

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/v/catalog/item/5acbeb40e4b0e2c2dd13d4da>

The screenshot shows a Microsoft Edge browser window. The address bar contains the URL: sciencebase.gov/catalog/item/5acbeb40e4b0e2c2dd13d4da. The page header includes the USGS logo and navigation links for Apps, Pin It, Classes, Apply!, Map Resources!, Design, French, GIS, Data Vis, Tools, Esri Training, Week 1, FlowingData, myNortheastern, ArcGIS Online, and Other bookmarks. The main content area displays a breadcrumb trail: ScienceBase Catalog → USGS Data Release Products → Changes in imperviousness f... Below this, a title reads "Changes in imperviousness for U.S. urban areas, 1974-2012". A "View" button is to the right. To the left, a "Dates" section lists Publication Date: 2018-04-10, Start Date: 1974-01-01, and End Date: 2012-12-31. A "Citation" section credits Falcone, J.A., 2018, Changes in imperviousness for U.S. urban areas, 1974-2012: U.S. Geological Survey data release, https://doi.org/10.5066/P975GGZQ. A "Summary" section describes the product as consisting of two sets of imperviousness calculations for 3,535 urban areas and urban clusters in the conterminous United States, using NLCD data and landuse-based coefficients from the USGS NAWQA Wall-to-wall Anthropogenic Landuse Trends (NWALT) product. A "Map" section shows a map of the United States with a dashed blue rectangle highlighting the study area, which includes major cities like Vancouver, San Francisco, Los Angeles, Chicago, and New York. A "Communities" section lists "USGS Data Release Products". A "Tags" section includes "Harvest Set: USGS Science Data Catalog (SDC)" and "Theme: Imperviousness, Land use, NLCD, NWALT". The bottom of the screen shows the Windows taskbar with various pinned icons.

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.

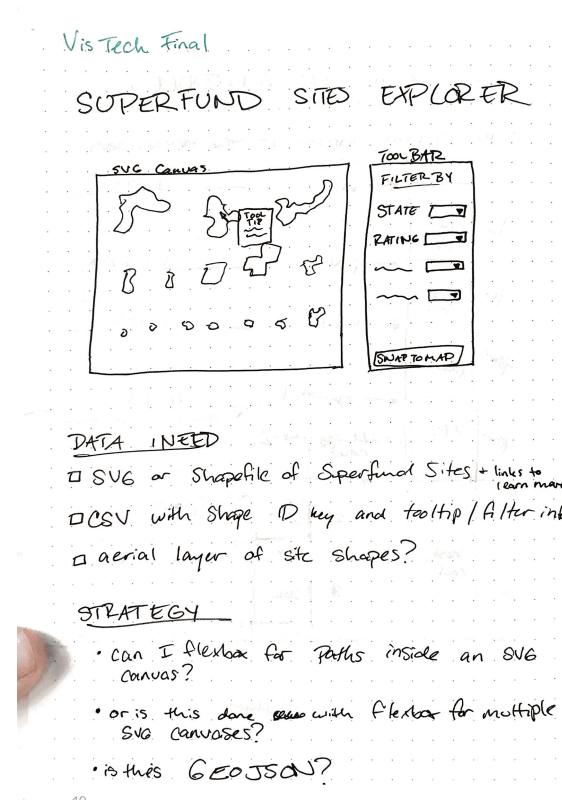
What would this look like if I made SVG shapes of all the outlines of Superfund Sites? I could order / sort them somehow, filter them by certain qualities, and tooltips could tell me more about them.

The screenshot shows a web browser window displaying an article from WIRED.com. The title of the article is "Huge Holes in the Earth: Open-Pit Mines Seen From Space". The main image is a satellite photograph of a massive open-pit mine, showing deep, irregular holes and surrounding landforms. To the left of the image is a "SHARE" sidebar with options for Facebook, Twitter, Comment, and Email. Below the main image is a row of smaller satellite thumbnails. The browser's address bar shows "wired.com/2009/10/gallery_mines/". The taskbar at the bottom includes icons for File Explorer, Task View, Google Chrome, Microsoft Edge, File Explorer, AI, Spotify, and others, along with the date "12/11/2019" and time "10:51 AM".

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.

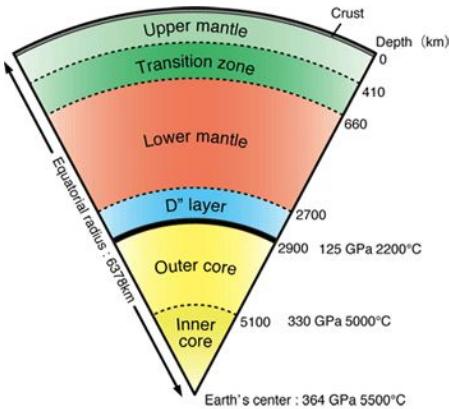
Billions of years! Millions of kilometers! Giga Pascals!

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.

