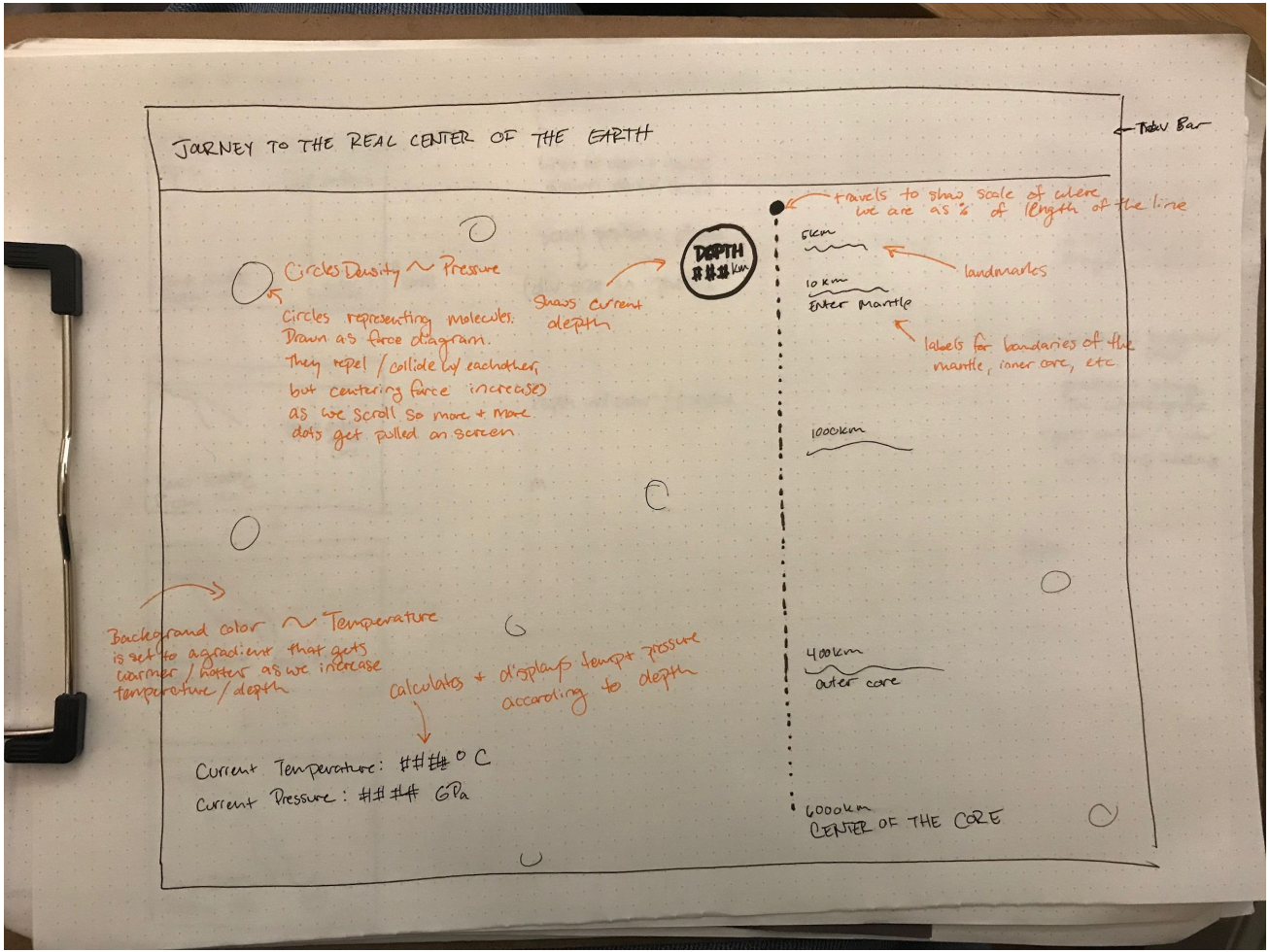
Simple shapes, flat colors, bold use of geometry. Used this for the color scheme and pointer.





