Investigating power variation in first breaks, reflections, and ground roll from different charge sizes

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ABSTRACT

We investigate variation in power from different charge sizes in first breaks, reflections, and ground roll components of a shot record. To observe power distributions, shot data from multiple charge sizes obtained in the Hussar low frequency experiment, conducted by CREWES, were analyzed using MATLAB. The first breaks, reflections, and ground roll were isolated using time windows defined by straight lines in x-t space. Upon defining these windows, the power in each component of the shot record was calculated by summing the squares of the samples in each window. Power was observed to increase quasi-linearly with charge size with the majority of power being present in the ground roll. Future work will include calculating the power in the F-K domain and conducting more charge-size tests in the field.

INTRODUCTION

Dynamite is a commonly used tool in exploration seismology to image the subsurface where the power of an explosion is directly related to the charge of the size used. On a seismogram, power is directly related to the square of the amplitude of the trace and as a result, the charge size plays a significant role in imaging features in the subsurface. By increasing the charge size of a dynamite shot, it is possible to substantially increase the amplitude of key seismic events on a seismogram. However, a direct link between charge size and reflection strength is difficult to establish because of many unknowns such as radiation pattern, earth attenuation, near surface variability, etc.

Reflections are of particular interest in seismic data processing as they contain most of the valuable information pertaining to the subsurface. Therefore, a better understanding of the link between the reflection power and charge size would greatly aid in survey design and interpretation. Consequently, it is important to understand how power is distributed in different components of a shot record, as it could potentially lead to improvements in imaging with dynamite.

FIELD SETUP AND RECORDING

To investigate power distribution in a seismogram test charges ranging in sizes between 1 and 4 kg were buried 15 meters deep at three separate locations along the seismic line used in the Hussar low frequency experiment conducted by CREWES in the Fall of 2011 (Margrave et al., 2011). The test charges were recorded by a three component geophone array with an interval of 10 m and a sample interval of 2 ms. Note that at each recording location there were five different receivers recording the data, however, we only used the vertical components of the 10 Hz receiver for analysis. Additionally, the shot records that were used to conduct this investigation have not been processed in any way, they are simply the raw recordings measured by the geophones in the field.

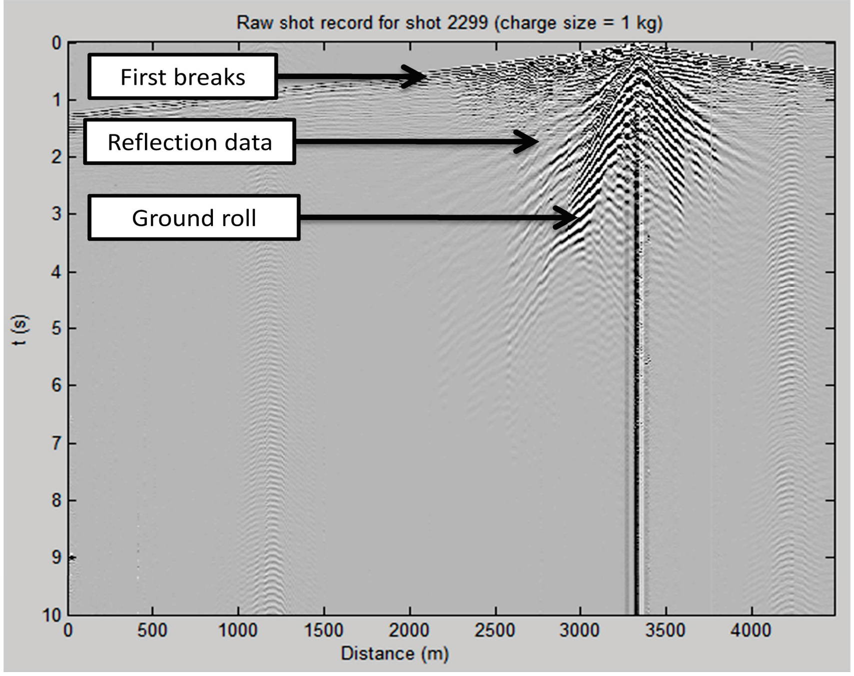

Fig. 1. Raw shot record containing first break, reflection, and ground roll data.