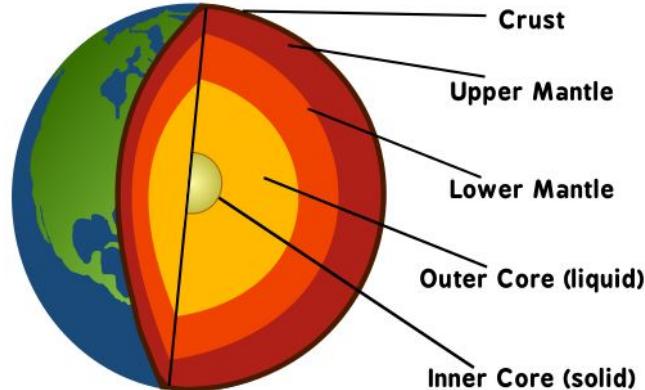
And current diagrams of this scale don't nearly do it justice.

Current Visualizations are frankly, terrible

Japan Synchrotron Radiation Research Institute (JASRI)



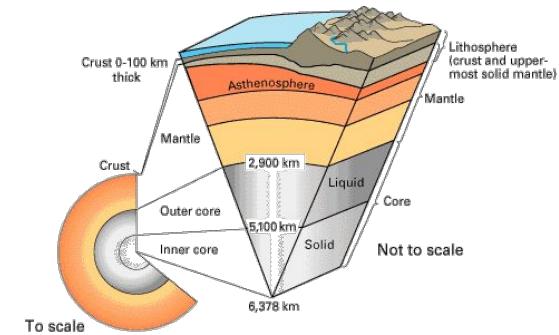
"Easy Peasy Homeschool"



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

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

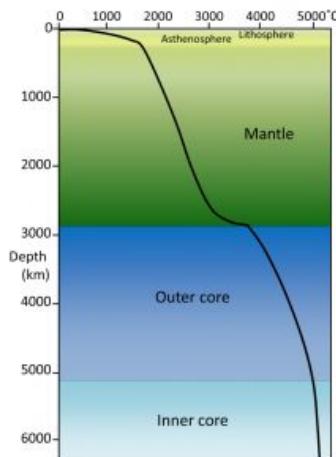
USGS, 1999



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

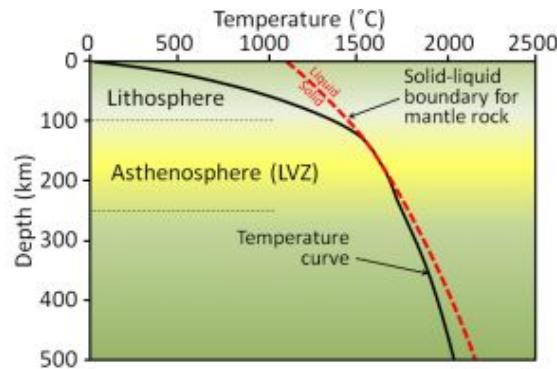
Other visualizations of the data are also very science-y

Physical Geology, Steven Earle



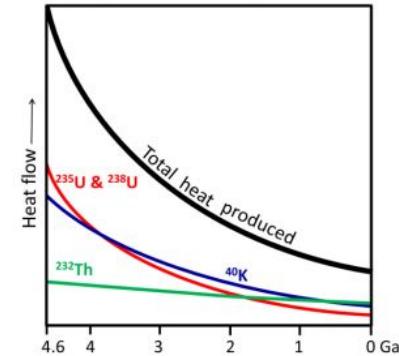
That color scheme, ugh! And why is there Pressure and temperature information only at a few locations?

"Easy Peasy Homeschool"



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

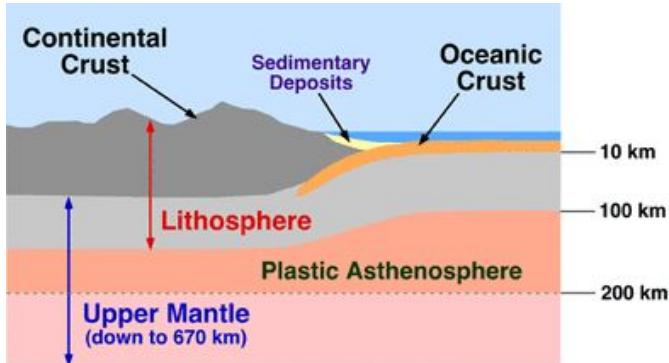
USGS, 1999



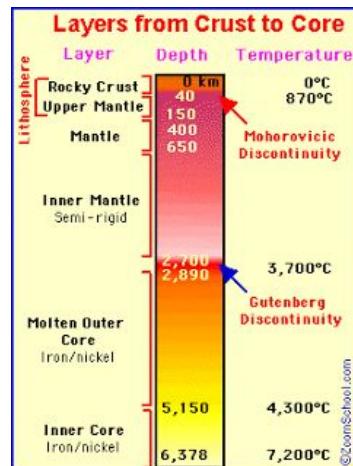
Reading the scale here is an afterthought - it would take some good thinking to realize that that crust is not actually that thick.

