Magna Earthquake Process Book

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Basic Info

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- Project Repository - https://github.com/armstrong06/dataviscourse-pr-MagnaEarthquakeSequence

Overview and Motivation

On 18 March 2020, an M5.7 earthquake occurred on the Salt Lake City segment of the Wasatch Fault. This is the largest earthquake to occur in Utah since a M5.0 in 1962 and damage estimates are greater than $150 million (Pang et al., 2020). Within the first hour of this earthquake occurring, ~21,000 individuals had submitted a felt report to the United States Geological Survey (USGS; 2020). As of 18 September 2020, 2,482 earthquakes have been catalogued by the University of Utah Seismograph Stations (UUSS; 2020) as part of the ongoing earthquake sequence relating to the main shock. There have been 6 notable and widely felt aftershocks greater than M4. Though earthquakes pose a significant safety risk to the densely populated Wasatch Front, earthquakes are a relatively foreign phenomenon to many of the individuals living here. Lack of information regarding earthquakes and circulated misinformation likely increased fear surrounding the Magna earthquake and its aftershocks. In our project, we would like to highlight important information specifically from the Magna earthquake sequence. In addition, we would also like to use the data to educate on earthquake properties and dispel some myths and misinformation surrounding earthquakes in general.

This project is mainly motivated by Alysha's involvement with the UUSS. Alysha has a degree in geophysics and currently a masters student with the UUSS. Guy and Andrew just think that the project and earthquakes are cool and would like to learn more over the course of completing the project.

References:

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Related Work:

We took inspiration from the USGS mainshock summary visualizations (https://earthquake.usgs.gov/earthquakes/eventpage/uu60363602/executive), the UUSS's interactive Recent Earthquake Map (https://quake.utah.edu/earthquake-center/quake-map) and aftershock map (https://quake.utah.edu/monitoring-research/2020-magna-earthquake-sequence), papers such as Pang et al., 2020, typical visualization formats for seismological data, the scatter plots in homework 4, and the interactive chart and table in homework 6.

Guiding principles:

Primary questions:

- What was the sequence of events in the Magna earthquake?
- Which earthquakes and aftershocks were part of this earthquake?
- What can someone expect during/after an earthquake?
- Where did these earthquakes occur (regional setting and historic overview)?
- How did the sequence evolve with respect to space and time?
- What are the aftershocks, how many occurred, and what are their depths?

Learn & Accomplish:

- Learn more about the details of an earthquake
    - Most people just think of an earthquake as a single massive event, with possible aftershocks, but there is a lot going on beneath the surface.
- Explain details of earthquakes:
    - Focal mechanisms, aftershocks, main shocks, magnitudes, magnitude and time relationships, focal mechanism and types of faulting, what size is physically possible for the region, Wasatch Fault and recurrence intervals
    - Visualization of what different magnitudes would look like:
        - Energy of earthquakes.
- Make an interactive visualization of the earthquake data.
    - Intuitive interactivity of the visualization
    - Some storytelling that highlights key/interesting events and data points.

Benefits

- Learn about earthquakes
- Provide accessible, detailed information about the Magna earthquake

Data

The data for each earthquake was downloaded from the United States Geological Survey (USGS) using their earthquake search tool (https://earthquake.usgs.gov/earthquakes/search/). The parameters for the search were latitude: 40.66667—40.86667, longitude: -112.2833—-111.8833, dates: 2020-03-18 00:00:00—2020:11:04 23:59:59, and minimum magnitude: -4. The main information coming from this source is earthquake latitude, longitude, depth, date, time, and magnitude and will be used in most of the visualizations. To create the cross-section, the earthquake latitude, longitude, and depth was projected onto a visually selected cross-section line between the coordinate points (40.725, -112.221) and (40.789, -111.850). The projection was done using the Generic Mapping Tool's pscoupe function (https://www.soest.hawaii.edu/gmt/). The output files from this function were manipulated to create a file with the main earthquake information and the x and y coordinates for the cross-section corresponding to distances along the cross-section line and depth. Felt report data for the mainshock called "DYFI Geospatial Data, Zip and city aggregated" was downloaded from the USGS (https://earthquake.usgs.gov/earthquakes/eventpage/uu60363602/dyfi/intensity). This data includes the number of felt reports by zip code and the intensity estimated from the felt reports. Felt reports are filtered to include only those from within Utah. The station data from the time of the mainshock was downloaded from the USGS (https://earthquake.usgs.gov/earthquakes/eventpage/uu60363602/shakemap/intensity). This data includes station names, networks, location, peak ground acceleration, peak ground velocity, and calculated intensity. The stations were filtered to only include stations maintained by the UUSS and within Utah. Quaternary fault data for Utah was downloaded from the Utah Geological Survey (https://geology.utah.gov/apps/qfaults/) as a kmz file and was converted to a geoJson file using https://mygeodata.cloud/converter/kmz-to-json.

Exploratory Data Analysis

We initially looked at a map of Utah with the different datasets plotted on it to explore the datasets. After getting the map of Utah to work, the earthquake sequence was plotted with lakes in Utah to ensure the placement of the earthquakes was correct with respect to the Great Salt Lake. Then, all the faults in Utah were plotted (Figure 1). There are quite a lot of faults, so we filtered the faults to only include the Wasatch Fault zone and the West Valley Fault zones. Next, we began exploring the data for the seismometers that recorded the mainshock (Figure 2). The data file we had include stations not maintained by the UUSS and some that were not in Utah, so we excluded these. Station coverage is very dense, especially in the Salt Lake Valley. So, we explored ways of filtering down the number of stations. This included looking at only using broadband or strong motion seismometers. However, most of the stations in the dataset are strong motion and this does not seem like the best way to reduce the data without reducing it too much. So, we have decided to keep all of the seismometers.

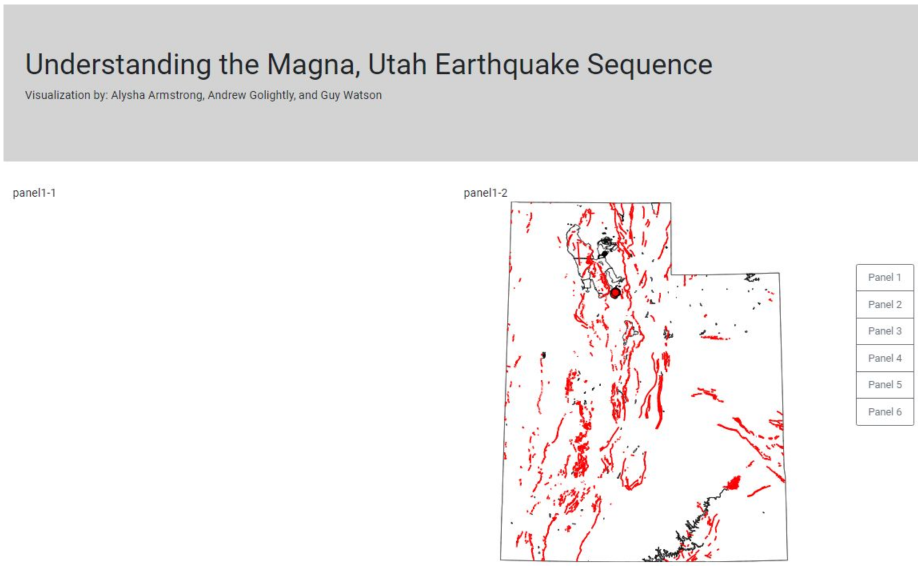


Figure 1. Map of Utah with all the faults plotted

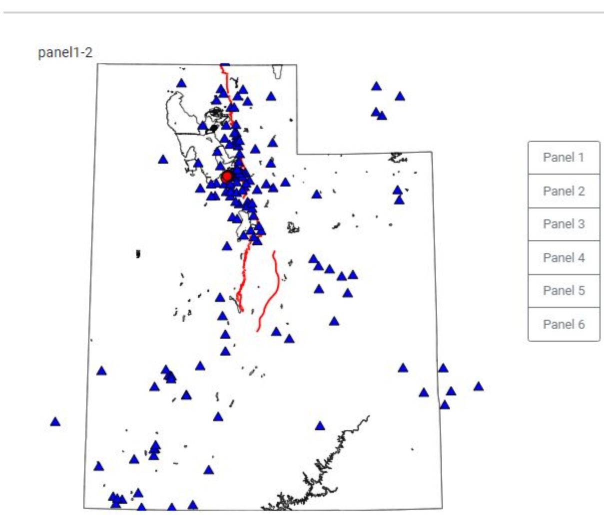


Figure 2. Map of Utah with only the Wasatch and West Valley faults and all seismometers from our dataset.

Design Evolution

Proposed Design

At the end of this document we have included all the steps we took to create the final design of the visualisation. These steps roughly follow the five design sheet methodology. It starts with the results of our brainstorming session, flows through three rough drafts, and finishes with a rough sketch of our final design.