Sketches

First idea, linked closely to the Light Year Calendar idea



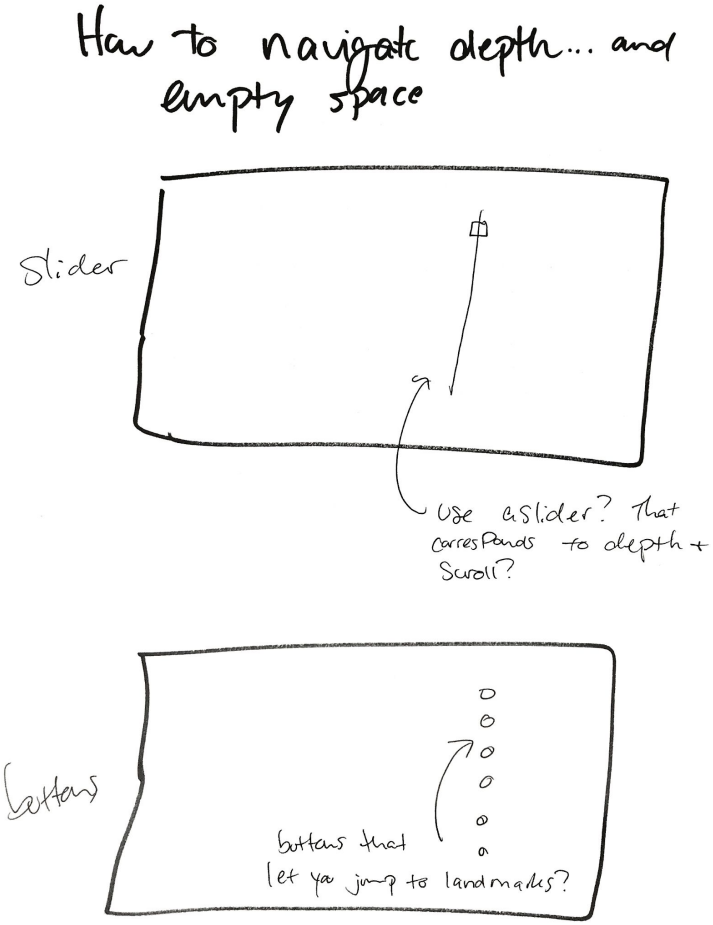
Sketches

So the first question is... how do I navigate depth?

I want to learn how to incorporate scrolling into the code, so I definitely want that to control most of what happens.

But to make it easier for the user to navigate empty space, should I add a slider? Or buttons?

I'd like to do that eventually, but due to time constraints, I had to abandon this idea just to get stuff done.



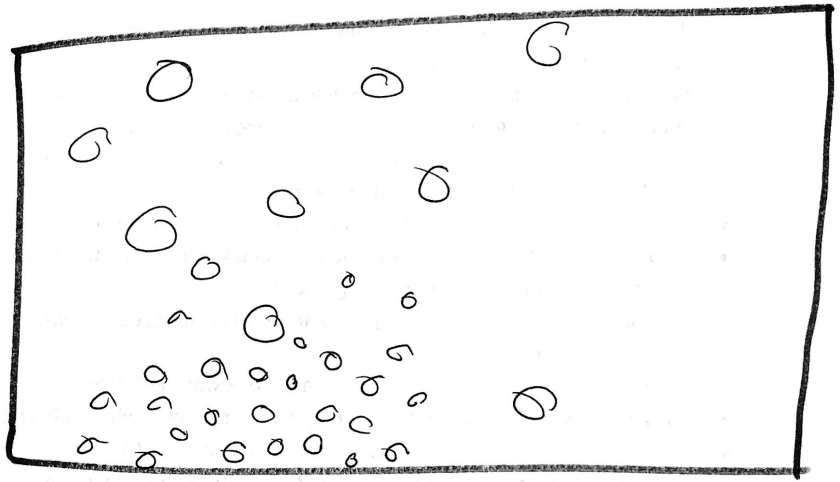
Sketches

My first thought was to visualize pressure by making a network of unconnected nodes, and making them squish together as depth increases.

A more elaborate version could have the nodes be elements, and change as the composition of the earth changes from siliates (Si and O) to mafic rocks and metals (Ni and Fe). That'd be cool!

How To show Pressure:

nodes + force diagram?