And the lingo is confusing

Herculea Jones



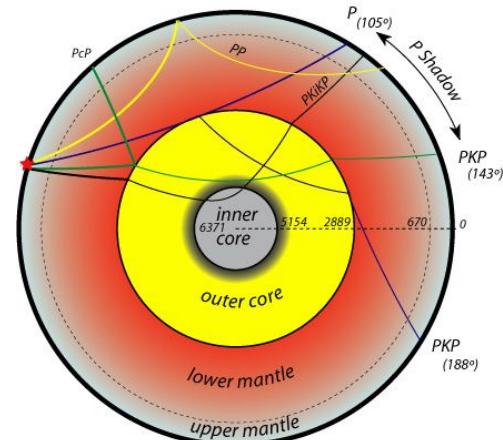
Geology IN



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

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

University of Sydney



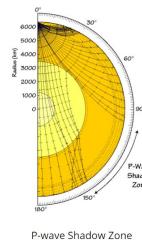
What the heck are these lines? And the labels? And the units?!

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 absorption 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).



(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* (lith=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* (asthen=weak) is the thin, 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 relatively distinct layer from the surface of the Earth. Crustal material contains lighter elements like Si, O, Al, Ca, K, Na, etc. Feldspars (Anorthite, Albite, Orthoclase) are common minerals in the crust (CaAl₂Si₂O₈, NaAlSi₃O₈, KAlSi₃O₈). 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 iron and magnesium. Olivine (Fe₂MgSiO₄) and pyroxene (Mg₂FeSiO₄) 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 "fudgy" 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.

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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 worldwide networks of three-component broad-band seismographs, there are more and more data, of better and better quality. At the initiative of the

Poirier, J. (2000). Introduction to the physics of the earth's interior. Retrieved from <http://ebookcentral.proquest.com>
Created from northeastern-stocks on 2019-12-03 11:14:29.

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)

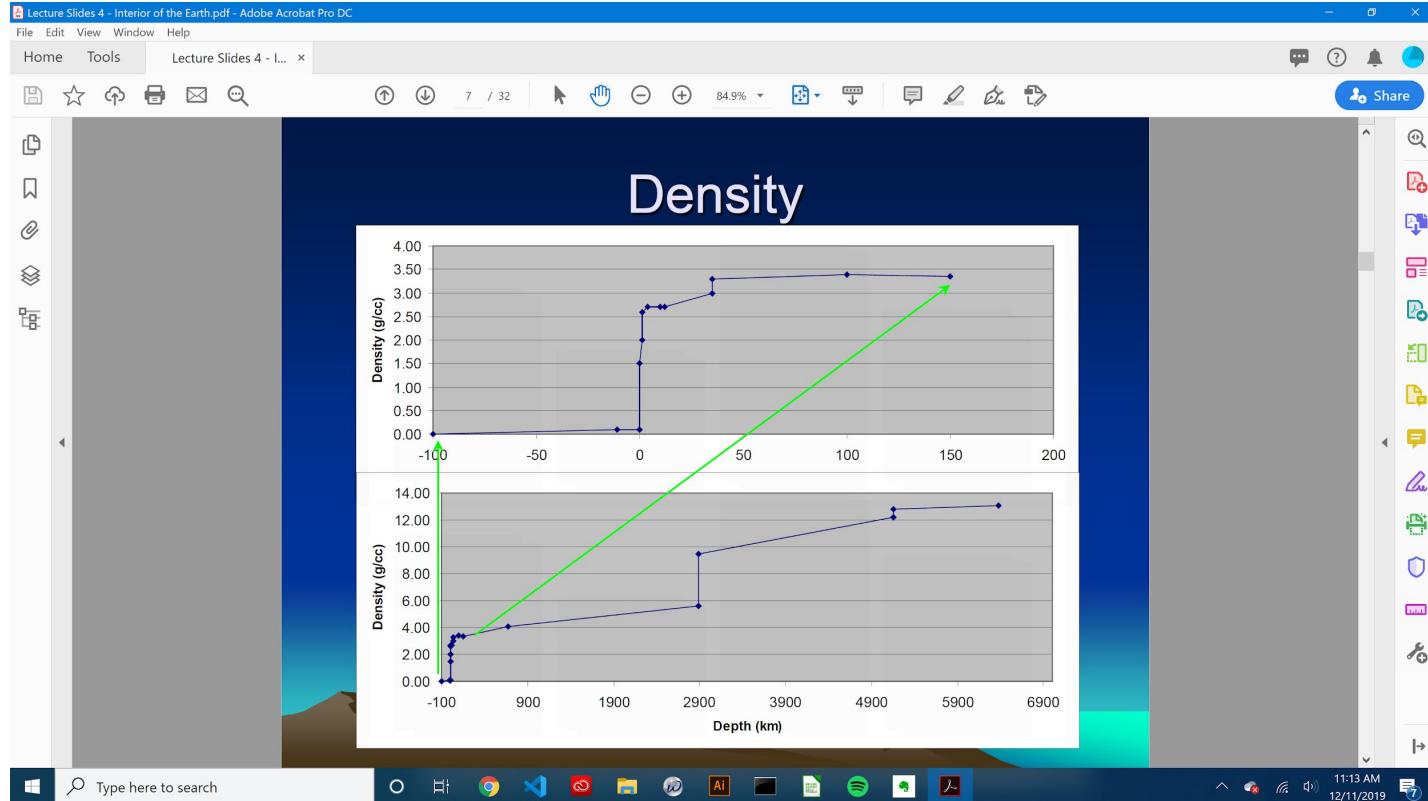
The full powerpoint is included in the
.data folder