Explanation of Final Proposed Design

We chose a design suited to a story-telling experience, where the user is presented with a long webpage that they scroll through, and in doing so, discover more about the topic presented. We will present various visualizations of different aspects of the Magna earthquake, starting with ones that show a broad overview, and diving deeper into more specific topics as the user scrolls deeper into the page. These visualizations will be accompanied by educational explanations. Our hope is to demystify earthquakes and their mechanisms, and to have a visitor leave with a deeper appreciation of the data collected from seismology stations that make analysis like this possible.

Features

Must-have Features

- Map - to show data
- Scrolling story-telling - visualization format
- Educational information - central purpose
- Linked views - enhances interactivity and brings the data to life

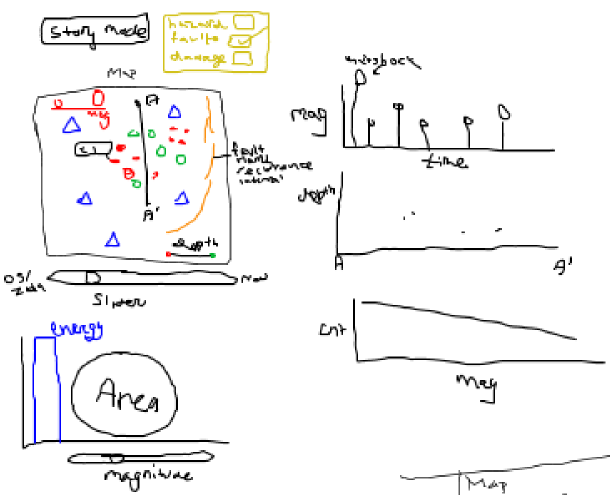
- Time, magnitude, and frequency relationships

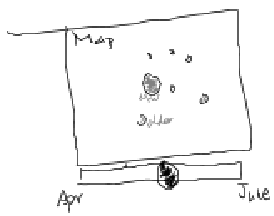
Optional Features

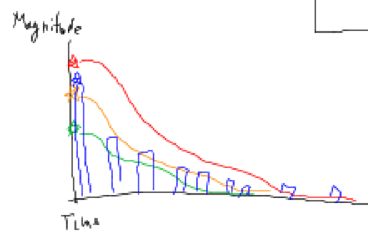
- View at the end with full interactivity
  - This is very high up, but not having this wouldn't cause the visualization to be worthless.
- Interactive educational 'widgets'
- Having nice animations / transitions on scroll
  - This would make it look better, but it's not critical
- Navigation - in other notable "scrolly-telling" visualisations we have viewed as part of this class, dots are arranged on the side which correspond to pages. The inclusion of this feature would be nice, but it's an entirely aesthetic improvement and doesn't affect the actual visualisation component. The efficacy of this addition is also dependent on our ability to add good transitions on scroll.

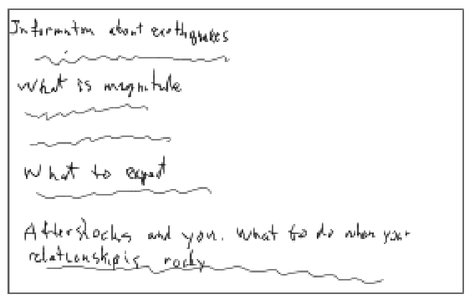
Project Schedule

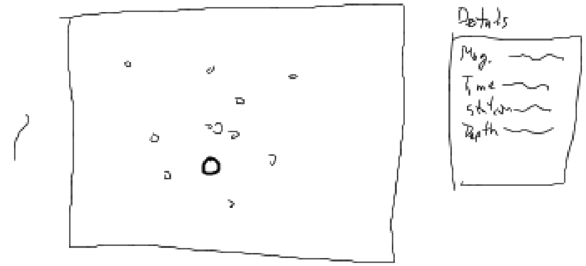
Week of:	**Milestone to be achieved**
Nov. 1	Data processing/import. Build the structure of the website
Nov. 8	Educational content and important views.
Nov. 15	Build out views
Nov. 22	Interactivity and optional goals.
Nov. 29	Polish. Presentation prep