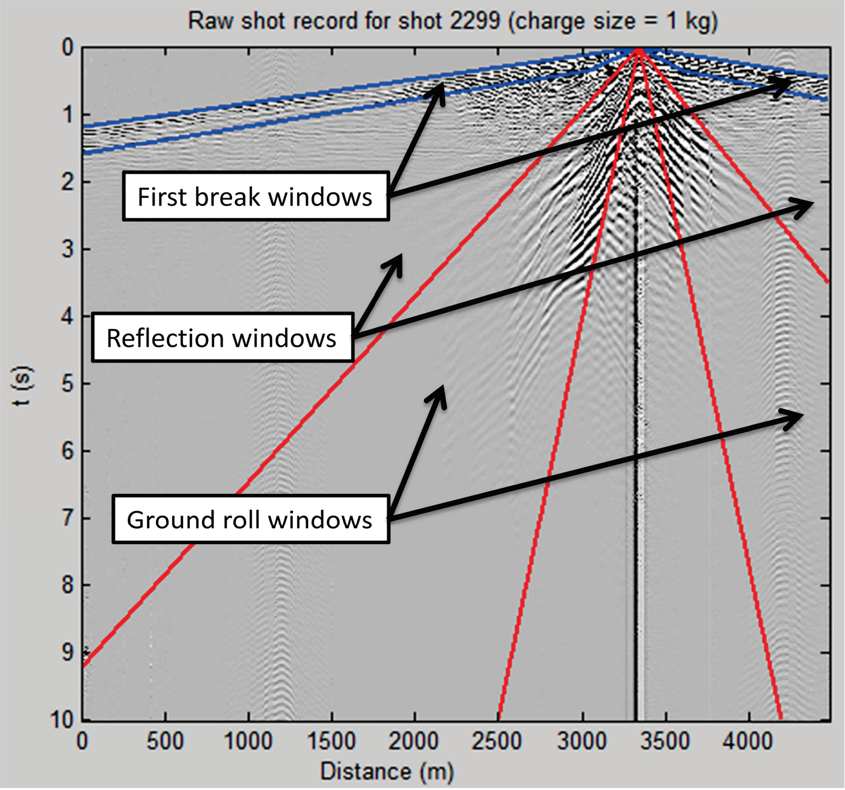

Fig. 2. Raw shot record containing the time windows used to isolate the first break, reflection, and ground roll data.