Journey to the Center of the Earth

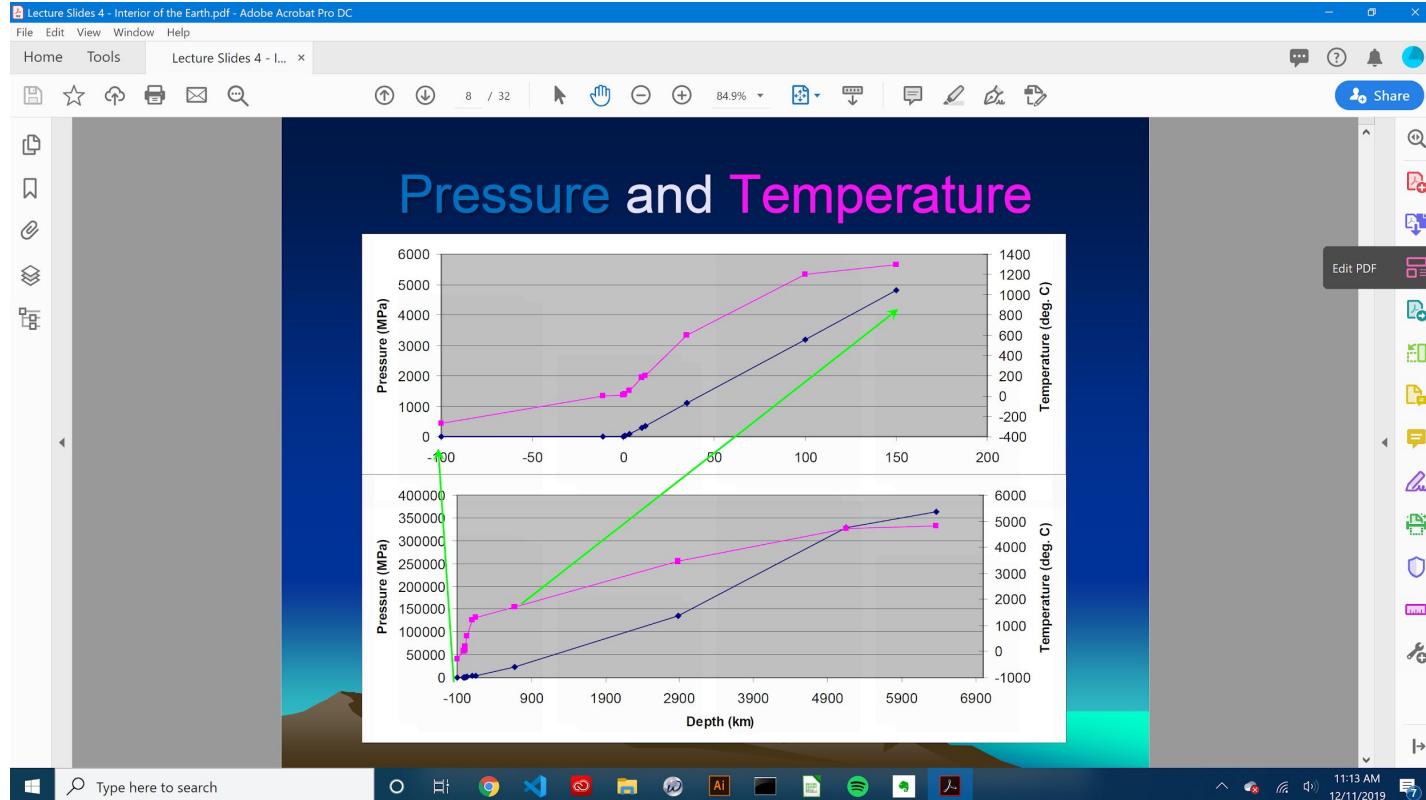


Apologies and/or thanks to Jules Verne, Larry Braille, Mike Wysession, Bruce Bolt, and many others...

He had all the data, collected from his colleagues



He had all the data, collected from his colleagues



And a bunch of extra information

Lecture Slides 4 - Interior of the Earth.pdf - Adobe Acrobat Pro DC
File Edit View Window Help
Home Tools Lecture Slides 4 - I... x 21 / 32 84.9% Share

The diagram illustrates the vertical structure of the Earth's interior. It features a vertical axis labeled 'Depth (km)' with major tick marks at 0, 50, 100, and 150. At the top, point 1 is labeled 'Surface'. Below it, points 2 through 5 are located within the 'Crust' layer, which is colored light orange. Point 6 is at the 'Crust - Mantle Boundary (Moho)', indicated by a horizontal dashed line. The 'Mantle' layer is shown in a light beige color, containing points 7 and 8. Point 7 is at approximately 100 km depth, and point 8 is at 150 km depth. A red arrow points downwards from point 7 towards point 8. The bottom of the diagram is labeled 'Asthenosphere (Mantle)'. The left side of the slide shows a grey sidebar with various icons.