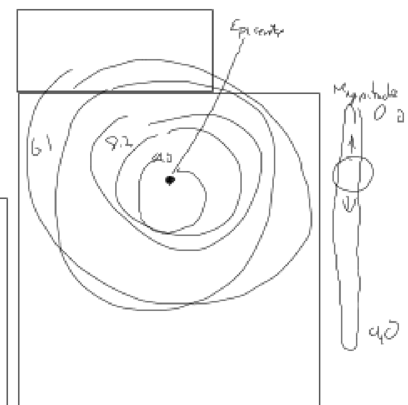


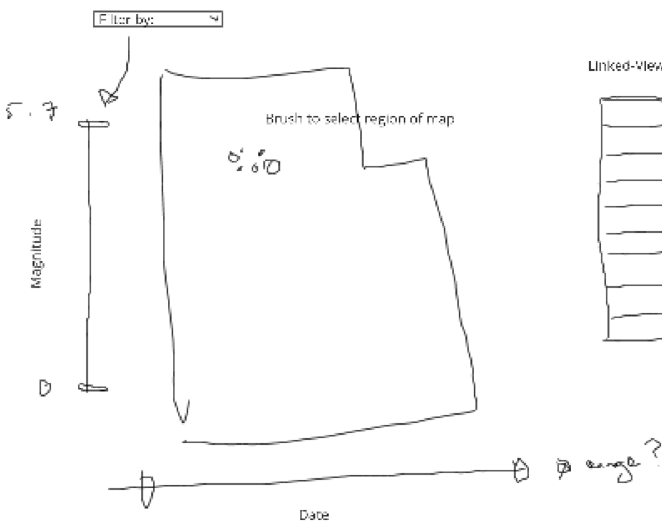




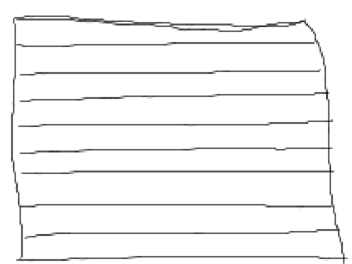




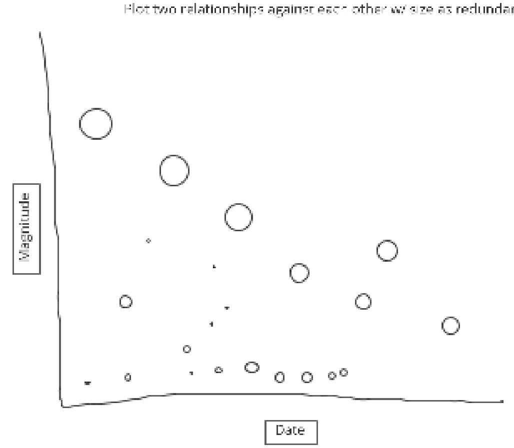


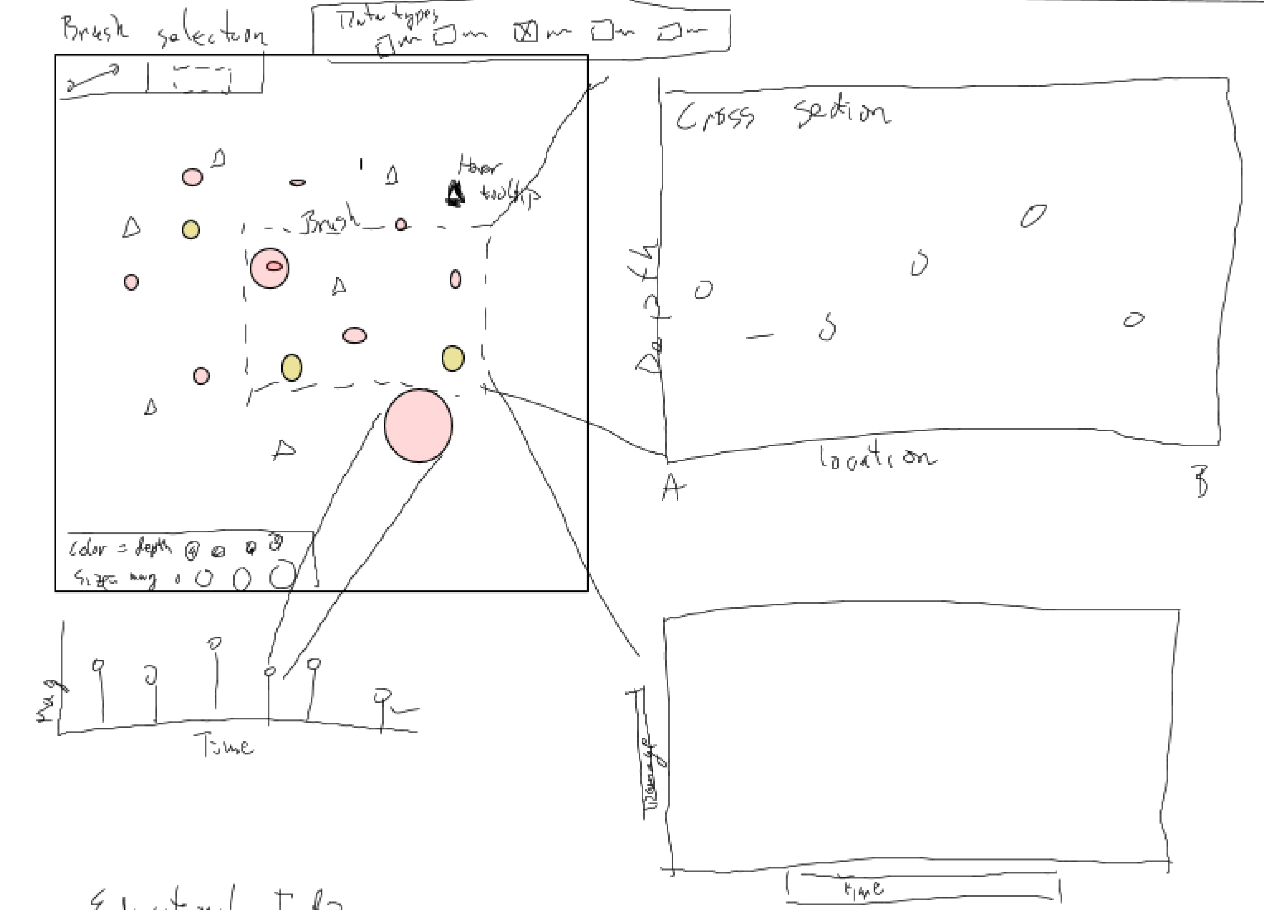


Linked-View Table w/ Details About Each Selected



Plot two relationships against each other w/ size as redundant encoding





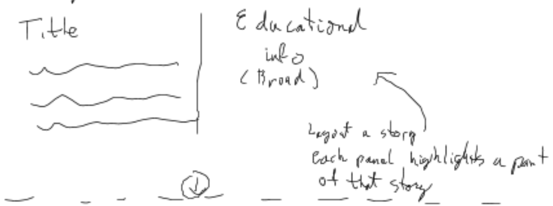
Educational Info

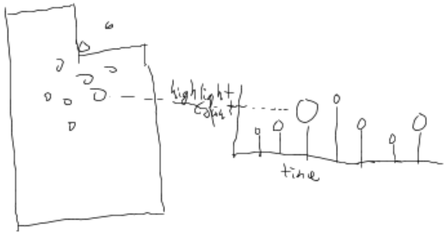
Discussion

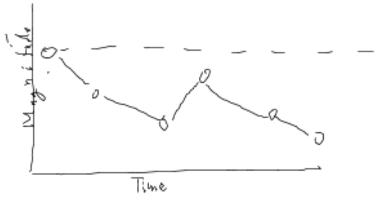
- \+ Lot of info
  - \+ Lot of drilling / views
- \+ Central map
  everything relates back
- \+ Lots of interactivity

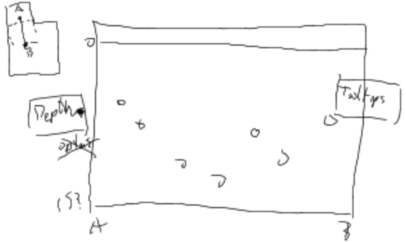
- − Data overload
  - • Different views
  - • rerepresent map w/ different interactivity
  - • Scrolly telling
    - • more education

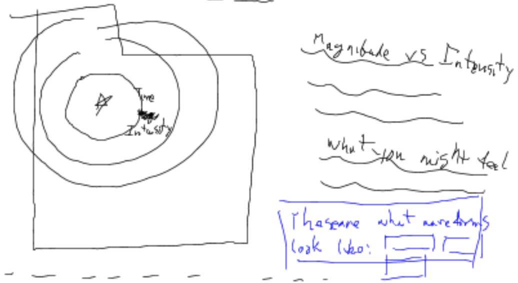
Scrolly-telling











Discussion

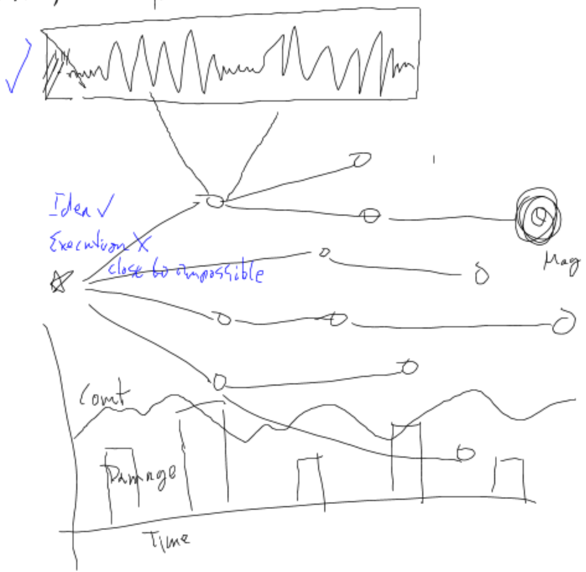
+ Breaking it up is more manageable
+ Story gives purpose
+ Guides the user
  + Prepares for and vis w/ all options
+ Much less cluttered

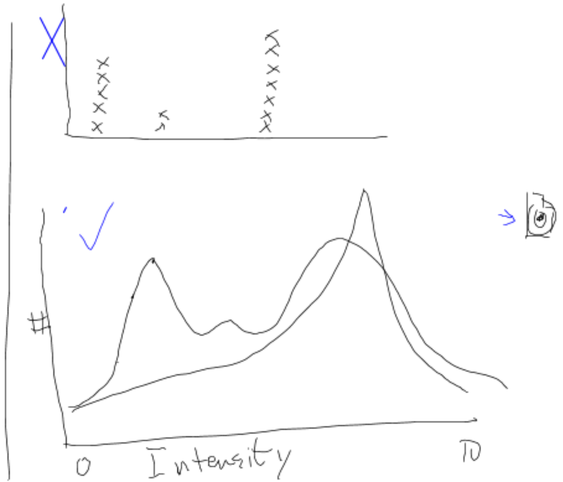
- Less drilling
- More limited in views
- A lot of panels

+/- Less technical

- Highlight some important technical aspect
- Draw on scientific visualizations
- Pretty: eye grabbing

Dropping the map





X or ✓

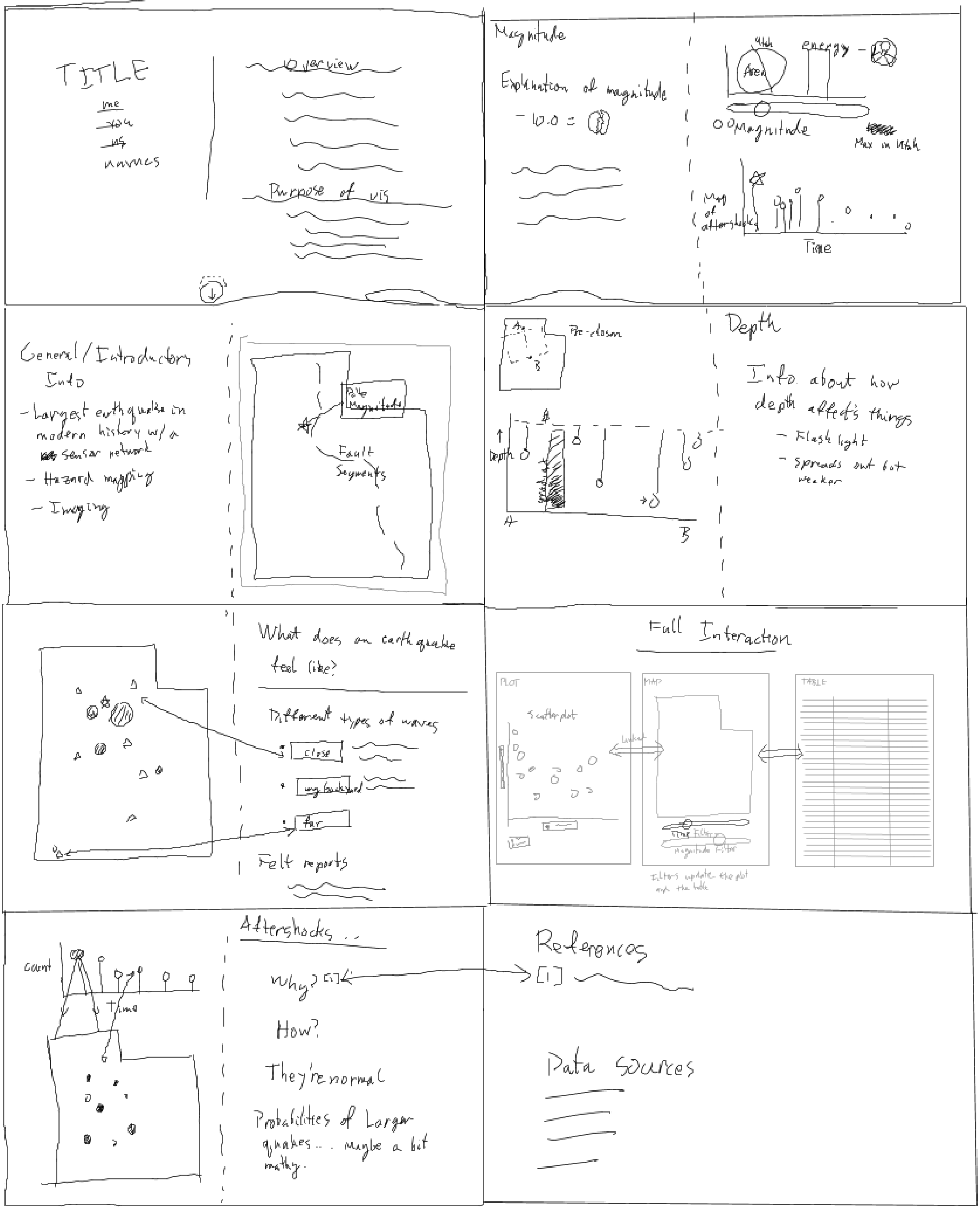
+ Different Interprets data w/out map
+ Parent/child is super cool
+ Waveform = cool factor

