Title: The Application of Wavelet Deconvolution for Noise Reduction in Seismic Data

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ABSTRACT

Seismic data plays a crucial role in investigating subsurface geological structures, but it is often contaminated by noise that reduces interpretability. This study investigates the application of wavelet deconvolution for enhancing seismic data quality by attenuating noise. The methodology involves the preprocessing of field data from Wyoming's Teapot Dome, implementation of trace-by-trace wavelet deconvolution, and evaluation of improvements. Key preprocessing steps include geometry correction, brute stack, refraction statics, and airblast and ground roll noise removal. Optimal deconvolution parameters of 85s operator length and 16s gap length are determined through testing. Results demonstrate wavelet deconvolution effectively improves resolution and signal-to-noise ratio by reducing noise levels across the frequency spectrum, with maximum attenuation at lower frequencies below 10 Hz. The technique successfully preserves reflection signals and geological information while removing noise components. This study underscores the value of wavelet deconvolution for practical applications in enhancing seismic data quality and enabling accurate subsurface characterization. Further optimizations of the algorithm through adaptive wavelet selection and tuning could extend its performance across diverse datasets.

INTRODUCTION

1.1 BACKGROUND TO STUDY

Seismic noise in geology, which is the study of rocks, pertains to the continuous vibrations of the ground that result from various factors. These vibrations encompass those generated by human activities, such as transportation and manufacturing.

Seismic noise refers to the constant ground vibrations that result from various sources, and it is a significant factor in geology since it aids in understanding the Earth's internal structure and composition. The sources of seismic noise are diverse, ranging from natural phenomena like ocean waves, wind, thunderstorms, and earthquakes, to human activities such as transportation, construction, and manufacturing. Transportation, specifically road and air traffic, is one of the most prominent sources of anthropogenic seismic noise, which can be detected by sensitive equipment such as seismometers. Construction activities that use heavy machinery, such as bulldozers and pile drivers, are also a source of human-generated seismic noise. Seismometers are devices used to measure and analyze seismic noise, recording the vibrations continuously to provide useful data for geologists and researchers. By analyzing the different types of seismic noise generated by natural and human activities, scientists can identify the sources of seismic noise and deduce Earth's geological features, such as fault lines and subsurface structures. Seismic noise is not only vital in geology, but it also has practical applications in engineering. For example, seismic noise data can be used to design structures and buildings that can withstand seismic activity, reducing damage during earthquakes. In summary, seismic noise is a crucial component of geology that has numerous applications in science and engineering

Obtaining accurate and reliable seismic data can be challenging due to the impact of noise. Seismic data is collected using sensors such as seismometers, which detect ground vibrations and convert them into electrical signals. Any unwanted signal can be considered noise and can interfere with the seismic signals, leading to errors in data analysis and interpretation

Different types of noise can affect seismic data. Ambient noise is generated by natural sources such as wind, ocean waves, and earthquakes. Ambient noise can mask the signals of interest, reduce the signal-to-noise ratio (SNR), and impact seismic data significantly. Anthropogenic noise is generated by human activities, including transportation, construction, and industrial operations. This type of noise is often high in frequency and can be problematic since it masks

seismic signals, thereby reducing the SNR of the data. In urban areas, where anthropogenic noise levels are high, this can be a significant challenge. Instrumental noise, generated by the sensors or other electronic components in the data acquisition system, can also impact seismic data. Using high-quality sensors and carefully designing the data acquisition system can help reduce this type of noise.

To minimize the impact of noise on seismic data, several techniques can be used. Filtering the data is one common approach to remove unwanted frequencies, such as high-frequency noise. Filtering can improve the SNR of the data, but it is important not to filter out signals of interest. Another approach is to use noise-reducing sensors, such as three-component sensors, which isolate the vertical and horizontal components of the ground motion. These sensors provide more accurate measurements and reduce the impact of noise on the data.

Noise can significantly affect seismic data, making it challenging to obtain accurate and reliable results. Different types of noise, including ambient, anthropogenic, and instrumental noise, can impact seismic data. Various techniques, such as filtering and using noise-reducing sensors, can be employed to minimize noise and improve the SNR of the data. Proper attention to noise reduction techniques can ensure that seismic data is accurate and reliable, thereby enabling better analysis and interpretation of geological features and processes.

Deconvolution is a technique in signal processing that is commonly used to remove the effects of a filter from a signal. In the context of seismic data, deconvolution is applied to remove the effect of the earth's filter from the recorded seismic signal. The earth's filter can distort or attenuate the seismic signal, which can result in reduced signal-to-noise ratio and poor data quality.

The use of deconvolution can improve the quality of seismic data by removing the unwanted signals, including the effects of the earth's filter and other types of noise such as ground roll noise and random noise. This process results in an increased signal-to-noise ratio, making the data easier to analyse and interpret.

Different algorithms are available for performing deconvolution on seismic data, including predictive deconvolution, Wiener deconvolution, and wavelet deconvolution. Predictive deconvolution involves the use of a predictive filter to remove the earth's filter from the seismic data. Wiener deconvolution, on the other hand, utilizes a statistical approach to estimate the signal and noise spectra and remove the effects of the earth's filter. Wavelet deconvolution involves decomposing the seismic signal into different frequency bands using wavelet transforms, and then removing the earth's filter effects from each band separately.

Deconvolution is not without its challenges, particularly in cases where the earth's filter is not accurately known. The quality of the deconvolution results is dependent on the accuracy of the estimated earth's filter and the quality of the recorded data. Moreover, deconvolution can be computationally intensive, particularly for large datasets, which can make it difficult to apply in real-time processing applications.

Deconvolution is a useful technique that can improve the quality of seismic data by removing the effects of the earth's filter and other types of noise. By removing these unwanted signals, deconvolution can enhance the signal-to-noise ratio, making it easier to interpret and analyze the data. However, it requires knowledge of the earth's filter, which can be challenging to estimate accurately, and can be computationally intensive, which can make it challenging to apply in real-time processing applications.

1.2 STATEMENT OF PROBLEM

Part of the problem being faced when presented with seismic data is the noise. The noise does mask some of the structures shown and as that acts as an obstruction to a wonderful interpretation of some of the geological structures within the earths subsurface.

1.3 AIM AND OBJECTIVES OF STUDY

The objective of this study is to investigate the use of wavelet deconvolution for noise reduction in seismic data. The study aims to assess the effectiveness of wavelet deconvolution techniques in enhancing the quality of seismic data and improving the accuracy of seismic interpretation. Specifically, the research will focus on the following aspects:

1 Evaluating different wavelet deconvolution algorithms: The study will review and compare various wavelet deconvolution algorithms that have been proposed in the literature. This

will include an analysis of their theoretical principles, computational efficiency, and effectiveness in noise reduction.

2 Investigating the performance of wavelet deconvolution for different types of noise: The study will assess the capability of wavelet deconvolution in reducing different types of noise commonly encountered in seismic data, such as random noise, ground roll noise, and acquisition-related artifacts. The analysis will involve the comparison of noise reduction efficiency and preservation of seismic signal features.

3 Assessing the impact of wavelet deconvolution on seismic interpretation: The study will examine the influence of wavelet deconvolution on the interpretability and reliability of seismic data. This will involve the evaluation of signal-to-noise ratio improvements, enhancement of weak signal features, and the potential for accurate identification of subsurface structures.

1.4 JUSTIFICATION OF STUDY

Seismic data can be impacted by unwanted signals known as noise, which interfere with the signals of interest such as seismic waves. The presence of noise can have adverse effects on seismic data, making it challenging to interpret and analyze.

Seismic data can be affected by different types of noise, including ambient noise, anthropogenic noise, instrumental noise, ground roll noise, multipath noise, and random noise, each with distinct causes and impact on the data. These types of noise can cause a decrease in signal-to- noise ratio, signal distortion, and masking of signals of interest.

Signal processing techniques, such as filtering, deconvolution, and noise suppression, can be used to reduce or eliminate unwanted noise while preserving the signals of interest. These techniques aim to improve the quality of the seismic data, resulting in better accuracy and reliability of seismic interpretation and analysis. Ultimately, these techniques can provide better insights into the properties and structure of the subsurface.

1.5 GEOLOGY OF THE AREA

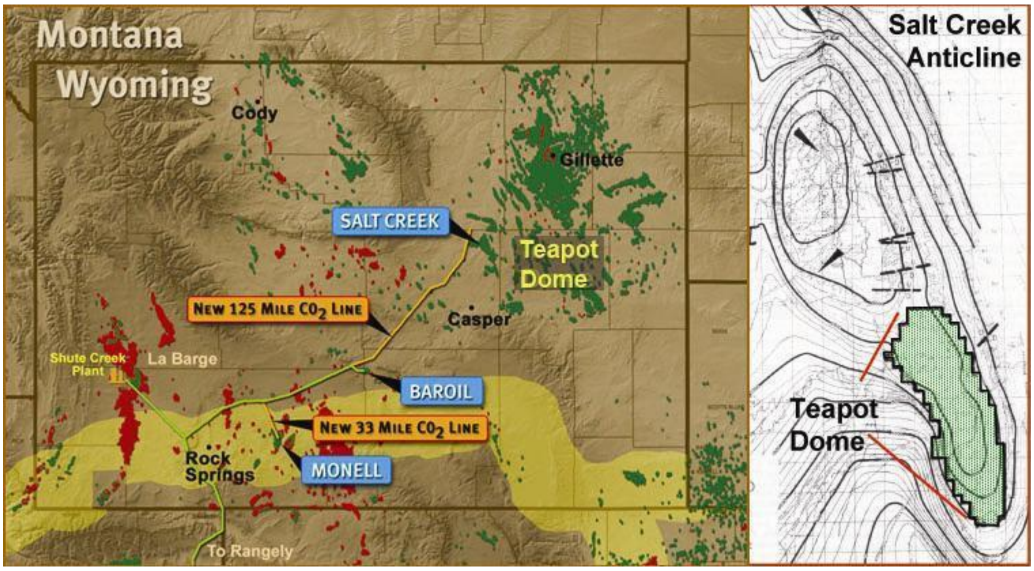
The Teapot Dome area in Wyoming, USA is known for its sedimentary rock formations, particularly the Phosphoria Formation and the Tensleep Sandstone. The Phosphoria Formation contains limestone, dolomite, shale, and phosphate beds with significant phosphate mineral deposits. On the other hand, the Tensleep Sandstone is a permeable reservoir rock crucial for oil and gas production.

The geological structure of the region has been influenced by faulting and folding, impacting the migration and accumulation of hydrocarbons. The Teapot Dome oil field, discovered in the early 1900s, gained notoriety due to its substantial oil production and its involvement in a

scandal surrounding the leasing of public oil reserves.

Today, the geology of the Teapot Dome area remains an area of interest for hydrocarbon exploration and production. Modern techniques are utilized to identify potential reservoirs and optimize production, ensuring the ongoing study and efficient utilization of the region's geological resources

Figure 1.5: Teapot Dome area in Wyoming



LITERATURE REVIEW

2.1 OVERVIEW OF SEISMIC DATA

Seismic data is commonly used in geological studies of the subsurface, as well as in oil and gas reservoir exploration and production. However, the data is frequently contaminated by various types of noise, which can compromise the quality and reliability of the data. Deconvolution is a commonly used technique for reducing noise in seismic data. Seismic data plays a crucial role in various fields, including oil and gas exploration, geological studies, and seismic imaging. However, seismic data is often contaminated with various types of noise, which can significantly degrade the quality and reliability of the data. Noise in seismic data can arise from various sources, such as environmental factors, acquisition systems, and subsurface heterogeneities. Therefore, effective noise reduction techniques are essential for improving the interpretability and accuracy of seismic data.

Wavelet deconvolution has emerged as a promising technique for noise reduction in seismic data. It is a signal processing method that aims to remove unwanted noise and enhance the signal of interest. Wavelet deconvolution employs the properties of wavelet transforms to decompose seismic signals into different scales or frequencies, allowing for targeted noise removal and signal enhancement. By selectively modifying the wavelet coefficients, wavelet deconvolution can effectively attenuate different types of noise, including random noise, ground roll noise, and acquisition-related artifacts.