Spot 7

Base of Lithosphere (~100 km):

- Actually gradational
- Occurs between 50 and 150 km
- Lithosphere is mostly solid (lithos=rock)
- Below is the Asthenosphere (astheno=weak)
- The tectonic plates are made of lithosphere
- Between plates and at Hot Spots, there are windows into the asthenosphere
- This is a mechanical (strength) boundary

11:14 AM 12/11/2019

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 withstand pressure and heat) and diamond it is designed to travel through any type of environment, withstanding 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 skyrocketed up to 5000 degrees and I am in liquid instead of the olivine green rocks. My surroundings 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://geologyportfolioxz.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>



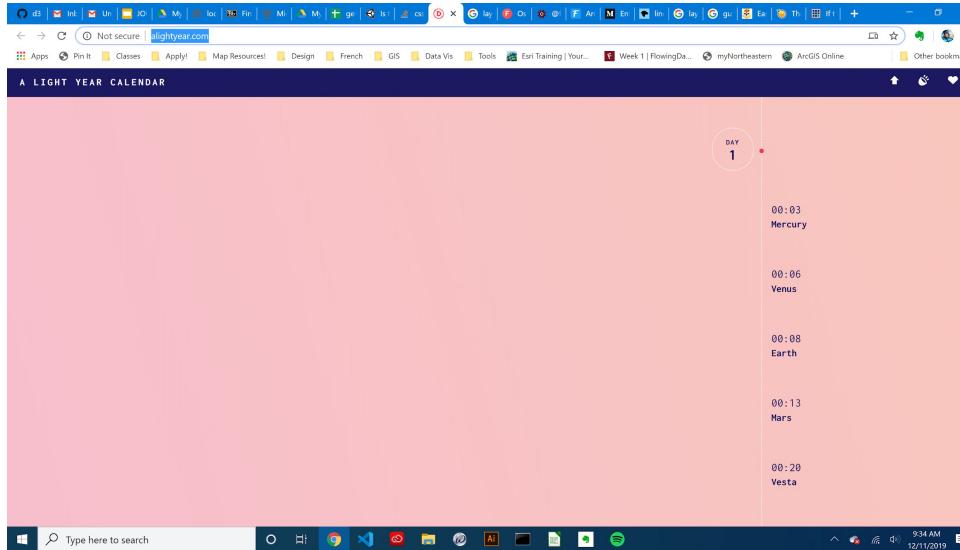
And there are several web platforms that show scale extremely well.

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



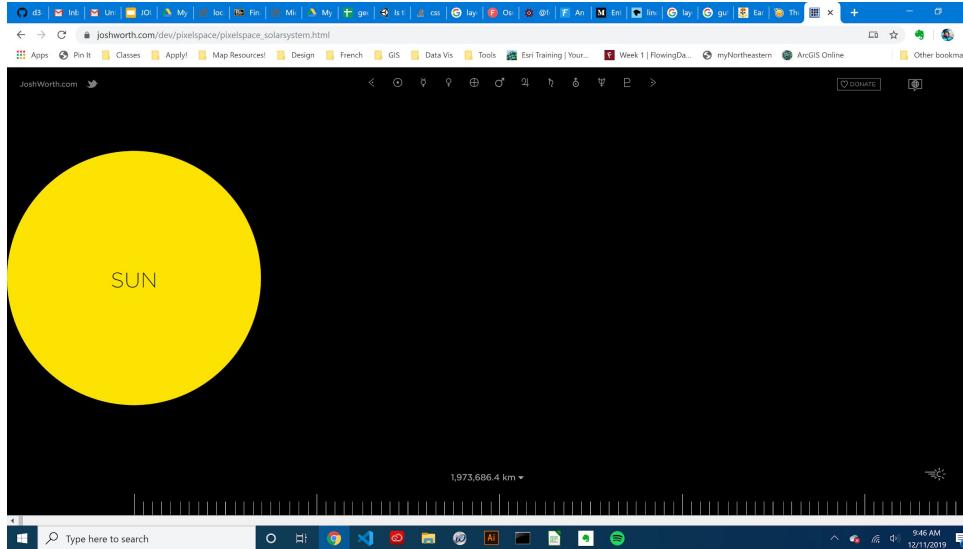
And there are several web platforms that show scale extremely well.