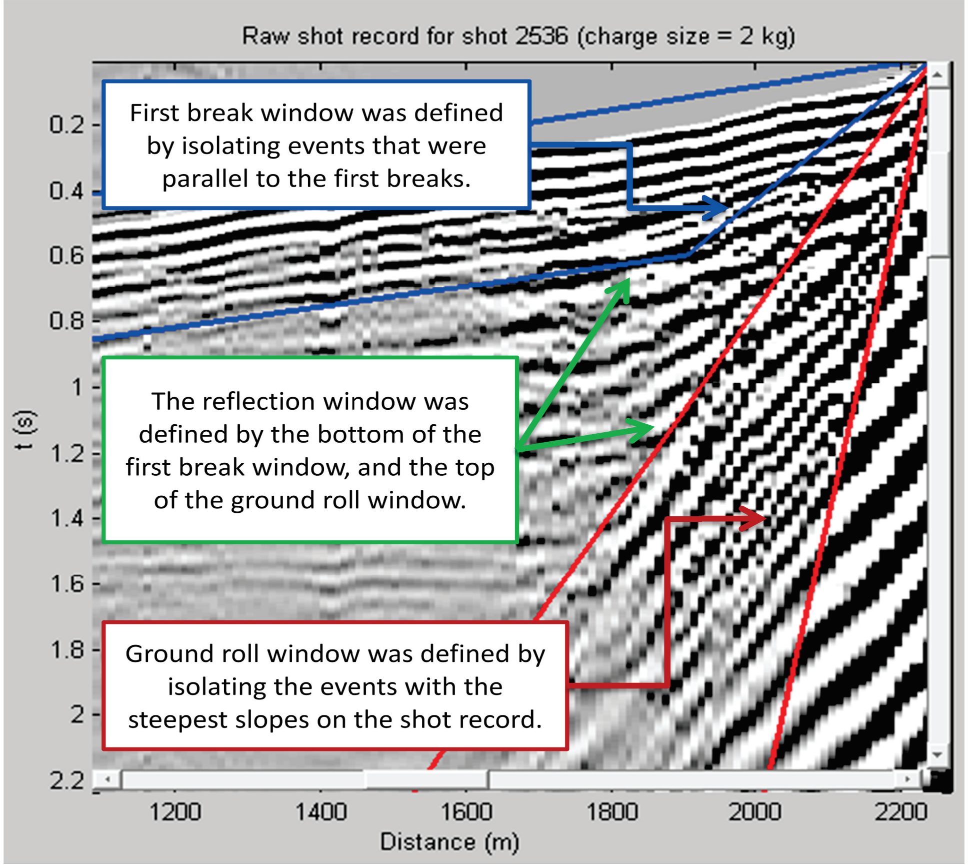

Fig. 3. Close up view of the time windows used to compute the power in each component of the seismogram.

COMPUTING POWER

In order to compute the power in each component of a seismogram, select events where isolated from the rest of the shot record based on a certain set of predefined criteria. Figure 1 shows a raw shot record along with the components of the seismogram that were analyzed in this investigation. These include the first breaks, reflections, and the ground roll. There are several extra features of this seismogram in particular that may have affected the outcome of the results. At roughly 4200 m as well as 1200 m, a distinct set of traces can be seen which would not normally be expected for a dynamite explosion. These traces show noise caused by active well production during the recording and may contribute to the overall power of the seismogram, resulting in a potential power increase that did not come from the dynamite.

Figure 2 shows the time windows that were used to calculate the power in each component of the seismogram and the criterion used to select these windows is illustrated in Figure 3. The ground roll was isolated from the rest of the seismogram by pinpointing events with the steepest time dip. The first breaks were isolated by separating out each event that was parallel with the first arrivals in each shot record. Note that a jagged line had to be used for the bottom window in the first breaks since there were distinct terminations of these events near the shot origin which can be seen in Figure 3. Lastly, the reflection window was defined as the area between the bottom of the first break window and the top of the ground roll window. It is obvious that the windows contain many more wave types than just the one for which they are named. The ground roll window contains reflections as well as ground roll for example. These windows are only expected to roughly characterize the wave type for which they are named.

Computation of power involved writing a code in MATLAB that could isolate a set of traces using the top and bottom of the windows for indexing. After isolating the traces, the code sums the square of all of the trace amplitudes contained within the bounds of the window, which yields the power for that window. The code has a built-in consistency check that calculates the total power in shot record by summing the squares of the entire trace. The remaining windows above and below the areas of interest are also analyzed so that the individual power in all of the windows are known. If the power in all of the windows combined is greater than the total power of the shot record, a status message is returned which indicates that there is a problem with the code. In each of the shot records analyzed, the consistency check was successful.

This code was used to analyze a total of 17 different shot records which contained data corresponding to charge sizes that ranged between 1 and 4 kg. The final results of this analysis can be seen in Figures 4 through 8, which show surface plots of the mean power in each component of the seismogram as well as the total shot power as a function of the charge size along the three separate locations used to carry out this survey.

DISCUSSION OF RESULTS

Observation of Figures 4 through 7 reveals a quasi-linear relationship between power and charge size, with most of the power being present in the ground roll. The overall power in each element of the seismogram, as well as the total shot power, increases with the charge size. The smallest power appears to be in the first breaks, but this is likely a simple consequence of the window size, and the largest amount of power is dissipated in the ground roll. The power of the reflections appear to be somewhere in between these two, however, the power in the reflections seems to increase more rapidly with charge size than the first breaks. Since the reflection window contains most of the valuable information pertaining to the subsurface it would be ideal to increase the power in this window using an increased charge size.

There also appears to be a great deal of variation in power between charges of the same size, which is most likely caused by the geology in the different locations in which these charges were detonated. The power in the ground roll has the largest increase with charge size out of all of the elements, however, ground roll is usually removed during signal processing. The data in Figures 4 through 7 suggests that the increase in ground roll power does not affect the increase in reflection power. For example, the power increase in Figure 5 for the reflections follow a very similar pattern as that of the ground roll in Figure 6 at all three locations. Thus, the increase appears to be uniform in both the reflections and the ground roll.

