The Link between Fracking Operations and Localized Earthquakes

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Abstract

This paper aims to answer the question of whether there is a measurable relationship between fracking and earthquakes. Does fracking for natural gas cause earthquakes in the region of operation? Some investigative journalism suggests there is a link, so the hypothesis of this paper is that there will be a link between fracking and earthquakes. Little research has been completed on the link between natural gas fracking operations and shallow, regional earthquakes. Given the data, there is a likely cause-effect relationship between fracking and earthquakes. Without more detailed data, the exact relationship between fracking operations and earthquakes is unknown because there are too many unaccountable variables. The data suggests there is an independent variable causing a change from typical earthquake patterns. With the data available, it is impossible to specify what aspects of the fracking operations are affecting earthquakes and how.

Introduction

Hydraulic fracturing (or “fracking”) is a natural gas extraction method that involves drilling a well into a sedimentary rock layer that contains natural gas. In order to release the gas up through the well for containment, the rock layer has to be cracked, dso there is space for the gas to escape out the well.d. Once the well is drilled, massive amounts of water (called fracking fluid) is pumped into the ground at extremely high pressures. The water forces open propagating cracks in the rock layer containing natural gas. Grains of sand are included in the fracking fluid, and when the water drains away the sand remains and keeps the cracks propped open. The process is effective, but severely weakens the sedimentary layers and has issues with waste production in the form of fracking fluid.

The relationship between earthquakes and fracking is a topic surrounded in controversy. Most of the information available online is investigative journalism pieces, and discussions of wastewater management in fracking operations. There is almost no academic literature regarding whether fracking can directly cause earthquakes. One particular article suggests the repression of such scientific research due to the political power of natural gas extraction companies. For example, of 15 reports commissioned by the Ministry of Economic Affairs in the Netherlands, only 1 was published (Voort and Vanclay, 2014). Research into the Oklahoma earthquakes mentioned below has not been published out of concern for the researcher’s academic tenure (Behar, 2013). Another reason for the lack of information about the relationship between earthquakes and fracking is the nature of fracking data. There is limited information available to the public, and most are press releases and financial claims for the benefit of stock holders and potential investors. No data on the precise location, scale or fracking depth is available to the public. Further, since location coordinates are confidential, it has not been possible for scientists to gather data at sites before operations begin so there is no way of measuring potential changes that arise from the fracking.

According to secondary sources, a growing body of science suggests a causal relationship between fracking and earthquakes (Booher, 2015). The province of Groningen, The Netherlands, has published the conclusion that around 1000 minor earthquakes in the region have been the result of gas extraction (Voort and Vanclay, 2014). Most of these earthquakes were less than a 3 on the Richter scale, and not strong enough to be felt by humans. The scale and frequency of earthquakes have been increasing over time however, and in 2012, a 3.6 scale earthquake hit the region. It was the largest earthquake ever experienced in the area. A report published in 2013 warned there was a 7% chance of a 4.0 to 5.0 scale earthquake (Voort and Vanclay, 2014). Illustrating my point is the story of an Oklahoma earthquake in 2011. It is possible that a dead fault, one considered to be at no risk of earthquake inducing movement, was reactivated by water injections due to fracking. (Behar, 2013).

The two oil and natural gas extraction companies I was able to confirm operating in the region are Progress Energy Ltd and Canbriam Energy Inc. Progress Energy’s gross annual production of natural gas and the BC annual production of natural gas are both available through publicly released claims until the year 2012, when they privatized. It is confirmed in one press release in 2004 there was “successful drilling in the foothills and Fort St. John plains areas of British Columbia”. Canbriam Energy provides a map on their website of their area of operation for oil and natural gas extraction (appendix). Therefore we can confirm that they too have drilling operations in the same region as Progress Energy.

My research will examine the link between fracking and earthquakes by analyzing earthquake data from a region known to have fracking operations. Data from the area will be plotted on a map, with the magnitude of each earthquake indicated by marker area. The depths and magnitudes, as well as the total number of earthquakes each year, are plotted on line graphs. The growth of Progress Energy Ltd is overlaid a graph of the total number of earthquakes.

Methods

Data on earthquakes was sourced from Natural Resources Canada. Based on the information I accessed regarding Progress Energy, I chose to use data from incremental, nine-month time spans every two years. There is data from 2004 until 2012. I also sampled a nine-month data collection from the year 1990. This data is prior to the formation of the two large companies in the region, and represent the control of earthquake data pre-fracking.

The fracking data is more indirect than the earthquake data. Through the public information released by the two companies in the region (Progress Energy and Canbriam Energy) I was able to ascertain they do having fracking operations in the region. Canbriam Energy provides a rough idea of their operation locations (see appendix). Progress Energy named the Fort St. John plains as their area of operation. Both these areas fall within a small enough region to provide a map of approximate location. Progress Energy also supplies annual gross daily production and BC daily production averages. The trend for Progress Energy annual production is plotted on a line graph. Overall, the fracking data provides reassurance that there are large-scale fracking operations in the region of my earthquake data collection.

Prior to uploading the data to code, there were some edits made to the original file. The original earthquake data was in a .txt format so I exported it as a .csv format. The data is uploaded using the pandas read\_csv function. A delimitor detector is used prior to uploading the data, to ensure the correct delimiter is being used. This reduces the chance for a formatting error. The fracking data was collected via public claims, so a .csv file had to have the data input by hand.

The data required some munging in order to plot it with matplotlib. There was an issue with data types within the columns; to solve the problem, one column was changed into a date-time column and the other was manipulated through RegEx. The ‘Date’ column was transformed into a date-time column. The ‘Time (UT)’ was deleted because it held no relevance to the scope of my study. The magnitude column and the depth columns were both series with both numerical and string (alphabetic) characters. This caused python to read the series as an object, not as a numeric float. This was solved through the implementation of Regular Expressions. RegEx was used to isolate and dissociate the string values from the series, turn them into their own list, and delete that list.