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

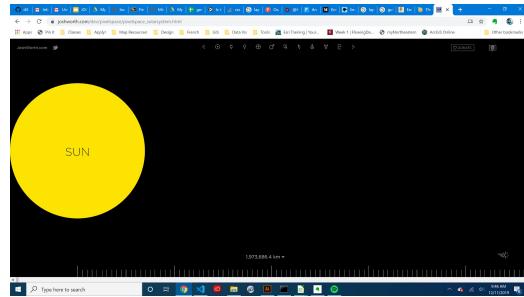
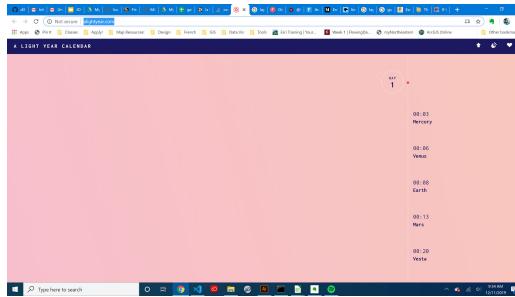


And there are several web platforms that show scale extremely well.

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.

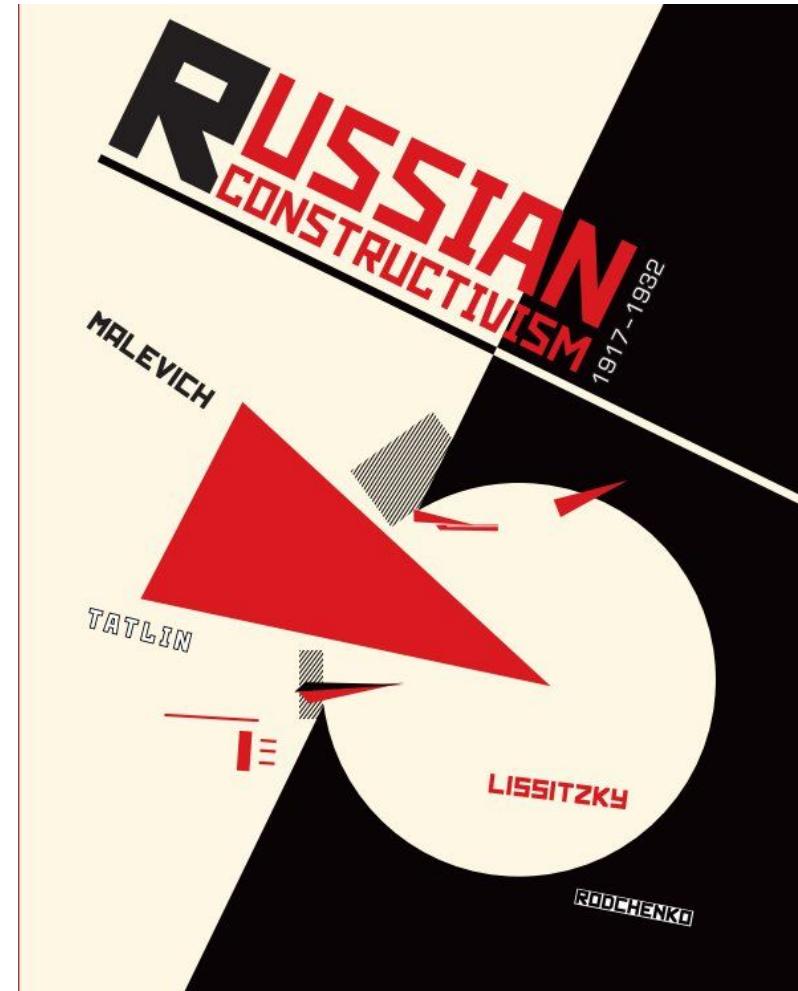
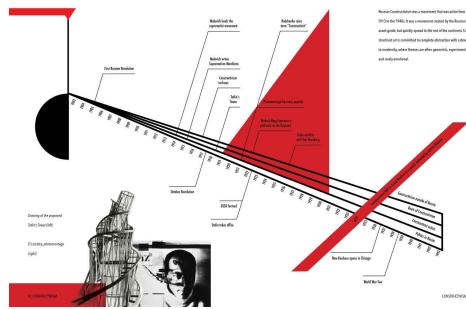
I learned a lot looking at their code - or what I could understand of it. They each did it really differently.

So I want to make one for the earth!