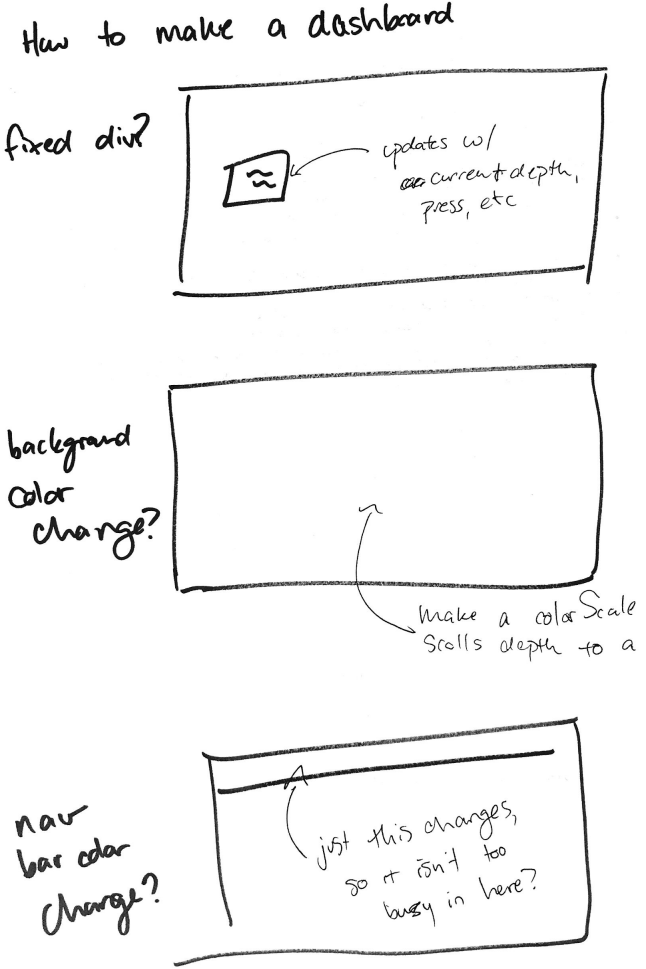
- nodes stay fixed in view, charge decreases as you go deeper so they compress?
- use the beeswarm idea to give it some clustering towards the y-axis

Sketches

What about temperature? I thought another way to encode a sense of temperature increase was to have the background color change. That was certainly cool! But I'd have to also change the text color, and that's a lot of things changing all at once.

What about changing just the nav bar? Even if it doesn't encode temperature itself, it gives a sense that it's getting hotter and adds some interest

Finally, I settled on having a dashboard appear when you start scrolling. The Dash shows all three changing things - depth, temperature, and pressure, and appears when you enter the svg canvas.

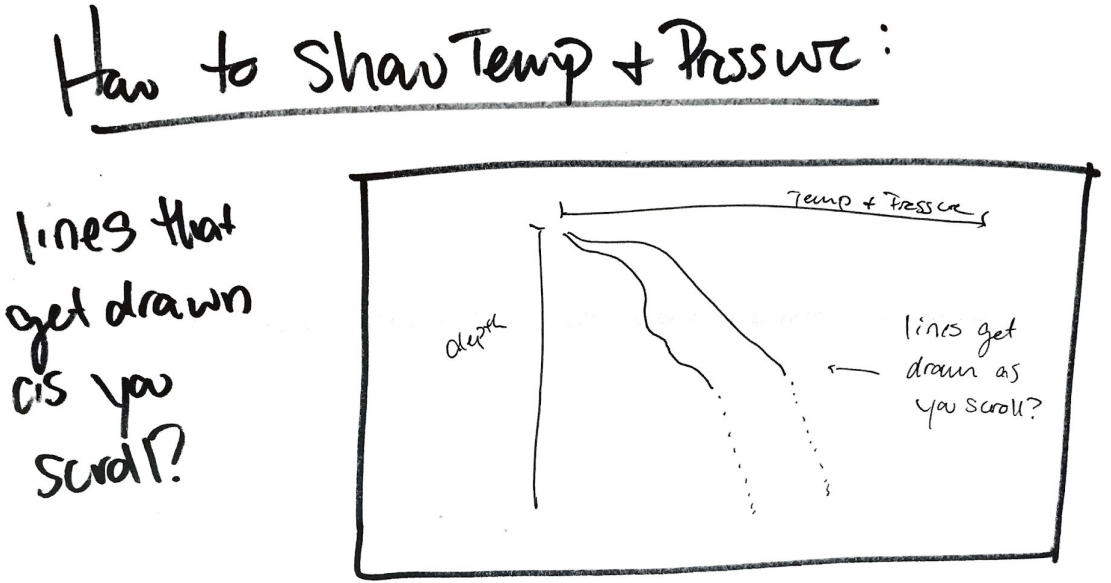


Sketches

What if instead of just giving a *sense* of increasing pressure, I actually showed the data?