- Data is very tied to geospatial data
= Basically a paper's north of data analysis

- Very hard to do
- Unintuitive
  - No context
- Not cohesive & No central vis
- Messy: whole dataset is laaarge

FINAL DESIGN

Majority of scrolly-telling design



Building the Website

Initially, we had all the data plotted together, however to keep the maps from getting too cluttered, we did not put the faults and seismometers on the same map (Figure 3). Because the earthquake sequence is quite local with respect to the map of Utah, we decided to only plot the main shock as a large star on these maps (Figure 4; Figure 5). To be able to better see the details of the sequence, we created a street map using the Google Maps API and plotted the earthquakes as circles with the magnitude encoded in the radius (Figure 6). This is nice because we can scroll and pan around, but the tool-tip does not seem to be very sensitive in this map and we will have to explore this. So far, our time vs magnitude plot is only a simple scatter plot, but we plan to encode depth in color and to add tool-tips, brush-selection and a time-slider (Figure 7).

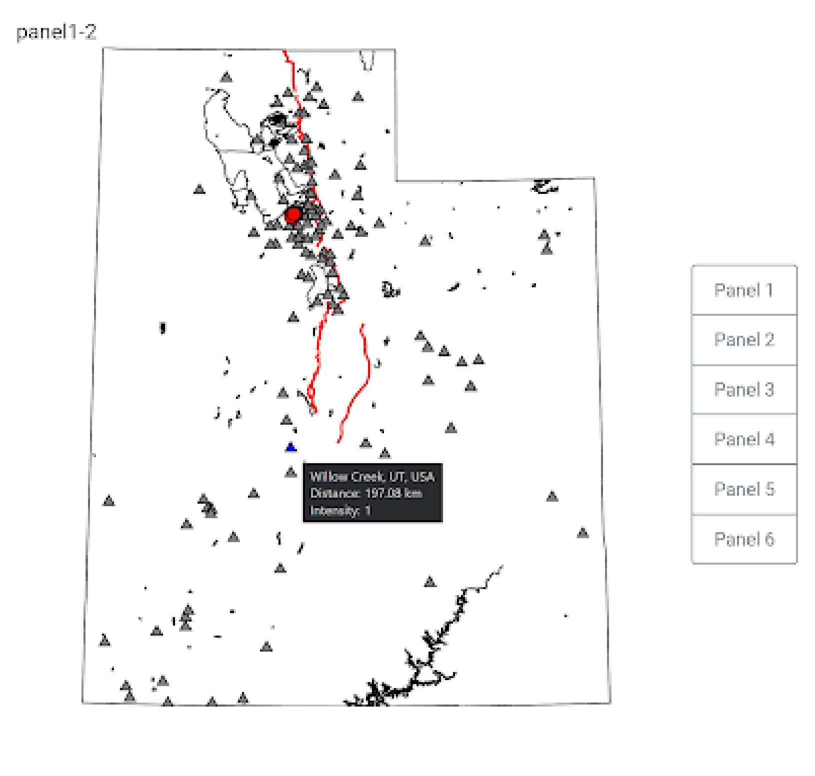


Figure 3. Map of select seismometers and faults with the earthquake sequence. Scrolly-telling navigation buttons clearly shown to the right, though they are not labeled yet.

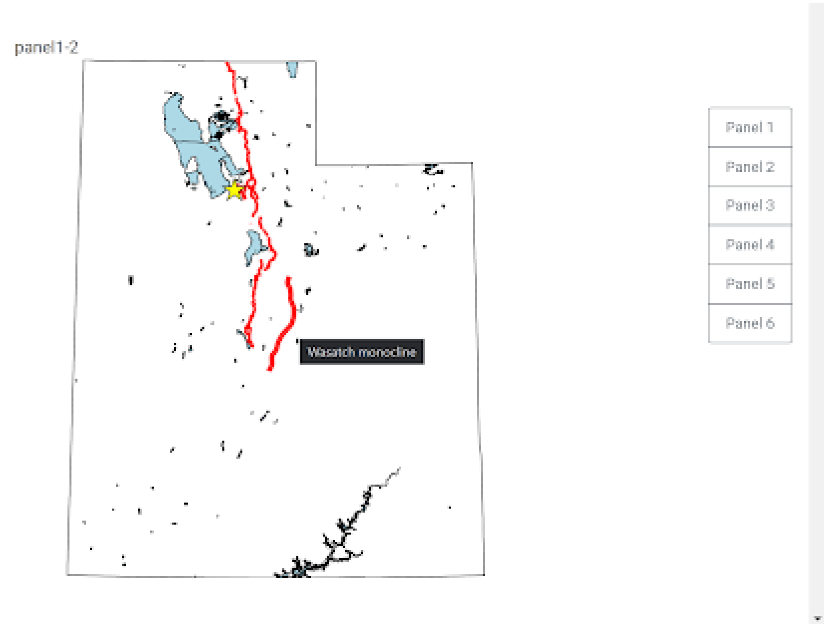


Figure 4. Map of Utah with select faults, Utah lakes, and the mainshock (star). Tool tip for on fault segment shown in the black text box.

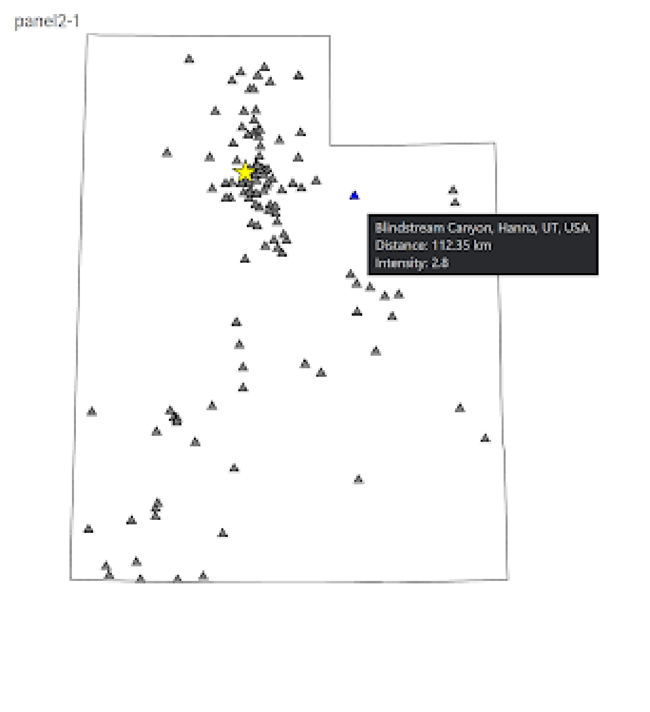


Figure 5. Map of Utah with just seismometers (triangles) and the mainshock (star). Tooltip with information regarding the blue seismometers shown in the black text box.