Design Inspiration

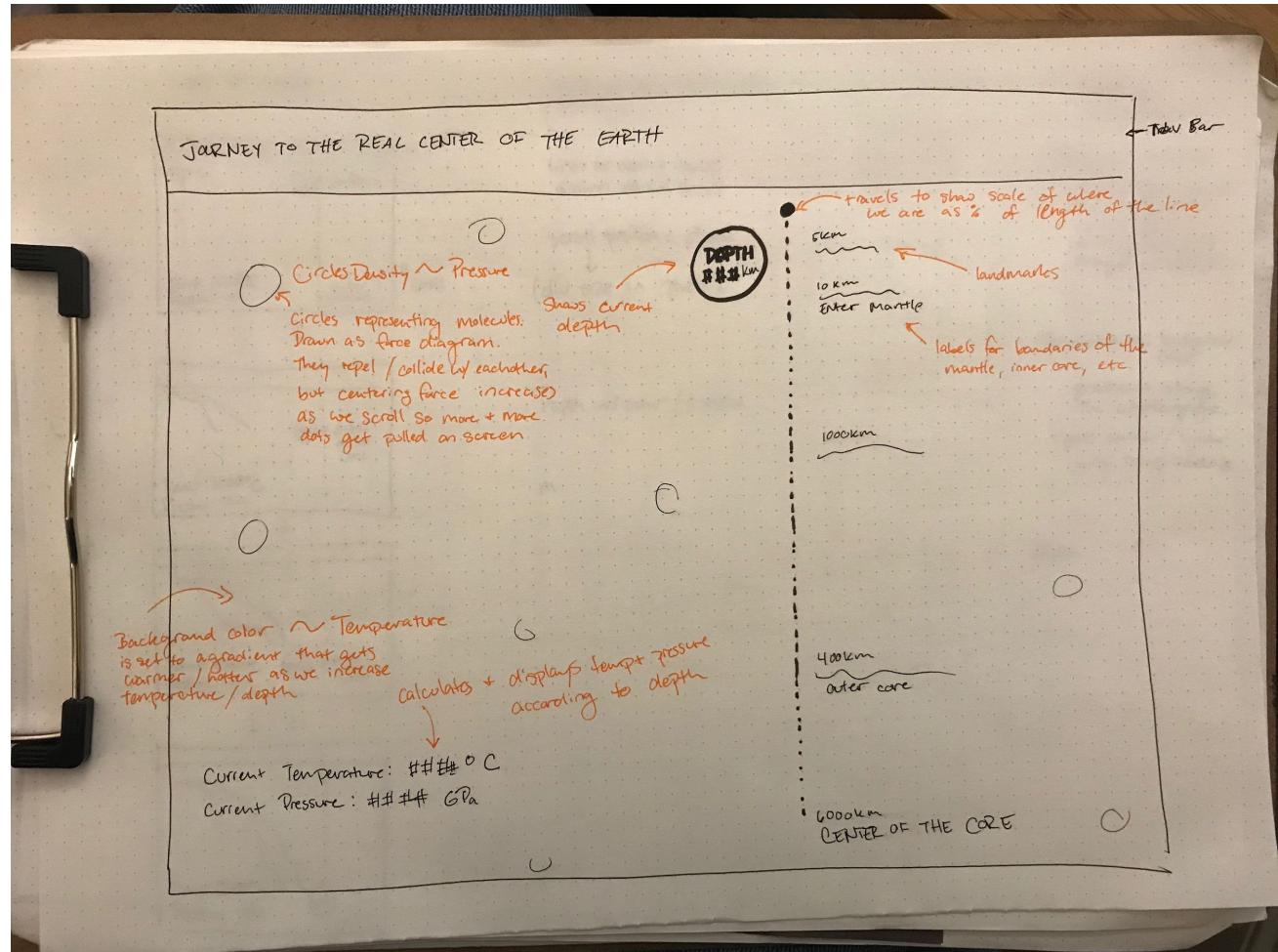
Russian Constructivism

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

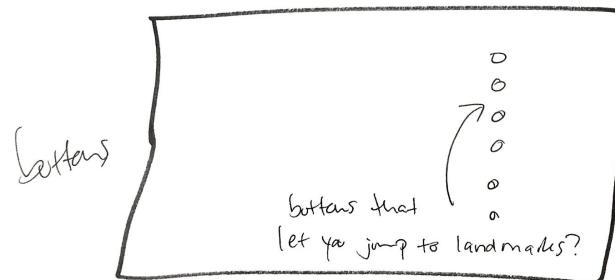
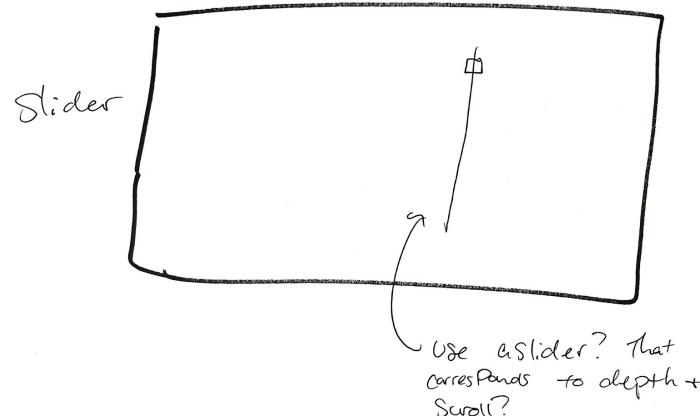
So the first question is... how do I navigate depth?

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.