2.2 SEISMIC DATA AND NOISE

Seismic data plays a fundamental role in geophysical exploration as it allows for the investigation of the Earth's subsurface structure. It provides valuable insights into the composition and properties of the subsurface, enabling geoscientists to locate and characterize a wide range of geological features, including oil and gas reservoirs, fault zones, and rock formations. The acquisition of seismic data predominantly relies on the seismic reflection technique, which involves the generation and recording of seismic waves as they propagate.

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The seismic reflection method employs seismic sources, such as explosives or vibrators, to produce controlled seismic waves. These waves travel through the Earth's layers and interact with subsurface interfaces, causing them to reflect and refract. Arrays of geophones or other sensors are used to record the reflected waves, known as seismic traces, which contain valuable information about the subsurface structures and properties.

Seismic data is typically represented in the form of a two-dimensional or three-dimensional grid composed of seismic traces, forming a seismic survey. Each trace corresponds to the recorded signal at a specific location and time. These traces are organized based on their spatial coordinates and the timing of the recorded signal. The time axis represents the travel time of the seismic waves, while the amplitude axis reflects the strength or intensity of the recorded signal.

The interpretation of seismic data involves a meticulous analysis of the patterns and characteristics exhibited by the seismic waves in order to infer subsurface structures. Geoscientists examine various attributes of the seismic data, such as seismic wave velocities, reflections, diffractions, and amplitudes, to identify geological features and make geological interpretations. By studying the reflections and other seismic attributes, subsurface structures, including stratigraphic layers, faults, and hydrocarbon reservoirs, can be accurately mapped and characterized.

Seismic data processing plays a critical role in enhancing the quality and interpretability of the acquired seismic data. Various processing techniques, including noise removal, deconvolution, stacking, and migration, are applied to the raw seismic data. These techniques aim to improve the signal-to-noise ratio, eliminate unwanted noise, enhance resolution, and accurately position subsurface reflections.

Seismic data is an indispensable tool in geophysical exploration, providing invaluable information about the subsurface of the Earth. Its acquisition, processing, and interpretation enable geoscientists to investigate and comprehend the geological features and structures that lie beneath the Earth's surface. Seismic data finds extensive applications in numerous industries, including oil and gas exploration, engineering, and environmental studies.

There are different types of noise that can affect seismic data. Noise refers to unwanted signals that interfere with the signals of interest. The various types of noise that can impact seismic data include:

1. Ambient noise: This type of noise is caused by natural sources like wind, ocean waves, and earthquakes, which can mask the signals of interest and reduce their signal-to-noise ratio.

2. Anthropogenic noise: This type of noise is caused by human activities such as transportation, construction, and industrial operations. Anthropogenic noise is often high in frequency and can mask seismic signals, reducing the signal-to-noise ratio of the data.

3. Instrumental noise: This type of noise is caused by the sensors themselves or other electronic components in the data acquisition system. High-quality sensors and careful design of the data acquisition system can help reduce this noise.

4. Ground roll noise: This is low-frequency noise caused by the earth's surface or near-surface geology. Topography, soil conditions, or geological structures can cause ground roll noise.

5. Multipath noise: This type of noise is caused by seismic waves reflecting off multiple surfaces before reaching the sensor. Multipath noise can lead to interference and distortions in the seismic data.

6. Random noise: This type of noise is random in nature and can be caused by factors like sensor noise, electronic noise, and thermal noise. Signal processing techniques like filtering and averaging can help reduce random noise.

2.3 WAVELET DECONVOLUTION

Seismic data plays a crucial role in geophysical exploration as it provides valuable insights into the subsurface structure of the Earth. It allows geoscientists to study and understand the composition and properties of the subsurface, aiding in the identification and characterization of geological features such as oil and gas reservoirs, fault zones, and rock formations. Seismic data is typically acquired using the seismic reflection technique, which involves generating and recording seismic waves that propagate through the subsurface.

The seismic reflection method employs various seismic sources, such as explosives or vibrators, to generate controlled seismic waves. These waves travel through the layers of the Earth and interact with subsurface interfaces, resulting in their reflection and refraction. Geophones or other sensors are placed on the Earth's surface or in boreholes to record the reflected waves, which are known as seismic traces.

Seismic data is commonly represented as a two-dimensional or three-dimensional grid of seismic traces, forming a seismic survey. Each trace corresponds to the recorded signal at a specific location and time. These traces are organized based on their spatial coordinates and the timing of the recorded signal. The time axis represents the travel time of the seismic waves, while the amplitude axis represents the strength or intensity of the recorded signal.

The interpretation of seismic data involves a meticulous analysis of the patterns and characteristics exhibited by the seismic waves, allowing geoscientists to infer the subsurface structures. Various attributes of the seismic data, including seismic wave velocities, reflections, diffractions, and amplitudes, are examined to identify geological features and make geological interpretations. By analyzing the reflections and other seismic attributes, geoscientists can accurately map and characterize subsurface structures such as stratigraphic layers, faults, and hydrocarbon reservoirs.

Seismic data processing plays a critical role in enhancing the quality and interpretability of the acquired seismic data. Several processing techniques, including noise removal, deconvolution, stacking, and migration, are applied to the raw seismic data. These techniques aim to improve the signal-to-noise ratio, eliminate unwanted noise, enhance resolution, and accurately position subsurface reflections.

Seismic data is an invaluable tool in geophysical exploration, providing essential information about the Earth's subsurface. Its acquisition, processing, and interpretation allow geoscientists to investigate and understand the geological features and structures that exist beneath the Earth's surface. Seismic data finds applications in various industries, including oil and gas exploration, engineering, and environmental studies.

2.4 PRINCIPLES BEHIND WAVELET DECONVOLUTION

Wavelet deconvolution is based on utilizing the localized and multiscale representation capabilities of wavelets to process seismic data. By applying a well-designed wavelet filter during the deconvolution process, the unwanted noise can be reduced, leading to an improved signal-to-noise ratio and enhanced interpretability of the seismic data.

It is essential to acknowledge that the effectiveness of wavelet deconvolution relies on the unique characteristics of the seismic data and the specific noise present in the dataset. Achieving optimal noise reduction results requires careful selection of suitable wavelet filters and parameter settings, as well as thorough evaluation and validation.

The principles underlying wavelet deconvolution encompass the following fundamental concepts:

1. Convolution: Convolution is a mathematical operation that combines two functions to generate a third function. In the context of wavelet deconvolution, seismic data undergoes convolution with a wavelet function or filter. Convolution is a mathematical operation represented by the asterisk (*) symbol. It involves combining two functions, denoted as f(t) and g(t), through an integral over a specific range. The process includes multiplying corresponding values of the functions at each point in time and summing up these products. Convolution finds wide application in various fields such as image processing, audio signal processing, and seismic data analysis. In seismic data processing, for instance, convolution is utilized to simulate how subsurface structures respond to seismic waves. By convolving the seismic source wavelet with the reflectivity series of subsurface layers, the resulting seismic trace represents the recorded data that can be analyzed for geological interpretation.

2. Wavelet Transform: The wavelet transform decomposes a signal into a set of wavelet coefficients at different positions and scales. It provides a representation of the signal in both the time and frequency domains, capturing local and global features.
The wavelet transform is a mathematical method that breaks down a signal into wavelet coefficients, providing a representation of the signal in both the time and frequency domains.

Unlike the Fourier transform, which uses fixed frequency sinusoids, the wavelet transform utilizes wavelets that are localized in both time and frequency.

To perform the wavelet transform, the signal is convolved with a set of wavelet functions, which are variations of a base wavelet that are scaled and shifted. These wavelet functions have a compact support, meaning they are non-zero only within a limited time range. This localized property enables the wavelet transform to capture both fine-scale and coarse-scale features of the signal.

The wavelet transform enables a multi-resolution analysis by decomposing the signal into different frequency components at various scales. This is achieved by applying the wavelet functions with different dilation and translation parameters. The outcome is a collection of wavelet coefficients that represent the signal's energy or amplitude at each scale and position.

Various types of wavelet functions can be employed for the wavelet transform, including the Haar wavelet, Daubechies wavelets, Morlet wavelets, and more. Each type of wavelet possesses distinct characteristics and is suited for specific signal types and applications.

The wavelet transform finds extensive applications in signal processing, image compression, data compression, denoising, feature extraction, and other fields. It facilitates a localized analysis of signals, capturing both temporal and spectral information, thus making it a powerful tool in diverse areas of research and engineering.

1. Deconvolution: Deconvolution is the process of undoing the effects of convolution. In wavelet deconvolution, the convolved seismic data is subjected to deconvolution using a wavelet filter, which separates desired signals from unwanted noise and artifacts.

Deconvolution techniques play a crucial role in enhancing the quality and interpretability of seismic data. By reducing noise and distortions while emphasizing desired signals, these techniques improve resolution and enable a more accurate identification of subsurface structures. Additionally, deconvolution enhances the precision of seismic attributes and facilitates seismic interpretation and reservoir characterization.

There are various deconvolution algorithms and approaches available, such as wavelet deconvolution, Wiener deconvolution, and spiking deconvolution. Each method possesses distinct advantages, limitations, and parameter settings. The choice of deconvolution technique depends on the specific characteristics of the seismic data and the objectives of the data processing task at hand.

2. Wavelet Filter: The wavelet filter employed in deconvolution is typically designed to possess a frequency response that closely matches or approximates the inverse of the wavelet used in the convolution process. The filter's objective is to amplify desired signal components w hile attenuating noise components.

3. Inverse Filtering: Wavelet deconvolution entails applying an inverse filtering operation, where the wavelet filter is employed on the convolved data to suppress noise and enhance the signal. The inverse filter functions as a noise attenuation operator.

4. Parameter Selection: The efficacy of wavelet deconvolution hinges on the selection of appropriate parameters, including the type of wavelet, filter length, and the degree of regularization or thresholding applied during the deconvolution process. These parameters should be chosen based on the specific characteristics of the noise and the seismic data.

By comprehending these principles, researchers and practitioners can effectively employ wavelet deconvolution techniques to improve the quality of seismic data by reducing noise and enhancing signal interpretability.

2.4 PREVIOUS STUDIES CONCERNING WAVELET DECONVOLUTION

A thorough examination of prior research on the utilization of wavelet deconvolution and its efficacy in reducing noise in seismic data reveals a substantial body of literature dedicated to this subject matter. Wavelet deconvolution has been extensively investigated as a technique aimed at enhancing the quality and interpretability of seismic data by mitigating various forms of noise. The ensuing review presents a concise summary of noteworthy discoveries and insights gleaned from previous studies in this domain.

In their study, Cheng and Wang (2019) examined the implementation of wavelet deconvolution to eliminate ground roll noise from seismic data. Their findings indicated that the employment of wavelet deconvolution yielded effective noise reduction and led to an improved signal-to-noise ratio in the data. This study underscored the capacity of wavelet deconvolution to address specific noise sources and augment the quality of seismic data.

Dou et al. (2019) delved into the use of wavelet deconvolution for reducing random noise in seismic data. They employed a spectral whitening technique based on wavelet deconvolution and demonstrated its efficacy in enhancing data quality and increasing the resolution of subsurface structures. The study accentuated the effectiveness of wavelet deconvolution in attenuating random noise and augmenting the signal content of seismic data.

Li et al. (2018) concentrated on the application of predictive deconvolution, a variant of wavelet deconvolution, to mitigate the effects of the Earth's filter on seismic data. Their research highlighted the significant reduction in distortion and attenuation resulting from predictive deconvolution, leading to an improvement in the quality of seismic data. This study shed light on the potential of wavelet deconvolution techniques, such as predictive deconvolution, to address specific challenges associated with the Earth's filtering effects.

Yousefi et al. (2016) investigated the utilization of Wiener deconvolution, incorporating wavelet techniques, to eliminate the effects of the Earth's filter and random noise from seismic data. Their study demonstrated that Wiener deconvolution enhanced the signal-to-noise ratio of the data and improved the accuracy of seismic interpretation. The research underscored the benefits of wavelet-based deconvolution in enhancing both the clarity and reliability of seismic data.

