USGS Earthquake Analysis

PRELIMINARY EXPLORATION OF MEASUREMENTS AND FACTORS OF EARTHQUAKES

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BACKGROUND

Of the world's many kinds of natural disasters, earthquakes are unique. While modern technology can provide early warnings for hurricanes, tornados, tsunami's, & floods, the timing of earthquakes is still unpredictable. Evacuating an area or seeking shelter is not feasible.

Shallow earthquakes generally tend to be more damaging than deeper ones. Seismic waves from deep seismic events must travel farther to the surface, which causes them to lose energy along the way.

While the *timing* of earthquakes is relatively unpredictable, our aim is to explore ways of predicting *where* earthquakes might occur, and the relationships with an earthquake's magnitude.

HYPOTHESIS

We believe that earthquakes are more likely to occur near fault lines and in areas where oil and gas drilling and production occur, especially when fracking activity is the means to increase oil production. Additionally, we believe that earthquakes with higher magnitude levels will be related to the depth of the earthquake.

SOURCE OF DATA

Our initial dataset comes from the US Geological Survey.[i] We downloaded a static .JSON file spanning 30 days (June 25 – July 25). This static file included data on 14,375 earthquakes.

DATA CLEANING AND EXPLORATION

The data we utilized for each earthquake were its location (latitude and longitude), depth, magnitude, time, and type of measurement used.

Other data available include:

- Number of people reporting that they felt an earthquake
- Significance
- Maximum Intensity

We chose not to explore the "Other" data at this time because a detailed analysis was outside the scope of this assignment.

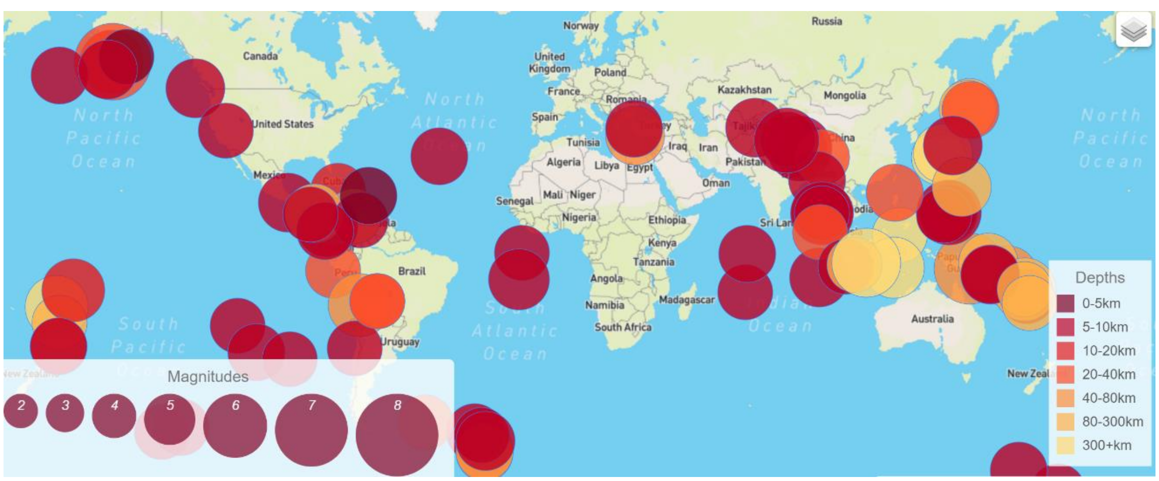
We were inspired by the [USGS Earthquakes Dashboard](). This dashboard contained Tectonic Plate map with dots indicating recent seismic activity. The bottom had a bar graph indicating how many earthquakes occurred in each of the last seven days. The right margin contained the Total Count and a column summarizing the description of recent events with a geographic location, magnitude, depth, date and time. The legend indicated how great the magnitude was, how long ago the event occurred, and stated the lines on the map signified the tectonic plates.

The data chosen for the study was first plotted on a map to show the geographic relationship with frequency, magnitude, and depth. This was done with JavaScript and the leaflet library. JavaScript and D3 were then used to plot the frequency of magnitudes, the relationship between magnitude and depth, and the frequency of each method of measuring magnitude.