How to navigate depth... and empty space



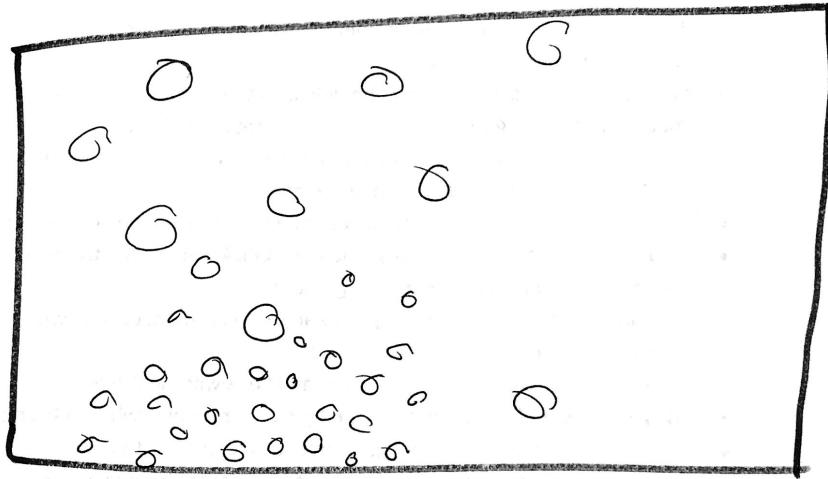
Sketches

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 silicates (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 decreased as you go deeper so they compress?
- use the beeswarm idea to give it some clustering towards the y-axis

Sketches

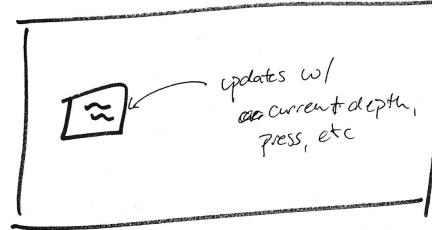
What about temperature? I thought another way to encode a sense of temperature increase was to have the background color change. That was certainly cool! But I'd have to also change the text color, and that's a lot of things changing all at once.

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

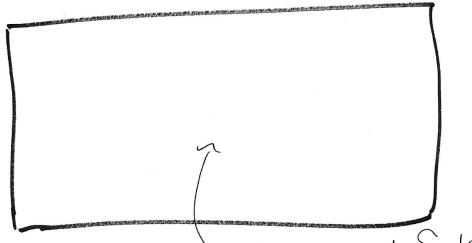
Finally, I settled on having a dashboard appear when you start scrolling. The Dash shows all three changing things - depth, temperature, and pressure, and appears when you enter the svg canvas.

How to make a dashboard

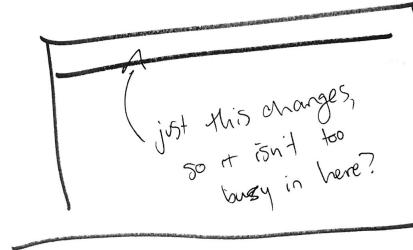
fixed div?



background
color
change?



nav
bar color
change?



Sketches

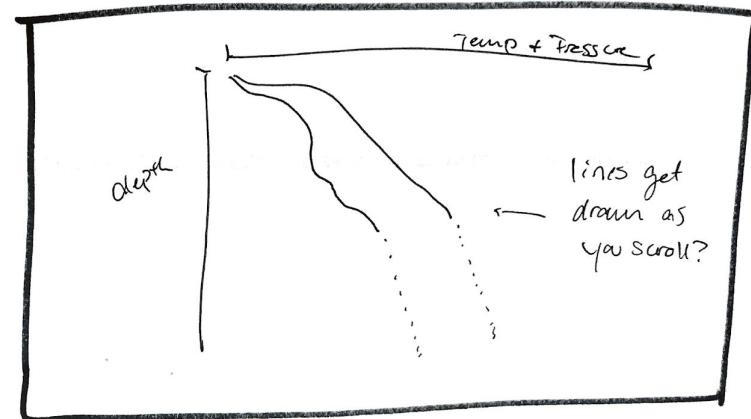
What if instead of just giving a *sense* of increasing pressure, I actually showed the data?

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.

How to Show Temp + Pressure:

lines that
get drawn
as you
scroll?



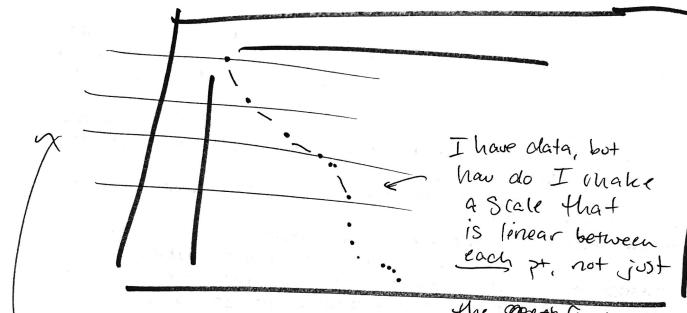
Sketches

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...

Interpolating Scales



do I need to make layers, and then use a different scale based on what layer "current Depth" is in?
That's a ton of if.. else statements

or can I use d3.interpolate?

Citations

Brainstorming

Fictional narrative: <https://geologyportfolioxz.weebly.com/>

Some diagrams: <http://herculeajonesdiv1.weebly.com/earths-4-layers.html>

<http://www.geologvin.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/12_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.