Santos and Tygel (2012) explored the application of blind deconvolution, a technique utilizing wavelet transforms, to reduce random noise and enhance the resolution of seismic data. Their study showcased the effective reduction of noise and improvement in the quality of seismic images achieved through blind deconvolution. The findings highlighted the potential of wavelet-based blind deconvolution for noise reduction and resolution enhancement in seismic data.

In essence, prior studies have consistently demonstrated the substantial potential of wavelet deconvolution techniques for noise reduction in seismic data. Techniques such as spectral whitening, predictive deconvolution, Wiener deconvolution, and blind deconvolution have exhibited effectiveness in reducing specific types of noise, improving the signal-to-noise ratio, and enhancing the quality and interpretability of seismic data.

However, it is important to note that the effectiveness of wavelet deconvolution methods may depend on various factors, including the characteristics of the noise, the specific wavelet functions and parameters employed, and the conditions of data acquisition and processing. Further research is warranted to optimize wavelet deconvolution techniques for different noise types and address challenges such as accurate wavelet estimation and computational efficiency. Nevertheless, the existing body of literature provides a solid foundation for the ongoing exploration and advancement of wavelet deconvolution for noise reduction in seismic data

2.5 COMPARISON WITH OTHER NOISE REDUCTION TECHNIQUE

Wavelet deconvolution is a widely used noise reduction technique in seismic data processing, and it offers several advantages and disadvantages when compared to other commonly employed noise reduction techniques. Understanding these pros and cons can help in evaluating the suitability of wavelet deconvolution for specific applications and identifying potential limitations. Let's examine the advantages and disadvantages of wavelet deconvolution in comparison to other noise reduction techniques.

2.5.1 ADVANTAGES OF WAVELET DECONVOLUTION:

1. Localization: One of the key advantages of wavelet deconvolution is its ability to perform localized analysis in both the time and frequency domains. Wavelets have a compact support and can capture localized features in the seismic data, making them effective in detecting and removing noise that is spatially and temporally confined. This localization property allows wavelet deconvolution to selectively remove noise while preserving the useful signal components.

2. Adaptability: Wavelets exhibit excellent adaptability to varying frequency content in seismic data. The multiscale nature of wavelets enables them to handle complex waveforms and transient signals commonly encountered in seismic recordings. This adaptability makes wavelet deconvolution suitable for addressing diverse noise sources, including random noise, ground roll, reverberations, and multiples.

3. Time-Frequency Resolution: Wavelet deconvolution provides a time-frequency representation of the seismic data, enabling a detailed analysis of the signal. By decomposing the data into different frequency components, wavelet deconvolution allows for a more accurate

representation of the signal's characteristics, such as amplitude and phase variations, at different scales. This improved time-frequency resolution helps in identifying and isolating noise components from the desired signal.

4. Preservation of Signal Features: Wavelet deconvolution has the advantage of preserving important features of the seismic signal during the noise reduction process. Unlike some other denoising techniques that may smooth or distort the signal, wavelet deconvolution retains the structural and textural details of the seismic data. This preservation of signal features is crucial for subsequent seismic interpretation and analysis.

2.5.2 DISADVANTAGES OF WAVELET DECONVOLUTION:

1. Wavelet Selection: The effectiveness of wavelet deconvolution heavily depends on the choice of wavelet function and its parameters. Selecting an appropriate wavelet that matches the characteristics of the seismic data and noise source is crucial for optimal noise reduction. However, wavelet selection can be challenging, and it requires expertise and careful analysis to ensure the chosen wavelet provides the desired denoising results.

2. Wavelet Estimation: Accurate estimation of the wavelet or impulse response is critical for successful wavelet deconvolution. The wavelet estimation process relies on various techniques, such as well-log information or other available data. However, obtaining an accurate estimation of the wavelet can be challenging, particularly in complex geological environments or when the reference data is limited.

3. Computational Complexity: Wavelet deconvolution can be computationally demanding, especially for large seismic datasets. The decomposition and reconstruction steps involved in wavelet transform operations require significant computational resources. Efficient algorithms and high-performance computing infrastructure are necessary to handle the computational complexity of wavelet deconvolution, which can increase the processing time and resource requirements.

4. Sensitivity to Noise Characteristics: The effectiveness of wavelet deconvolution may vary depending on the characteristics of the noise present in the seismic data. While wavelet deconvolution excels at reducing specific types of noise, such as random noise or ground roll, it

may not be equally effective in handling other types of noise, such as coherent noise or ambient noise. The performance of wavelet deconvolution can be influenced by the similarity between the noise and the chosen wavelet function.

It is important to note that the choice of noise reduction technique depends on the specific characteristics of the seismic data, the nature of the noise sources

METHODOLOGY

3.1 DATA ACQUISITION

Seismic data acquisition is an essential step in the exploration and production of oil and gas reserves. It involves capturing and recording subsurface information by generating and detecting seismic waves, which offer valuable insights into the geological structures and properties of the Earth's subsurface.

The process of seismic data acquisition typically encompasses the following key stages:

1. Survey Design: This initial step involves designing the seismic survey, including defining the survey area, selecting the survey geometry (e.g., 2D or 3D), and planning the placement of seismic sources (such as vibrators or explosives) and receivers (geophones or hydrophones).

2. Source Generation: Seismic sources, such as vibrators for land surveys or air guns for marine surveys, are employed to produce controlled energy waves that propagate through the subsurface. These waves travel through rocks, reflect off subsurface boundaries, and provide information about the layers, properties, and potential hydrocarbon reservoirs.

3. Wave Propagation: The generated seismic waves traverse the subsurface and interact with various geological formations. They undergo reflection, refraction, and diffraction at different interfaces, enabling the capture of valuable data about the rock layers and their characteristics.

4. Receiver Detection: Seismic receivers, strategically placed in the survey area, detect the seismic waves that have propagated through the subsurface. Geophones or hydrophones convert the mechanical vibrations of the waves into electrical signals, which are then recorded for subsequent analysis.

5. Data Recording: Data acquisition systems record the detected seismic signals. These systems capture the analog signals from the receivers and convert them into digital format

for storage and further processing. The recorded data includes essential parameters such as arrival time, amplitude, and other relevant information about the seismic waves.

6. Quality Control: Rigorous quality control measures are implemented throughout the data acquisition process to ensure data accuracy and reliability. This involves monitoring the performance of seismic sources and receivers, verifying data integrity, and addressing any technical or environmental issues that may affect the quality of the data.

7. Data Processing: After acquisition, the recorded seismic data undergoes extensive processing utilizing various techniques such as noise removal, deconvolution, velocity analysis, migration, and inversion. These processing methods aim to enhance the quality of the signals, improve resolution, and generate images or models of the subsurface structures.

8. Interpretation: Geoscientists and seismic interpreters analyze the processed seismic data to interpret subsurface features, identify potential reservoirs, and detect geological anomalies. This interpretation provides valuable insights that inform decision-making in exploration, reservoir characterization, and production planning.

Seismic data acquisition is a complex and sophisticated process that requires meticulous planning, precise execution, and stringent quality control. It plays a vital role in the oil and gas industry by enabling accurate imaging of the subsurface and facilitating the discovery and production of hydrocarbon resources.

3.2 SHEARWATER REVEAL SOFTWARE

Reveal, developed by Shearwater GeoServices, is a robust seismic processing software designed to support the analysis and interpretation of seismic data in the oil and gas industry.These are some of the key features Reveal has to offer:

1. Data Loading and Quality Control: Reveal offers efficient data loading capabilities, allowing users to import seismic data in various industry-standard formats. It includes reliable quality control tools to ensure data integrity and accuracy.

2. Pre-Stack Processing: The software provides a comprehensive suite of pre-stack processing tools. These tools encompass geometry correction, noise reduction, deconvolution, wavelet estimation, velocity analysis, and more. By improving the signal-to-noise ratio and resolving seismic reflections, these processes enhance data quality.

3. Time and Depth Imaging: Reveal supports both time and depth imaging workflows, featuring advanced algorithms for pre-stack time migration (PSTM), pre-stack depth migration (PSDM), and full waveform inversion (FWI). These imaging techniques enable detailed and accurate representations of subsurface structures.

4. Amplitude-Versus-Offset (AVO) Analysis and Inversion: Reveal empowers users to perform AVO analysis and inversion, extracting valuable information about subsurface lithology, fluid properties, and potential hydrocarbon indicators from seismic data.

5. Attribute Analysis: The software encompasses a wide range of attribute analysis tools tailored for seismic data. Users can extract and visualize various attributes such as coherence, AVO, curvature, and dip. These attributes provide additional insights into geological features and aid in interpretation.

6. 3D Visualization and Interpretation: Reveal offers powerful 3D visualization capabilities, allowing users to interactively navigate through seismic volumes. It supports horizon picking, fault interpretation, and the creation of geological models. This enhances the interpretation process and improves understanding of subsurface structures.

7. Collaboration and Integration: Reveal facilitates collaboration among geoscientists by supporting data exchange and integration with other software and workflows. It ensures seamless integration with industry-standard tools, enabling efficient collaboration on seismic projects.

8. Scalability and Performance: The software is designed to handle large-scale seismic datasets efficiently. It leverages parallel processing and optimization techniques to deliver high-performance computations and reduce processing time.

9. User-Friendly Interface: Reveal features an intuitive and user-friendly interface, allowing users to navigate the software with ease. It offers customizable workflows and display options,

empowering users to tailor the software to their specific needs and preferences.

Reveal is a comprehensive seismic processing software that empowers geoscientists and seismic interpreters with advanced tools for data processing, imaging, attribute analysis, and interpretation. Its user-friendly interface, scalability, and continuous development make it a valuable asset in the exploration and production of oil and gas resources.

3.3 PRE-PROCESSING

The pre-processing of seismic data is of paramount importance in the fields of geophysics and exploration geology as it plays a critical role in enhancing the quality, reliability, and interpretability of the data.
The process of pre-processing seismic data holds immense importance in the fields of geophysics and exploration geology. It serves as a crucial step in enhancing the overall quality, reliability, and interpretability of seismic data. By undertaking pre-processing, various benefits are achieved, including improved data quality, noise reduction, enhanced signal clarity, and consistent data integrity. These outcomes, in turn, facilitate more precise interpretations, minimize uncertainties, and provide a solid foundation for informed decision-making in diverse aspects of exploration and production within the oil and gas industry

3.3.1 DATA CONVERSION

The SEG Y format is widely used in the seismic industry to store and exchange seismic data. It is a binary file format that comprises a series of 3200-byte trace headers followed by the seismic trace data.

Each trace header in the SEG Y format contains essential information about the seismic data, such as sample rate, number of samples, data format, acquisition parameters, and trace identification. The trace data represents the amplitude values recorded at regular time intervals.

When converting data from SEG Y format in Reveal, a seismic processing software, the software utilizes sophisticated algorithms and functions to read and interpret the SEG Y file. It extracts the trace headers and seismic trace data from the SEG Y file and applies various processing steps to manipulate and enhance the data, improving its quality and making it more suitable for analysis and interpretation.

3.3.2 BINNING DATUM

Binning datum refers to the process of organizing seismic data into bins or grid cells to facilitate structured analysis. In Reveal, a seismic processing software, binning datum is accomplished using specific functionalities and algorithms designed for spatial organization.

Here is a breakdown of how this process is carried out in Reveal:

Creation of Spatial Grid: The first step involves defining the binning grid by specifying the dimensions of the grid, such as the number of cells in the x, y, and z directions, as well as the size of each grid cell. The grid can be regular, with uniform cell sizes, or irregular, with varying cell sizes or shapes based on the survey area.