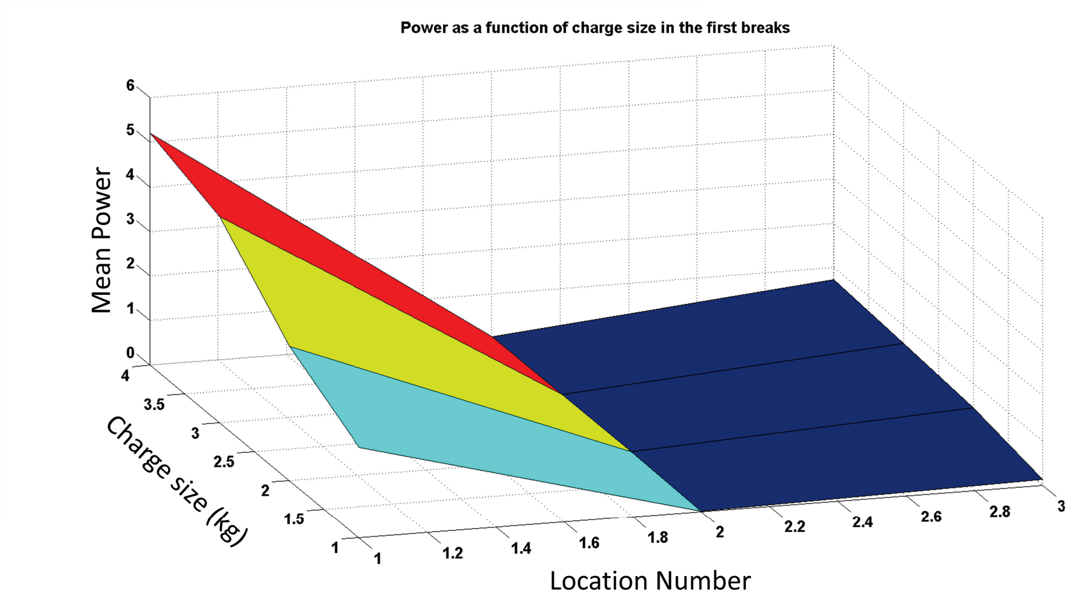

Fig. 4. Mean power in the first breaks as a function of the charge size along three separate locations used in this study.

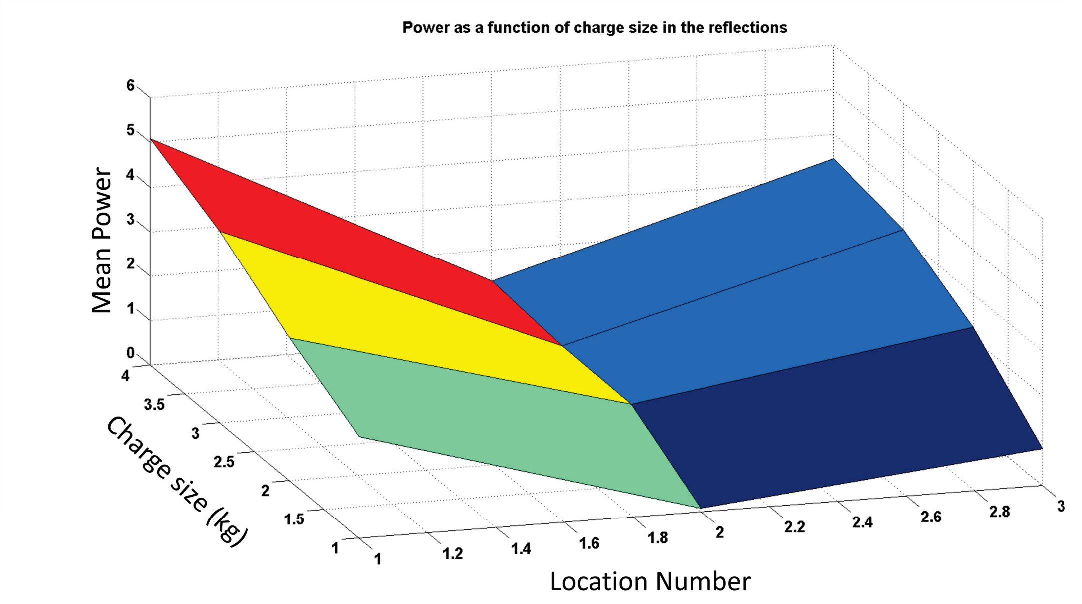

Fig. 5. Mean power in the reflections as a function of the charge size along three separate locations used in this study.