panel3-2

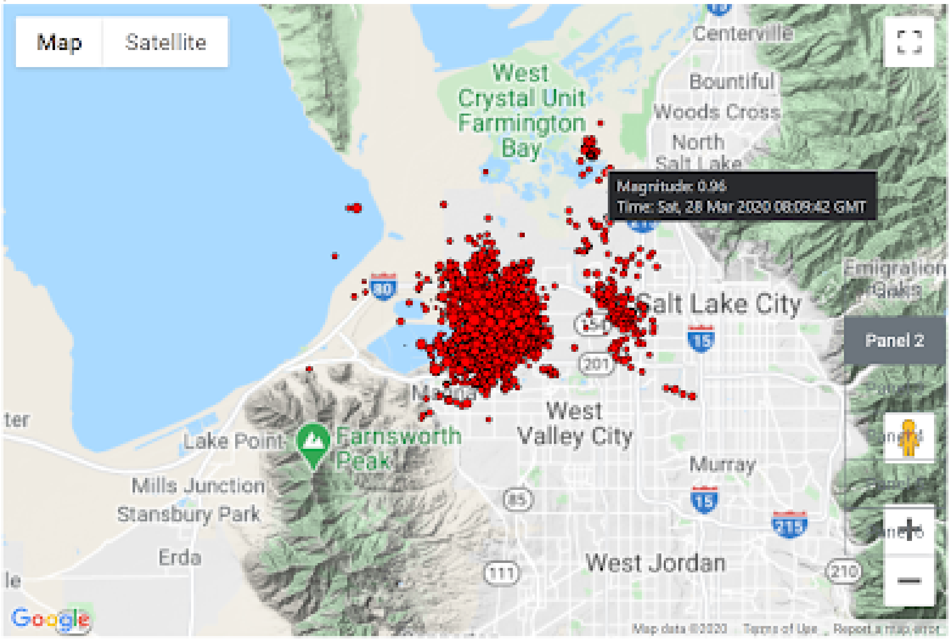


Figure 6. Google API street map view of the aftershock sequence. Tooltip for earthquake magnitude and date shown in the black textbox.

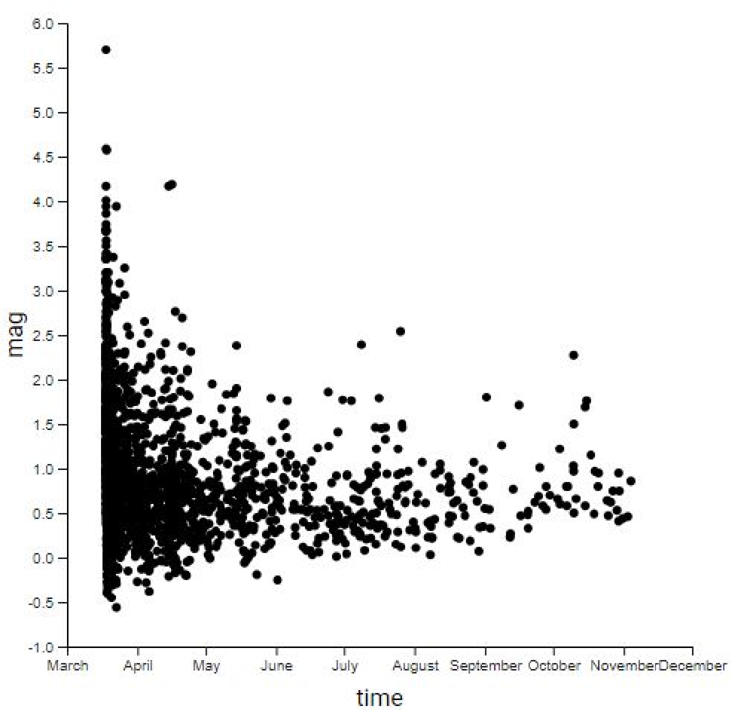


Figure 7. Initial time vs magnitude plot.

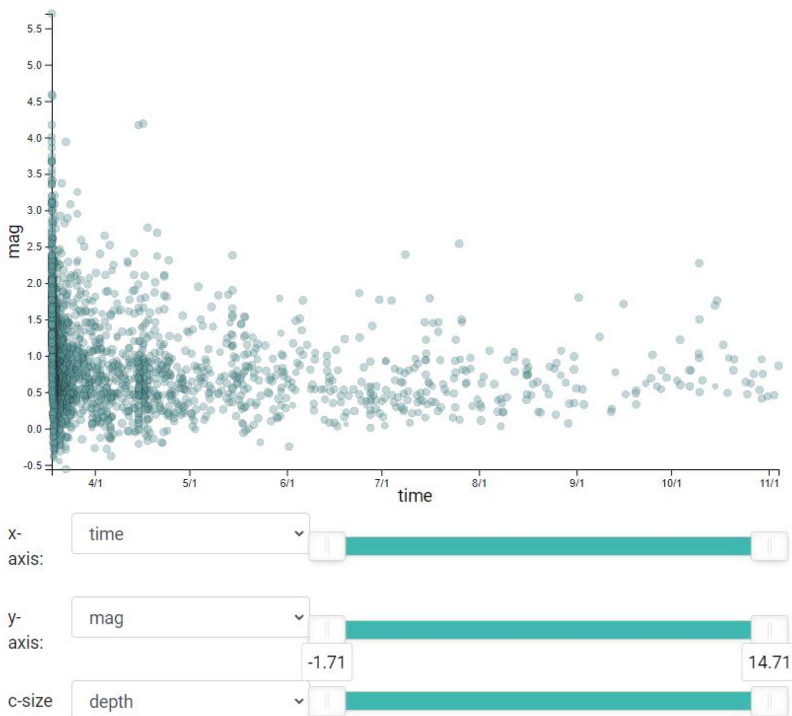


Figure 8. Scatter plot with drop-down axis and circle size features selection and sliders bars to filter the data.

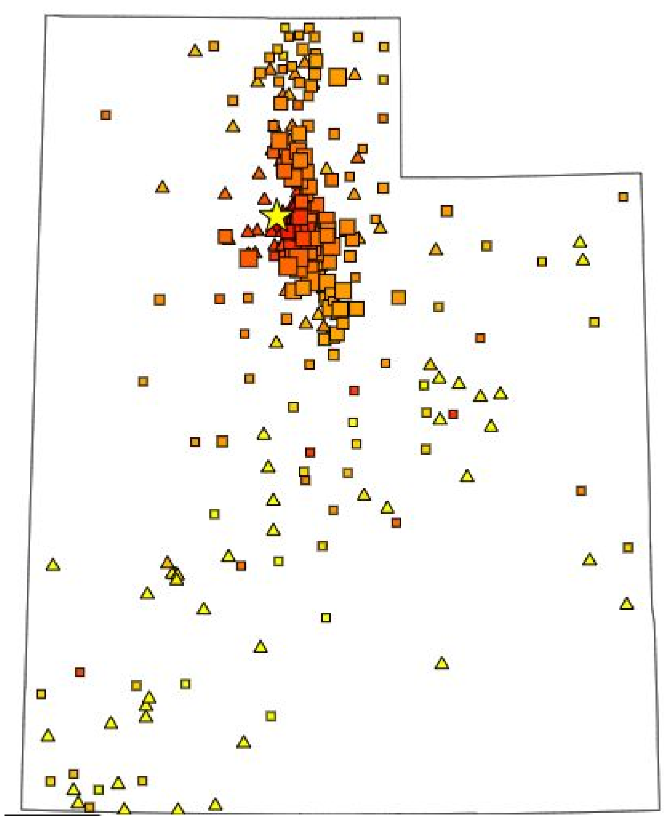


Figure 9. Initial visualisation of the felt reports and seismometers. Squares represent the felt reports (where size encodes number of reports and color encodes intensity) and triangles represent the seismometers (color encodes intensity on same scale).