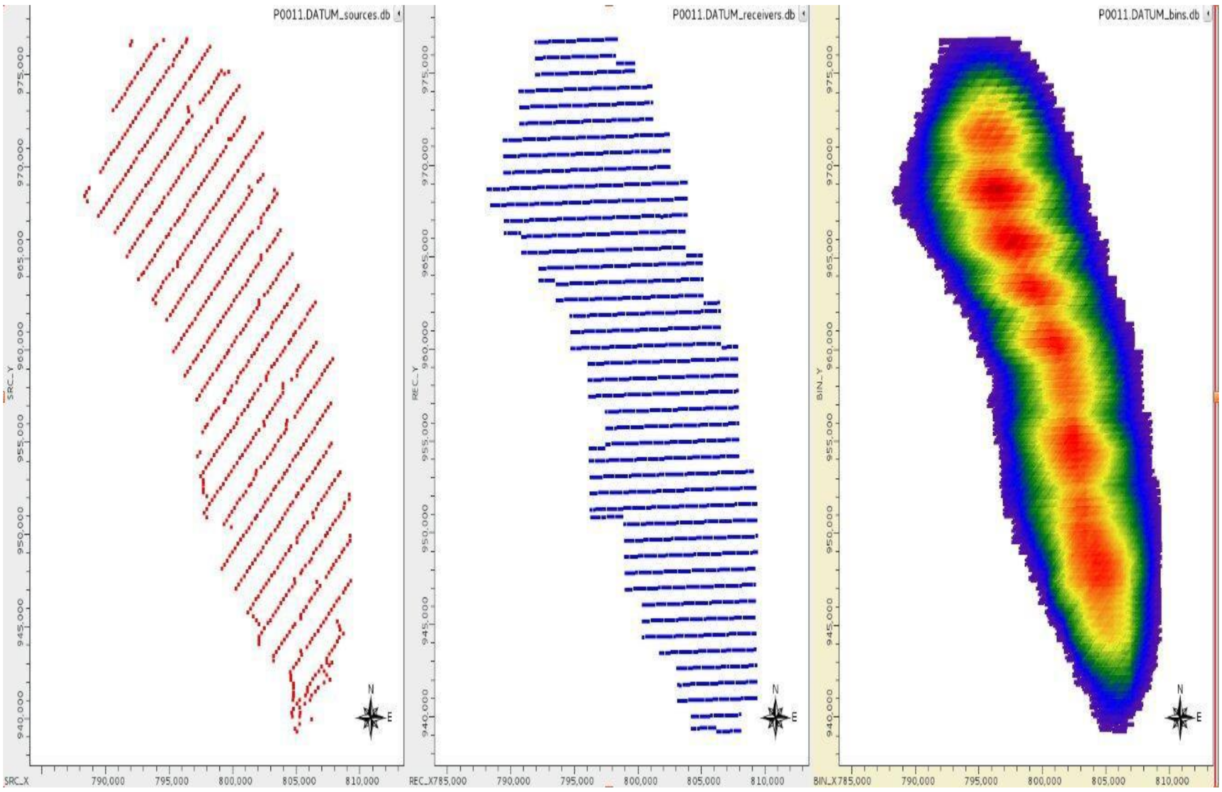
1. Trace Assignment: Once the grid is established, the seismic traces are assigned to their respective grid cells based on their spatial coordinates. Reveal utilizes trace headers containing information like x, y, and z coordinates to determine the appropriate bin for each trace. This assignment is automated within the software using the predefined grid parameters.

2. Binning Parameters: Binning in Reveal also involves specifying additional parameters to optimize the process based on specific objectives or requirements. These parameters may include trace density preferences within each bin or the desired sorting order of traces within each cell.

3. Data Aggregation: After trace assignment, the seismic data is aggregated within each bin. This aggregation encompasses various operations such as stacking, averaging, or statistical analysis, allowing for the generation of representative data within each bin. These operations aid in reducing noise, improving signal quality, and providing a consolidated view of the data within each grid cell.

4. Binned Data Output: The final outcome of the binning datum process in Reveal is a gridded representation of the seismic data. Each grid cell contains a summarized representation of the seismic information, facilitating easier visualization, analysis, and interpretation. The binned data can be further processed and analyzed using other tools and functionalities within Reveal or exported for utilization in external software or workflows.

Figure 3.3.2 : Binning Datum at source and receiver



3.3.3 GEOMETRYY DATUM

Geometry datum, in the context of seismic data processing, refers to a fundamental reference point or coordinate system used to define the spatial positioning of seismic traces within a seismic dataset. It serves as the basis for accurately locating seismic measurements and interpreting the subsurface structure.

In the seismic processing software Reveal, establishing the geometry datum involves a series of steps:

1. Defining the Coordinate System: Users can define the coordinate system parameters within Reveal, including the measurement units, origin (reference point), and orientation.

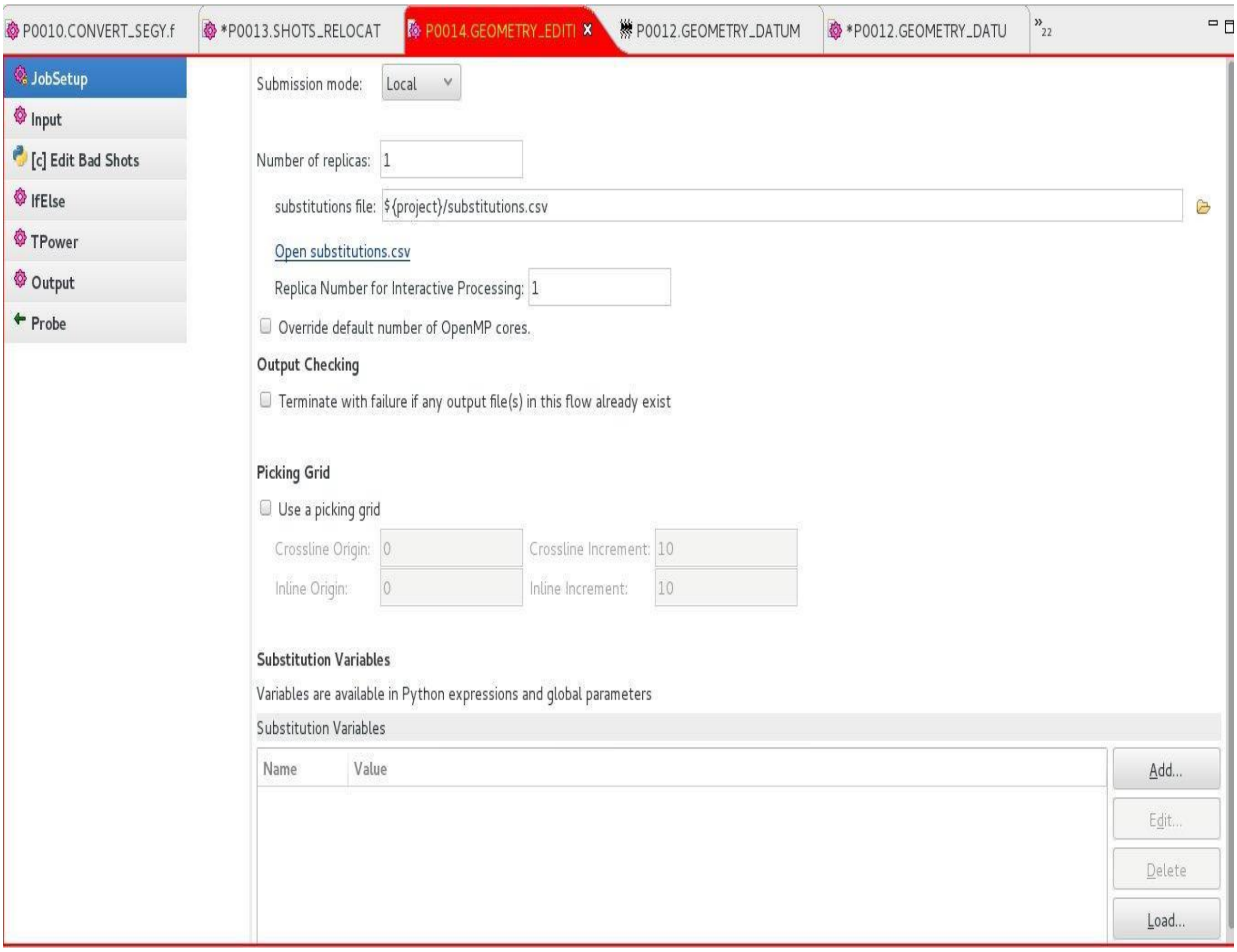
2. Trace Positioning: Reveal provides tools to assign spatial positions to individual seismic traces based on their recorded locations. This can be accomplished using navigation data from systems like GPS or inertial measurement units (IMUs) utilized during data acquisition.

3. Datum Transformation: If the seismic data was acquired in a different coordinate system

than the desired geometry datum, Reveal allows users to perform datum transformations. This involves accurately converting the trace coordinates from the original system to the desired geometry datum using mathematical algorithms.

4. Geometry Quality Control and Editing: Reveal incorporates quality control tools to evaluate the accuracy and consistency of the geometry datum. Users can visually assess the spatial distribution of seismic traces, identify any outliers or inconsistencies, and make necessary adjustments to ensure alignment with the desired geometry datum.

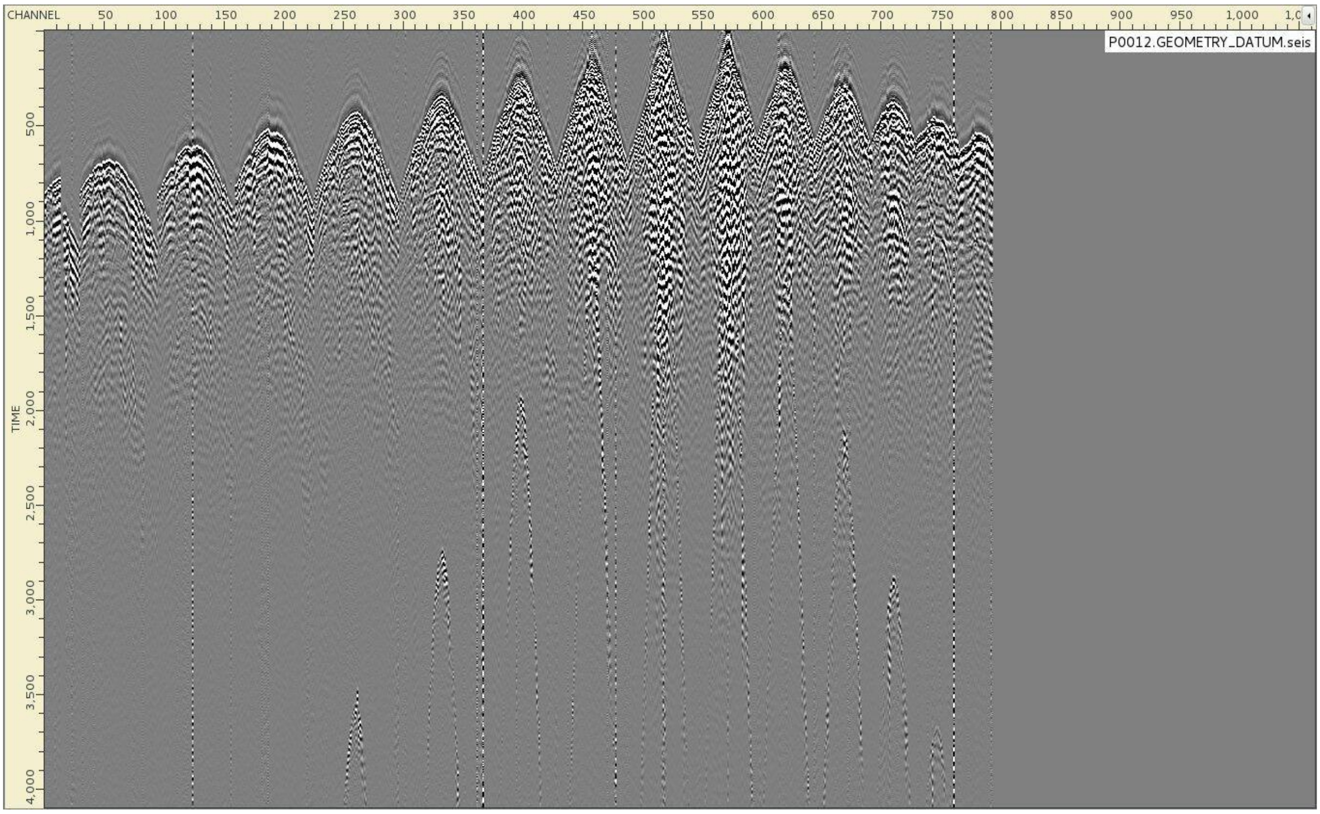
Figure 3.3.3 : Geometry datum processing flow in reveal



1. Geometry Correction: In situations where errors or discrepancies are identified in the geometry datum, Reveal offers tools to correct and refine the positions of seismic traces. This may include applying corrections based on known reference points or utilizing interactive editing features to manually adjust individual trace positions.