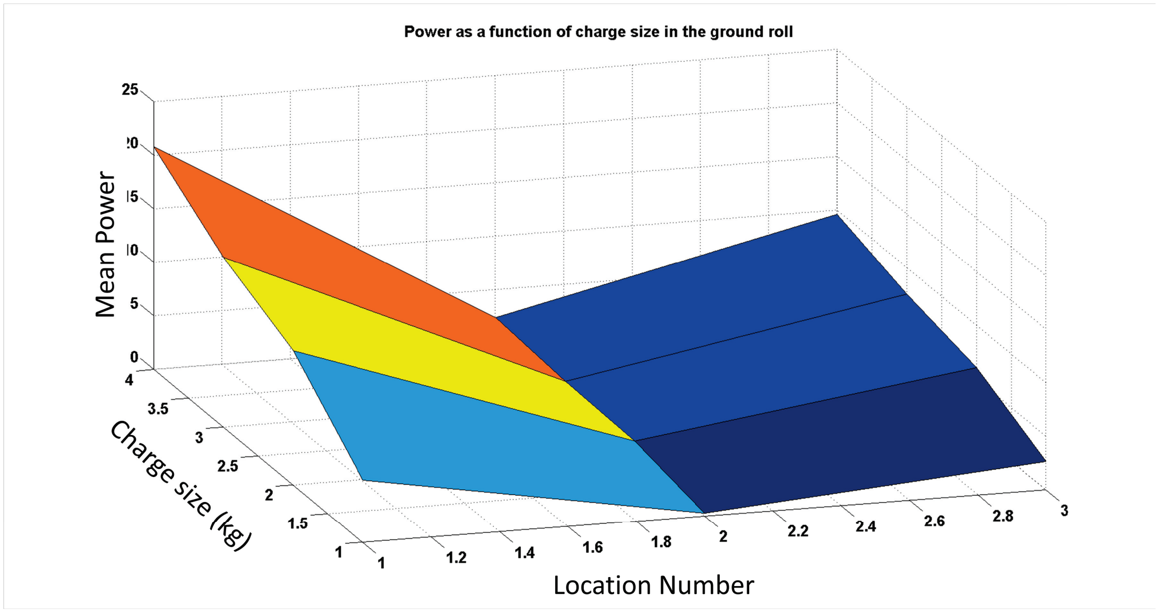

Fig. 6. Mean power in the first breaks as a function of the charge size along three separate locations used in this study.

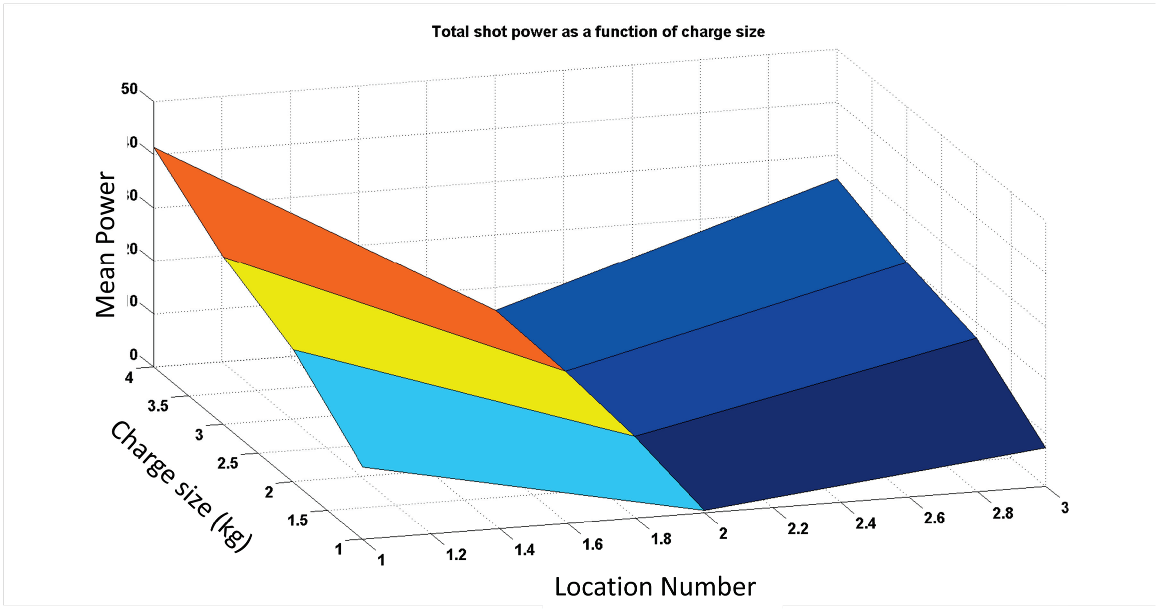

Fig. 7. Mean total shot power as a function of the charge size along three separate locations used in this study.