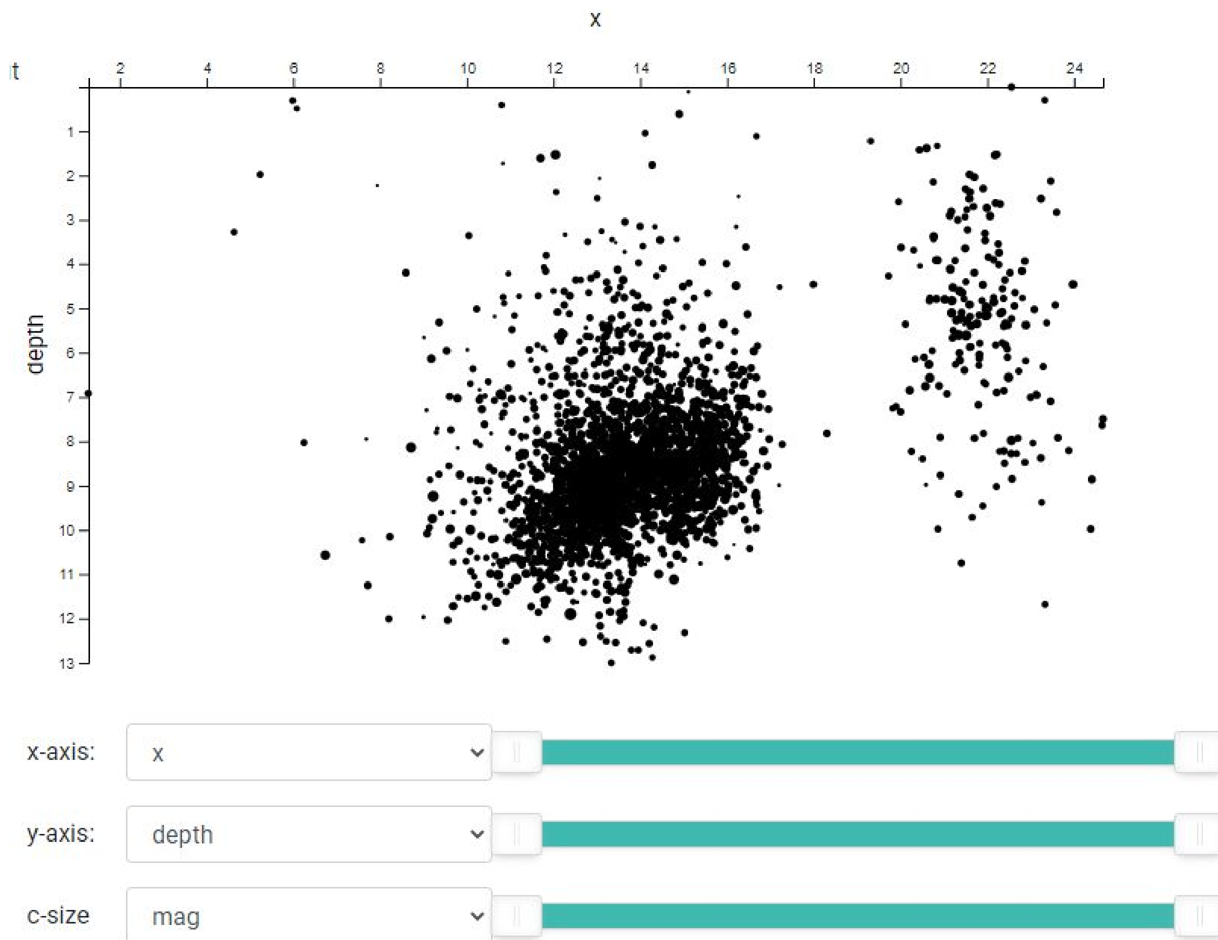


Figure 10: Shows initial implementation of the depth section. Features an inverted y-axis to relate better to the data.

On March 18, 2020 a M5.7 earthquake occurred near Magna, UT [1]

This earthquake occurred in the Wasatch Fault Zone, a west-dipping normal fault system that stretches approximately 350 km from Fayette, UT to Malad City, ID.

A normal fault is formed by extension, which causes the block of earth on top of the fault to slide down relative to the block below. This is why we have mountains to the east of the Wasatch Fault Zone and valleys to the west. Other kinds of faults are strike-slip faults like the San-Andreas in California and thrust faults, which usually occur at subduction zones where one tectonic plate is being pushed under another plate.

The Wasatch Fault Zone is made up of 10 individual faults that are each ~30-60 km long and are called fault segments. The five central fault segments are the most active faults and can produce the largest earthquakes. These are the Brigham City, Weber, Salt Lake City, Provo, and Nephi segments.

A recurrence interval is an estimate of how often large earthquakes occur on a fault and is calculated using paleoseismology, or the study of historic earthquakes. By averaging the amount of time between large earthquakes occurring on a fault segment in the past, estimates of when the next large earthquake may occur can be made. The recurrence interval is ~900-1300 years for the 5 central Wasatch Faults. These are just estimates though and there is no way to predict earthquakes.

Though the Magna earthquake was the largest earthquake occurring in the Wasatch Fault Zone recently, it is considered a moderately sized earthquake. The 5 central segments of the Wasatch Fault Zone can produce earthquakes with magnitudes between 7 and 7.5. In the last 6000 years paleoseismology has determined that there have been at least 22 large earthquakes on the central segments.

Large earthquakes are a major hazard of living near the Wasatch Fault Zone and everyone should be prepared for one.

Figure 11: Shows an initial implementation of the text portion of the website. This uses the natural and familiar paragraph format to display all the information at once.

On March 18, 2020 a M5.7 earthquake occurred near Magna, UT [5]

This earthquake occurred in the Wasatch Fault Zone, a west-dipping normal fault system that stretches approximately 350 km from Fayette, UT to Malad City, ID. [1]

Figure 12: Shows final iteration of the text portion. Uses Bootstrap Carousels to break the information into digestible pieces. It's also a significant aesthetic improvement.

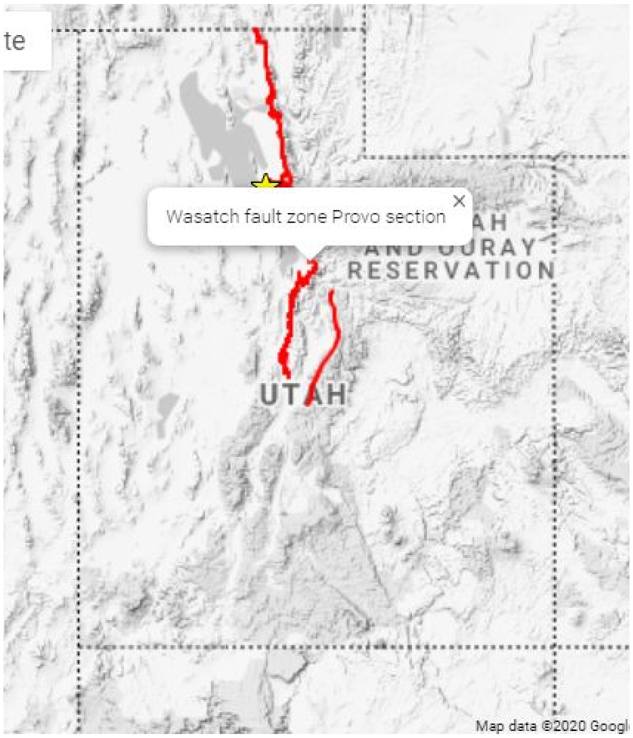


Figure 13: Shows the final design for the introduction section. Like previous designs, shows the fault lines and the main quake and allows users to interact with them to view more information. It uses the Google Maps API unlike the prior iteration.

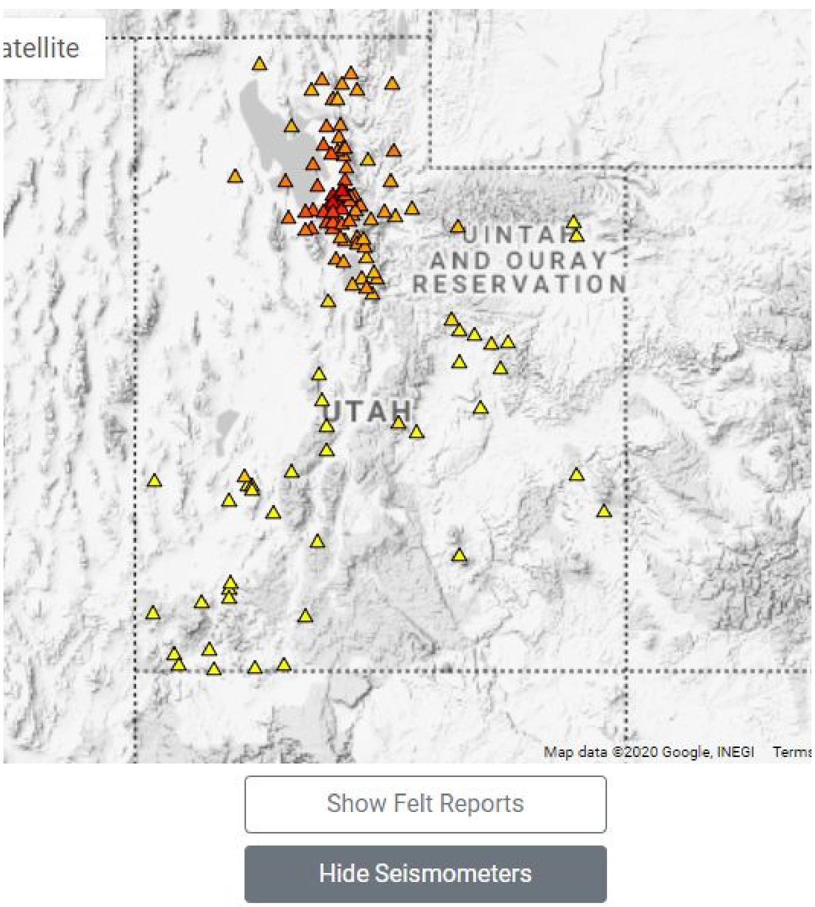


Figure 14: Shows the final design for the intensity section. It was also switched to the Google Maps API. Additionally, it features buttons to show and hide the different measures we use. For both marks the color encodes the intensity they recorded. The rectangle size (felt report) encodes the number of reports received, and these are aggregated by ZIP code. Tooltips with more information appear on hover for both felt reports and seismometers.