The index of the dataset is then changed to be a Date-Time value. This is completed by changing the Date column from a float64 dtype to a Date-Time dtype. The Date column is then made to be the dataset index. This is helpful because many of my plots are plotted over time. The Date-Time function allows for easy manipulation of the index. The magnitude and date is graphed using a line graph to represent the range of magnitudes each year. The x-axis shows dates throughout the nine-month period (via the Date-Time index), and the y axis indicates the magnitude of each earthquake. The fracking data is also represented over time. More specifically, the gross daily production of Progress Energy is graphed as a function of time over years.

I chose to represent the location and magnitude of earthquakes in a nine-month period with a bubble plot, overlaid a geographic map of the region. The area of the bubble represents the magnitude of the earthquakes. This plot clearly displays the relative position and magnitude of the earthquakes to one another. The standard deviation of the earthquake magnitudes is 0.624, so the bubble areas are all relatively similar. The x and y limits of the plot are matched with the coordinates of the four corners of the map in the background. This ensures the earthquakes are accurately coordinated on the latitude and longitude axes.

Each plot is saved in the repository in which the code is run. The code can be found at: https://github.com/jsully1/final\_project-1

Results

The maps reveal some changes in the data over time. The earthquake data, when plotted against a geographic location, shows recurrent and high-density regions earthquakes. The clusters are not present in the exact same location each year, but shift around the map. The exception to this is one location South of Dawson Creek that has more earthquakes each year than the surrounding region.

The yearly frequency of earthquakes has increased over time. It is particular interest that the fracking regions see the highest increase in earthquakes. The difference is especially obvious between the years 1990 and 2012.

There was a very slight increase in the typical magnitude of the earthquakes experienced in the region over time. The range in 1990 is \_\_\_ and the range in 2012 is \_\_\_\_. The maximum magnitude is generally one earthquake a year that falls between a 4.0 and a 4.5 on the Richter scale. The one exception to this was in the year 1990, when there was a 5.1 magnitude earthquake.

The earthquakes are all low magnitude (<4 on the Richter scale), and shallow, meaning less than \_\_\_\_\_. When compared to the map provided by Canbriam Energy (appendix), there is a higher degree of earthquake activity within the known area of fracking operations, compared to the surrounding region. The number of regional earthquakes increases dramatically (from 0 to >20) between the years of 1990 and 2012.

There is a slight increase in the depth of earthquakes over time, with shallower earthquakes happening each year. More specifically, there are no earthquakes that occur deeper than 25 km below the ground prior to the year 2008.

Result plots can be found at: https://github.com/jsully1/final\_project-1

Discussion

The most compelling evidence supporting my hypothesis are the maps that show earthquake location and magnitude (appendix). The increase of earthquakes within one specific area suggests an independent variable is affecting earthquake frequency. Given that there are large-scale fracking operations in the region, it is possible the fracking is causing earthquakes. There are some clusters of earthquakes that appear and disappear over the years. If the earthquakes were a result of local tectonics, there would be more consistent earthquakes along local structural weaknesses (such as a fault or plate boundary). Clusters and their seemingly random appearances and disappearances in distinct areas are likely not the result of structural weakness. Based on these facts, I would suggest the clustered earthquakes are a direct result of the fracking operations. There are no other industries operating in the area that could explain the anomalous earthquake clusters. It is possible there is more intricacies to the cause of the earthquakes. It might not be the fracking itself instigating earthquakes, but the wastewater disposal or well drilling that is the direct cause. Without more detailed data on the drilling, fracking, and other operational logistics, it is impossible to pinpoint the exact variable.

Based on the trend of increased magnitude reported in the Netherlands due to local fracking, there should be higher magnitude earthquakes than in 1990. The “Magnitude over Time” plot refutes the hypothesis because it shows no relevant change in the outlier earthquake magnitudes between 1990, 2008 and 2012. The typical earthquake has changed in range, as mentioned in the results. Statistical analysis would be needed to confirm the significance or insignificance of the range increase. The largest earthquake recorded in our dataframe is from the year 1990. The Netherlands case suggested there would be greater disparity between earthquake magnitudes. In terms of our results, we would expect to see more cases of high (>5) magnitude earthquakes in the region. The lack of outliers does not necessarily indicate anything about the cause of earthquakes in the Fort St John region because the structural integrity of the fracking location could be playing a role in increased magnitude extremes in the Netherlands. This does not necessarily mean that there is not a relationship between earthquakes and fracking. More data analysis, including statistical analysis, is required to truly confirm the existence, or non-existence, of a relationship.

Overall, the data suggest there is a relationship between earthquakes and fracking. The anomalous earthquake clusters and their change over time is not typical for natural earthquakes. With the data available, it is impossible to specify what aspects of the fracking operations are affecting earthquakes and how.

References

Behar, Michael. 2013. Mother Jones. Whose Fault. Vol. 38 Issue 2, p34-64. 7p.

Booher, Jacob. 2015. Environmental Law (00462276). FRACKING-CAUSED EARTHQUAKES: HOW ALLEGED THREATS COULD TRIGGER THE CORPS OF ENGINEERS' SECTION 10 JURISDICTION. Vol. 45 Issue 1, p235-255. 21p

van der Voort, N. and Vanclay, Frank. 2014. Environmental Impact Assessment Review. Social impacts of earthquakes caused by gas extraction in the Province of Groningen, The Netherlands. Vol. 50, p1 - 5