ANALYSIS

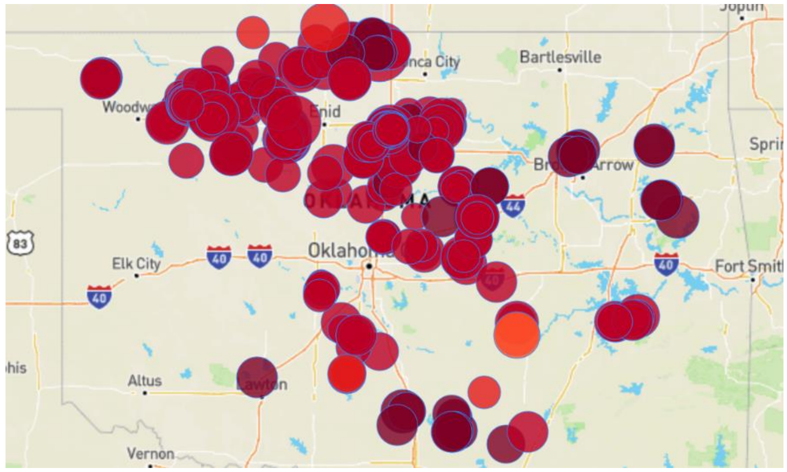
EARTHQUAKE LOCATION BY MAGNITUDE AND DEPTH

Our first visualization explores the relationships between location, and earthquake frequency, magnitude, and depth. The bottom left legend indicates that the radius of the circle correlates to the Magnitude of the seismic event, whereas the legend on the bottom right shows that depth at which the earthquake occurred. As we mentioned in the background, shallow earthquakes tend to be more damaging (Dark Red) but deeper ones (Light Yellow) tend to be felt further away.



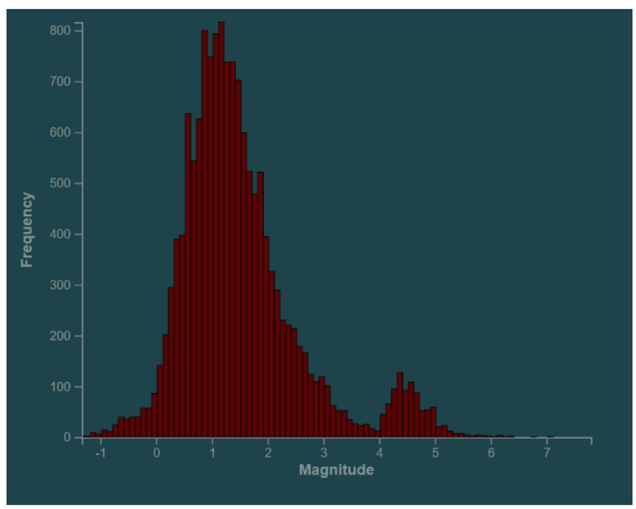
Before filtering out magnitude, there is a large difference in the number of earthquakes reported in each region. Of the total 14,375 earthquakes recorded in this time period, ~96.2% were recorded inside the US and its territories, or along its borders and coasts. Of the 95 earthquakes greater than 5 on the Richter scale, this share drops to ~25.2%. This suggests that this data is only collected from American stations.

When looking at the locations of each earthquake on this map, one can see that earthquakes typically occur near the fault lines of the tectonic plates. While this was already assumed, we also wanted to explore the relationship between oil and gas fracking and earthquakes.



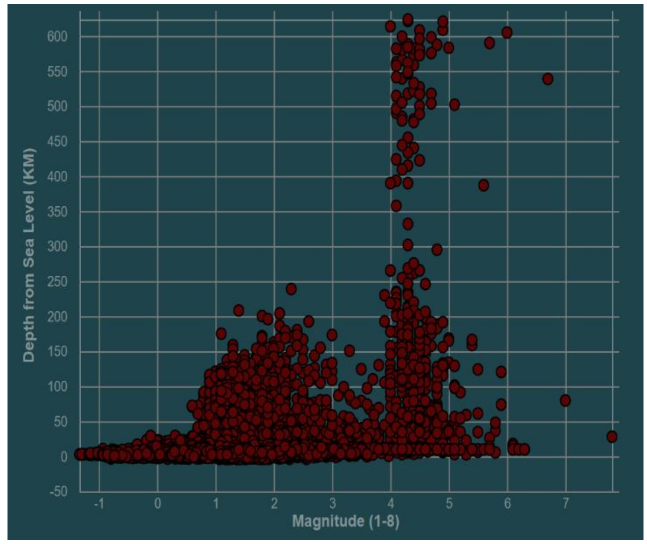
Despite not being located near a major fault line. Oklahoma has numerous reported earthquakes. However, North Dakota reported no earthquakes and West Texas has far fewer reported earthquakes. If the frequency of earthquakes were cause by oil and gas extraction one would expect to see a similar frequency in all three states where fracking takes place.