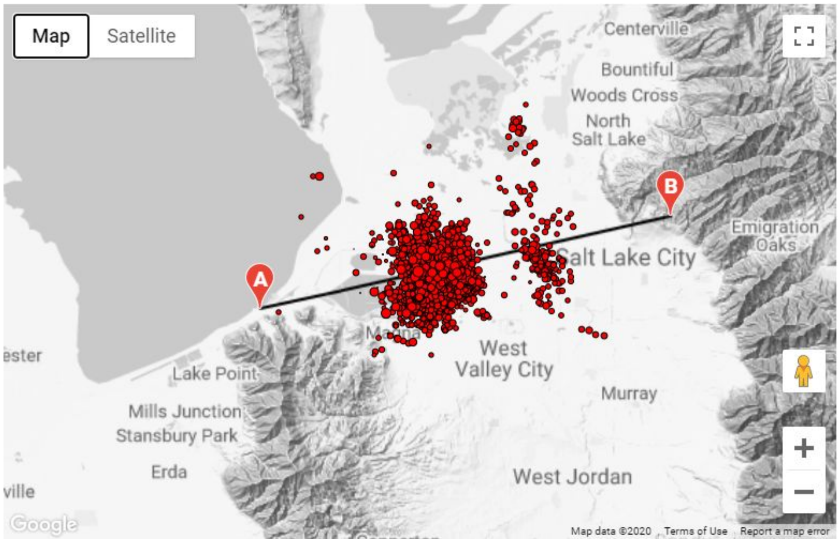


Figure 15: Shows the final design of the aftershock map. Circles represent earthquakes and size encodes the magnitude. This design is largely unchanged from previous iterations, but we include markers indicating where the cross section for the depth map is taken from. Users can gain more information on specific quakes by hovering over circles.

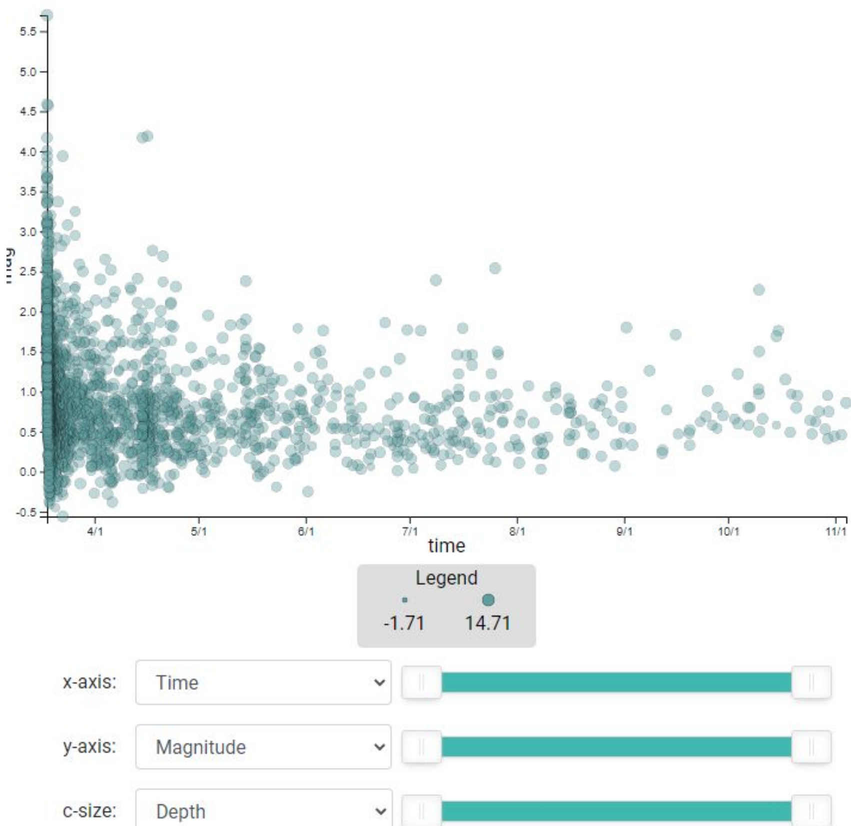


Figure 16: Shows the final scatterplot design for the magnitude section. Users have control over how the data is displayed through dropdowns and sliders which update in response. In contrast to previous designs, this has formatting improvements and includes a legend for circle size. It also adds the ability to hover over points to get additional information.

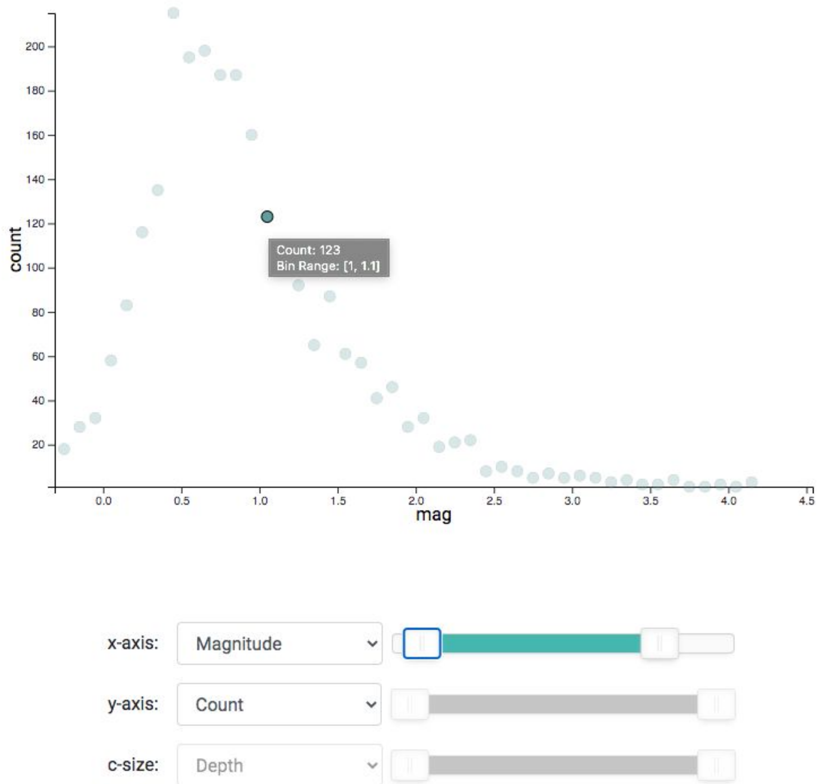


Figure 17: Shows the possibility of changing the dimensions of the axes. In this configuration, the y-axis and the circle size sliders are greyed out, since the data is binned. The tool tip will adapt to the user's choices and display relevant information about the highlighted point

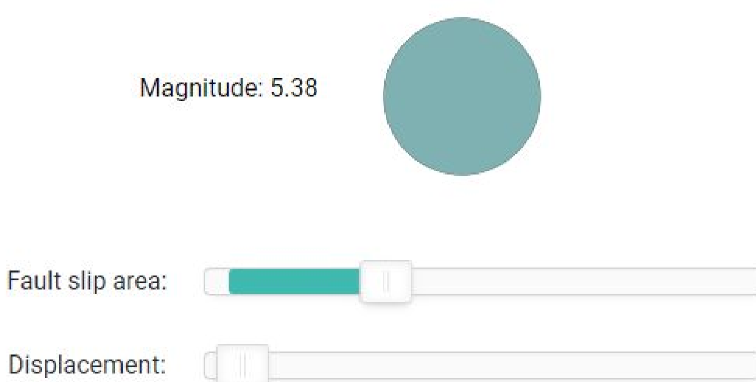


Figure 18: Shows interactive widget showing effect of fault slip and displacement on magnitude.