By precisely establishing the geometry datum in Reveal, users can ensure that seismic traces are accurately positioned in the spatial domain. This facilitates reliable interpretation of subsurface structures, accurate analysis of amplitudes, and the extraction of dependable attributes.

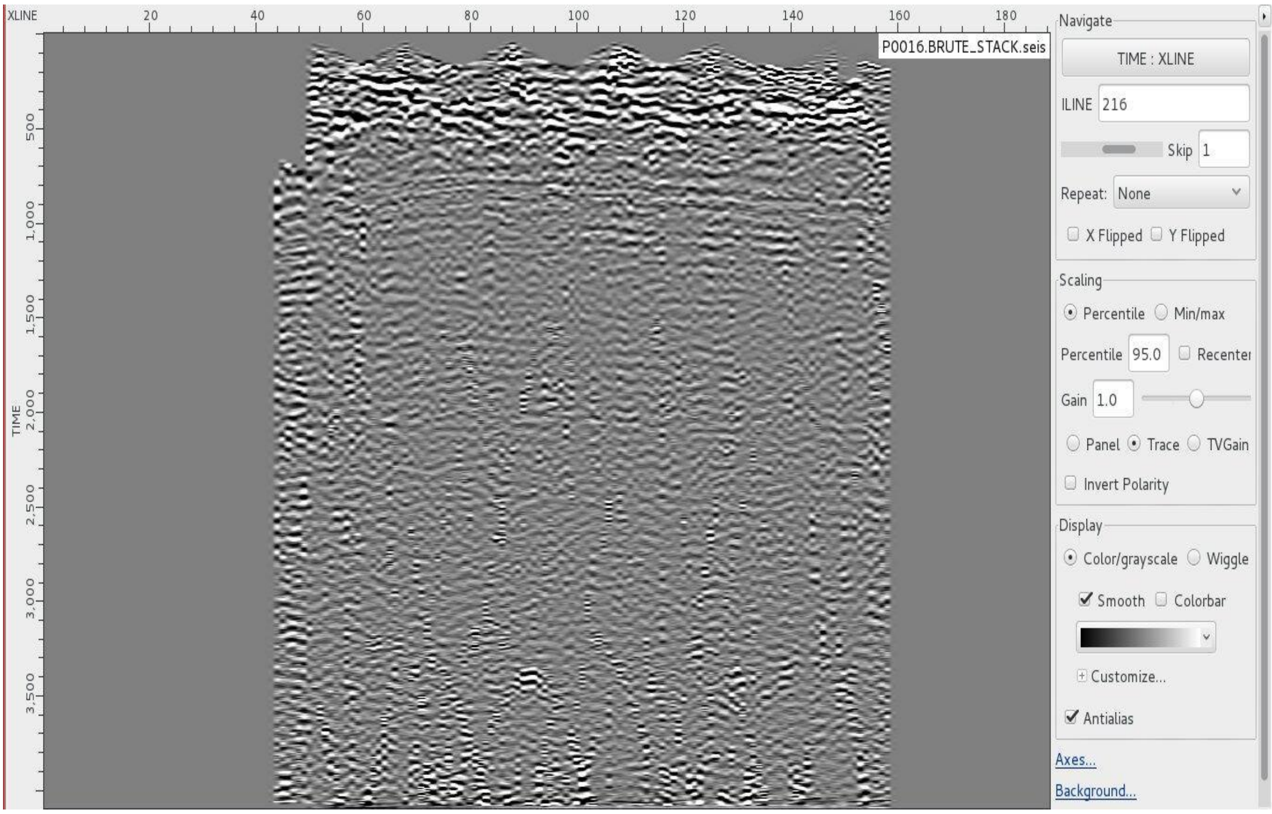
Figure 3.3.3.1 : Seismic section with geometry correction done



3.3.4 FIRST BRUTE STACK

The primary objective of the brute stack process in Reveal, as well as in seismic data processing as a whole, is to improve the quality and interpretability of seismic images. By combining and stacking seismic traces, the coherent signals are amplified, resulting in enhanced visibility of subsurface features, while random noise is minimized. Ultimately, this process provides high-quality seismic data for detailed analysis, interpretation, and informed decision-making in various applications within the oil and gas industry. This first brute stack is being done just to see if the sections are starting to make geological sense. This gives an idea of what the geology of the area is as well as some of the very evident structures within the subsurface.

Figure 3.3.4 : Brute Stack



3.3.5 REFRACTION STATICS

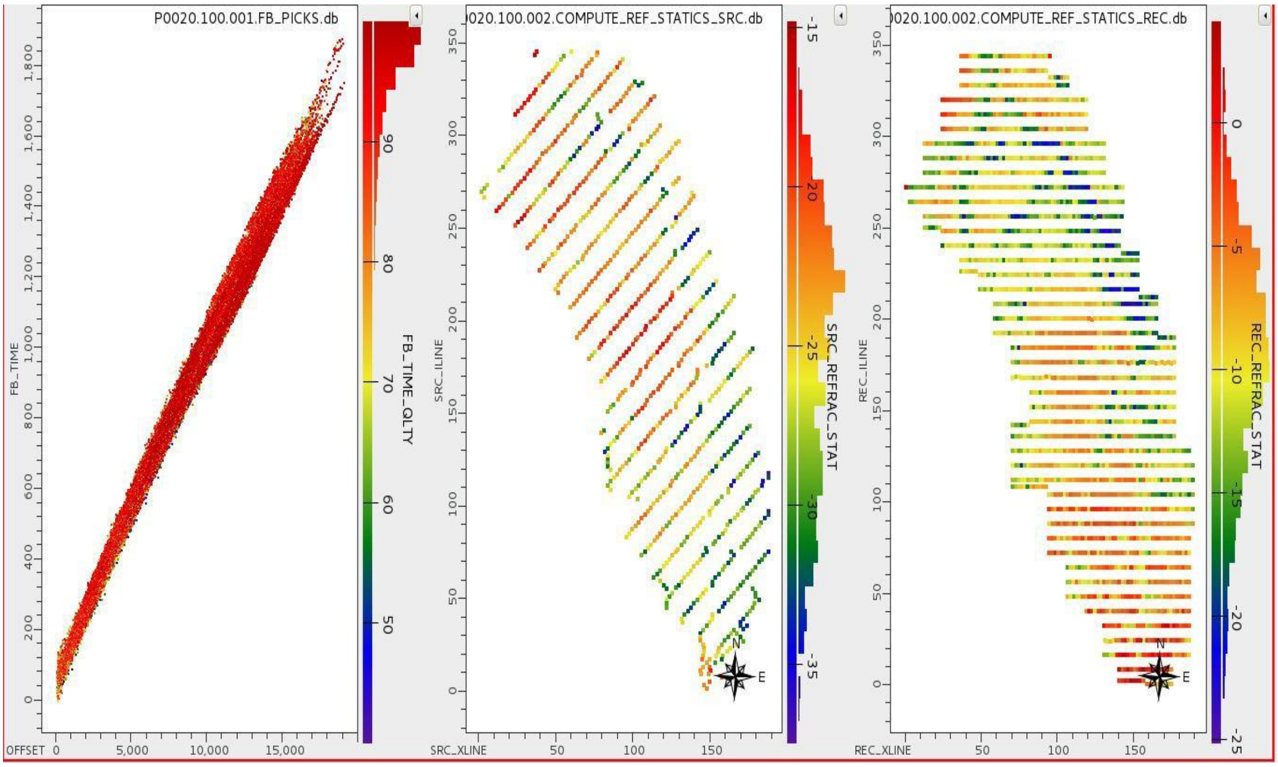
Refraction statics correction or refraction statics analysis, is an essential process in seismic data processing. Its main objective is to account for the influence of velocity variations near the surface on seismic data. By adjusting for the time delays caused by changes in seismic wave velocity as they traverse different subsurface layers, refractor statics enables more accurate imaging of the subsurface.The incorporation of refraction statics within Reveal is instrumental in enhancing the precision and dependability of seismic data interpretation by mitigating the impact of near-surface velocity anomalies. This process significantly improves the clarity of subsurface structure imaging and enhances the capability to detect and map geological characteristics, such as faults, stratigraphic layers, and potential hydrocarbon reservoirs. Refraction statics analysis in Reveal is a vital element that ensures the accurate and reliable analysis of seismic data.

3.3.5.1 FIRST BREAK PICKING

First break picking is an essential step in the processing of seismic data. It involves the identification of the exact arrival time of the initial and prominent energy arrival, known as the "first break," within seismic traces. This arrival time holds valuable information about the subsurface layers and finds applications in tasks such as calculating seismic velocities and constructing seismic models.The significance of first break picking in refraction statics correction lies in its ability to provide reliable information about the velocity structure of the subsurface. Accurately identifying the first break enables the estimation of travel times and velocities of seismic waves as they propagate through the subsurface layers.

By ensuring precise first break picking, the refraction statics correction process can effectively account for velocity variations and accurately position seismic events in time. This leads to improved subsurface imaging and interpretation, ultimately enhancing the overall quality and reliability of seismic data analysis in exploration and geophysical studies.

Figure 3.3.5.1: First break pick



3.4 NOISE ATTENUATION

In the realm of seismic data analysis, noise refers to unwanted signals or disturbances that interfere with the desired seismic signals. It poses a significant challenge in accurately interpreting subsurface information and affects the overall quality and reliability of seismic data. Understanding the distinct characteristics of different types of noise is crucial for effectively processing and interpreting seismic data.

1. Ambient Noise: Ambient noise arises from natural sources and encompasses various signal types unrelated to the subsurface structure under investigation. This includes phenomena like wind, ocean waves, and earthquakes. Ambient noise can mask or overshadow the desired seismic signals, leading to a diminished signal-to-noise ratio (SNR) and potentially obscuring important subsurface features.

2. Anthropogenic Noise: Anthropogenic noise is generated by human activities and has a notable impact on seismic data. Examples of anthropogenic noise sources include transportation (road and air traffic), construction, and industrial operations. Anthropogenic noise tends to occur at higher frequencies and may overlap with the frequency range of seismic signals. This can distort or mask seismic signals, reducing the overall SNR and affecting data quality.

3. Instrumental Noise: Instrumental noise arises from sensors or electronic components used in the data acquisition system. Imperfections in sensors, electronic interference, and other instrumental factors introduce noise into the recorded seismic data. Instrumental noise can influence the accuracy and reliability of seismic measurements, resulting in errors during data analysis and interpretation.

Each type of noise exhibits specific characteristics that impact seismic data:

1. Frequency: Noise can span a broad range of frequencies. Ambient noise, such as wind and ocean waves, covers a wide frequency range, while anthropogenic noise tends to be concentrated at higher frequencies. Instrumental noise can manifest in different frequency bands depending on the characteristics of the data acquisition system.

2. Amplitude: Noise varies in amplitude, ranging from minor fluctuations to significant disturbances. The amplitude of noise signals determines their visibility in relation to the desired seismic signals. High-amplitude noise can overpower weak seismic signals, making them challenging to detect and analyze.

3. Temporal Variability: Noise can exhibit temporal variability, fluctuating over time. For example, anthropogenic noise levels may vary throughout the day or week due to changes in human activity patterns. Considering the temporal variability of noise is important when designing data acquisition strategies and processing techniques.

3.4.1 AIRBLAST NOISE

Airblast noise pertains to a form of anthropogenic noise that arises from the detonation of explosives. This specific type of noise has notable implications for the quality and interpretation of seismic data. Airblast noise can be identified on seismic data through several distinctive characteristics. Below, are key indicators to recognize the presence of airblast noise:

1. Abrupt Amplitude Increase: Airblast noise typically manifests as a sudden and significant spike in the amplitude of seismic traces. This sharp rise in signal intensity stands out among the surrounding seismic signals.

2. High-Frequency Content: Airblast noise often exhibits a concentration of energy in the higher frequency range of the seismic data. It appears as a short-duration, sharp signal compared to the longer-duration seismic reflections.