I'd love to have a line chart draw as you scroll down the screen, interpolating between the few points that we have.

I don't want it to make the canvas too busy though, with the landmarks and all.

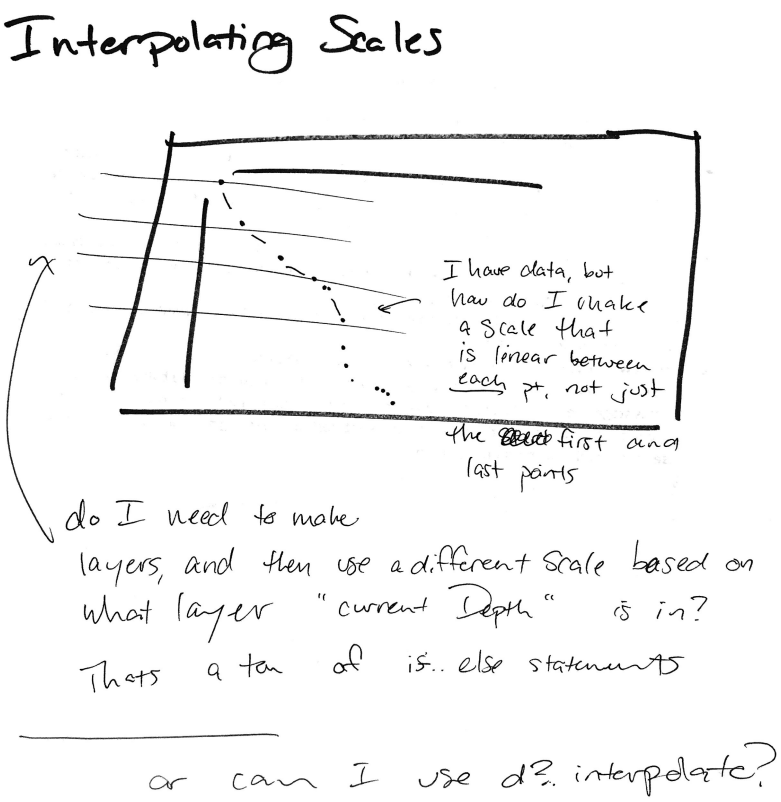


Sketches

But if I'm drawing lines, I need to make ways to interpolate the value between the given data points. I only know about scaleLinear, so should I make a series of if statement that determine what layer I'm in based on the depth?

And based on what layer I'm in, use a certain linear scale?

There must be an interpolation function, but since I decided not to draw the lines in this iteration, I didn't need to do this. One day I'll learn about d3.interpolate though...



Citations

Brainstorming
Fictional narrative: https://geologyportfoliokxz.weebly.com/
Some diagrams: http://herculeajonesdiv1.weebly.com/earths-4-layers.html
http://www.geologyin.com/2015/08/what-is-earths-average-temperature.html#

Scale-Scrolling sites:
Deep Sea: https://neal.fun/deep-sea/
Light Year Calendar: http://alightyear.com/
Solar System: https://joshworth.com/dev/pixelspace/pixelspace_solarsystem.html

The Science
Temperature gradients: https://opentextbc.ca/geology/chapter/9-2-the-temperature-of-earths-interior/
https://www.e-education.psu.edu/earth520/content/l2_p25.html
Tim Bechtel's Introduction to Earth, Environment, and Humanity "Journey to the Center of the Earth" slides, included in the .zip

Coding
Interpolation: https://observablehq.com/@d3/d3-interpolate
Positioning: https://www.w3schools.com/css/css_positioning.asp
Sticky nav bar: https://www.w3schools.com/howto/howto_js_navbar_sticky.asp
Literally every demo and snippet from class all semester.
Plus extra snippets and a skype call with the angel-sent-to-earth, Steven Braun.