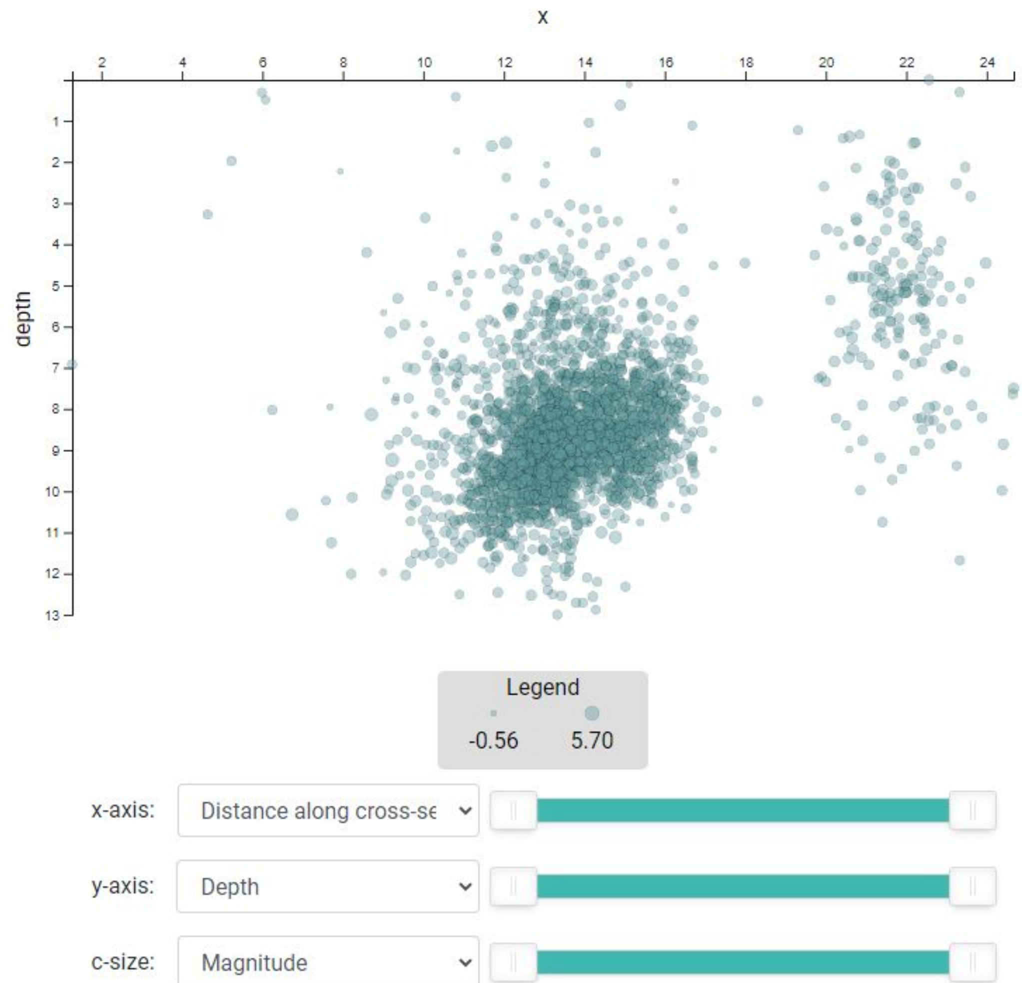


Figure 19: Shows final design of depth scatterplot. Like Fig. 16 there are dropdowns and sliders for the user to customize how the data is presented.

Final Reflection on Website Design

We started out with a strong emphasis towards the story-telling aspect, since we were both worried about data overload as well as a simplistic visualization that was hard to drill down into the data. Having multiple views allowed us to customize each one to support a particular point.

One of the most major changes happened in the meeting with the TA to discuss the progress on the project. Most of the boiler-plate was there and the visualizations were fleshed out, but the TA pointed out that having two different styles of maps -- GeoJson and Google Maps -- was a bit jarring. Since a major advantage of using the Google Maps API is the ability to zoom and move around the map freely, we chose to move all the maps to that format. This ability was almost crucial for the aftershocks map, where the data is so clustered together that without zooming, it blends together. Changing over the fault lines and seismograph maps lets the user more easily examine the data, as well as unify the look of the website.

Having educational text alongside the visualizations was always the goal with the design we chose. The original sketches suggested that linked highlighting between the text and the visualization would provide interaction. As the designs became more fleshed out, the educational text took on more of an explanatory role, educating the reader and drawing attention to features on the visualization. The visualizations changed their interactivity from showing linked sets to giving the user the ability to examine and filter the data as they wish, by manipulating range sliders and changing the data displayed on a particular axis. We can present the user with a sane default, but let them explore the data and discover patterns on their own.

A major departure from the original design was the move away from linked views between the sections. This is something that we thought we wanted to do in our initial design (and it's listed as a "must-have" feature) but after some initial designs it became apparent that linking views between sections would be more confusing than helpful. Additionally, as each section visualizes different portions of the data (i.e. aftershocks vs fault lines vs magnitude), while these pieces could be consolidated it would greatly limit our ability to use the visualisations to inform users about the Magna Earthquake sequence. For these reasons we decided to move away from the linked views (between sections) and add a higher degree of interactivity to the visualisations we created.

One issue we consistently ran into was the quantity of data; the sequence contains over 2,000 aftershocks, and visualizing all of these appropriately was quite the challenge. As previously mentioned, the use of the Google Maps API for Javascript was beneficial as it allows users to zoom in and more closely examine the data displayed on each of the map visualisations. This was difficult to implement but overall a good change from the initial design which mapped the data onto GeoJSON outlines. Another key design decision was the inclusion of dropdowns and sliders on all the scatterplots. The dropdowns allow users to select the indicator used for the x-axis, y-axis, or size of the circle, and the sliders allow users to refine the results. Again, adding these features was nontrivial; however, by adding them we allow users to explore the dataset. In addition, the use of dropdowns and sliders adds some structure to this exploration, and prevents users from getting “lost” in all the data available. As a final way of making the data more accessible, we’ve added the ability for the user to hover over or click on data points to get more information about it.

Implementation:

Of the features we listed as “must-have” features, the only one we are missing is the linked views. As previously mentioned, linking views between the sections proved detrimental to our overall goal of informing users about earthquakes and the Magna Earthquake Sequence specifically, so we opted to move away from that. However, we have included a wide variety of interactable and useful maps which assist in our overall goal of informing the user. Additionally, we have shown the time, magnitude, and frequency relationships through several scatter plots that are almost fully interactable and customizable by the user. We have packaged the maps and scatter plots in a “scrolly-telling” format, where each section has text that is informative and closely tied to the data.

The first section (Fig. 12 & 13) shows the main quake and a selection of the fault lines in Utah. This demonstrates how the earthquake event was tied to the existence of fault lines in Utah; additionally, the text provides a wealth of auxiliary information which supports the visualisation well.

The second section (Fig. 14) discusses and examines intensity in relation to earthquake. It shows how (as one would reasonably expect) the felt intensity of earthquakes is directly related to the distance of the person or seismometer to the epicenter of the earthquake. It reinforces this seemingly common idea with qualitative data from people (felt reports) and quantitative data (seismometers). The text for this section again reinforces the visualisation and explains the meaning and measurements for magnitude.

The third section (Fig. 15) talks about aftershocks; for people who haven’t experienced an earthquake before, aftershocks are equally scary and in many ways more so because they are random and reincite any potential trauma from the main quake. The visualisation here shows all of the earthquake events; users have the ability to zoom in to view specific regions of the map or hover over individual circles to view more information about that specific earthquake. The map also includes markers which show where the cross section for Fig. 19 comes from.

The fourth section (Fig. 16) allows users to explore the relationships between magnitude, time, and depth. Additionally, users can use the scatter plot to view relationships between location and time, although this feature is less useful and a secondary function to the aforementioned relationships. By playing with the sliders and dropdowns, users can customize how much and what data is shown (Fig. 17). As with previous sections, the text is equally important and serves to explain what magnitude means, as well as give a brief description of the scatterplot. We were also able to include a small widget (Fig. 18) which allows users to explore the relationship between fault-slip area, displacement, and magnitude.

The fifth and final section (Fig 19) shows users how depth affects felt intensity. This is explained clearly in the text, and as with the previous section (Fig. 16) the scatterplot in this section is highly customizable and interactable.

Our implementation of the project meets the initial requirements we set up for ourselves; additionally, we were able to fit in some of the “nice to have features” like the interactive widgets and true “scrolly-telling” style animation via a right side navbar(as opposed to having users only scroll through). The project was intended to educate, and to that end it includes highly informative yet concise text. Additionally, each panel has a visualisation with some degree of interactivity to try and engage users with the data and illustrate the concepts described by the text. For these reasons, it represents a well planned and well implemented visualisation of the Magna, Utah Earthquake Sequence.

Evaluation:

Through our visualization we were able to answer all our primary questions. We give an explanation of the regional and historic setting of the earthquakes through text in our introduction slide and provide context through a map of Utah with the relevant faults and the mainshock locations. We explain the aftershock sequence and what can be expected with aftershocks through text and various views of the aftershock data. We provide the information necessary for users to have a decent understanding of the data they are looking at and what it means, such as magnitude, intensity, and depth. The visualizations, especially the scatter plots, highlight the important information and points that we wanted to make and also allow the user to explore the data and various combinations of the data. Overall, our visualization meets our goals of helping others learn more about earthquakes through accessible and detailed information about the Magna earthquake sequence. We also learned that there are a lot of faults in Utah through our data.

One improvement that could be made would be to add more user interaction. For example, we could allow the user to filter intensity data by intensity and depth. We could also highlight the important features of the data better such as highlighting the various segments of the Wasatch fault and displaying their recurrence intervals and most recent large earthquakes. Features like this could be incorporated into the carousel text panels so that there was more interaction between the text and visualization and the user could engage with both simultaneously. Also, incorporating waveform data for the user to interact with would be neat. However, all of the most important elements have been implemented, and we have a functional, complete presentation.