3. Repetitive Pattern: Airblast noise generated by explosive detonations during seismic surveys may display a repetitive pattern. This pattern occurs due to the systematic nature of the explosive source, with repeated detonations happening at regular intervals.

4. Lack of Geological Correlation: Unlike seismic reflections that correspond to subsurface geological features, airblast noise does not exhibit a coherent relationship with the targeted geological structures. Instead, it appears as random or non-geological events on the seismic section.

5. Spatial Consistency: Airblast noise caused by explosives tends to be spatially consistent across seismic traces or shot locations. If the noise consistently appears throughout the seismic data, it suggests the presence of airblast noise.

By carefully analyzing these characteristics, including abrupt amplitude changes, high- frequency content, repetitive patterns, lack of geological correlation, and spatial consistency, one can effectively identify and differentiate airblast noise from the desired seismic reflections. This recognition is vital for accurate interpretation and analysis of subsurface information in seismic data.

3.4.1.1 CONCEPT BEHIND THE AIR BLAST NOISE

The physics concept behind air blast noise pertains to the transmission of pressure waves through the air medium. When a compressed air source or explosive charge is discharged, it initiates a sudden and intense surge in air pressure. This heightened pressure subsequently expands outward from the source as a compression wave, commonly known as a blast wave.As the blast wave travels through the air, it generates alternating regions of high and low pressure, causing fluctuations in air pressure that manifest as sound waves. These sound waves are perceived as noise and can be detected by seismic sensors.

During seismic data acquisition, the presence of air blast noise presents a significant challenge as it interferes with the desired seismic signals, impacting the acquisition of accurate and reliable data. The noise contaminates the recorded seismic traces, leading to a decreased signal- to-noise ratio and compromising the quality of the seismic data.

3.4.1.2 DENOISING PROCESS FOR THE AIRBLAST NOISE IN REVEAL

The denoising process in Reveal, a seismic processing software, is specifically designed to address air blast noise. This process involves several sequential steps and utilizes various techniques to effectively reduce or remove the impact of air blast noise from seismic data. Here is an overview of the denoising process in Reveal:

1. Initial data assessment: The seismic data is thoroughly examined to identify the presence of air blast noise. This can be achieved by visually inspecting the seismic traces or conducting frequency analysis to detect noise-related frequency peaks.

2. Noise characterization: Once air blast noise is identified, its characteristics are estimated. Reveal employs advanced algorithms and statistical methods to determine the dominant frequency range, statistical properties, and temporal behavior of the noise.

3. Noise reduction techniques: Reveal employs a combination of denoising techniques tailored to air blast noise mitigation. These techniques include:

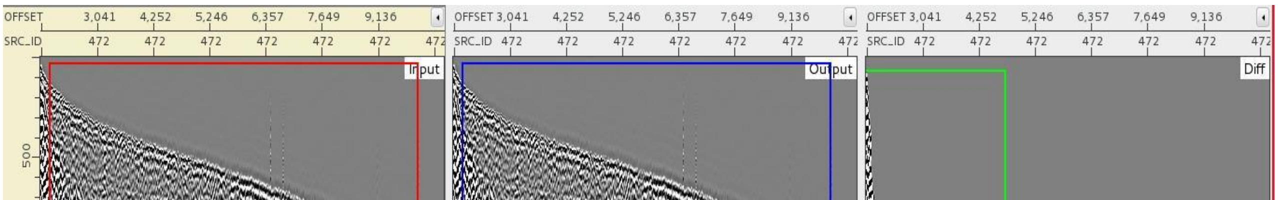
4. Frequency domain filtering: By applying bandpass or frequency domain filters, the software selectively attenuates the noise within the identified dominant frequency range associated with air blast noise. This allows the preservation of desired seismic signals while reducing the noise components.

5. Statistical denoising: Reveal utilizes statistical methods to model the noise and separate it from the seismic data. Techniques like spectral subtraction, wavelet denoising, or time- frequency analysis are applied to identify and suppress the noise components based on their statistical properties.

6. Adaptive filtering: Reveal incorporates adaptive filtering algorithms that dynamically adjust their parameters based on the specific characteristics of the air blast noise. These filters continuously update their coefficients to minimize the impact of the noise while preserving the desired seismic signals.

7. Quality evaluation: Following the denoising process, Reveal performs a thorough assessment of the denoised seismic data. This evaluation includes analyzing the signal-to-noise ratio, comparing the denoised data with reference or pre-denoising data, and conducting visual inspections to ensure the effective removal of air blast noise without significant distortion of seismic signals.

Figure 3.1.4.2 : Quality evaluation for the air blast noise removal



By following these steps and employing specialized denoising techniques, Reveal aims to enhance the quality of seismic data by effectively reducing or eliminating air blast noise. This enables more accurate interpretation and analysis in various seismic applications.

3.4.2 GROUND ROLL NOISE

Ground roll noise refers to a distinct type of noise commonly encountered in seismic data, characterized by the presence of low-frequency energy that manifests as a noticeable waveform or oscillation within the seismic traces. It arises due to the interaction between seismic waves and near-surface geological features, such as weathered layers, soft sediments, or fluid-filled formations.

The term "ground roll" is used to describe this noise owing to its specific rolling or wave-like pattern. It typically exhibits a continuous, low-frequency oscillation with a relatively smooth waveform. Ground roll noise generally occupies a frequency range lower than that of the desired seismic signals, typically spanning from a few hertz to several tens of hertz.

Several key characteristics help identify ground roll noise in seismic data:

1. Low Frequency: Ground roll noise predominantly consists of low-frequency energy, exhibiting a slower oscillation compared to higher-frequency seismic signals.

2. Broadband Spectrum: The energy of ground roll noise extends across a range of frequencies, encompassing the lower end of the seismic spectrum.

3. Continuous Waveform: Ground roll noise appears as a continuous waveform that persists throughout the seismic data, displaying a rolling or undulating pattern.

4. Dispersion: Ground roll noise experiences frequency-dependent dispersion, leading to a frequency-dependent arrival time of the ground roll waveform across different seismic traces.

5. Non-reflective Nature: Ground roll noise is typically non-reflective and does not provide direct information about subsurface reflectors or geological structures.

Comprehending the characteristics of ground roll noise is vital for its identification and subsequent reduction or suppression during seismic data processing. By distinguishing ground roll noise from desired seismic signals, processing techniques can be applied to mitigate its impact and enhance the clarity and interpretability of the seismic data.

3.4.2.1 CONCEPT BEHIND THE GROUND ROLL NOISE

Ground roll noise in seismic data is a result of the physical interaction between seismic waves and geological features near the Earth's surface. This phenomenon occurs when surface waves, such as Love waves and Rayleigh waves, propagate along the Earth's surface instead of penetrating deeper into the subsurface.

Love waves are horizontally polarized shear waves that travel near the surface, while Rayleigh waves combine longitudinal and transverse motion. These waves are generated by seismic sources and interact with near-surface geological layers, such as weathered layers, soft sediments, or fluid-filled formations.

When seismic waves encounter these near-surface features, changes in velocity and impedance occur, leading to partial reflection, transmission, and diffraction. The interaction between the incident waves and the near-surface layers gives rise to ground roll noise.

Ground roll noise is characterized by low-frequency energy, which arises from the longer wavelengths of surface waves. These waves travel longer distances and interact with a larger surface area, resulting in the continuous, low-frequency oscillation observed in seismic data.

The specific attributes of ground roll noise, including its rolling or wave-like pattern, low frequency, broadband spectrum, and non-reflective nature, can be comprehended by considering the physics of surface wave propagation and their interaction with near-surface geology.

To summarize, the physics behind ground roll noise involves the interaction between surface waves and near-surface geological features. It encompasses the generation, propagation, reflection, and diffraction of surface waves, which ultimately give rise to the distinct characteristics observed in seismic data.

3.4.2.2 DENOISING PROCESS FOR THE GROUND-ROLL NOISE

The ground roll denoising process in Reveal, a seismic processing software, aims to effectively remove or suppress the unwanted ground roll noise present in seismic data. Ground roll noise typically appears as low-frequency energy and can obscure or distort the seismic signals of interest.

Within Reveal, the ground roll denoising process involves several sequential steps:

1. Frequency Filtering: The seismic data is subjected to a bandpass filter to isolate the frequency range associated with the ground roll noise. This filter selectively reduces the unwanted low-frequency energy while preserving the desired seismic signals.

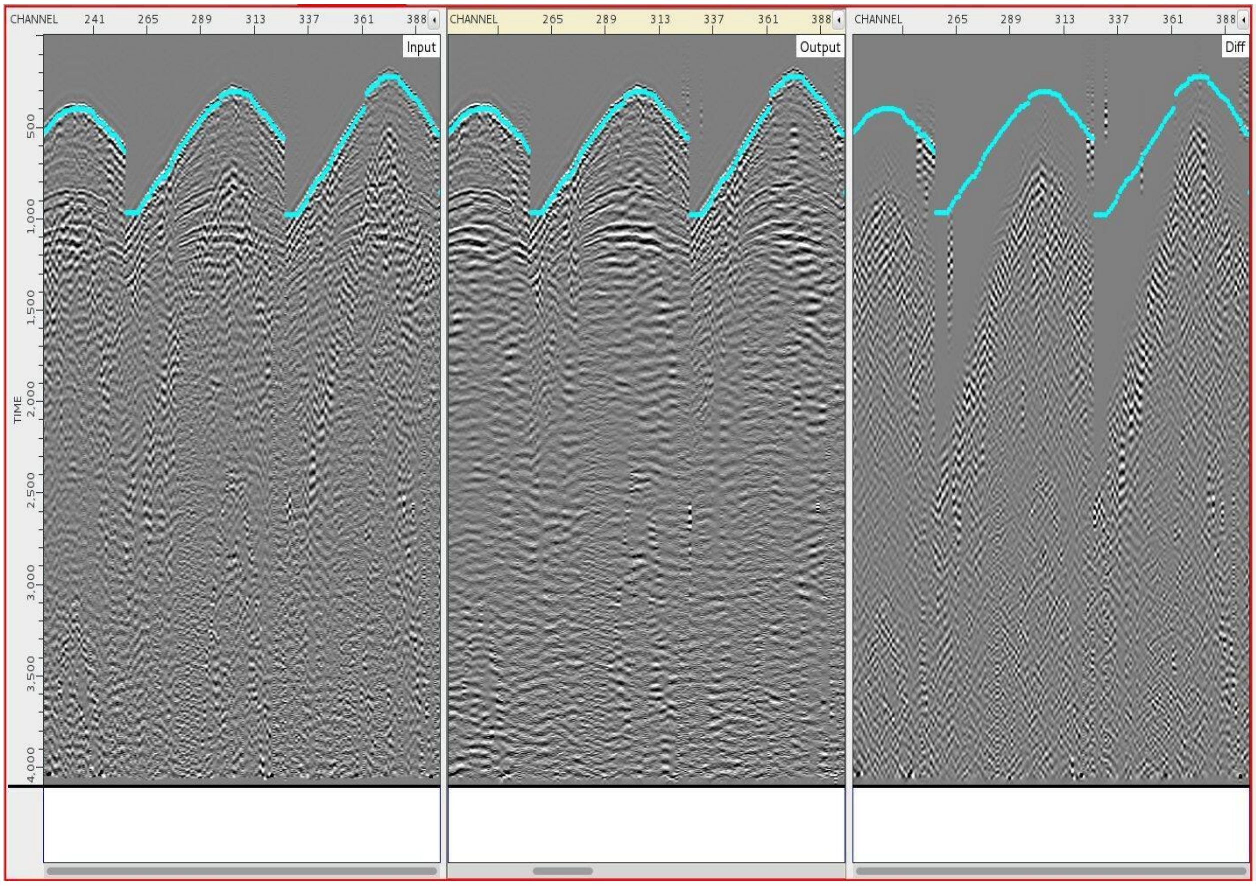
2. Time-Frequency Analysis: Time-frequency analysis techniques, such as the Short-Time Fourier Transform (STFT) or the Continuous Wavelet Transform (CWT), are utilized to decompose the seismic data into time-frequency components. This analysis helps identify the time intervals and frequency bands where the ground roll noise is most prominent.