FREQUENCY OF MAGNITUDES



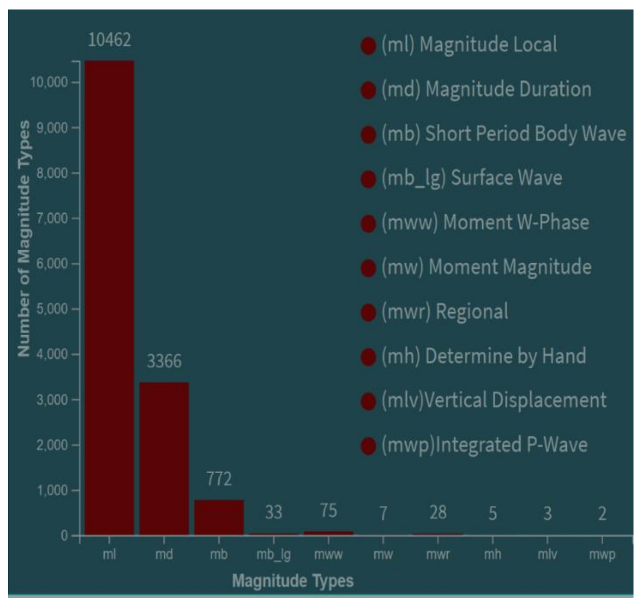
When plotting a histogram, magnitudes have an interesting distribution. Magnitude appears to be bimodal, with peaks close to 1 and 4.5 on the Richter scale. It should be noted that the Richter scale is already logarithmic, so a linear measurement would have a much different distribution.

DEPTH VS MAGNITUDE



Exploring the relationship between depth and magnitude, there appears to be an increase of depth for earthquake magnitudes between 1-3. Curiously, there appears to be a sudden increase of intermediate (70-300KM) and deep (300KM+) earthquakes with a magnitude between 4-5.

METHODS OF MEASUREMENT



Magnitude is measured by the maximum motion recorded by a seismograph. This can be done using a variety of instruments with different scales. Our analysis shows that the most common scales used are:

- Magnitude Local (ML)
- Magnitude Duration (MD)
- Magnitude Body-Wave (MB)

ML, aka the Richter Scale, is a measurement of the maximum amplitude of the ground shaking. MD measures the total duration of waves. MB, measures the first few seconds of P-Waves, aka compressional waves, this is the first signal from an earthquake.

CONCLUSIONS & LIMITATIONS

Being able to mitigate damages and lives lost from earthquakes requires an ability to predict their location, frequency, and magnitudes. Our analysis shows that the fault lines of the tectonic plates are good predictors of earthquakes. This does not explain the large cluster of quakes in Oklahoma. While this is an area with a lot of oil and gas extraction activity, a similar number of quakes comparable in Texas and North Dakota was not recorded.

When looking at the distribution of magnitudes, and plotting magnitude vs depth, there is a sudden increase of earthquakes between 4-5 on the Richter Scale. These earthquakes also have a wider range of depths. One possible explanation for this is the distance from which an earthquake was measured. Our map suggests that most recording stations in the dataset are within US borders. As such, smaller earthquakes that are further from the US, or at greater depths could be under reported.

FUTURE ANALYSIS

Because of the limitations of this study, future work should limit the data to earthquakes located in and near the US. An over representation of low magnitude earthquakes in the US could explain the bi-modal distribution.

While Oklahoma appears to be the only major energy producing region with a large cluster of earthquakes, this does not exclude a relationship between oil & gas extraction, and earthquakes. Because fossil fuel production has been down during the pandemic, this may have reduced the frequency of earthquakes in nearby regions. An in-depth study of the historical records of earthquakes to compare this data to the historical oil & gas extraction records may help to determine a connection between fracking and earthquakes.

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[i] *USGS Earthquake Hazards Program*, U.S. Geological Survey, 25 July 2020, earthquake.usgs.gov/.