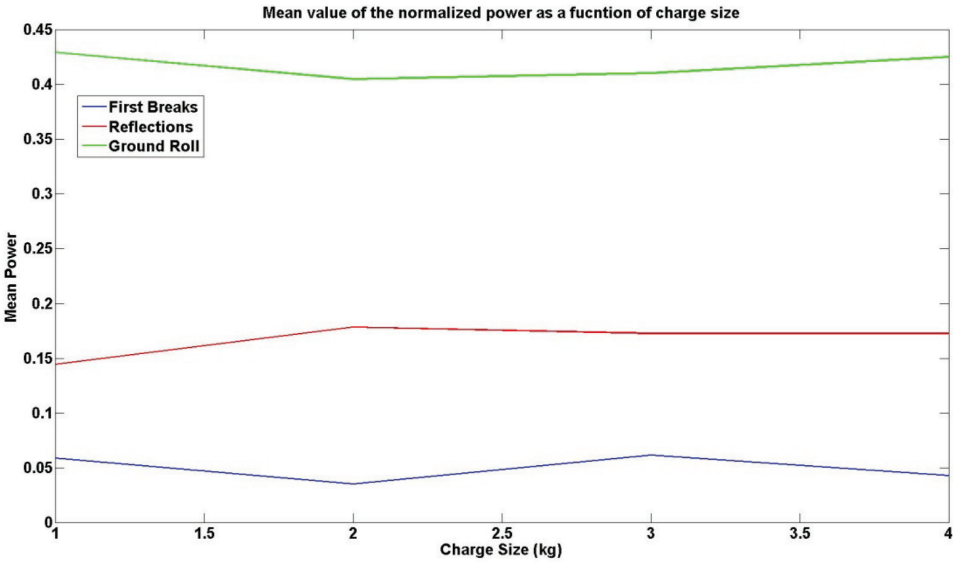

Fig. 8. Normalized mean power with respect to the total shot power at all locations in the study.

It is also worthwhile to note that the power increase in each element with charge size appears to be similar in form to the increase in the total shot power. This is evidence for a uniform increase in power throughout the entire seismogram. However, the drastic difference in amplitudes for each element at all locations is indicative of uneven power distribution throughout the subsurface. Figure 8 shows the normalized power for each element of the seismogram. All of the locations have been combined into a single data set and the power has been normalized with respect to the total power of each individual shot. Therefore, each value of mean power in this figure can be thought of as a percentage of the total shot power. Observation of this data reveals an approximately constant power distribution of each element despite the increase in charge sizes. This suggests that the fractional power of each element is constant regardless of the size of the charge used.

There are several sources of error that may have been present during the course of this investigation which potentially caused some inaccuracies in the final results. As mentioned before, traces contain input from external power sources (producing wells). Additionally, Figure 3 shows that some of the first break data near the shot origin has been cut out when we were accounting for the termination of these events near the shot origin. Since the top of the reflection window is defined as the bottom of the first break window, it is entirely possible that some of the reflection power spectra contain data that should have been in the first breaks and vice-versa. Also, it is highly likely that there is significant reflection power in the ground-roll window.

CONCLUSIONS

Based on the results of this investigation, it can be concluded that the relationship between power and charge size follows a somewhat linear pattern, where power increases with larger charge sizes. Most of the power in a seismogram is contained within the ground roll, with the least amount being present in the first breaks. Despite this uneven distribution of power, the fractional power of each element remains constant despite the increase in charge size.

It can also be concluded that the power of the reflections can be increased by using a larger charge size and will be unaffected by the increase in power of the other elements of the seismogram. It may also be worthwhile to investigate the relationship between power and the depth at which a charge is buried to see if there is another way to control the distribution of power in a seismogram. To improve the quality of the data, it may also be worth investigating the impact the extra traces had on the final power spectrums. One of the challenges associated with this task however is the potential to remove traces that are a result of the dynamite explosion, and no the production wells.