3. Ground Roll Estimation: Based on the identified time-frequency components, an estimation of the ground roll noise is derived. This estimation incorporates statistical properties or specific characteristics of the ground roll noise.

4. Noise Subtraction: The estimated ground roll noise is then subtracted or attenuated from the original seismic data. Various techniques, such as adaptive subtraction algorithms or spectral shaping methods, are employed to effectively eliminate the ground roll noise while minimizing any adverse effects on the desired seismic signals.

5. Quality Control: To ensure the denoising process is successful, quality control measures are applied. Visual inspection, data comparisons, and quantitative assessments of the signal-to- noise ratio and preservation of important seismic features are performed to evaluate the accuracy and reliability of the resulting seismic data.

Figure 3.4.2.2 : Quality evaluation for ground roll noise removal



Reveal's ground roll denoising process utilizes advanced algorithms and signal processing techniques to efficiently reduce the impact of ground roll noise on seismic data. By eliminating or suppressing this unwanted noise, the software enhances the quality and interpretability of the seismic data, enabling more accurate analysis and interpretation of subsurface structures.

3.5 SCAMP CORRECTION

The SCAMP correction, also known as Surface Consistent Amplitude and Phase correction, is a seismic data processing technique employed to address variations in amplitude and phase response caused by near-surface effects. This method is crucial for ensuring accurate and reliable interpretation of seismic data and subsequent processing stages.

Near-surface layers, including weathering, topographic irregularities, and shallow geological structures, can introduce distortions to the seismic wavefield, leading to frequency-dependent changes in amplitude, phase shifts, and variations in reflection amplitudes. These distortions pose challenges to accurately interpreting the subsurface.

To overcome these near-surface distortions, the SCAMP correction technique is applied to seismic traces. It involves estimating the amplitude and phase response of the near-surface layers using methods like stacking or velocity analysis. These estimated responses are then utilized to calculate correction values for each seismic trace.

The SCAMP correction is typically performed in the common midpoint (CMP) domain, where seismic traces from different source-receiver offsets are collected and analyzed. Correction values are determined by comparing the amplitudes and phases of seismic traces at each CMP location with the estimated near-surface response. These correction values are then applied to the seismic traces to restore the desired amplitude and phase characteristics.

By applying the SCAMP correction, the seismic data is effectively normalized, compensating for the effects of near-surface layers. This normalization enables more precise amplitude analysis, improved identification of subtle subsurface features, and enhanced imaging of geological structures.

It is important to consider factors such as data quality, survey design, and the complexity of the near-surface geology when estimating the near-surface response in the SCAMP correction process. Iterative approaches may be utilized to refine the correction values and optimize the accuracy of the correction.

3.6. AUTO-CORRELATION

Auto-correlation is a fundamental technique used in seismic data processing to assess the similarity between a seismic trace and a time-shifted version of itself. It measures the correlation or resemblance between adjacent samples within a single trace.

When performing SCAMP (Surface Consistent Amplitude and Phase) correction, auto-correlation plays a crucial role and holds great importance. It is utilized to estimate the response of the near-surface layers and extract valuable information about the seismic wavefield.

By applying auto-correlation to seismic traces, we can identify recurring patterns and gain insights into the periodicity, dominant frequencies, and time delays present in the data.

In the context of SCAMP correction, auto-correlation helps determine the surface-consistent amplitude and phase response of the near-surface layers. By applying auto-correlation to seismic traces with different offsets, we can detect variations in amplitude and phase caused by the near-surface effects.

Through auto-correlation analysis, we can recognize repetitive patterns and shifts in the seismic wavefield resulting from the near-surface layers. This information is essential for accurately estimating the near-surface response, which is crucial for effective SCAMP correction.

The estimated near-surface response obtained through auto-correlation is then used to calculate correction values for each seismic trace. These correction values compensate for the amplitude and phase distortions caused by the near-surface effects.

The significance of auto-correlation in SCAMP correction lies in its ability to characterize and quantify near-surface variations. By accurately estimating the near-surface response, SCAMP correction can effectively normalize seismic data and minimize the impact of near-surface distortions.

Additionally, auto-correlation assists in identifying time shifts and frequency changes resulting from the near-surface effects. This information is vital for aligning and correcting seismic traces, restoring the desired amplitude and phase characteristics.

By providing a clearer representation of subsurface structures and reflectivity, accurate estimation of the near-surface response through auto-correlation enhances the interpretation of seismic data. It improves data quality, reduces the influence of near-surface distortions, and contributes to more reliable and precise SCAMP correction.

In summary, auto-correlation is a fundamental component of SCAMP correction, enabling the assessment of near-surface response and facilitating the correction of amplitude and phase variations induced by near-surface effects. Its role in improving seismic data quality and supporting accurate interpretation and analysis is of significant importance.

3.7 TRACE BY TRACE DECONVOLUTION

Trace-by-trace deconvolution also known as Wavelet deconvolution is a seismic data processing technique that focuses on removing the influence of the earth's filter from individual seismic traces. Its purpose is to restore the original waveform of each trace by dividing it with an estimated earth's filter response.

To perform trace-by-trace deconvolution, an estimate of the earth's filter response is obtained using a reference waveform, such as a well-recorded trace or a synthetic waveform based on known subsurface properties. This reference waveform represents the desired seismic signal without the effects of the earth's filter.

Using convolutional deconvolution, a mathematical operation, the seismic trace is divided by the estimated earth's filter response in the frequency domain. This operation effectively cancels out the effects of the earth's filter, resulting in improved signal quality.

The primary goals of trace-by-trace deconvolution are to enhance resolution, maintain accurate amplitude representation, and overall improve the quality of seismic traces. By removing the distortions introduced by the earth's filter, it enables a clearer visualization of geological features, enhances the identification of subsurface reflections, and facilitates more accurate interpretation of the seismic data.

Trace-by-trace deconvolution treats each trace individually, allowing for tailored processing of different seismic signals. This approach takes into consideration the unique characteristics and variations present in each trace, ensuring precise removal of the earth's filter effects.

3.7.1 PARAMETER TERMINOLOGIES USED DURING DECONVOLUTION

1. GAP LENGTH: The gap length parameter in the deconvolution process determines the maximum allowable size of missing data or gaps in the seismic traces during the operation. It controls how Reveal software handles traces with incomplete or absent data.

When performing deconvolution in Reveal, it is common to encounter traces that have gaps or missing data due to various factors like data acquisition issues or processing artifacts. The gap length parameter allows users to specify the maximum size of these gaps.

During deconvolution, Reveal applies the deconvolution operator to each trace, which requires continuous data. If a gap in a trace exceeds the specified gap length, it is considered too large and is not deconvolved. In such cases, the deconvolution process skips or ignores these gaps, preserving the original data in those areas.

Selecting an appropriate gap length is important as it affects how the deconvolution process handles missing data. A longer gap length allows larger gaps to be tolerated, but it may result in less accurate deconvolution results when dealing with significant data gaps. On the other hand, a shorter gap length ensures that only smaller gaps are processed, but it may lead to incomplete deconvolution for traces with longer gaps.

The choice of gap length depends on the specific characteristics of the seismic data, the extent of missing data, and the desired deconvolution objectives.

2. OPERATOR LENGTH: In Reveal, users are given the flexibility to define the operator length as part of the deconvolution settings. The choice of operator length takes into account several factors, such as the unique characteristics of the seismic data, the desired level of deconvolution, and the specific project goals. Increasing the operator length allows for a more detailed deconvolution process, effectively removing shorter-duration events or undesired effects from the seismic traces.

However, it's important to note that using a longer operator length can introduce potential distortions or artifacts in the data, especially if it exceeds the actual duration of the seismic events of interest. On the other hand, opting for a shorter operator length better preserves the high-frequency content of the seismic data, but it may not effectively eliminate longer-duration events or unwanted effects. Striking the right balance in determining the optimal operator length involves weighing the need to maintain signal fidelity against mitigating undesired effects. This careful trade-off ensures that the deconvolution process achieves the desired outcome while minimizing any potential drawbacks.

3.7.2 PARAMETER TEST

Parameter testing plays a vital role in seismic data processing, offering substantial importance in achieving accurate and reliable results. By systematically exploring and evaluating different processing parameters, researchers can optimize the outcome and ensure a faithful representation of subsurface features.

The significance of parameter testing lies in its ability to assess the impact of various processing parameters on seismic data. Through methodical testing of different parameter combinations, researchers can analyze their effects on data quality, signal enhancement, noise reduction, and the preservation of essential geological characteristics.

Parameter testing allows for the fine-tuning of processing algorithms to achieve optimal results. It helps identify parameter settings that amplify weak signals, reduce noise, improve resolution, and maintain amplitude fidelity. This iterative process of testing and refining parameters leads to enhanced data quality and a deeper understanding of the information embedded in the seismic data.

Furthermore, parameter testing aids in recognizing and addressing potential artifacts and biases introduced during processing. By systematically varying parameters, researchers can identify combinations that introduce unwanted effects or distortions. Thorough testing and evaluation enable the minimization or elimination of these artifacts, ensuring the integrity and reliability of the processed seismic data.

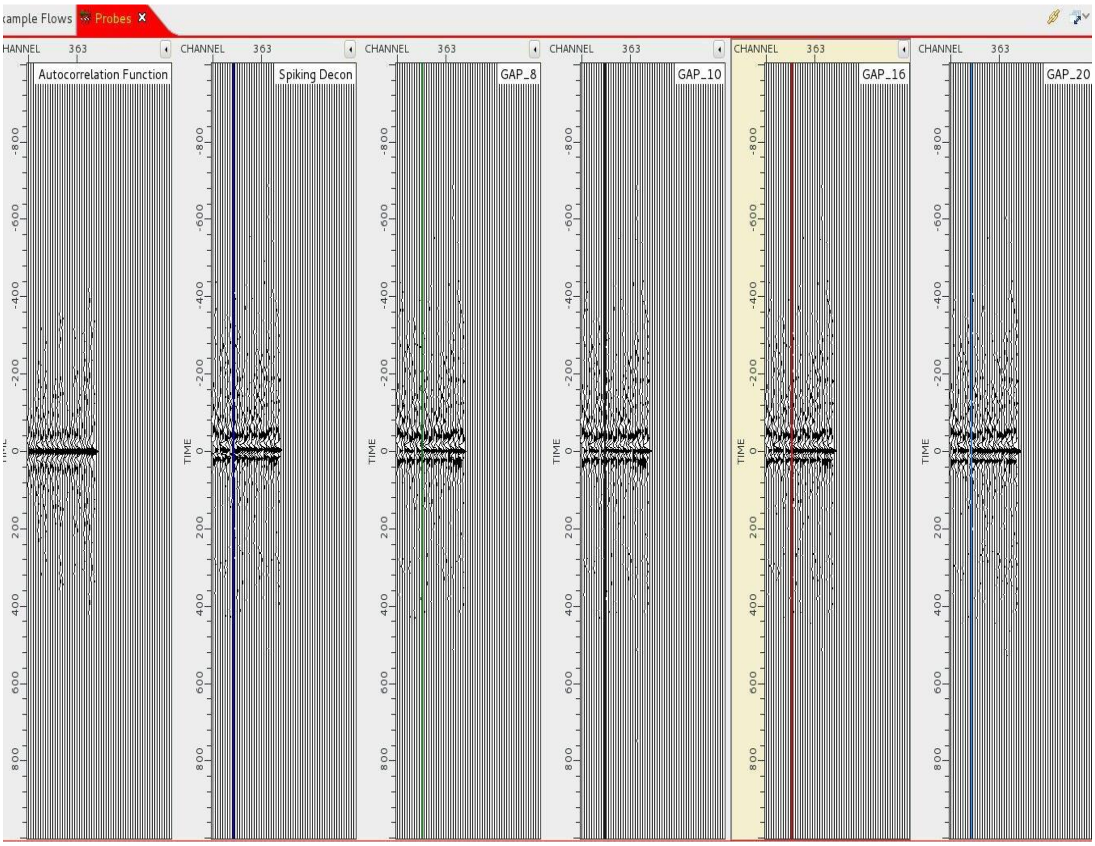
Additionally, parameter testing provides insights into the sensitivity of processing algorithms to different parameter choices. It helps researchers understand the trade-offs between parameters and make informed decisions based on specific goals and requirements. This knowledge assists in selecting appropriate parameter values tailored to the geological context, data characteristics, and exploration objectives.

In conclusion, parameter testing is a crucial step in seismic data processing, enabling parameter optimization, algorithm refinement, and artifact identification. It significantly contributes to improving data quality, enhancing signal interpretation, and ensuring the reliability of seismic data for accurate subsurface characterization and informed decision-making in exploration endeavors.

3.7.2.1 PARAMETER TEST FOR THE GAP LENGTH

During the parameter test for the Gap length, several lengths were tested but the following values chosen below were picked according to my preference.

Figure 3.6.2.1 : Parameter test for the gap length

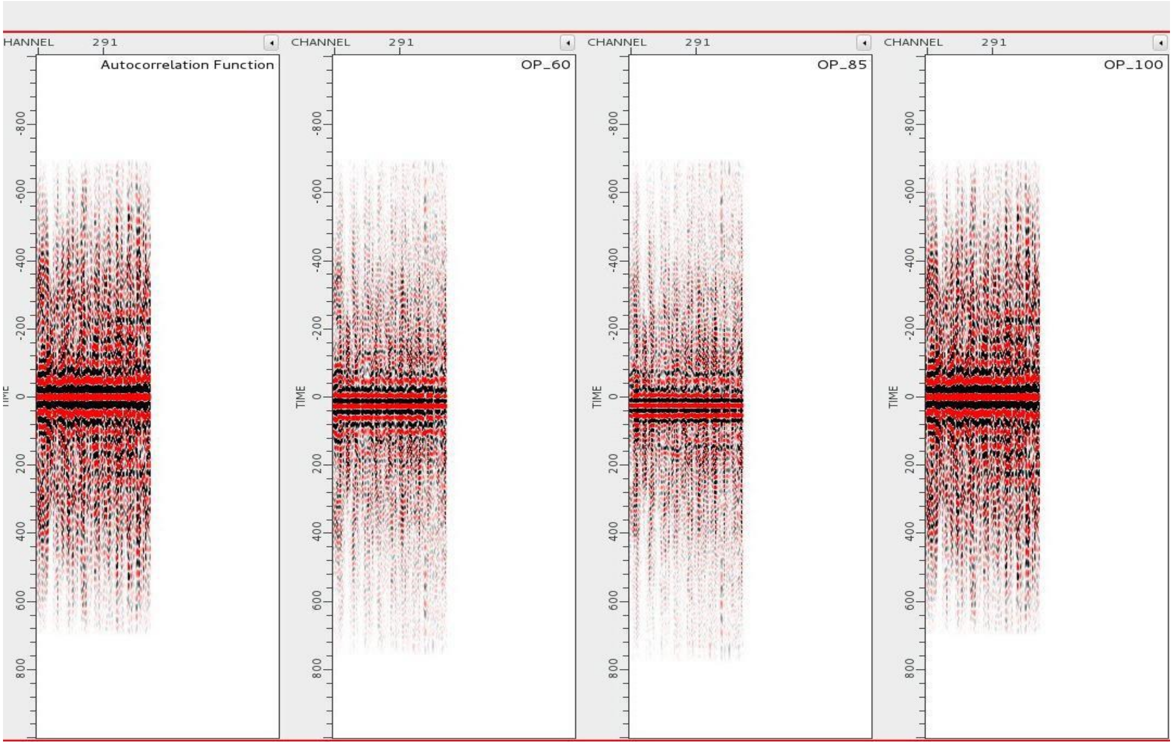


The above diagram shows the effect of the parameter values on the data. For this Gap length parameter test between 8seconds,10seconds,16seconds,20seconds, I chose the best parameter value to be 16seconds

3.7.2.2 PARAMETER TEST FOR OPERATOR LENGTH

During the parameter test for the Operator length, several lengths were tested but the following values chosen below were picked according to my preference.

Figure 3.6.2.2 : Parameter test for operator length



The above diagram shows the effect of the parameter values on the data. For this Gap length parameter test between 60seconds,85seconds and 100seconds, I chose the best parameter value to be 85seconds

RESULTS AND DISCUSSION

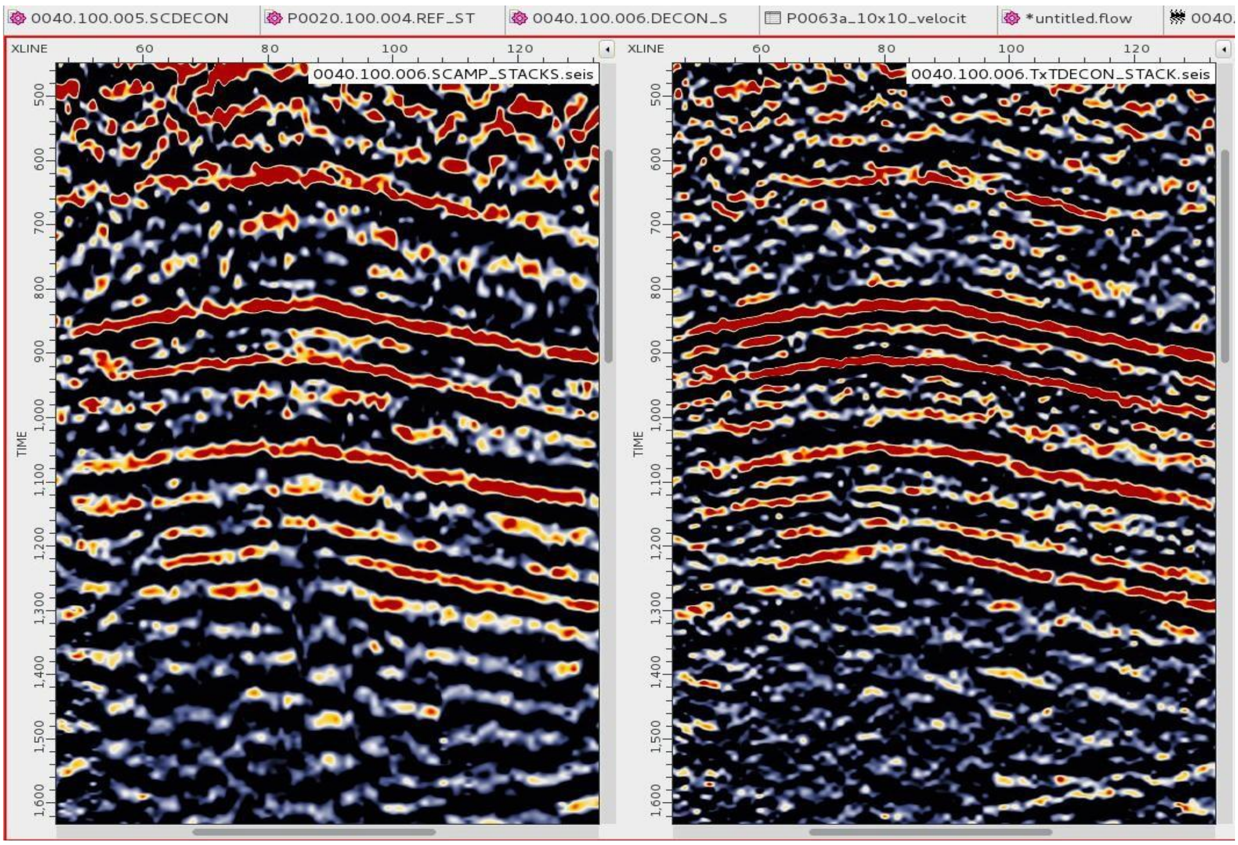
4.1 INTRODUCTION

This Chapter provides the results from the deconvolution process as well as all the pre-processes that was done on the seismic data.

4.2 PRESENTATION OF RESULT

In this project the study aimed to assess the effectiveness of wavelet deconvolution techniques in enhancing the quality of seismic data and improving the accuracy of seismic interpretation. Below is a shot of the seismic section that clearly shows the effect of the deconvolution process on the data.

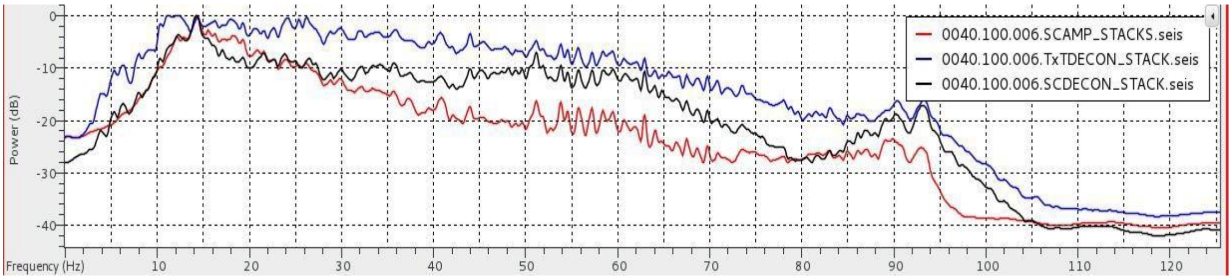
Figure 4.2 : Seismic section before and after the deconvolution process



4.3 PERFORMANCE EVALUATION

Ultimately the goal of this project is to denoise the data and primarily boost the signal to noise ratio.

Figure 4.3 : Performance of filter on the frequency spectrum



As seen from the figure above, the performance of the trace by trace deconvolution (represented by the blue graph line on the frequency spectrum) which is the wavelet deconvolution shows itself to be more capable when it comes to recovering signals lost at important amplitudes when looking at it on the frequency spectrum.

CONCLUSION AND RECOMMENDATIONS

5.1 SUMMARY OF FINDINGS

In this project, the application of wavelet deconvolution for noise reduction in seismic data was investigated. The project yielded the following significant findings:

1. Improved Resolution: The implementation of wavelet deconvolution successfully enhanced the resolution of seismic data. By effectively eliminating noise components, the deconvolution process produced sharper and clearer seismic images. This improvement in resolution enabled better identification and characterization of subsurface geological features.

2. Effective Noise Reduction: Wavelet deconvolution proved to be highly effective in reducing noise levels within seismic data. By isolating and attenuating noise signals, the technique substantially improved the signal-to-noise ratio, resulting in cleaner and more accurate representations of subsurface structures. This noise reduction significantly enhanced data interpretability and reduced uncertainty in seismic interpretations.

3. Preservation of Signal Features: A noteworthy aspect of wavelet deconvolution was its ability to preserve essential signal features while removing noise. The deconvolution process selectively separated the desired seismic signal from unwanted noise components, ensuring the retention of critical geological information in the processed data. This preservation of signal features maintained the fidelity and accuracy of the seismic data during the noise reduction process.

4. Applicability and Practicality: The findings underscored the practical applicability of wavelet deconvolution for noise reduction in seismic data. The technique demonstrated its versatility across various datasets and consistently delivered improvements in resolution and noise reduction. These positive outcomes highlight wavelet deconvolution as a valuable tool for real-world applications in seismic data processing.

5.2 CONCLUSION

In conclusion, wavelet deconvolution proved to be an effective approach for reducing noise in seismic data, resulting in enhanced resolution and reduced noise levels. The technique exhibited its potential for improving data interpretability and facilitating accurate characterization of subsurface geology. These findings contribute to the advancement of seismic data processing techniques, furthering our understanding of subsurface geological structures.

5.3 CONTRIBUTION TO KNOWLEDGE

This project significantly contributes to the existing knowledge in geophysics by highlighting the benefits and effectiveness of wavelet deconvolution in reducing noise and improving resolution in seismic data. The practical insights gained from this study empower researchers, geoscientists, and industry professionals to enhance the quality and reliability of seismic data interpretation, ultimately advancing our understanding of subsurface geological structures.

5.4 RECOMMENDATION

To improve the quality and interpretability of seismic data, it is recommended to integrate wavelet deconvolution as a standard step in seismic data processing workflows. By adopting this technique routinely, the resolution can be enhanced, and noise levels can be reduced, leading to more accurate subsurface characterization.Although wavelet deconvolution has shown effectiveness, there is still scope for additional research and development. Exploring different variations and optimizations of the algorithm, such as adaptive wavelet selection and parameter tuning, can enhance its performance and applicability across diverse seismic datasets.

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